SIXTH FRAMEWORK PROGRAMME

FP6-2004-INCO-DEV-3

PRIORITY A.2.3.: Managing Arid and Semi-arid Ecosystems

Second Periodic Activity Report
(01.01.2008 – 31.12.2008)
January 2009

ANNEX 4-2-8: Report on innovative bioenergy complexes
Deliverable D4.6 (Lead contractor: EUBIA, Due date: December 2008)

COMPETE

Competence Platform on Energy Crop and Agroforestry Systems for Arid and Semi-arid Ecosystems - Africa

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COMPETE is co-funded by the European Commission in the 6th Framework Programme – Specific Measures in Support of International Cooperation (INCO-CT-2006-032448).

INTRODUCTION

This report comprises the results from the work accomplished under task 4.6 and 4.7 of the project COMPETE (Competence Platform on Energy Crop and Agroforestry Systems for Arid and Semi-arid Ecosystems - Africa), co-funded by the European Commission in the 6th Framework Programme – Specific Measures in Support of International Cooperation (Contract No. INCO-CT- 2006-032448).

The report was elaborated under leadership of the European Biomass Industry Association with assistance from the COMPETE consortium.

Editing and Reporting: COMPETE - North-South Cooperation on promising bioenergy schemes

January 2009

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1 Generalities

1.1 Introduction

Africa is characteristic of the developing countries and shows the major problems those countries are confronted with: a big population, rising energy consumption, low energy efficiency and pollution problems. The effects are global and the solution is possible only in global co-operation.

The scope of this document is to stimulate the north-south cooperation on the identification of promising bioenergy schemes and commercially required technologies already in existence in Europe that could be applied in Africa.

Biomass technologies are in many aspects adequate for both developed and developing countries, because of the following characteristics:

- They rely on the utilisation of resources that, in principle, are generously present in countries at every level of development: energy crops and waste. So, nearly each country can diversify its energy supply, covering a large part of the energy consumption with local resources.
- Bioenergy creates many jobs on many different intellectual levels and in many different economic sectors (agriculture, industry and services). This is especially advantageous for a country where labour is not too expensive.
- Biomass technology produces solid, liquid and gaseous fuels for various applications. This flexibility is important for developing countries like in Africa where the applications are very wide.
- Biofuels are useful for low tech consumers, like users of stoves, and high tech consumers, like users of hydrogen. There are even process chains that convert biomass into intermediate and useful products, giving at each step added value. These chains address distinct markets at distinct technological levels. The configuration of them will determine which of the possible products are made. Therefore, these chains are flexible economic tools for developing and developed countries at the same time, providing a base for cooperation.
- Biomass is CO_2 neutral but also other emissions are lower than with conventional fuel, or absent (sulphur). In the African case, the interest is to use the resources already used (like wood) but in a more efficient way exploiting a major part of the energy content.
- Biomass technology is at the same time applicable to many raw materials and complex. This makes it at the same time a very flexible discipline and a field that requires co-operation.

Africa represents an emerging market for European actors that want to co-operate in the field of bioenergy technology. Rapid growth and market reforms are driving increased demand for foreign investment and advanced technologies that will help Africa meet its energy needs while protecting its environment. The energy sector is a particularly promising area for bioenergy cooperation because the equipment used in households as well as industrial level are decades old.

The aim of this document is to describe the market conditions for European bioenergy technology (i.e. carbonisation, stoves, gasification, microdistillery) for the exploitation of the biomass residues that are produced in arid and semi-arid area of Africa.

It comprises an extensive list of technological processes, for each of which a short description will be given, with its strong and weak points, the market opportunities and some suppliers.

1.2 Technical preamble

Bioenergy is defined as the complex of all technological means and systems for processing and utilisation of biomass for energetic purposes.

The main difference between Bioenergy and other renewable energy systems consists in the energy resource supply (fuel) involved. In the first case biomass must be produced, recovered, supplied to the plant, which make biomass a rather expensive fuel, while for the other RE the fuel (wind, solar radiation, water) is available at no-cost.

Biomass refers to all terrestrial or aquatic organic material deriving from the photosynthetic process and represents the solar energy stored in chemical form in plants and animals.

By this process atmospheric CO_2 and water absorbed from the soil are combined under the effect of solar radiation to produce cellulose and hemi-cellulose carbohydrates (C4 – C5 sugars) and about 25% of lignite.

Three different photosynthetic path ways are found in plants: 1) the Calvin or C3 cycle; 2) the C4 – di carboxylic acid pathway; 3) the Crassulacean acid metabolism (CAM) pathway, like in the succulent pineapple plant that fixes large amount of CO_2 (as organic acid) at night, converting them into carbohydrates during the day; because the primary CO_2 assimilation occurs at night when the temperature is lower, these plants limit the amount of water transpired (lower water inputs).

The C4 (i.e. sugar – cane, sweet-sorghum, corn, miscanthus, etc…) and CAM plants are good candidates for **biomass energy crops** cultivated on marginal lands of arid or semi-arid regions of the planet, because their photosynthesis processes are highly efficient at high temperatures and they need low amounts of water during growth.

Here below some examples of typical biomass productivity in Natural Ecosystems are presented for comparison:

BIOMASS PRODUCTIVITY OF NATURAL ECOSYSTEMS			
Climatic zone	Type of biomass plants	Net biomass productivity t/ha per year (fresh)	Location
Temperate zone	Beech forest Oak pine forest Spruce forest Grassland	11.95 13.50 14.50 32.00	Denmark New York Germany New Zealand
Tropical	Forest Oil-palm Forest	60 37 13.40	West Indies Congo Ivory Coast
Fresh water	Fresh water ponds Sewage pond	9.5 – 15.0 56	Denmark California
Marine	Algae (average) Algae (average)	1 2 – 6	Open Ocean Coastal Zone
BIOMASS PRODUCTIVITY OF AGRICULTURE ECOSYSTEMS			
Temperate zone	Corn Corn	25 – 40 30	Average / USA Europe
Tropical zones	Sugar cane Sweet-sorghum Rice	77 70 3.4 – 5.5	Brazil Europe – China – USA Sri Lanka

There is now a wide consensus that, over the coming decades, modern biofuels derived from biomass will provide a substantial amount of alternative energy. In the long term, together with other renewable sources, biomass has the technical capacity to deliver a large part of future global energy needs.

Biomass provides not only nutritional energy (food) in form of starch, sugars, vegetal oil, but also energy and a wide range of industrial commodities like structural materials, paper, chemicals, medicines, etc.

The present world consumption of wood and agro-forestry residues is estimated at:

Energy use: ~ 3.6 billion tonnes/year (15.9% of total primary energy consumption)

Industrial use: ~ 2 billion tonnes/year

1.3 The advantages of biomass

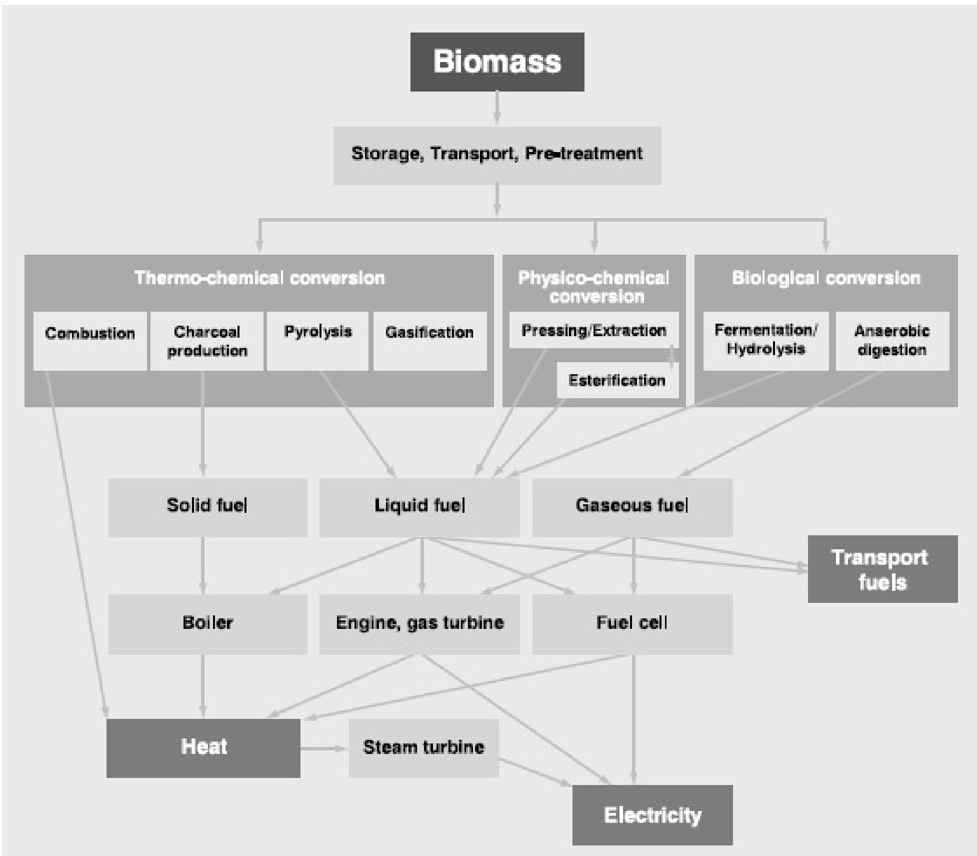
Biomass is widely available and represents a local, clean and renewable resource. In developing countries, the increased planting of biomass crops, especially on land currently considered marginal, would have a beneficial effect on such phenomena as deforestation, desertification and loss of biodiversity, as well as climate change mitigation.

In industrialised countries even a small amount of biomass can play an important role in sustainable development because it can:

- Make valuable use of agro-industrial residues, avoiding the cost of their disposal as waste
- Provide marginal agricultural areas or surplus areas with new development opportunities
- Supply modern technologies for conversion and utilisation
- Guarantee local energy supply and therefore economic and political - autonomy
- Can create and promote markets for refined biomass that can be easily stored, transported and used for heating
- Contribute to the avoidance of additional CO_2 being emitted into the atmosphere

1.4 Range of biomass sources

The Biomass resources can be classified according to the supply sector, as shown in the table below. Most of them can be considered in African Arid and Semi arid area or the area adjacent urban area regarding the Industry and main part of waste sector.



Supply sector	Type	Example
Forestry	Dedicated forestry	Short rotation plantations (e.g. willow, poplar, eucalyptus)
	Forestry by-products	Wood blocks, wood chips from thinnings
Agriculture	Dry lignocellulosic energy crops	Herbaceous crops (e.g. miscanthus, reed canarygrass, giant reed)
	Oil, sugar and starch energy crops	Oil seeds for methylesters (e.g. rape seed, sunflower)
		Sugar crops for ethanol (e.g. sugar cane, sweet sorghum)
		Starch crops for ethanol (e.g. maize, wheat)
	Agricultural residues	Straw, prunings from vineyards and fruit trees
	Livestock waste	Wet and dry manure
Industry	Industrial residues	Industrial waste wood, sawdust from sawmills
		Fibrous vegetable waste from paper industries
Waste	Dry lignocellulosic	Residues from parks and gardens (e.g. prunings, grass)
	Contaminated waste	Demolition wood
		Organic fraction of municipal solid waste
		Biodegradable landfilled waste, landfill gas
		Sewage sludge

A wide range of terrestrial biomass materials are useful for energy conversion, including:

- Wood in all its forms
- Straw and sugar cane bagasse
- Fibrous agricultural residues
- Urban and industrial waste products (an average of 40% of solid municipal waste is organic material)
- Dried plants and sludge from water purification or animal wastes
- Sugar crops (sugar cane, sugar beets, sweet sorghum, etc…)
- Oil crops (sunflowers, rape seed, palm oil etc)

The introduction of dedicated bioenergy crops, and especially fast growing crops (such as willow, miscantus, sweet sorghum, etc.) on marginal agricultural land, could supply huge amounts of sustainable energy with high positive energy ratio (outputs / inputs) and very low noxious emissions during combustion. It would also create numerous rural jobs on a worldwide scale in areas where most of population is living, thus fighting the exodus of unemployed people towards already crowded cities.

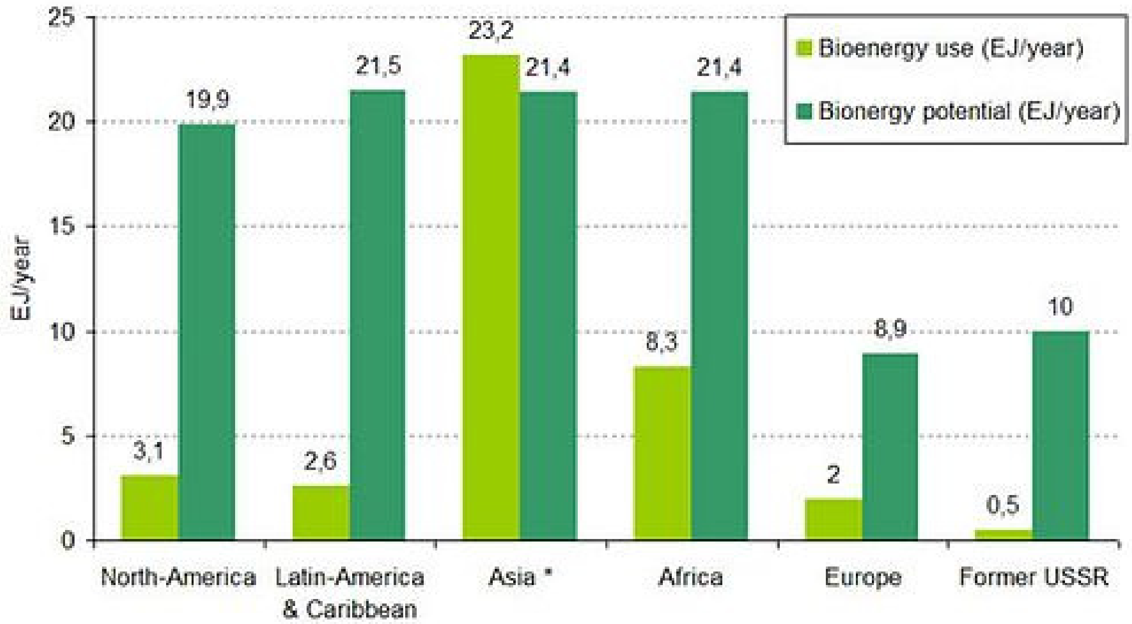
Energy crop productivity is still at a very early stage of deployment in comparison to food crops; major impact can therefore be obtained, with reasonable support, only in the longer term. But the potential especially of lignocellulosic biomass resources both worldwide and in Europe is considerable and represents in a long term a realistic alternative to fossil fuels, by providing great benefits to the environment, by helping to fulfil the Kyoto commitments and beyond and to local economies.

1.4.1 World bioenergy potential

Bioenergy could in principle provide all the world's energy requirements, but its real technical and economic potential is much lower. The WEC Survey of Energy Resources (2001) estimates that bioenergy could theoretically provide 2900 EJ/y, but that technical and economic factors limit its current practical potential to just 270 EJ/y.

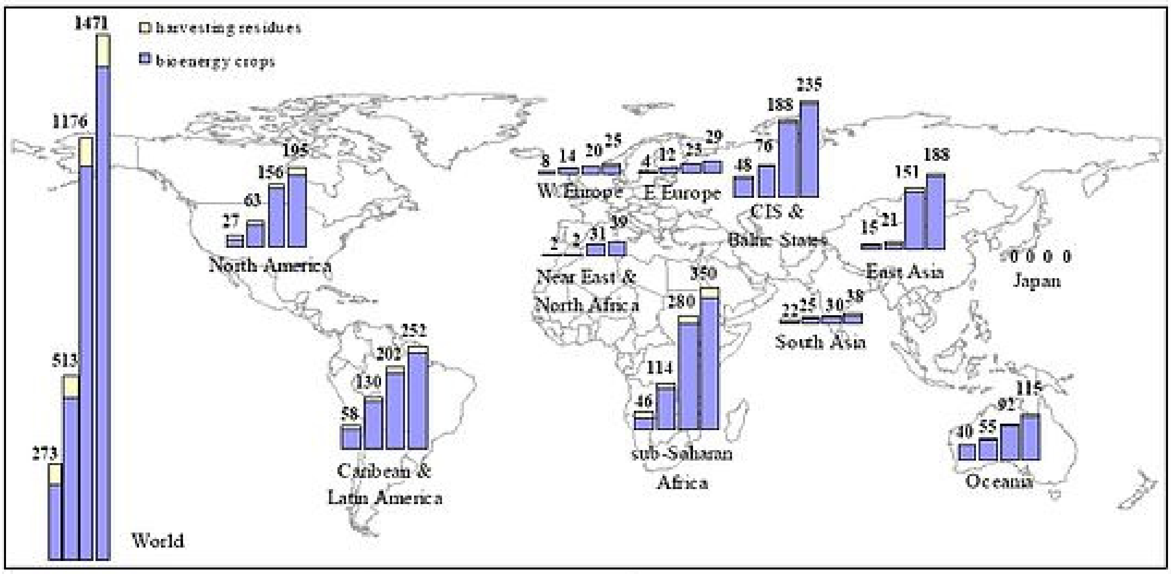
The table below shows the potential and current use of bioenergy by region. Even with the current resource base, it is clear that the practical potential of bioenergy is much greater than its current exploitation. Obstacles to greater use of bioenergy include poor matching between demand and resources, and high costs compared to other energy sources. Projections by the WEC, WEA and IPCC estimate that by 2050 bioenergy could supply a maximum of 250–450 EJ/y, representing around a quarter of global final energy demand. This is consistent with the table below, which puts the technological potential of bioenergy at 30% of global energy demand.

Fig 1.: Current technical potentials and biomass use compared to primary energy consumption (PEC) from fossil fuels & hydro



Source: Kaltschmitt, 2001

Fig. 2: Sustainable bioenergy production potential for the worlds regions under four scenarios by 2050



Total bioenergy production potential in 2050 in scenarios 1 to 4 (EJy^{-1}; the left bars is scenario 1, the right bar is scenario 4).

Source of graph: E. Smeets, A. Faaij, I. Lewandowski (2004). A quickscan of global bio-energy potentials to 2050: analysis of the regional availability of biomass resources for export in relation to underlying factors, Copernicus Institute - Utrecht Universit.

Fig. 3: Estimation of global conventional and biomass resources

Energy category	Million toe	EJ
Oil statistics (ENI, 2003-2004)		
Annual oil extraction	3850	161.2
World oil reserves	149600	6263.5
World energy statistics (IEA, 2003)		
World annual primary energy supply	10376	434.4
- Oil	3715	155.5
- Coal	2379	99.6
- Natural gas	2169	90.8
- Renewables & Waste	1121	46.9
- Nuclear	695	29.1
- Hydro	228	9.5
- Other (includes geothermal, solar, wind, etc.)	52	2.2
EUROSTAT, EU-25 Energy statistics (2002)		
Annual gross inland consumption (GIC)	1680	70.3
Share of renewable energy sources in GIC	95	4.0
Share of bioenergy in GIC	62	2.6
EU-25 (+Bulgaria, +Romania) biomass available potential (BTG, 2004)		
Biomass available potential by 2010	183	7.7
Biomass available potential by 2020	210	8.8
EUBIA		
2020 biomass potential in the EU-25	200	8.4
2050 biomass potential in the EU-25	400	16.7
EU-25 forest biomass, crop residues and energy crops (Ericsson, Nilsson, 2004)		
Scenario 1 (short term, 10-20 years)	105	4.4
Scenario 2a (medium term, 20-40 years; low harvest)	184	7.7
Scenario 2b(medium term, 20-40 years; high harvest)	220	9.2
Scenario 3a (long term, >40 years; low harvest)	375	15.7
Scenario 3b (long term, >40 years; high harvest)	451	18.9
World bioenergy potential from forestry by 2050 (Smeets et al., 2004)		
Low demand	764	32.0
Medium demand	1027	43.0
High demand	1242	52.0
Bioenergy technical production potentials from agricultural residues and bioenergy production on surplus agricultural lands to 2050 (Smeets et al., 2004)		
World min.	6520	273.0
World max.	35134	1471.0
West Europe min.	191	8.0
West Europe max.	597	25.0
East Europe min.	96	4.0
East Europe max.	693	29.0

1.4.2 Bioenergy Production Potential in Developing countries

For three quarters of the world's population living in developing countries, biomass is the most important source of energy. With increases in population and per capita demand, and depletion of fossil-fuel resources, the demand for biomass is expected to increase rapidly in developing countries. On average, biomass produces 35 % of the primary energy in developing countries, but many sub-Saharan countries depend on biomass for up to 90 %. Biomass will remain an important global energy source in developing countries well into the next century.

1.5 Energy value of biomass

Biomass is in general wrongly considered as a low-quality fuel. Because today many available modern efficient, low pollution utilisation technologies use liquid or gaseous fuels it is more convenient to convert solid biomass into liquid or gaseous biofuels (accepting an energy conversion loss around 25% - 30%).

1t of dry biomass ≈ 0.41 TOE

Despite its wide use in developing countries, biomass is used with very low efficiency applications. The overall efficiency in traditional use (e.g. cooking stoves) is only about 5 to 15 per cent, and biomass is often less convenient to use compared with fossil fuels. It can also be a health hazard in some circumstances. For example, cooking stoves can release particulates, carbon monoxide (CO), nitrous oxides (NOx) and other organic compounds in poorly ventilated homes, often far exceeding the recommended World Health Organisation levels. Furthermore, inefficient biomass utilisation is often associated with the increasing scarcity of hand-gathered wood, nutrient depletion, and the problems of deforestation and desertification.

The next paragraphs will propose technologies that permit the use of Biomass in a more efficient and safe way.

1.6 Description and characterization of the actual bioenergy consumption

The use of Bioenergy has a lot of advantages but is also limited by some barriers limiting its expansion. The list of advantages and inconvenient is presented here below and some solution to improve the extension of bioenergy development are proposed. Finally the main conversion processes actually used in Europe will be listed.

1.6.1 Bioenergy characterisation

➢ **<u>Bioenergy key drivers and advantages</u>**

Some bioenergy key drivers consist in its contribution to:

- the reduction of energy dependency on energy imports and thus, the increased security of supply
- the climate change mitigation (bioenergy use decrease net greenhouse gas emissions and some other noxious gas emissions compared to fossil fuels, thus contributing to fulfil the Kyoto commitment) and the fight against desertification
- stable employment opportunities in rural areas and among small and medium sized enterprises; this in turn fosters regional development, achieving greater social and economic cohesion at community level.

Other important advantages of bioenergy are as follows:

- Widespread resources are available
- Biomass resources show a considerable potential in the long term, if residues are properly valorised and dedicated energy crops are grown. Bioenergy makes valuable use of some wastes, avoiding their pollution and cost of disposal
- Biomass has the capacity to penetrate every energy sector: heating, power and transport. Bio-fuels can be stored easily and bioenergy produced when needed
- Bioenergy creates worldwide business opportunities for EU industries
- Biofuels are generally bio-degradable and non toxic, which is important when accident occur.

➢ **Barriers to bioenergy,**

Here below are listed the specific actions against the Bioenergy expansion and driving forces to support these activities

Barriers to bioenergy expansion

- Physical characteristics of biomass quite different
- Lack of small capacity efficient units for cogeneration using solid biomass
- costs of bioenergy technologies and resources
- competitiveness strongly depends on the amount of externalities included in the cost calculations
- resource potentials and distributions
- lack of organisation in supply structures for the supply of biofuels
- local land-use and environmental aspects in the developing countries
- administrative and legislative bottlenecks.
- Biomass if not refined (pellets/briquettes) is biologically instable

Overcoming these barriers

- improving the cost-effectiveness of conversion/utilisation technologies;
- developing and implementing modern, integrated bioenergy systems (multicrops-multiproducts)
- it took farmers thousands of years to develop plants that are especially suitable for food. There is therefore a considerable potential in developing dedicated energy crops productivity
- establishing bioenergy markets and developing bioenergy logistics (transport and delivery bioenergy resources and products)
- Valuing of the environmental benefits for society e.g. on carbon balance.

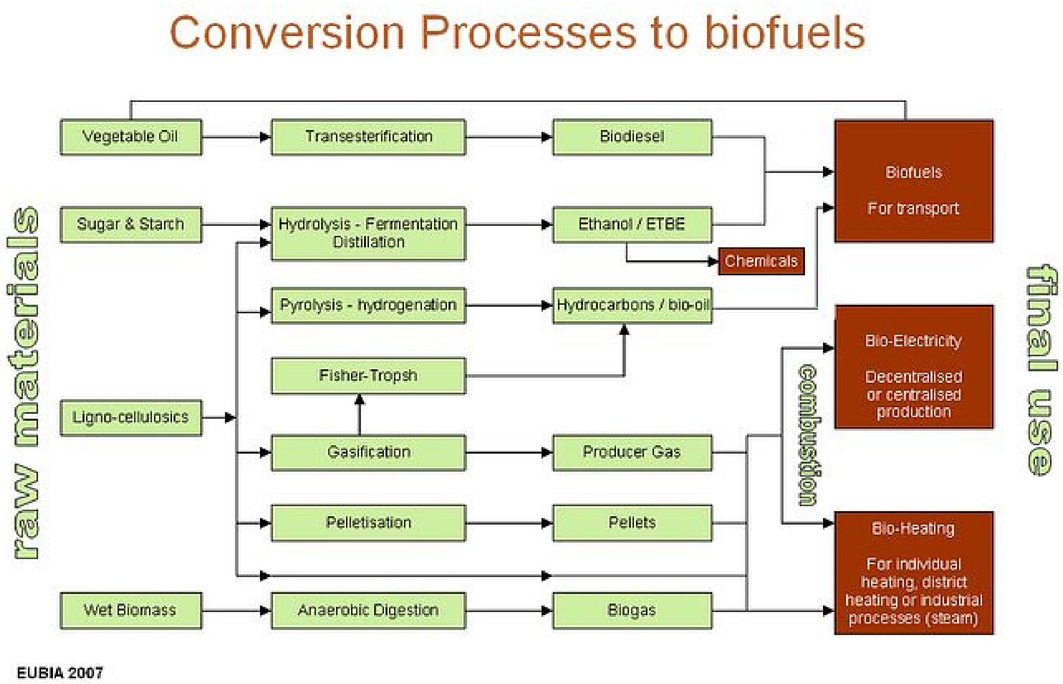
1.6.2 Conversion Routes to Bioenergy

The energy available in biomass may be used either by direct use as in combustion, or by initial upgrading into more valuable and useful fuels such as charcoal, liquid fuels, producer gas or biogas. Thus, biomass conversion technologies can be separated into four basic categories:

- direct combustion,
- thermo-chemical conversion processes (pyrolysis, gasification),
- bio-chemical processes (anaerobic digestion, fermentation)
- physico-chemical (the route to biodiesel).

The processes of each category will be presented in details in the following paragraph.

Fig. 4: Conversion processes to biofuels



1.7 Analysis of E.U. Bioenergy technologies commercially available

1.7.1 Solid Biomass pre-treatment (Biopellets and briquettes)

Three of the four possible biomass products - lignocellulosic materials, starch, sugar, and vegetal oils, - are harvested mainly for human nutrition. Pre-treatment and storage technology is therefore already widely available. For a modern utilisation of lignocellulosic biomass (the largest market potential) one of the basic requirements is to transform this huge amount of humid resource into a “real energy carrier”.

This transformation should make biomass easily to handle, store and transport over large distances and be tradable at inter-regional and international level.

Biomass therefore has to be pre-treated and refined through drying and compactation processes (pelletisation or briquetting) if an efficient international market for bioenergy must to be established.

The other significant contribution from bioenergy in a longer term will be the production of liquid biofuels for transport (bioethanol, biomethanol, biodiesel).

Tables here below show the density of original wood residues compared with the refined product, and specific characteristics of wood pellets and shows the main logistical and economical interest of those pretreatments..

Fig. 5: Density of Wood Wastes

By-products	**Density (kg/m^3)**
Oak bark	200
Hardwoods sawdust	130
Oaks sawdust	235
Beech sawdust	220
Hardwoods chips	175
Beeches chips	135
Oaks chips	135
Voluminous coniferous wastes	240
Voluminous oaks wastes	430
Voluminous residues of Spruce	320 to 350
Voluminous residues of pine	350 to 380
Leafy	400 to 450

Fig. 6: Bulk density of Refined Biomass

Chips: 150 - 282 kg/m^3
Briquettes: 520 - 680 kg/m^3
Pellets: 650 - 700 kg/m^3

More promising than briquettes, biopellets currently look most likely to be able to satisfy the range of domestic and industrial fuel uses (from a few kWs to hundreds of MWs) involving the modern automated fuel handling and controlled combustion processes now commercially available. Biopellets are suitable for both heat and power production but also for the expected future production of synthetic bio-fuels.

Fig. 7: Heat value of different fuels

Fuel	kWh/Kg
Biopellets	4.7
Coal	5.5
Oil	12.3

1.7.2 Increasing interest for biomass derived Biofuels

Besides biomass materials that are used in a traditional way, directly as fuel (such as firewood), most biomass resources need to be converted into solid, gaseous or liquid biofuels for utilisation in modern and efficient utilisation systems. There are two kinds of conversion process: **biochemical** and **thermochemical**. In the first process, involving anaerobic digestion or alcohol fermentation, fuel is obtained by means of chemical reactions caused by the presence of enzymes, fungus and microorganisms. With the second process, involving carbonisation, gasification or pyrolysis technology, either solid, gaseous or liquid biofuels are obtained by the action of heating and of a catalyst.

Biofuels can be used for heating, for cogeneration (simultaneous production of electric energy and heating) or for mobility (transport). This is an application of major interest in Europe for its large potential impact in supply volume and reasonable production costs.

The commercial technologies available today for the conversion of biomass resources into solid, liquid or gaseous biofuels and for the production of heat, power or for transport, these can be subdivided into two main categories:

- Small scale technologies for decentralised bioenergy production (activity relevant for rural development)
- Medium to large-scale technologies and schemes for centralised bioenergy production (industrial activity)

With the second category there are no real problems in the availability of commercial technologies at a reasonable cost and reasonable efficiency. But the absence, in most of countries, of a legal frame for operation and of adequate incentives have discouraged investors to enter in the sector. Meanwhile, there is a worldwide scarcity, however, of small capacity systems and technologies needed for diffused applications in rural areas.

This deficiency should be addressed for the following reasons:

- Social stability can only be achieved if the tendency of the labour force to concentrate in cities is reduced. With its complex multidisciplinary nature, biomass can offer great possibilities for new work activity involving people at all possible levels of education;
- Energy and transport biofuels can be produced also by small plants deployed in large numbers in rural areas (decentralised production) redistributing both economic benefits and energy to people living in these districts;
- Small-scale plants will make better use of the many types of local biomass resources that exist everywhere, reducing the problems and cost of transport.

Here enclosed the wide range of bioenergy sectors and technologies required in the three steps of the biomass chain (biomass resource procurement and pre-treatment, conversion and utilisation) are shortly summarised. The difficulty in the identification of optimised bioenergy actives is due to the complexity and wide range of possible options available for a choice.

1.7.3 Biomass for Heat and Power

Some variety of biomass are utilized to generate bioenergy (electricity and heat) through combustion from agro-industries (bagasse), from residues, post harvest (corn stalks) from animal manure, wood wastes from forestry, Industry residues from food, paper industries and biogas from the digestion of agricultural and other organic waste could provide between 40EJ and 170EJ of energy per year.

Biomass can be converted for power generation using several processes. Generally, the majority of biomass-derived electricity is produced using a steam cycle process, in which biomass is burned in a boiler to generate high-pressure steam, that flows over a series of aerodynamic blades causing a turbine to rotate, which in response turns a connected electric generator to produce electricity.4 5 Compacted forms of biomass such as wood pellets and briquettes can also be used for combustion. This system is known as the direct-fired system and is similar to the electricity generation process of most fossil-fuel fired power plants.

Biomass can also be burned with coal in a boiler of a conventional power plant to yield steam and electricity. Co-firing biomass with coal is currently the most cost-efficient way of incorporating renewable technology into conventional power production because much of the existing power plant infrastructure can be used without major modifications.6 7 Co-combusting coal and biomass in large-scale coal plants is claimed to have significantly higher combustion efficiency (up to 45 percent) than dedicated-biomass plants (30 to 35 percent using dry biomass and 22 percent for MSW)8 According to the U.S. Department of Energy and the Coal Utilization Research Council, conventional pulverized coal in modern plants can yield 45 to 50 percent efficiency and have the potential to achieve 70 to 80 percent efficiency with advances in future gasification technologies.9 10 Co-firing technology options have been tested in Northern Europe, the United States, and Australia in approximately 150 installations using woody and agricultural residues.11

1.7.4 Biogas for Heat and Power and transport

- **Anaerobic Digestion**

Biogas can also be created through *anaerobic digestion* of food or animal waste by bacteria, in an oxygen-starved environment. The final product of this form of digestion is a biogas that contains a high volume of methane along with carbon dioxide. Methane-rich biogas can be used for heating or for electricity generation in a modified internal combustion engine.12 Advanced gasification technologies are necessary to produce biogas with sufficient energy for fuelling turbines.

The conversion of animal wastes and manure to methane/biogas can bring significant environmental and health benefits. Methane is a GHG that is 22-24 times more powerful as CO2 in trapping heat in the atmosphere13. By trapping and utilizing the methane, GHG impacts are avoided. In addition, pathogens present in manure are killed by the heat generated in the biodigestion process and the material left at the end of the process provides a valuable fertilizer.

Biodigestion is employed successfully in various countries, and particularly in China and India where is has contributed to energy provision to rural populations, abatement of negative environmental impacts of livestock production, and the production of organic fertilizer. Its impact on sanitation, clean cooking and heating and in the creation of small and medium enterprises in rural areas is very positive.

- **Gasification**

Through the process of *gasification*, solid biomass can be converted into a fuel gas or biogas. Biomass gasifiers operate by heating biomass in an oxygen-free, high temperature environment that breaks it down to release a flammable, energy-rich synthesis gas or ‘syngas’.14 This gas can be burned in a conventional boiler, or used instead of natural gas in a gas turbine to turn electric generators. Biogas formed through gasification can be filtered to remove unwanted chemical compound and can be used in efficient power generation systems known as ‘combined-cycles’, which can combine steam and gas turbines for electricity generation and can yield up to 60 percent efficiency of coal-fired plants.15 The first integrated gasification combined cycle (IGCC) plant fuelled by 100 percent biomass (from straw) was successfully demonstrated in Sweden from 1996 to 200016. IGCC plants elsewhere could become economically competitive using black-liquor from the pulp and paper industry as a feedstock, but further analysis is required.17

1.7.5 Biofuels for Transport

Liquid biofuels are liquid renewable energy sources from living things.

The transport sector in the E.U. derives almost 95% of its energy needs from oil. New solution and diversification of the transportation fuel supply converting new ideas into practical solution and through the deployment of domestic alternative biofuels from agriculture could be advisable and useful also to reduce the transport related pollution (especially in congested urban areas) and to contribute to rural development, in particular in marginalized areas no more competitive for food production. Of course natural gas in the short-medium term will play a strategic role also with the production of high purity synthetic liquid hydrocarbons - through syngas obtained from natural gas.

From biomass the same types of transport fuels can be obtained; among the promising alternative liquid or gaseous biofuels, the most interesting are indicated in the table here below:

Biofuels with largest future potential

- **Bioethanol**
- **Biodiesel** (methyl -ester of vegetal oils)
- **Biomethanol**
- **Biodimethyl Ether** (Bio DME)
- **Bio ETBE** (contains 47% biomethanol)
- **Bio MTBE** (contains 36% biomethanol)

- **Biogas** (fuel gas derived from the biodegradable fraction of wastes with ~ 60% of methane)
- **Biohydrogen** (hydrogen produced from biomass)
- **Synthetic biofuels** (synthesised hydrocarbon or mixtures of hydrocarbon derived from biomass through several conversion processes)

These biofuels have been listed also in the new EC Directives recently approved for the promotion of renewable biofuels for transport. Biofuels derived from renewable biomass resources (including biohydrogen and synthetic biofuels) have the technical and economic potential of large-scale replacement of the fossil ones.

In a short term, the great potential for biofuels to penetrate the strategic sector of transport yet is represented by liquid alcohol such as bioethanol and biomethanol. Research in this area has greatly expanded across Europe, the Unites States, Brazil and Japan, covering the entire alcohol production, distribution and utilisation process from the selection of high-yield cultivars for the production of biomass feedstock to the performances assessment of alternative and neat alcohol fuels or blends in engines..

But now a broad spectrum of public decision-makers has been interested in the applications of alternative fuels and biofuels as given in the above table as examples in order to solve specific problems.

The main characteristics of different biofuels are shortly illustrated here below:

- **Bioethanol (BIO - ETOH)**

Is a colourless, good liquid fuel with its chemical formula: C_2H_5OH. This biofuel is an already refined product and it is a potential good transport fuel for gasoline blending, reformulation and substitution especially when optimised ethanol engines (now under development) will be commercially available. At present the world production is limited to 23 mio m^3 / year and most is obtained from sugar cane (Brazil) and starch (corn - USA). Intensive R & D activity to obtain bioethanol from lignocellulosic feedstock is under way. Bioethanol production in the EU is ~ 0.8 mio t/year. The estimated (conservative) bioethanol worldwide potential is more than 2 billion t/y at a likely cost of 30 $/bbloe (200 $/$m^3$) through large industrial and decentralised production units. Energy ratio: 1.3 – 4.0 depending on the crop. Developing countries have large possibility for future bioethanol production and export for low resource production cost and also because the bioethanol investment cost are much lower (1/3) of sugar investment costs. Bioethanol is 70% less energetic than gasoline providing lower autonomy in existing engine technology and vehicles.

- **Biomethanol (BIO - MEOH)**

Biomethanol can be produced from synthesis gas, mixtures of H_2 and CO, derived from biomass (bio-syn-gas) via a well - known cathaoxygen and steam or by steam reforming of charcoal. At present methanol is mostly produced from natural gas (world production 27 mio t/year) with a conversion efficiency of ~ 55% and at a cost of Biomethanol has the potential of substituting the synthesis methanol.

- **Biodiesel**

At world level the average diesel - oil consumption is ~ 145 l / person and widely available. The interest for substitution with vegetal - oils (which are technically good fuels) locally produced is significant. In Europe there is a specific crop (rapeseed with a productivity of 1.00 - 1,5 t/ha of oil extracted from the seeds) of particular interest for farmers. But because the vegetal oils are not a very good fuel for direct injection engines (because of their high viscosity and thermal instability) it has been found a good solution by transforming the vegetal oil in ester (lower viscosity, good stability, complete miscibility with diesel oil) as follows: 1 t (oil) + 100 kg methanol = ester + 100 kg glycerine. In Germany there is already a significant production and 1600 refuelling stations.

- **Bio-ETBE** (Bio-Ethyl Tertiary Butyl Ether)

Is a colourless, flammable, oxygenated hydrocarbon with its chemical formula: $C_2 H_5 OC_4 H_9$. This biofuel is produced by mixing bioethanol (48% in volume) and tertiary butanol (or bioethanol and iso-butylene) and reacting them with heat over a catalyst. This biofuel (octane rating: 112) can be used in existing gasoline engine without any modification with excellent performance and environmental benefits replacing aromatics and benzene. Bio-ETBE is acceptable for direct refinery blending and for common pipeline transport.
In Europe the motivation for promoting the use of biofuels is based on the growing interest in diversifying the EU fuel supply for the transport sector which presently is nearly 100% dependent on oil, and expecting a high increase in future demand, whilst improving the viability of indigenous biomass resources.

- **Bio-MTBE** (Bio-Methyl-Tertiary Butyl Ether)

Is similar to Bio-ETBE and obtained by mixing biomethanol (36% in volume) and tertiary butanol with heat over catalyst.

- **Biogas** (a mixture of ~ 60% of methane and ~ 40% of CO_2)

Is produced most by anaerobic fermentation of very humid biomass (livestock liquid manure, sludges, wastes, etc...). Small size plants are widely diffused in developing countries (~ 10 mio units in China), large plants are deployed most in industrial countries for treatment or urban sludges or for disposal of agro-industrial wastes.

- **Biohydrogen**

For production of hydrogen from biomass 3 different but associated routes have been followed in this project. The first is the fermentation of sugars to hydrogen, CO_2 and organic acids by thermophilic bacteria at approx. 70 ºC, Stage 1 of the bioprocess. The second is the subsequent conversion of organic acids in the effluent to hydrogen and CO_2 in the presence of light at ambient temperature, Stage 2 of the bioprocess.

The third route is the thermochemical conversion of residues which can not be converted by anaerobic bacteria. Supercritical water gasification is employed here to convert non-fermentable residues in biomass to hydrogen and CO_2.

- **Biosyntetic Fuels**

A wide range of very clean synthetic fuels can be obtained from "biosyngas" derived from biomass by "Fischer - Tropsch" process.

The F.T. stands out as the most attractive process because:

- It can produce a wide range of high quality fuels and some of high value, like:
  - F.T. bio-diesel oil (sulphur free)
  - Bio-olefins
  - Bio-Middle Distillates
  - Bio-nafta
  - Bio-methane
  - Etc...
- The market for its products is well established;
- There is no need of new refuelling infrastructure;
- There is no need of major engine modification;
- Its production cost is higher than for biomethanol but reasonable;
- Can be operated economically in remote locations today when the crude-oil price is approx. 40 $/bbl

.

- **Bio-Dimethyl Ether (Bio-DME)**

Is similar to LPG (a mixture of propane and butane) in terms of physical characteristics. It can be used as substitute for LPG or as oxygenated addictive in transport fuels or as diesel-fuel substitution. A potential 2% contribution to the diesel-oil pool (134 mio t/y in year 2010) is considered possible in a medium term but biomass must complete with natural gas. DME could be produced from bio-syn-gas by direct catalytic conversion of CO; it will be more expensive than biomethanol.

At present DME is produced from pure methanol by an acid catalyst (Aluminium Oxide or Aluminium Silicate) in a fixed bed a low pressure and temperature (260 °C – 350 °C). The resulting mixture (DME + methanol + water) is separated by distillation. Direct conversion of CO in DME (now under development) will be more economical.

The main issues deriving from the use of alcohol biofuels for blending or reformulation are:

- These biofuels offer an important option for reducing CO pollution, precursor of ozone formation, in urban areas by ensuring also more complete combustion (up to 30%);
- Alcohol fuels have a much higher octane rating than gasoline, increasing power output and reducing engine knock (octane busters);
- Alcohol fuels have a lower energy density, compensated (in part) by the higher combustion efficiency.

It is expected that a bioethanol will be produced in the EU in the medium term at a level of around 250 €/m^3 by the adoption of optimised crops (such as sweet sorghum/corn) and the fully integrated processing of all feedstock components (grain, sugar, lignocellulosic).
For promotion of decentralised bioenergy production (very important for rural development programmes) small size activity and technologies are mostly required.

1.7.6 Small Scale Commercial Technologies

➢ **Pelletisation & briquetting technologies in particular:**

Innovative, cost-effective pelletisation plants with an output of 1-5 t/hr are now commercially available. Small mobile pelletisation units with an output of 200 Kg/hr, able to be mounted on a tractor and travel to inaccessible difficult areas will be available. These can convert any type of humid biomass into pellets (ϕ 6-12 mm). This new refining technology (extraction of 21% of humidity and compaction) requires only about 4% of its biomass energy content, in comparison with conventional production process of pellets requiring about 10% of their energy content.

➢ **Small Cogeneration Units**

- Capacity range commercially available: 70 – 500 kWe. These systems are based on atmospheric gasifier-engine generator. Total electrical efficiency: ≈ 19%.
- Pollutant emissions within EC standards.
- Capital investment cost: 2,800 €/kWe.
- Co-generation production (power, heat / cooling) can be obtained.
- Potential markets: groups of houses/villages, shopping centres, hotels, tourist centres, clinics, schools, agro-industrial centres, SMEs, co-operatives, for remote sites/islands.

- **Synthesis Gas Generators**

Syngas is a mixture of CO and H_2 gas (carbon monoxide and hydrogen) and well known in industrial countries (before the natural gas arrival on the market) as 'town gas'. In fact it has been used in large quantities until the last century in many countries. Charcoal pellets obtained by carbonisation of biomass pellets can replace anthracite and can be converted into syn-gas through an innovative low-cost integrated and energy saving process (patent pending). Small units (3.5 kg pellets/hr) can supply enough syngas to cover the cooking needs (all year around) of a village of 100 inhabitants. Bigger commercial units could supply cooking fuel for a city of 200,000 people.

Production cost of this Bio-syn-gas in the EU is estimated at around 300 €/TOE. In China, Africa and developing countries the production cost could be 170 €/TOE, competitive with LPG (consumer cost in rural China 190-360 €/TOE, in Africa 570 €/TOE.

Syngas can also be utilised in small micro-turbine-gas cogenerator/trigeneration units (30-100 kWe).

- **Micro Distilleries for Bioethanol**

Capacity range: 1 to 10m^3/day.
Capital investment: ~ 1,200 €/m^3 per day (in favourable climatic situations).

Several types of sugar and starch crops can be utilised. Production of a low-grade (95°) bioethanol is the best option in terms of cost: this low-grade fuel is adequate is pure enough for several applications, including engines, microgas turbines or as cooking fuel.

Decentralised production of bioethanol by small distilleries (in parallel to centralised production by large plants) can enlarge the rural development effects although with some increase in its production costs. However, the full exploitation of crops with a simultaneous production of several co-products will compensate in part for this economic disadvantage.

- **Microgas-Turbine Co-/Trigeneration Systems Fed with Biofuels (liquid or gaseous)**

Capital investment cost: ~ 1000 €/kWe
Fuels: low-grade ethanol, vegetal-oil, bio-syn-gas, biogas
Very low Nox, CO and particulate emissions
Very low operating cost
Suitable for trigeneration: production of electricity + heat + cooling / freezing
Potential interest for peak-power supply
Potential markets: hotels, schools, tourist resorts, clinics, islands population, small desalination plants, SMEs, agro-industries

- **Clean Carbonisation Plants for Charcoal Pellets Production**

Input material: large size pellets from any type of biomass (humid-forestry residues, wastes, agriculture residues, grasses, energy crops or biomass mixtures
Capacity range: 500 – 30,000 t/y
Capital investment cost: 330 €/t charcoal/y
Production cost of charcoal in Europe around 180 €/t, in China $ 110/135/ton.

- **Plants for the Production of Activated-coal**

Input material charcoal pellets
Capacity range: 100 - 10,000 t/y
Capital investment cost: about 1,300 €/t act-coal produced per year
Production cost around 600 €/t (market value 1,300 €/)
Suitable for purification process of liquids/gases, important for example for drinking water
Suitable for purification in petrochemical complexes, agro-industrial processing plants etc.

- **Biogas Plants**

Efficient commercial technologies (small to medium capacity) are available in many EU countries.

- **Heating, Climatisation, Freezing Units utilising Biofuels**

A large variety of heating (stoves, boilers) or commercial absorption refrigeration systems are available which can be coupled to the low temperature exhaust of biomass heat co-generation.

As far as concerns large industrial bioenergy plants for centralised commercial energy production that are widely available in the EU these are summarised in table here below.

1.7.7 Large Scale Commercial Technologies

- **Biomass power plants (above 2 MWe).**

Many reliable and sound technologies based on combustion steam-condensing plants fuelled by solid biomass or gas/steam turbine c.c. Plants fuelled by liquid biofuels (low-grade bioethanol, biomethanol) are commercially available in the EU.

- **Large plants for heat production** (100 MW+) for industrial use or for district heating

➢ **Bioethanol** (up to 600,000 t/y) and **Biomethanol** (100,000 t/y) plants,
although in many cases, unfortunately, the economic risk discourages their deployment. The now approved EC Directives on complete detaxation of biofuels should improve the perspectives and promote these biofuels.

➢ **Bio-syn-gas/Biohydrogen plants** (capacity 5,000 ÷ 20,000 t/y)
can be installed requiring modest adaptation of commercial available technologies.

➢ **High capacity biogas plants**
processing organic wastes of different origin are now widely available.

➢ **Large-scale integration of commercial bioenergy complexes**
within petroleum refinery infrastructures for the production of heat, power bio-hydrogen and for reformulation of gasoline/diesel with bio-ethanol / bio-methanol to obtain higher-grade, less polluting transport fuels, could now being envisaged.

At present, taking into account the situation and needs of the arid and semi arid area in Africa, only the small-scale technologies summarised in the previous table have been considered, and will be more extensively analysed in the following chapter because these:

- are relevant for a decentralised clean energy production
- only SME are involved and require particular assistance
- smaller financial efforts are required

For large plants, only co-firing of coal / biomass pellets are mentioned, because in this case large amount of biomass (supplied by farmers and cooperatives) will be needed for operation of large power plants with obvious impact on rural employment.

1.7.8 Sustainability Considerations

Sustainable development has been defined by the World Commission on Environment and Development (WCED) as *"a development that ensures the needs of the present generation without compromising the ability of future generations to meet their own needs.* Sustainable development is generally seen as a multidimensional concept, of which the economic, social and environmental dimension are most often discussed.

Regarding the economic dimension, at the level of individuals, objectives of sustainable development are to achieve personal welfare by efficient allocation of scarce resources, to meet (at least) basic human needs, and to eliminate poverty. At the company level - an objective is to obtain and maintain a competitive market position. At the national and international level a main aim is to obtain and maintain a healthy economy. Finally, a key objective regarding the environmental dimension of sustainable development is to obtain and to maintain a healthy condition for humans, animals and plants. Protecting biodiversity and avoiding unacceptable environmental risks play an important role in this respect.

Biomass energy, with its many different faces, confirms this dual picture. A part of the traditional use of biomass, mainly for cooking and heating in developing countries, is not sustainable. One of the reasons for this is that, according to several authorities, it may contribute to desertification and other forms of land degradation. Unsustainable harvesting of biomass may also contribute to a decline of the worldwide carbon buffer in forests and thus affect climate change.

However, modem use of biomass, i.e. to produce electricity, steam and biofuels, has the potential to give a positive contribution to sustainable development. It is a source of CO_2 - neutral energy, which can reduce CO, emissions to the atmosphere when it replaces fossil energy carriers. Moreover, sustainable cultivation of energy crops has the potential to improve degraded land, e.g. by adding additional carbon to the soil and reducing the risk of erosion.

Regarding emissions, it is possible, to convert biomass into other energy carriers with little contaminating emissions, when there is good control of the combustion process.

Another important contribution to sustainable development is the potential of energy plantations to create new employment opportunities in rural areas. labour requirement of biomass energy is generally relatively high, especially regarding the cultivation of energy crops. Strongly related to this is the import substitution effect that local biomass energy production may have in developing countries.
http://www.biomatnet.org/secure/Other/S1265.htm

- **Environmentally Sustainable**

One of the key drivers to bioenergy deployment is its positive environmental benefit, in particular regarding the global balance of green house gas (GHG) emissions. IEA Bioenergy Task 38 (Greenhouse Gas Balances of Biomass and Bioenergy Systems) investigates all processes involved in the use of bioenergy systems on a full fuel-cycle basis with the aim of establishing overall GHG balances. This is not a trivial matter, because biomass production and use are not entirely GHG neutral. In general terms, the GHG emission reduction as a result of employing biomass for energy, read as follows:

Fig. 8: Budget breakdown of GHG emission savings

+	avoided mining of fossil resources
–	emission from biomass production
+	avoided fossil fuel transport (from producer to user)
–	emission from biomass fuel transport (from producer to user)
+	avoided fossil fuel utilisation

The real gains are made with the last issue, i.e. that of avoided emissions from the use of fossil fuels. There are indications that the balance of the other four matters is not neutral, and in fact slightly negative for the biomass system. Two GHG emission types are omitted from the above balance: the negative emission (capture) as a result of biomass growth, and the positive emission as a result from using the biomass fuel. They are considered to cancel out.

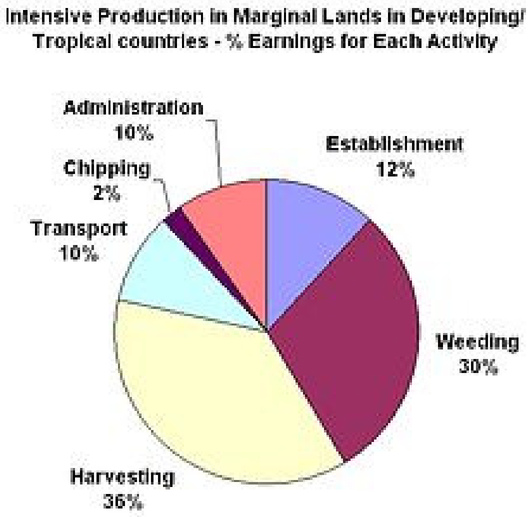
- **Socially Sustainable**

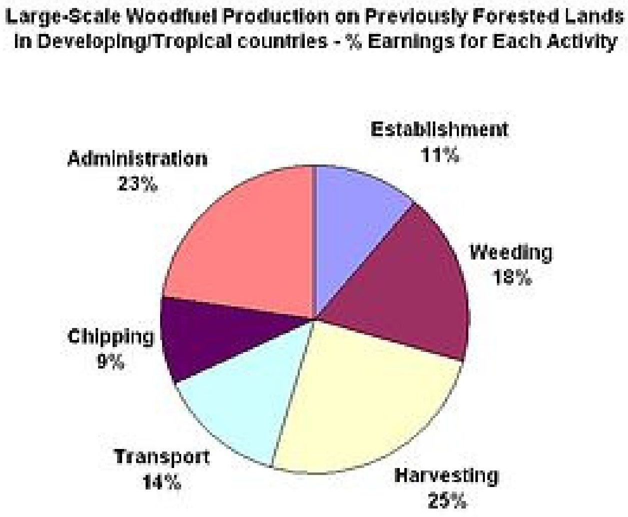
Employment Figures for Developing Countries:

The employment as reported from Domac, J. et al (2005) "Socio-economic drivers in Implementing Bioenergy Projects", Biomass & Bioenergy, shows the importance of bioenergy in developing countries. The objective is to increase the efficiency of this biomass utilisation, with better technology and application so they get the most out of the biomass available and to grow biomass at a sustainable rate which is not overtaken by consumption.

Country	Estimated Employment	Description and Nature of Employment
Pakistan	600,000	Many are involved in production, conversion, and transportation. Ratio between traders and gatherers is 1:5
India	3-4 million	The woodfuel trade is the largest source of employment in the energy sector
Philippines	700,000 (production) 140,000 (trade)	Biomass energy production and trade
Brazil	700,000	Ethanol Industry
	200,000	Charcoal Industry
Kenya and Cameroon	30,000	Charcoal production only
Ivory Coast	90,000	Charcoal production only

The follow graphs show the difference the Earnings for each activity of the bioenergy cycle in developing or tropical countries. The figures come from Hector, B., 2000, "Forest fuels-rural employment and earnings", Department of Forest Management and Products, SLU, SE-750 07, Upsala, Sweden. Depending on the type of bioenergy chain, the different activities vary quite considerably. For example administration costs account for 10% of intensive farming total costs whereas in large-scale woodfuel forestry it accounts for 23% of total cost. Also harvesting agricultural land is proportionally more costly than forestry with figures of 36% and 25% respectively. Many factors influence the differences, not just the physical differences in the biomass, between food crops and trees such as density, weight and bulk size but also the size of the estate, whether harvesting equipment is affordable for smaller producers.





Bioenergy is a decentralised energy option whose implementation presents positive impacts on rural development by creating business and employment opportunities. Jobs are created all along the bioenergy chain, from biomass production or procurement, to its transport, conversion, distribution and marketing. Bioenergy appears as the most labour-intensive sector among renewables. The jobs created range from manual ones to specialised engineering and administration positions. Through liquid biofuels, bioenergy can also offer agriculture an opportunity to diversify its market outcomes.

From the perspective of bioenergy projects, the term employment usually includes three different categories. Direct employment results from operation, construction and production. In the case of bioenergy systems, this refers to the total labour necessary for crop production, construction, operation and maintenance of conversion plants, and for the transportation of biomass. Indirect employment is jobs generated within the economy as a result of expenditures related to biomass fuel cycles. Indirect employment results from all activities connected, but not directly related, such as supporting industries, services and similar. The higher purchasing power, due to increased earnings from direct and indirect jobs may also create opportunities for new secondary jobs, which may attract people to stay or even to move in. These latter effects are referred to as induced employment. The main issue is whether the bioenergy project will provide earnings that are high enough for long enough to make it worthwhile to mobilise local resources for implementation.

- **Economic Sustainability**

The cost of biomass fuel supply depends on the cost of producing or recovering the biomass feedstock and costs incurred for its transport and pre-processing prior to use in ana electricity generation plant. Biomass feedstock costs vary widely from negative values, in the case of some residues requiring disposal, to relatively high costs in the case of some dedicated energy crops.

a) Biomass fuels are characterized by lower energy density compared to solid and liquid fossil fuels, the cost of transporting biomass fuels is, as a consequence, relatively high and transport distance plays an important role in biomass fuel economics, particularly road transport. Appropriate transportation methods will depend mainly on distance, but also on the transport infrastructure available and applicable regulations (e.g. maximum payload in terms of weight or volume transported).

Road transport may be suitable only for relatively short distances (< 150 km). other transportation methods, such as rail, barge and ship, would be preferred over longer distances, in general, road transportation contributes significantly to the delivered cost of biomass fuel.

b) Direct combustion of biomass in dedicated plants or co-firing with fossil fuels, mainly coal, are the main routes at present for electricity production from biomass. Dedicated bioelectricity plants are usually of modest scale (<50 MWe) because of the dispersed nature of biomass supplies, their low energy density and consequently high transportation costs. But, combustion systems using steam turbine based power generation are characterized by higher specific capital costs (€/kW) and lower efficiency at smaller scales, with the lower capacity limit for a combustion plant is estimated to be around 5 MWe. As a result, most existing plants have electrical efficiencies between 15% and 25% due to small scale and trade-offs between investments in more expensive equipment and efficiency reductions.

Gasification technology holds promise for electricity generation at different scales. At capacities between a few tens of kW and 5 MWe fixed bed gasifiers coupled with reciprocating engines and small turbines could generate electricity with efficiencies of about 25%.

At capacities above 30 MWe circulating fluidized bed gasifiers coupled with combined cycle steam and gas turbines could generate electricity with efficiencies between about 40 and 50%. However, gasification systems are currently and the pre-commercial stage and demonstration projects are required to prove the long-term reliability of the technology and reduce its cots.

The cost of electricity depends on the supply economics of biomass feedstock, power generation technology, scale of operation and the extent to which retrofit is possible in the case of co-firing or parallel-firing with fossil fuel (e.g. coal).

2 Pre-treatment technologies

2.1 Chipping

A forest chip production system consists in processing biomass into commercial fuel and transport it from source to plant. The main phases of chip procurement are purchase, cutting, off-road transport from stump to roadside, secondary transport from roadside to the utilisation unit. The system offers the organization, logistics and tools to control the process.

The efficiency of a procurement system is highly dependent on both the environment and the infrastructure in which it is operating. Economic, social, ecological, industrial and educational factors, as well as local traditions, also have an effect. Consequently, no single production system is optimal in all countries or in all conditions within a given country.

The integration of forest chip production with the procurement of roundwood opens up possibilities for cost savings. It is feasible to use the existing transport equipment for forest biomass when possible. However, due to differences in handling properties and destinations, special equipment is also needed.

Several alternative production systems are in use, and each system employs special equipment that is not necessarily compatible with other systems. Poor compatibility increases the commercial risks for contractors and plants when they invest in new equipment and it may result in underemployment and unnecessary shifting of harvesting machines and trucks from one site to another.

2.1.1 Technology overview

Before chipping starts it must be planned where the wood chips are to be stored or if they are to be loaded into containers. If the chips will be forwarded by the chipper, it is important that the distance is as small as possible. Often it will increase the productivity of the chipper if a tractor with a trailer is used to forward the chips from the stand to the storage or the container.

A chipper consists of a basic machine with an engine and a driver's cab. The front end is equipped with a chipping device and a crane which feeds the trees into the chipper. At the rear end there is a tipping container. There are purpose-built self-propelled chippers as well as systems based on a large agricultural trailer trailing a chip van. The feeding system of the chipper is equipped with a hopper to facilitate feeding and with hydraulic rollers pulling the trees into the chipper.

There are three basic chipper types:

- the disc chipper: consisting in a heavy rotating disc with rectangular grooves provided with knives running radially from the shaft. The chips produced by a disc chipper are fairly uniform
- the drum chipper: consisting in a rotating drum where knives are embedded in 2-4 longitudinal grooves in the curved surface.The chips produced are less uniform than those from a disc chipper

- the screw chipper: with this one the chips are cut by a conical screw with a sharp peripheral edge. Screw chippers can produce larger chips than disc chippers and drum chippers. Some types comminute the wood into chunks of 150 mm length. Chips from this type of chipper are usually wider as well.

The exploitation of whole-tree chips for fuel is of great significance to forestry as the production and sales of chips permit to carry out the necessary silvicultural measures.

Fig. 9

Fig. 10

Chips are typically produced in connection with three different forestall tasks:

1. Thinning of young conifer stands
2. Clear-cutting of old mountain pine stands
3. Clearing of residue from old spruce stands

In terms of volume the first two tasks are clearly the most dominating and they are also the ones where the wood chip production means most to forestry.

2.1.2 Technology production: Systems and handling of Forest Residues

The current technology of harvesting of forest residues and chips will be discussed. There are several methods to harvest forest residue fuel. Information on following subjects has been considered for the raw materials:

- Selection of production sites for harvesting of logging residues for fuel
- Yield of harvested logging residues for fuel
- Harvesting technology of forest residues for fuel
- Organisations that harvest logging residues for fuel
- Harvesting costs of forest residue chips for fuel
- Logging residue chips' quality
- Environmental impacts of harvesting logging residues for fuel

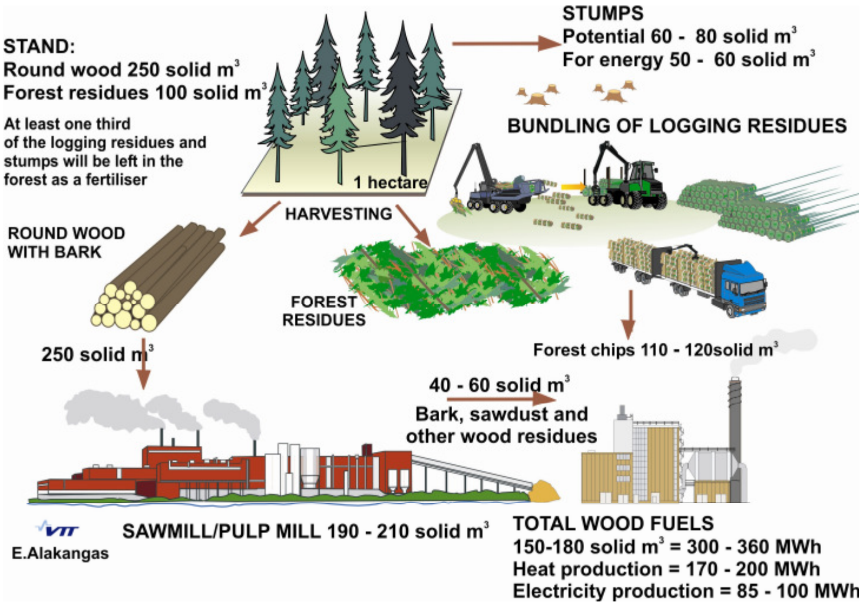


Figure 11: Yield of different wood products and fuel from 1 hectare of spruce stands for final cutting (VTT)

2.1.2.1 Logging residue production sites

On an atypical felling site of spruce, approximately 100 m3 solid of logging residue per hectare accrues while 200 to 250 m3 solid of merchantable wood per hectare is harvested. Nowadays recovery rate of logging residue is 65-75 % in Finland. Usually forest residue is harvested in summer time, when logging residue is dry. Swedish studies during winter indicated that the recovery rate of logging residue was 75 %.

A good harvesting site is described as:

- As much spruce as possible; good recovery rate and productivity.
- Fertile soil
- A sufficiently large felling site or a concentration of stands
- Easily traversed, well bearing ground,
- No undergrowth which hinders logging,
- Short terrain transport distance and,
- A spacious roadside storage area for long distance transport

Advantages of harvesting logging residue

- Nutrient leaching to waterways is decreased
- Soil preparation can be accomplished with less radical means
- More natural development in regeneration areas
- Because planting can be done earlier, regeneration areas are not covered with grass and there is less need for fighting against grass
- Planting is easier, it is often possible to use smaller sapling

- Aesthetic and recreational value of involved areas is enhanced
- Forest regeneration costs are remarkably decreased and
- Forest regeneration is faster and results are expected to be better.

Possible disadvantages of harvesting logging residue

- Organic material is removed from the nutrient cycle
- The amount of humus protecting the soil is decreased
- Some nutrients are removed from the ecosystem
- Risk of acidification is increased and
- Danger of growth losses.

2.1.2.2 Industrial timber harvesting

When working at a final felling site the harvester operator cuts trees on either one or both sides of the strip road. It is possible to harvest logging residue if the residue is located in fairly large, clearly delineated piles beside the strip roads and have not been run over. This requires that working methods are modified in such a way that logging residue is piled on either side of the harvester.

Harvesting logging residue is possible if:

- Logging residue is placed in fairly large and clearly delineated piles,
- They have not been run over by forest machines and
- Logging residue is piled on the side of strip roads.

When harvesting logging residue in piles:

- The recovery rate of logging residue is higher,
- The forest haulage of logging residue is more productive and
- Logging residue is cleaner and of better quality

2.1.2.3 Production technology of logging residues from final felling stands

A forest chip production system consists of a sequence of individual operations performed to process biomass into commercial fuel and to transport it from source to plant. The main phases of chip procurement are purchase, cutting, off-road transport from stump to roadside, comminution, measurement, secondary transport from roadside to mill and receiving and handling at the plant. The system offers the organization logistics and tools to control the process.

The main methods used for production of forest chips are:

a) 'Chipping at the roadside landing' method: logging residue are hauled to the roadside landing all year round from the surroundings of the terminal.
Specifications of a good logging residue chipper:

- High productivity
- Long feeding table
- Must have forced feed but be resistant to clogging
- Drum chippers are not as sensitive to impurities as disc chippers
- Drum chippers produce a more even quality of chips than crushers

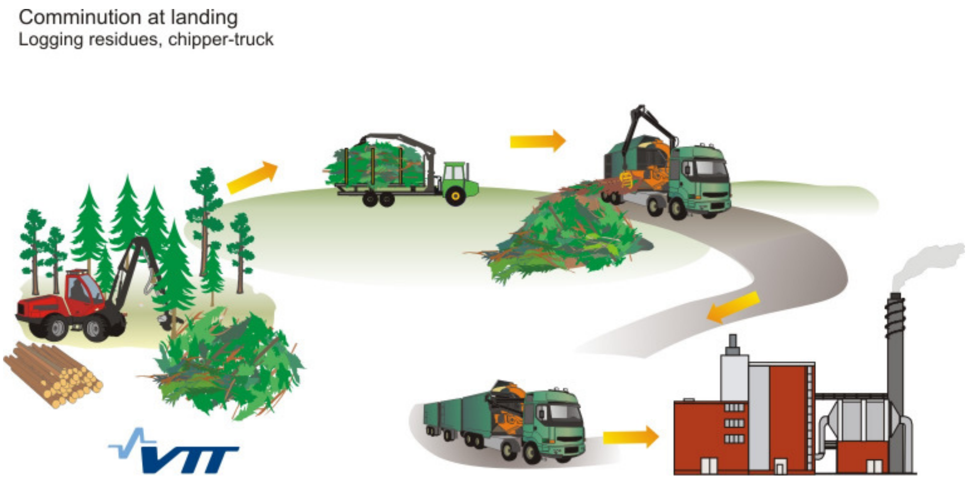


Figure 12 : Chipping of forest residue at the road side (VTT)

b) 'Chipping at the terminal' method: The production phases of the forest residues harvesting chain of forest residues for fuel based on the chipping at fuel terminal.

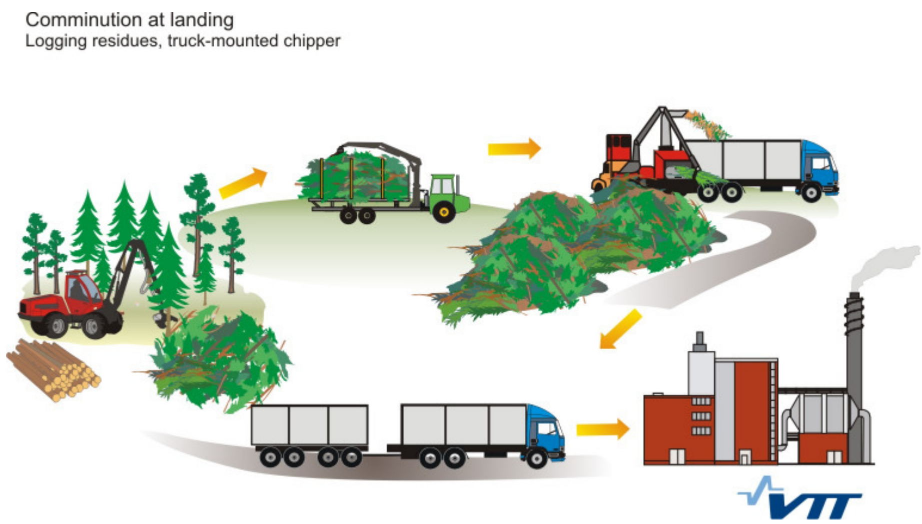


Figure 13 : Chipping of forest residue at the terminal (VTT)

c) ‘Chipping at the stand’ method: Terrain chipping is based on a single machine - the so called ‘terrain chipper’, which chips forest residues into a container at the stand and hauls the chips in a container to the landing or to the roadside.
The advantages and disadvantages of terrain chipping:

- Terrain chipping does not involve a hot chain
- Organisation of work is easier
- Storage space requirements are less than for roadside chipping
- It is difficult to produce good quality chips around the year
- Poor ability to work in difficult terrain conditions
- Competitiveness weaker in long forest haulage distances than it is in road side chipping

d) A promising alternative for transporting whole logging residues **is bundling before long distance transport and chipping at power plant.**

Chipping/crushing logging residue at the end use facility

- Hot chain problems are avoided
- Chipping/crushing can be done more economically than in terrain or by the roadside
- Productivity is 20% better than for roadside chipping
- Chipping at the end use facility is the most economical option when the transportation distance is less than 55km
- Lorry transport of logging residue is not economical without compacting
- The profitability of transportation can be improved either by compacting the load or extending the load space
- Heavy crane must be used

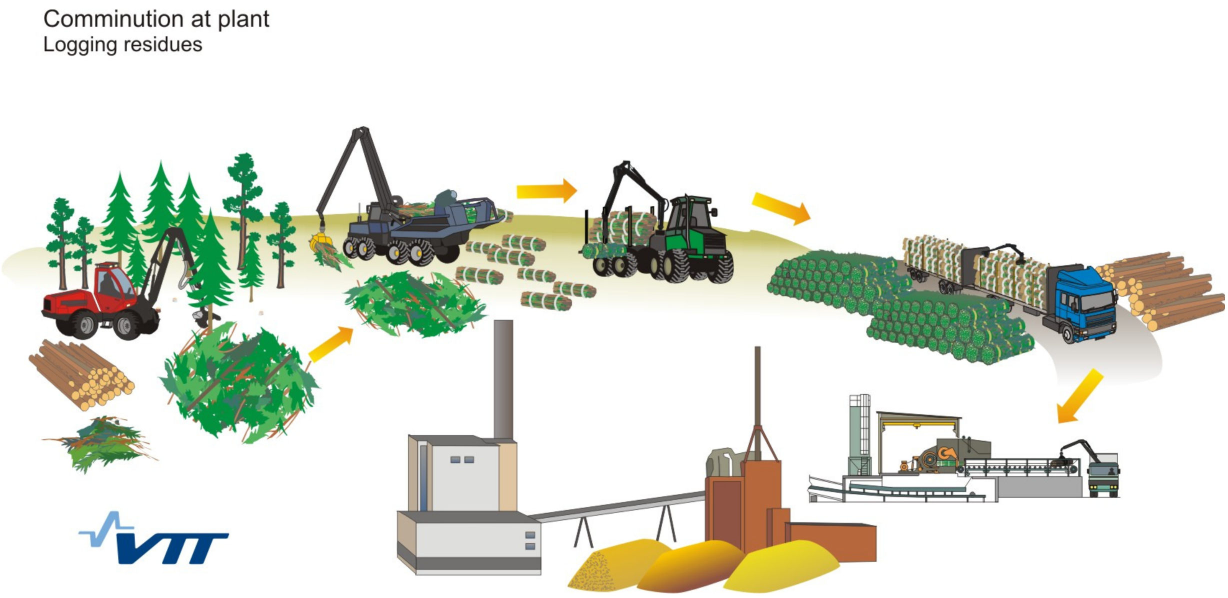


Figure 14: Bundled forest residue chipped or crushed at power plant (VTT)

2.1.2.4 Production of forest residues from thinning

Thinning attempts to replicate the forest's natural development, the aim normally being to achieve a uniform age composition. Thinning is used to ensure growing space for the forest's best trees by felling those with retarded growth and those which are diseased and of poor quality.

Many times the felling for wood thinning is made manually with a chainsaw, using a felling-piling technique. The smaller the harvested trees are, the more profitable it is to harvest them manually. Thus logging sites with only energy wood should be harvested manually using the felling piling method

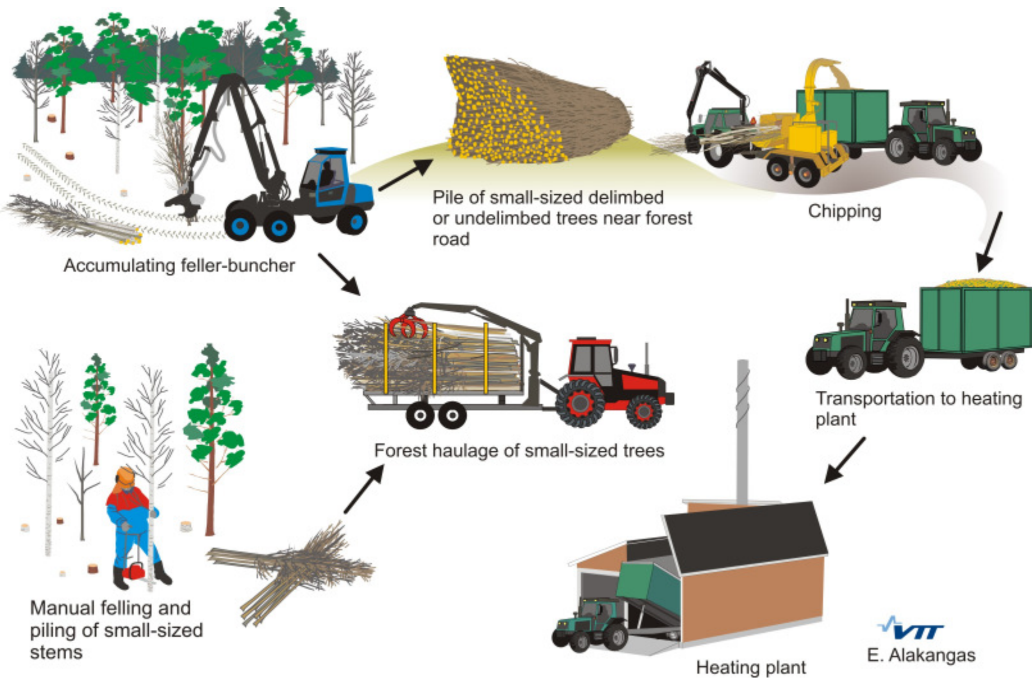


Figure 15: Whole-tree chip harvesting chain from first thinning and first commercial thinning when only wood fuel chips are produced (VTT)

2.1.2.5 Production of stump and root residue

The stump-root system is defined as all wood and bark of a tree below the stump cross-section. Stump-root systems can only be salvaged from clear-cutting areas. Extraction of stumps is carried out with heavy machines and, therefore, only stumps from saw timber-sized trees can be accepted. The removal of stump-root systems facilitates site preparation for regeneration. It also involves an opportunity to exterminate the root rot fungus from the stand, since the fungus survives in a regeneration area in the stumps and gradually infects the next generation of trees.

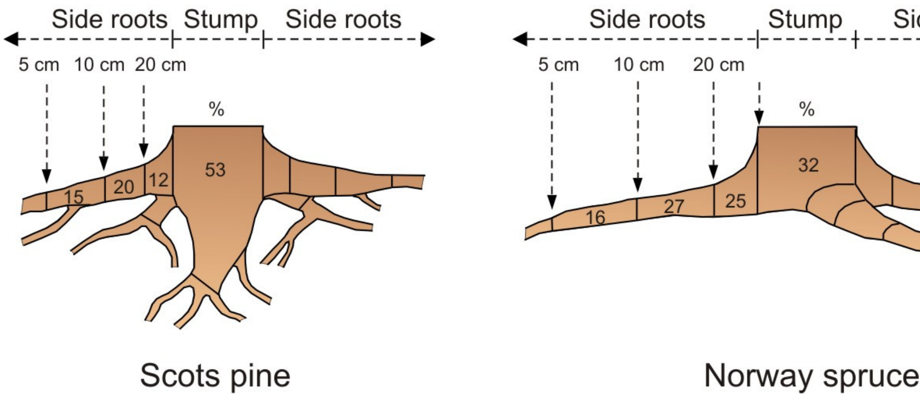


Figure 16: Distribution of dry mass in a stump-root system of saw timber-sized trees. Under 5cm root sections excluded (Hakkila 2004)

2.1.3 Main European pelleting mill manufacturers

2.1.3.1 Pezzolato S.p.a.

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12030 Envie (Cuneo) Italy
Tel: +39-0175-278077
Fax: +39-0175-278421
Email: info@pezzolato.it
Web: www.pezzolato.it

- ***Disk chipping machines***

The Pezzolato series "H" *disk chippers*, are made mainly to produce material for heating systems with screw feeding from small or big diameter logs. The material chipped through the action of knives, passes after micro-knives and additional knives put in the conveyor. This sequence guarantees a good calibration of the final product even for small diameter screws.

The range includes machines able to reduce the volume of large masses of green or dry material, including logs and branches with diameters from 10 to 25 cm. The feature that distinguishes chipping machines is the size of the inlet for the material to be chipped and the two toothed rollers which, via independent hydraulic activation, bring the material to the cutting flywheel, onto which the knives are attached. Long experience has allowed structuring this flywheel so to ensure the highest cutting efficiency over time, without any particular maintenance.

An electronic "no stress" protection device automatically adjusts the feeding flow of the material to be chipped, according to the available power and the effort that the quantity of chipping material takes. This device lengthens the life of the machine.

The chipped material is then expelled via the unloading conveyor equipped with an orientable deflector which allows directing the chip flow to the ground or in a container. PEZZOLATO chipping machines - meeting the requirements of our clients - can be operated either via the tractor power take off, or with an independent petrol, diesel or electric engine.

SPECIFICATIONS

Chipping machine model		***H 780/200***	***H 880/250***	***H980/300***
Tractor minimum power	Hp/kw	60/44	80/59	90/66
Diesel engine power	Hp/kw	60/44	80/59	150/110
Choppable max diameter	mm	200	250	300
Loading opening dimension	mm	1360x940	1460x1100	1620x1100
Disk diameter	mm	780	880	980
Disk thickness	mm	35	45	47
Knives	n°	3	2/4	2/4
Production per hour	mc	10/15	15/20	25/30
PTO version weight	Kg	920	1440	2040

SPECIFICATIONS

Chipping machine model		PZ100	PZ150	PZ250
Tractor minimum power	Hp/kw	13/10	20/15	no
Diesel engine power	Hp/kw	11/18	28/20 - 35/26	80/59-108/80
Loading opening dimension	mm	690 x 400	1110 x 730	1305x 886
Disk diameter	mm	520	680	1050
Disk thickness	mm	22	28	37
Knives	n°	2	2	2
Production per hour	mc	2/3	8/10	20/25
PTO version weight	Kg	365	750	1500

➢ ***Drum chipping machines***

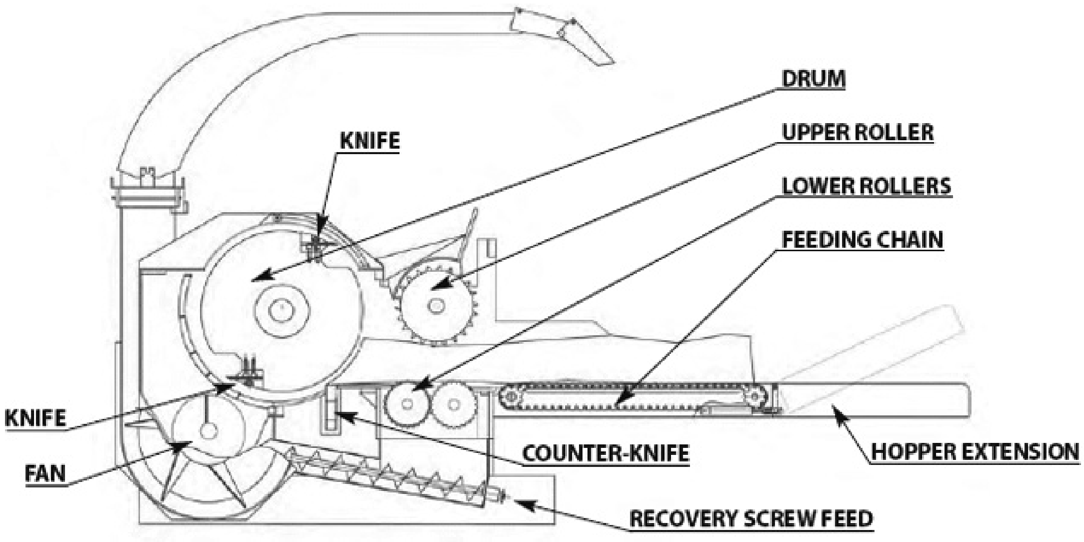
Pezzolato series "PTH" *drum chipping machines*, have remarkable advantages in comparison with the disk chippers because, dimensions being equal, the width of the feeding opening is very much wider and this helps the feeding of the chipping material (tops, brushes, etc.).

Then, it is possible to add a grille from which the chipped material comes out only when the wished size is reached: and even when low value material is chipped (dead branches, saw-mill waste, etc.), a final calibrated product is obtained; this is not possible with a disk chipping machine.

The chipped material is pushed by a screw towards the fan and expulsed by the discharge conveyor (adjustable at 360°).

The machines can be driven with a tractor PTO or a diesel engine, with a trailer for low or high speed.

The machines have a No Stress electronic device which adjusts the feeding in function to the available power.



PTH 1000/1000

Big dimension drum chipping machine

Especially indicated for forestry companies, consortiums, and energy production plants from biomass and for contracting companies that need to make a high production without renouncing quality of the chipped material. Interchangeable grids are in fact available for obtaining different sizes of chipped material. PTH1000/1000 can fill a 350q container in less than an hour.

SPECIFICATIONS

Chipping machine model		PTH 480/660	PTH 700/660	PTH 900/820	PTH 1000/1000
Tractor minimum power	Hp/kw	100/74	120/88	200/147	no
Diesel engine power	Hp/kw	170/125	230/169	300/220-430/316	430/316-590/434
Loading opening dimension	mm	480x400	640x400	950x400	1000x700
Disk diameter	mm	400	400	450	550
Knives	n°	2	2	2	2
Production per hour	mc	20/30	40/50	100/120	130/150
PTO version weight	Kg	4530	5300	12300	16500

2.1.3.2 Gandini Meccanica

Via della Valletta, 5
46040 Guidizzolo
Mantova - Italy
Tel.: +39 0376 818741
Fax: +39 0376 818465
e-mail: info@gandinimeccanica.com
web: www.gandinimeccanica.it

The series of chipping machine for the utilization in sites of media, big and large dimensions. Composed from six models for every specific requirement.

- ***Chipper line 04 series***

This type of chipping machine has been designed to solve the shredding problems in medium sizes yard.
04 MTS
The MTS version of chipping machines is equipped with a self contained engine, fixed axla and wheels and can be towed by any type of trunk into which can be loaded directly the chipped material. This version can be available with an air-cooled gasoline engine of 20 Hp or with a water-cooled diesel engine of 28 Hp and with a standard anti-noise protection cover.
04 TPS

This type of chipping machine has been designed to solve the shredding problems in medium sizes yard.
The TPS version is designed to be hitched at the hydraulic lift of any type of tractor and it is driven by the cardan joint.

- ***Chipper line 05 series***

This type of chipping machine has been designed to solve the shredding problems in medium/large sizes yard.
05 MTS
The MTS verison of chipping machines is equipped with a self contained engine, fixed axle and wheels and can be towed by any type of trunk into which can be loaded directly the chipped material.
05 TPS
This type of chipping machine has been designed to solve the shredding problems in medium/large sizes yard. The TPS version is designed to be hitched at the hydraulic lift of any type of tractor. The rotating feeding chute allows to be suitable for any requirement and need in working yard.

- ***Chipper line 09,13 series***

This type of chipping machine has been designed for the big yards of pruning and cleaning operations.
09-13 MTS
The MTS version is equipped with its own anti-noised engine. It is arranged to be towed by any type of truck on which is ejected the shredded material.
09-13 TPS
The TPS version of this range of chipping machines is designed to be hitched to the three point linkage of any tractor from which is powered by the PTO shaft.

Chipper line 35 series

35 TPS
This type of chipping machine has been designed for big yards of cutting operations.

The chips obtained from this machine are suitable for industrial purposes (paper, heating, pressed panel).

CHIPPER LINE	09 TPS	09 MTS	13 TPS	13 MTS	35 TPS
Power requireds by tractor [HP]	50/100	-	60/120	-	140/200
Power engine [HP]	-	50/60	-	80	-
Numbers of cylinders	-	4/4T	-	4T	-
Diameter of shuttle cock [mm]	850	850	850	850	1200
Cock's depth [mm]	45	45	50	50	60
Number of blades	3	3	4x2T	4x2T	3x2T
Production per hour [Kg]	5000	5000	6000	6000	40000
Chip's lenght	10/13	10/13	7/10/13	7/10/13	-
Max diametre of wood [mm]	260	260	280	280	-
Sending measures [cm]	170x224 x345	180x270 x230	170x224 x345	180x300 x230	-
Machinery's weight [Kg]	1000	1500	1200	2000	-
Chip's exit a 360°	O	O	O	O	O
Turning mouth	-	O	-	O	-
Dispositive NoStress	S	S	S	S	O
Counter	S	S	S	S	O
Electrical commands	O	O	O	O	O
Lights	S	O	S	O	-
Cardan tree	O	-	O	-	O
Soundproof coffer	-	O	-	O	-
O = optional - **S** = di serie					

2.1.3.3 Laitilan Metalli Laine Oy –Laimet

Garpintie 130, FIN-23800 Laitila
Tel: +359-2-856014
Fax: +358-2-856015
Email: laitilan.metalli@laimet.com
Web: www.laimet.com

The high efficiency LAIMET chippers are suitable for chipping all sorts of wood: sawn surfaces, tree tops, thinned out trees as well as logging waste. LAIMET chippers also chip frozen wood efficiently.

By changing the type of blade, chips of different sizes - ranging from 15 to 200 mm in length may be produced. The chips produced are even and splinter-free, and are suitable for heating purposes, as pulp chips, as mulch in horticulture, as animal litter, in covering cultivated land and fields, in composts, when building up green areas, etc. LAIMET chippers are number one in productivity, with efficiency remaining high even in demanding conditions. Operation is quiet, construction is simple, and there are few parts that wear out.

All LAIMET chippers are tractor or diesel engine powered. However, electrically driven versions of the models HP-21, HP-25, HP-35 and HP-50 are also available.

- *PS 10 Series*

The LAIMET PS-10 is a tractor driven, handy and efficient chipper intended for use on farms, in forestry, and in parks and gardens. The operation is based on a cylindrical screw blade, which also functions as a feed unit making a separate manual feed unnecessary. The screw blade is sharpened without removing the blade, using a separate sharpening unit (standard equipment).

The LAIMET PS-10 produces splinter-free and even one-size chips (10-15 mm). The rate of production ranges from 2-6 m3/h. The PS-10 can chip all sorts of wood and branches of sizes up to 100 mm.

The LAIMET PS-10 is reliable in operation and need little maintenance. It is a sensible choice when otherwise worthless waste is to be utilized, or if the chips are to decompose in the environment.

- *HP-21 Series*

The LAIMET HP-21 is a tractor or diesel powered reliable basic chipper for agricultural and forestry use, as well as for contract chipping.
Like all LAIMET HP chippers, the HP-21 uses a conical screw blade, which efficiently produces splinter-free and even quality chips of five different sizes, ranging from 15-25 mm up to 60-100 mm.

The rate of production ranges from 20 to 40 m3/h, depending on the blade used as well as the size and type of the wood. The HP-21 can chip all sorts of wood and branches of sizes up to 180 mm.

Two electrically driven versions of the LAIMET HP-21 are also available: the HP-21 LS (low speed) and the HP-21 HS (high speed).

The high-quality chips produced by the LAIMET HP-21 are suitable for use in heating, in covering cultivated land and fields, in composts, as pulp chips, and as animal litter. The low service costs of the LAIMET HP-21 offer you great savings.

- *HP-21 LS TR, HP-21 LS, and HP-21 HS series*

Laimet HP-21 LS TR is a tractor driven LowSpeed chipper. The needed power source is relatively low. The chip outlet pipe is lower than other tractor driven models, it's anyway able to blow the chips in to a agriculture tractor trailer.

The needed gearbox to reduce the speed is a Finnish made Peurala gear

Laimet HP-21 LS is the reasonable chipper to the saw mills and wood industry to chip the sawn waste material, slabs and other residue material. The chipper is relatively quiet, it doesn't need any additional noise protection. The chip quality is suitable for the heating plants and middle size heating owens. When screening the chips can be used for the pulp/paper industry.

The gear motors we are using are the famous and thrustable NordGear and SEW-products.

Laimet HP-21 HS is an electric motor driven chipper especially for the wood industry and sawmill needs to produce the best quality of pulp / paper chips. The common chip quality without any screening is 104...110 %.
HP-21 HS Slope- model is a special chipper to chip the cross cut pieces and other small and short pieces of wood.

- *HP-25 Serie*

The LAIMET HP-25 is a tractor or diesel powered heavy chipper for professional use. Like all LAIMET HP chippers, the HP-25 uses a conical screw blade, which efficiently produces splinter-free and even quality chips of five different sizes, ranging from 15-25 mm up to 60-100 mm.

The rate of production ranges from 40 to 120 m3/h, depending on the blade used as well as the size and type of the wood. The HP-25 can chip all sorts of wood and branches of sizes up to 230 mm. Two electrically driven versions of the LAIMET HP-25 are also available: the HP-25 LS (low speed) and the HP-25 HS (high speed).

The LAIMET HP-25 is a sensible choice for the chipper contractor. The high-quality chips are suitable for use in heating, in covering cultivated land and fields, in composts, as pulp chips, and as animal litter. The low service costs of the LAIMET HP-25 offer you great savings.

Laimet HP-25 LS is a robust and strong chipper for the wood and saw mill industry. This chipper is especially made to meet the requirements of effective chipping and good quality. There are three different size of HP-25 LS chippers; the wood diameter can be 23 cm, 25 cm or even 28 cm. Two bigger modal are named "HP-25 LS MAXIM".

The alterations for MAXIM-models are the modified and stronger bottom anvil, the strenghtened frame of the chipper and the wider feding opening for the wood. The feeding chute of MAXIM-models is stronger as well.

Laimet HP-25 HS is an electric motor driven chipper especially for the needs to produce big quantities of the best quality of chips. The range of users are the big wood indystry companies and big saw mills.The normal chip quality, without any screening, is app. 104 to 110%.

HP-25 HS model is the reasonable chipper e.g. for the big plywood factories, saw mills etc.

- *HP-35 series*

The LAIMET HP-35 is a tractor or diesel powered heavy chipper for professional use. Like all LAIMET HP chippers, the HP-35 uses a conical screw blade, which efficiently produces splinter-free and even quality chips of five different sizes, ranging from 15-25 mm up to 60-100 mm.

The rate of production ranges from 80 to 140 m3/h, depending on the blade used as well as the size and type of the wood. The HP-35 can chip all sorts of wood and branches of sizes up to 280 mm.

The LAIMET HP-35 is a sensible choice for the chipper contractor. The high-quality chips are suitable for use in heating, in covering cultivated land and fields, in composts, as pulp chips, and as animal litter. The low service costs of the LAIMET HP-35 offer you great savings.

- *HP-50 Series*

The LAIMET HP-50 is a diesel powered heavy chipper for professional use. It is the largest of the LAIMET chippers, intended primarily for producing large timber pieces for heating.

Like all LAIMET HP chippers, the HP-50 uses a conical screw blade, which efficiently produces splinter-free and even quality chips of three different sizes, ranging from 20-30 mm up to 100-150 mm.

The rate of production ranges from 100 to 200 m3/h, depending on the blade used as well as the size and type of the wood. The HP-50 can chip all sorts of wood and branches of sizes up to 500 mm.

The LAIMET HP-50 is a sensible choice for the large chipper contractor. The high-quality chips are suitable for use in power stations, in composts, or wherever there is a special requirement for large chips. The low service costs of the LAIMET HP-50 offer you great savings.

A special chrusher for HP-50 is available. This equipment will crush the possible big pieces of wood to be suitable for the gasifying process.

	HP-21	**HP-21 LS**	**HP-21 HS**
Total weight	1000 kg	1300-1500 kg	1600-1700 kg
Rotating mass	360 kg	360 kg	360 kg
Chip production	20-40 m^3/h	10-40 m^3/h	20-40 m^3/h
Power requirement	60-80 kW	22-37 kW	45-75 kW
Feed opening	210 x 315 mm	210 x 315 mm	210 x 315 mm
Feed rate	0,4-0,8 m/s	0,1-0,3 m/s	0,5-1,3 m/s
Rate of rotation	540-1000 r/min	122-205 r/min	600-1000 r/min
Blade (length of piece)	3/104 (15-25mm) 2/80 (20-30mm) 3/160 (20-30mm) 2/104 (20-30mm) 1/80 (30-50mm) 2/160 (30-50mm) 1/104 (40-70mm) 1/160 (60-100 mm)	2/80 (20-30mm) 3/160 (20-30mm) 2/104 (20-30mm) 1/80 (30-50mm) 2/160 (30-50mm) 1/104 (40-70mm) 1/160 (60-100mm)	3/104 (15-25mm) 2/80 (20-30mm) 3/160 (20-30mm) 2/104 (20-30mm) 1/80 (30-50mm) 2/160 (30-50mm) 1/104 (40-70mm) 1/160 (60-100mm)

	HP-25	**HP-25 LS**	**HP-25 HS**
Total weight	1800 kg	2500-2600 kg	2350-2500 kg
Rotating mass	800 kg	800 kg	800 kg
Chip production	40-120 m^3/h	10-40 m^3/h	40-120 m^3/h
Power requirement	100-200 kW	37-55 kW	45-90 kW
Feed opening	250 x 430 mm	250 x 430 mm	250 x 430 mm
Feed rate	0,4-0,8 m/s	0,1-0,3 m/s	0,5-1,3 m/s
Rate of rotation	540-1000 r/min	122-205 r/min	600-1000 r/min
Blade (length of piece)	3/104 (15-25mm) 2/80 (20-30mm) 3/160 (20-30mm) 2/104 (20-30mm) 1/80 (30-50mm) 2/160 (30-50mm) 1/104 (40-70mm) 1/160 (60-100 mm)	2/80 (20-30mm) 3/160 (20-30mm) 2/104 (20-30mm) 1/80 (30-50mm) 2/160 (30-50mm) 1/104 (40-70mm) 1/160 (60-100mm)	3/104 (15-25mm) 2/80 (20-30mm) 3/160 (20-30mm) 2/104 (20-30mm) 1/80 (30-50mm) 2/160 (30-50mm) 1/104 (40-70mm) 1/160 (60-100mm)

	PS-10	**HP-35**	**HP-50**
Total weight	130 kg	3000 kg	6500 kg
Rotating mass	30 kg	1300 kg	2100 kg
Chip production	2-6 m^3/h	80-140 m^3/h	100-200 m^3/h
Power requirement	15 kW	200-300 kW	400-500 kW
Feed opening	100 x 100 mm	400 x 430 mm	600 x 700 mm
Feed rate	0,1-0,4 m/s	0,4-0,5 m/s	0,2-0,5 m/s
Rate of rotation	200-600 r/min	540-1000 r/min	100-200 r/min
Blade (length of piece)	2/85 (10-15mm)	3/104 (15-25mm) 2/80 (20-30mm) 3/160 (20-30mm) 2/104 (20-30mm) 1/80 (30-50mm) 2/160 (30-50mm) 1/104 (40-70mm) 1/160 (60-100mm)	2/104 (20-30mm) 1/104 (40-70mm) 1/220 (100-150mm)

2.1.3.4 Silvatec Skovmaskiner Aps

Silvatec Skovmaskiner A/S
Fabriksvej 6
DK-9640 Farsø, Denmark
Tel: (+45) 9863 2411
Fax: (+45) 9863 2522
E-mail: silvatec@silvatec.com
Web: www.silvatec.com

Production, sale and service of SILVATEC forestry machines, harvesting heads and self propelled chipping machines. Production, import, sales and service of the huge Silvatec programme of specialized machinery for Christmas trees, decorative greenery and other row cultures within the forestry environment.

SILVATEC 878 CH CHIPPER

Chipping unit:
Chipper SILVATEC 1200, disc diameter 1200 mm, front feeding, feeding speed up to 70 m/min., 2 knives, infeed opening 350 x 350 mm, feeding power: 2000 kp, infeed chute with tiltable bottom plate, length of chips : 15 - 35 mm.

Engine:
MERCEDES OM 906 LA, Intercooler 205kW/278 HP/2300 rpm. Max. torque 1100 Nm from 1250 to 1500 rpm. Fuel capacity: 350 l.

Transmission:
Hydrostatic-mechanical. Two mechanical gears. Bogie axles with planetary gears. All wheel drive/transfer gear box with differential. Traction approx. 12 tons. Differential lock front and rear.

Speeds :
1st gear: 0 - 6.5 km/h
2nd gear: 0 - 26.0 km/h

Brake system: Built-in wet multiple disc brakes. Spring brake as parking brake.

Hydraulic system:
Hydraulic oil capacity: 200 l. 140 l/min/2000 rpm. for the crane and the chip container. 2 separate pumps for the feeding rollers, capacity 2 x 90 l/min./2000 rpm. For cooling and filtration circuit 80 l/min/2000 rpm. Load-sensing pressure system, separate pumps for crane and feeding system, total 280 l/min. Oil cooling with circulation and filtration system. Working pressure 210 bar.

Steering system:
Articulated frame steering +/- 50 degrees. Steering with proportional levers and orbitrol steering.

Electrical system:
24 volt. Alternator 200 Amp. 10 working lamps, 70 W.

Crane:
CRANAB CRH 3 parallel crane, reach 6.0 m, lifting torque 36.3 KNm, slewing torque 10 KNm, slewing angle 250 degrees, rotator GV3, grapple CRANAB I15.

Cab:
ROPS, FOPS and OPS approved. Rubber mounted. Double LEXAN screens (noise insulating and safety). Heat and air conditioning. Air-suspended driver's seat with adjustable armrests. Radio/CD.

Tyres:
600 x 22.5 (standard)
700 x 22.5

Dimensions:
Length 9850 mm. Width from 2170 mm to 2600 mm dependent on tyre dimensions. Weight approx. 19500 kg. Ground clearance: 580 mm.

Chip-container:
Placed over rear bogie, capacity approx. 16 m3, high rearward tipping with built-in cylinders, self-levelling system for the container +/- 10 degrees. Indicator of full container.

Equipment:
Monitor in the cabin, camera at the back of the container. 6 kg fire extinguisher. Filling system for fuel and hydraulic oil. Hazard light and warning triangle.

Options:
Extra working lamps.
Vacuum pump on the hydraulic system.
Horizontal feed roller on infeed chute.

2.2 Pelletisation

2.2.1 Densification-related advantages

Some practical problems are associated with the use of biomass material (sawdust, wood chips or agricultural residues) as fuel, mainly related to the high bulk volume, which results in high transportation costs and requires large storage capacities, and to the high moisture content which can result in biological degradation as well as in freezing and blocking the in-plant transportation systems.

In addition, variations in moisture content make difficult an optimal plant operation and process control.

All those problems may be solved by densification of biomass, which consists in compressing the material to give it more uniform properties. The main advantages of densified fuels, compared to non-densified ones are the following:

- An increased bulk density (from 80-150 kg/m^3 for straw or 200 kg/m^3 for sawdust to 600-700 kg/m^3 after densification), resulting in lower transportation costs, reduced storage volume and easier handling.
- A lower moisture content (humidity <10%), favouring a long conservation and minor losses of product during the storage period.
- An increased energy density and more homogeneous composition, resulting in better combustion control possibilities and thereby higher energy efficiency during combustion.

The major disadvantage is the relatively high-energy cost for the pelleting process, increasing the price of the end product.

Densified products can be found as briquettes or as pellets.

Heating value, Moisture content and Chemical characteristics are more or less the same for both but the density and strength are a little bit higher for pellets.

The major difference is the size, making pellets easy to use in fully automatic operation, from household appliances to large-scale combined heat and power (CHP) plants.

Comparison between briquettes and pellets

	Briquettes	Pellets
Appearance		
Raw material	Dry and grinded wood or agricultural residues. Raw material can be more coarse than for pelleting, due to the larger dimensions of final product	Dry and grinded wood or agricultural residues
Shape	Cylindrical (generally Ø 80 to 90 mm) or parallelepiped (150*70*60 mm)	Cylindrical (generally Ø 6 to 12 mm, with a length 4 to 5 times the Ø)
Structure	Relatively friable, fragile	Stable, hard, without dust
Bulk density	600 – 700 kg-m3	600 – 700 kg-m3
Aspect	Mostly "rough"	"Smooth"
Transport	Unit, palet	Bulk, bags, big bags
Handling	Manual use	Manual or automatic use

Source: http://www.itebe.org/telechargement/pelletclub/promill220501.ppt

2.2.2 Pelletising technology overview

The process of pellet manufacturing was first developed for the livestock feed industry. The main steps are (see figure below):

- comminuting of the raw material,
- drying, palletising, cooling

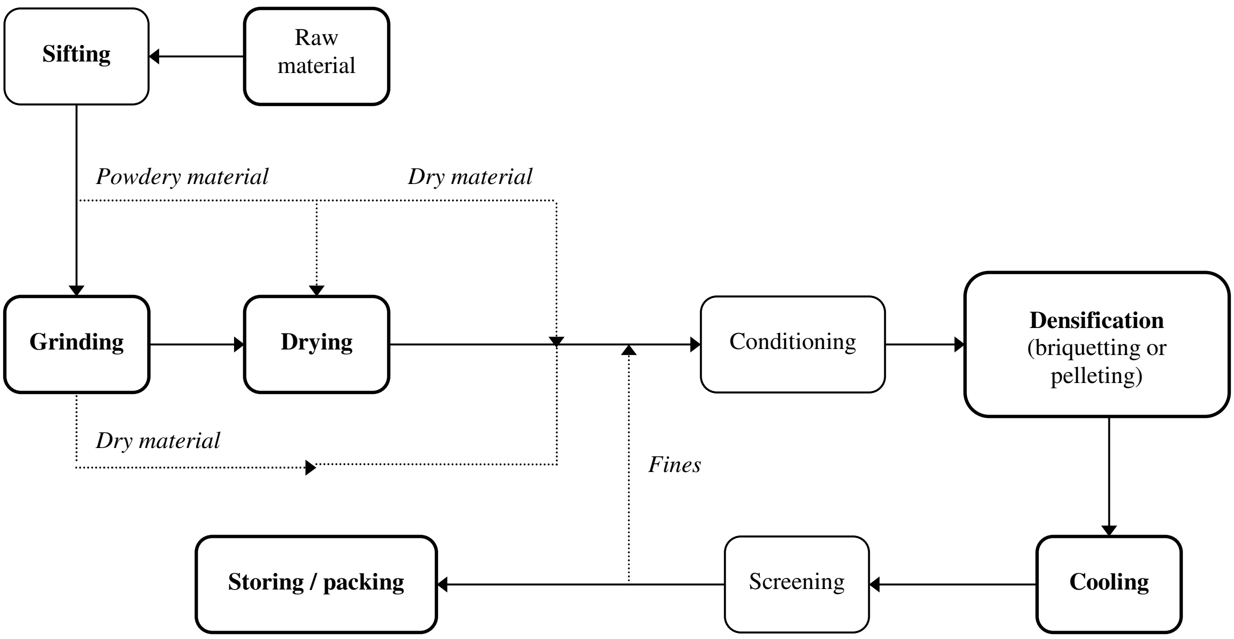


Fig 17: Basic steps of densification processes

The raw material is first freed from heavy contaminant (rocks, metals and other foreign material), and then grinded in a hammermill or a chipping machine. The particle size has to be uniformised to maximum dimension (approximately 85 % of the minimum thickness of the pellet to be produced).

The often-high moisture content of the raw material makes drying necessary. The product from the hammermill is afterwards transported to a dryer (generally a rotary drum type one) where the moisture content of the uniformly dimensioned particles is reduced to about 10 %.

Generally lignin content in wood is high enough to bind alone the wood pellets, but if other raw material are pelletised (e.g. straw), the feedstock can be conditioned with steam.

The conditions required for this process is a cascade mixer and the addition of steam at 90-100°C in the proportion of 5% of raw material's weight. The use of binding agents has also been investigated as a means to increase fuel pellets hardness and thus reducing the dust and fines generated during their transport and handling. Possible binding agents for wood include starch, molasses, natural paraffin, plant oil, lignin sulphate and synthetic agents.

After that, particles are moved to the pellet mill, where the pellets are extruded through the action of rollers acting on a perforated matrix. On the outer side, a knife cut off the pellets at the desired length.
Two main types of pellet presses can be distinguished:

- flat die types: has a circular perforated disk on which two or more rollers rotate and force the material through the holes.
- ring die types: features a rotating perforated ring on which rollers (normally two or three) press on the material to the inner perimeter.

Generally, the same pellet mills are used for pelleting wood and straw, but from one product to another, steel dies and rollers are changed. For straw (in comparison with sawdust), the thickness of the dies has to be more important.

The typical power value for pellet presses on the European market can be considered to stand between 200 and 500 kW.
Small experimental devices can be found from 3 kW power, the biggest mills scoring over 550 kW.

The output range for pellet presses ranges from about a few hundreds of kg up to 10 ton/h, the most common ones being 4-6 t/h. In relation with the quality of the raw material, milling production yields are usually higher for straw than for wood. For example, with the same pellet press of 250 kW, a 4 t/h output can be expected for wood pellets, and a 5t/h output for straw pellets while it would amount 20 t/h for feeding granulates (which do not meet the same quality standards).

Finally pellets are screened. Generally, it is reported that at the exit point of the press sawdust pellets present a 3-4% of fines, whereas for straw, fines proportion could amount 10%.

In most cases, those fines are re-used in the process, whether as a fuel in a combustion device or as raw material in the pellet mill.

A European company has developed a pelletising technology whose process is new: the pellet mill has two dies, and raw material is pressed between them from outside towards the inside cavity of each dye. According to technical specification, specific electric consumption ranges from 25 to 45 kWh/t depending on the type of wood.

The system operates without the need of any additives and maximum operating temperature of the dies is 55 to 60℃ which avoid vapours emissions and permit direct bagging without cooling stage, which lower the investment costs. Another advantage is that material with up to 30 to 35% humidity can be handled, thereby doing away with the need for a dryer.

In Europe, pellets are mainly made from sawdust and wood chips (softwood as well as hardwood). Until now, agricultural residues are hardly used because they present a higher ash content, which further induces problems regarding slagging, fouling and dust emissions during the combustion phase.

General characteristics of straw pellets, and wood pellets and their respective raw materials

	Density (kg/m^3)	Moisture (% w.b.)	LHV (MJ/kg)	Ash (% d.m.)	Energy density (GJ/m^3)
Straw (chopped)	50	10-20%	14.5	5	0.7
Straw (big bales)	130	10-18 %	14.5	5	1.9
Straw pellets	600	<10 %	15.0	5	9
Wood chips	250	10-50 %	11-17	0.5	4.3
Sawdust	200	20-50 %	12-17	0.5	3.4
Wood pellets	650	<10 %	17.5	0.5	11.4
Coal	850	10-15 %	24	12	20.4

LHV (Lower heating value) varies according to moisture content; Energy density are calculated for dried material.

Energy demand for wood pelletising (including all stages from grinding to cooling) is generally comprised in the large range of 80 to 150 kWh/t for electricity with up to 1000 kWh/t for heat consumption required for the drying of raw material if the latter is very wet.

2.2.3 Main European pellet mill manufacturers

Below is given a list (alphabetical order) of the main pellet mill manufacturers in Europe.

2.2.3.1 Amandus Kahl

Dieselstrasse 5-9, D-21465 Reinbek, Germany
Tel: +49(40) 727 71-0, Fax: +49(40) 727 71-100
Web: www.amandus-kahl-group.de

The current production range of Kahl flat die pelleting presses consists of 12 different sizes: die diameter 175 - 1,250 mm; drive motor 3 - 400 kW; roller diameter 130 - 450 mm; pellet diameter 2 - 40 mm. Slip-on gears drive the small presses, while low-noise and low-wear worm gears with preceding belt drive the big presses.

Pellet presses for producing small (14-175) medium and large quantities

Type	**14-175**	**33-390**	**33-500**	**34-600**	**38-600**	**38-780**	**37-850**	**39-1000**	**45-1250**	**60-1250**
Die diameter mm	175	390	500	600	600	780	850	1000	1250	1250
Roller diameter/width mm	130/29	230/77	230/77	280/102	280/102	280/102 or 350/102	350/132	450/156	450/192 or 450/156	450/192
Number of rollers	2	2	3	3-4	3-4	3-5 or 3-4	3-5	3-5	4-5	4-5
Drive motor kW/min^{-1}	3	15-30/ 1500*	15-30/ 1500	45-55/ 750	55-75/ 1500*	90-110/ 1500*	132/ 1500*	160-200/ 1500*	200-250/ 1500*	2 x 160-200 /1500*
Roller speed m/s	0.5-0.8	2.2	2.4	2.7	2.6	2.6	2.5	2.6	2.7	2.6
Perforated die area cm^2	106	617	840	1382	1382	1916	2695	3850	5900	5900
Machine weight kg with motor	260	1150	1300	2330	2250	3000	4600	5400	9000	9370

The dimensions indicated refer to the biggest drive motor available.*other speeds possible

2.2.3.2 Bühler AG

CH-9240 Uzwil, Switzerland
T.: +41(71)9551111
F.: + 41 (71) 955 33 79
Web: www.buhler.ch

Buhler develops wood pelleting process by further developing its technological expertise from the field of animal feed manufacture. The latest pellet mill generation is capable of achieving a throughput of 4.5 to 6 metric tons per hour with a pellet diameter of 6 millimeters. With an installed power of merely 250 kilowatts and a die diameter of 900 millimeters, this throughput capacity is second to none. The pellet mill sold last, which was supplied to Southern Germany, exceeded the guaranteed capacity of 4.5 metric tons per hour within an extremely short time. The capacity of one Pellet Press RWPR (picture) is 5 to 6t/h wood pellets.

2.2.3.3 M.B.Z. Günther Zahn Mühlen- und Pelletiertechnik

Ostpreußenstraße 59 40822 Mettmann-Obschwarzbach
+49 2058 / 89 59 09 +49 2058 / 89 66 86
info@mbz-pelletpressen.de www.mbz-pelletpressen.de

M.B.Z. pellet mills are constructed of very sturdy, high quality materials. Their designs allow quick and easy access to all parts of the machine. The design also includes high dynamic and static load bearings for working under harsh conditions with products such as alfalfa, pulp, trash, etc.

The compact design positions the motor at the top of the pelletiser and uses direct belt transmission for smooth operation and reduced installation space. Two-motor models feature an auxiliary transmission that drives the core unit by means of a Special, High Performance Gear tooth Belt. The machine also includes safety interlocks that stop the machine if opened or overloaded. All models can be supplied with two mould widths, with no modification of power. A large diameter, three-roller system achieves better balance by reducing the force exerted on the mould, thus extending its life. Optional: Large capacity Feeder-Conditioner MDG and Thermo-conditioner, depending on the product to be pelletised.

MODEL		M.B.Z.-40	M.B.Z.-100	M.B.Z.-150	M.B.Z.-180	M.B.Z.-220	M.B.Z.-270	M.B.Z.-300	M.B.Z.-360	M.B.Z.-440
Main motor	HP	30-40	75-100	125/150	180	220	270	2 x 150	2 x 180	2 x 220
-M 1-	Kw	22-30	55-75	90-110	132	160	200	2 x 110	2 x 132	2 x 160
Mixer motor	HP	3	7,5/15	10/20	25	30	40	40	60	60
-M 2-	Kw	2,2	5,5-11	7,5-15	18,5	22	30	30	45	45
Dosing unit	HP	0,75	1,5	3	4	4	4	4	4	4
-M 3-	Kw	0,55	1,1	2,2	3	3	3	3	3	3
Inside die Ø	mm	280	354	452	550	650	750	750	850	950
Ext. central die Ø	mm	360	445	560	664	780	900	900	1.010	1.120
Die track width	mm	60	103/125	113/150	150/177	172/200	200/245	245	200/260	280/300
Totale die width	mm	106/135	155/177	180/217	217/244	275/303	310/340	340	310/370	385/405
Effective die surface area	mm^2	52.778	139.015	213.000	305.835	408.407	577.267	577.268	694.292	895.353
Die speed	m/seg	5,5	5,5	6,5	5,5/7	5,5/7	5,5/7	5,5/7	5,5/7	5,5/7
Weight	Kgs	1.180	2.850	4.440	6.664	8.600	11.600	13.620	12.500	14.000
Volume	m^3	2,1	3,6	5,2	8,8	12.5	15.7	22.9	24.2	26.6

2.2.3.4 Münch Edelstahl GmbH

Weststraße 26, D-40721 Hilden, Germany
Tel:+49 (0)21 03 58 99-6, Fax:+49 (0)21 03 58 99-77
Web: www.Muench-Edelstahl-GmbH.de

Münch manufactures for wood pelletising pellet presses and complete lines including eventual necessary pre-grinding in the range of 0,2-10 ton/h. Münch has developed a special design for wood particles with a moisture content of up to 50%, which is unique in the market of wood pelletising. The pellet presses have, if required, an oil lubrication system, which increases the operation time. Münch pellet presses can also be used for hardwood and MDF, are easy to maintain and need only short maintenance periods. Automatic control, temperature control and sprinkler equipment are options which Münch can provide on request. Tests can be done in Münch own testing centre.

Münch pelletmills RMP are operating on all continents and range from 7-450 HP, single or twindrive, are extendable to double-pelleting, longterm-conditioning, fat-coating at the die and automatic control. By vertical feeding and low speed of rotation, these pelletmills are most suitable for the processing of difficult products, such as straw and grass.

2.2.3.5 Promill Stolz

RN 12 - F-28410 Serville, France
Tel: +33 (0)2 37 38 91 93, Fax: +33 (0)2 37 43 21 84
Web: www.promill-stolz.fr

Promill Stolz manufactures a wide range of pellet mills, robust and high performance mechanical systems. The resulting pellet quality complies with the most severe commercial standards. Promill Stolz is the partner of a wide national and international clientele working in the wood transformation sector. This company produces hammer crushers (refiners), chip presses, cooling apparatus and offers technical support in the creation of whole units.

Its main strength: its activity is export-orientated. Among its clients are some the major pelletization units such as Brikettenergi in Sweden (www.brikettenergi.se), Hansa Graanul in Estonia (www.hansagraanul.ee) which produces by itself 80,000 tons of wood pellets annually which is five times the French production or Flexheat with its 20 annual output and, finally BVG in Lithuania. On the picture: "Evolution" pellet mill, 200-250 kW power, with a capacity of 2.5 to 4 t/hour.

2.2.3.6 Salmatec - Salzhausener Maschinenbautechnik GmbH

Bahnhofstraße 15 D-21376 Salzhausen, Germany
Tel +49 4172 98 97-0 Fax +49 4172 13 94
Web: www.salmatec.de

Salmatec manufactures and delivers pelleting technologies for the densification of numerous materials i.e. plastics, paper, wood, fertiliser etc. Rotating die (internal diameter from 450 mm to 950 mm) and motor capacities from 44 to 400 KWh for the manufactoring of wood-pellets and similar products. Salmatec offer specially reinforced modifications to three of the Maxima presses: the 500k, 620-700k and the 840-200k.

The capacity of these machines ranges from 500-4000 kg/h depending on the preliminary treatment of the processed material. All varients are based on the same proven Maxima machines using a robust housing construction with integrated brackets for mounting symmetrically mounted driving motors for an equal distribution of power to the mainshaft, and rotor assembly through the noise free vee belt drive which opperates with low friction loss. The pelletizer doors are made from rust free high-grade steel, which encloses the rotating die. The Maxima range can also be fitted with hydraulic roller gap adjustment and also a quick die change option.

2.2.3.7 Sprout Matador

Andritz AG, Stattegger Strasse 18, A-8045 Graz, Austria
Tel: +45 72 160 300, +43 316 6902-0, Fax: +45 72 160 301
Web: www.andritz.com/ANONIDZ5842C14961770E5F/ft

The ring dies pellet mills manufactured by Sprout Matador range in size from 30 to 560 kW with 620 to 14000 cm^2 of die working area. Below, Sprout Matador pellet mill specifications, and pellet mill belt driven (up) and gear driven (down).

Pellet mill type PMV	Pellet mill type PM	Die press area		Max. Power	
Belt driven	Gear based	cm2	In2	kW	HP
PMV2		620	96	30	40
PMV515W		2555	396	110	150
	PM615W	3016	468	160	220
	PM615XW	3581	555	160	220
PMV717W		4178	648	200	275
PMV717XW		5498	852	200	275
	PM717W	4178	648	250	350
	PM717XW	5498	852	250	350
	PM30	4459	691	315	425
PMV919W		5432	842	560	800
PMV919XW		7147	1108	560	800
PMV919TW		8577	1329	560	800
	PM919W	5432	842	560	800
	PM919XW	7147	1108	560	800
	PM919TW	8577	1329	560	800
	PM1219W	11400	1767	560	800
	PM1219XW	14313	2290	560	800

2.2.3.8 Tritec GmbH

Robert-Bosch-Straße 2D-89264 Weißenhorn, Germany
Fon +49 (0)7309 / 428499-0
Fax +49 (0)7309 / 428499-99
Web: www.tritec-pelletiertechnik.de

Technical data for Paladin pellet mill series

Paladin	350 - 106	600 B-130/170	600 D/HR-141	1200 D-141/175
Drive power (kW)	74/90 kW	90/110 kW	110/150 kW	150/180 kW
Motorwellendrehzahl: (Upm)	1500	1500	1500	1500
Matrizeninnendurchmesser: (mm)	452	550	650	650
Roller speed m/s	5,2/6,5	4,6/5,7	5,4/6,0	4,8/6,0
Matrizenbreite (mm)	106	130 / 170	141	141 / 175
Number of rollers	3	2 / 3	2 / 3	2 / 3
Roller diameter/width mm	208	248	298	298

Technical data for Paladin pellet mill series

Paladin	**1600 / 175 - 1600 / 210**	**2000-250**	**2000-175/210**	**2400**
Drive power (kW)	180/ 220	220/264/320	220/264/320/400	200/ 264/ 320/ 400
Motorwellendrehzahl: (Upm)	1500	1500	1500	1500
Matrizeninnendurchmesser: (mm)	850	880	850	850
Roller speed m/s	4,7 / 6,2	4,9/5,5/6,75	4,4/7,0	4,4 / 7,0
Matrizenbreite (mm)	175/ 210	250	175/210	175/210
Number of rollers	2 / 3	2 / 2 HRV 3	2 / 3	2 / 3
Roller diameter/width mm	390	404 / 420	390	390

2.2.3.9 List of European manufacturers of biomass combustion appliances

Here below, names and addresses of pellet appliances manufacturers have been gathered in a list table. This list is not exhaustive.

Company	**Address – Tel / Fax**	**E-mail / Web**	**Products**	
UE member states				
AUSTRIA				
ABK GmbH	Wolbell 17 A-6094 AXAMS Tel.: +43 (5234) 67124		Small-scale pellet furnaces	
Anton Eder GmbH Stahl- und Kesselbau	Weyerstraße 350 A-5733 BRAMBERG Tel.: +43 (6566) 7366 Fax: +43 (6566) 8127	http://www.eder-kesselbau.at	Small-scale pellet furnaces Brand/Model: Pellevent	
Blaim Ges.m.b.H.	Ödenteichgasse 8 A-3580 HORN Tel.: +43 (2982) 3667 Fax: +43 (2982) 3667 4	http://www.solarprofi.at	Pellet furnaces	
Calimax Entwicklungs- & Vertriebs GmbH	Interpark FOCUS 3 A 6832 Rothis Tel.: +43 (5523) 51300	http://www.calimax.at	Pellet stoves (Sandor: 7-10 kW, Solida: 7-10 kW, Twist: 7-10 kW), pellet stoves associated to hot water systems (Twist 50/50, Twist 80/20)	
Compact Heiz- und Energiesysteme GesmbH	Koaserbauer-Str. 16 A-4810 GMUNDEN Tel.: +43 (7612) 73760 0 Fax: +43 (7612) 73760 17	http://www.gilles.at/	Pellet furnaces	
Ernst Gerlinger	Froschau 79 A-4391 WALDHAUSEN Tel.: +43-(0)7260-4530 Fax: +43-(0)7260-45304	gerlinger@biokompakt.com http://www.biokompakt.com/	Small-scale pellet furnaces Brand/Model: Biokompakt AWK	
Guntamatic	Heiztechnik GmbH Bruck-Waasen 7 A-4722 PEUERBACH Tel.: +43 (7276) 2441 0 Fax: +43 (7276) 3031	http://www.guntamatic.at/	Small-scale pellet furnaces Brand/Model: Biostar	
Fröling Heizkessel- u Behälterbau GesmbH	Industriestraße 12 A-4710 GRIESKIRCHEN Tel.: +43 (7248) 606-0 Fax: +43 (7248) 606 600	http://www.froeling.com/index.htm	Small-scale pellet furnaces Brand/Model: Pelletherm, Turbomatic	
Hargassner GmbH	Gunderding 8 A-4952 WENG Tel.: +43 (7723) 5274 Fax: +43 (7723) 5274 5		Small-scale pellet furnaces	
Herz Feuerungstechnik GesmbH	Sebersdorf 138 A-8272 SEBERSDORF Tel.: +43 (3333) 2411 0 Fax: +43 (3333) 2411 73	http://www.herz-feuerung.com	Small-scale pellet furnaces Brand/Model: Pelletfire, Pelletstar	
Hoval Gesellschaft mbH.	Hovalstraße 1 A-4614 MARCHTRENK Tel:+43 (0) 7243 / 550 0 Fax:+43 (0) 7243 / 550 15	http://www.hoval.at/	Small-scale pellet furnaces Brand/Model: BioLyt	
Josef Binder Maschinenbau und Handels-gesmbH	Grazer Vorstadt 120 b A-8570 VOITSBERG Tel.: +43 (3142) 22544 Fax: +43 (3142) 22544 16	http://www.binder-gmbh.at/	Medium and large scale pellet furnaces	
Kalkgruber Solar- und Umwelttechnik GmbH	Werkstraße 1 4451 St. Ulrich / Steyr Austria Tel,+43 (0)7252 / 50002-0 Fax:43 (0)7252 / 50002-10	http://www.kalkgruber.at	Small-scale pellet furnaces	
KWB - Kraft und Wärme aus Biomasse	Raab 235 A-8321 St. MARGARETHEN Tel.: +43 (3115) 6116 0 Fax: +43 (3115) 6116 4	http://www.kwb.at/	Small-scale pellet furnaces	
Lohberger Heiz- und Kochgeräte GesmbH	Landstraße 19, A-5231 SchalchenPostfach 90 A-5230 MATTIGHOFEN Tel.: +43 (7742) 5211 0 Fax:+43 (7742) 5211 109	http://www.lohberger.com/	Small-scale pellet furnaces	
ÖkoFEN Forschungs- und Entwicklungs Ges.m.b.H.	Gewerbepark 1, 4133 Niederkappel Tel.: +43 (7286) 7450 Fax:+43 (7286) 7450 10	http://www.pelletsheizung.at/	Small-scale pellet furnaces Brand/Model: Pellematic	
Perhofer-Bio-Heizungs-GmbH & Co.KG	Waisenegg 115 A-8190 BIRKFELD Tel.: +43 (3174) 3705 0 Fax: +43 (3174) 3705 8	http://www.biomat.at/	Small-scale pellet furnaces Brand/Model: Biomat	
Rendl Heizkessel & Stahlbau GesmbH	Siezenheimerstraße 31a A-5020 SALZBURG Tel.: +43 (662) 433034 0 Fax: +43 (662) 433034 39		Small-scale pellet furnaces	
RIKA MetallwarengesmbH & Co KG	Müllerviertel 20 A-4563 MICHELDORF in OÖ Tel.: +43 (7582) 686 41 Fax: +43 (7582) 686 43	http://www.rika.at/	Pellet single stoves (Premio: 6 kW, Visio: 8 kW; Integra II: 9 kW)	
Scheibelhofer GmbH & Co. KG	Jahnstraße 5 A-8280 FÜRSTENFELD Tel.: +43 (3382) 5050 0 Fax: +43 (3382) 5050 82	http://www.spirit-of-fire.com	Pellet fired tiled stove	
Sommerauer und Lindner Heizanlagenbau SL-Technik GmbH	Trimmelkam 113 A-5120 St. PANTALEON Tel.: +43 (6277) 7804 Fax: +43 (6277) 7818	http://www.sl-heizung.at/	Small-scale pellet furnaces	

Company	**Address – Tel / Fax**	**E-mail / Web**	**Products**	
Sonnenkraft Vertriebs GesmbH Österreich	Sonnenkraft Österreich Vertriebs GmbH Industriepark A-9300 St. Veit/Glan Tel.: +43 (0)4212 45010	http://www.sonnenkraft.at/	Pellet single stoves Brand/Model: Compello	
Viessmann GmbH	Lerschstraße 11 A-4600 WELS Tel.: +43 (7242) 62381-0	http://www.viessmann.at	Small-scale pellet furnaces Brand/Model: Vitolig 300	
Windhager Zentralheizung AG	Anton-Windhagerstraße 20 A-5201 SEEKIRCHEN Tel.: +43 (6212) 2341 0 Fax: +43 (6212) 4228	http://www.windhager-ag.at/	Small-scale pellet furnaces	
Wolf Klimatechnik GmbH	Eduard-Haas-Straße 44 A-4034 LINZ Tel.: +43 (732) 385041 0 Fax: +43 (732) 385041 27	http://www.wolf-heiztechnik.at	Small-scale pellet furnaces Brand/Model: Pellevent	
BELGIUM				
VYNCKE ENERGIETECHNIEK N.V.	Gentsesteenweg 224 B-8530 Harelbeke BELGIUM Tel : + 32 56 730 630 Fax : + 32 56 704 160	mail@vyncke.com www.vyncke.be	Combustion and boiler systems for decentralized power stations (1-10 MWe) and turn-key energy plants (1-65 MWth) for various homogenous secondary fuels, such as demolition wood, Refuse Derived Fuels (RDF), packing materials, paper waste, etc.	
DENMARK				
Baxi A/S	Smedevej DK-6880 TARM Denmark Tel.: +45-97-37 15 11 Fax: +45-97-37 24 34	http://www.baxi.dk/	Small-scale pellet furnaces Brand/Model: Multi-Heat	
Passat Energi A/S	Vestergade 36, Ørum DK-8830 TJELE Denmark Tel.: +45-8665 2100 Fax: +45-8662 3028	E-mail: info@passat.dk http://www.passat.dk	Small- and medium scale pellet furnaces	
Alcon ApS Ingeniørfirma	Kingosvej 25 DK-7470 Karup +45 86 66 20 44 +45 86 66 15 17	alcon@post6.tele.dk www.alcon.nu	Smal-scale (pellets, grain, straw) + large boiler systems (pellets <> 1MW)	
Ansaldo Vølund A/S	Falkevej 2 DK-6705 Esbjerg Ø +45 76 14 34 00 +45 76 14 36 00	www.volund.dk	Large boiler systems (pellets > 1 MW)	
Argusfyr Energiteknik A/S	Lynager 10 DK-2605 Brøndby +4586260500 +4586260884	sales@argusfyr.dk www.argusfyr.dk	Large boiler systems (pellets and wood chips, <> 1MW)	
CN Maskinfabrik ApS	Skovløkkevej 4, Tiset DK-6510 Gram +45 74 82 19 19 +45 74 82 19 20	cnm@io.dk www.cn-maskinfabrik.dk	Small scale systems (pellets, straw, grain)	
Danergi A/S	Danergi ApS Nupark 51 DK-7500 Holstebro Tel. +45 96 12 72 90 Fax +45 96 12 72 91	sax@danergi.dk www.danergi.dk	Small scale systems (pellets stoves, boilers for pellets and grain) + large boiler systems (pellets and wood chips <> 1MW)	
Danish Energy Systems A/S	Topstykket 16 | DK-3460 Birkerød | Denmark | Phone: +45 33 32 56 33 | Fax: +45 33 32 56 34	des@des-dk.com www.des-dk.com	Small scale (boilers for straw) + Large boiler systems (straw <> 1MW)	
Danstoker A/S	Industrivej Nord 13 DK-7400 Herning +45 99 28 71 00, +45 99 28 71 00	bio-fuel@danstoker.dk www.danstoker.dk	Large boilers (wood chips, straw, pellets <> 1MW) Boilers from 0,2 - 60 MW	
DanTrim A/S	Islandsvej 2 DK-7480 Vildbjerg +45 97 13 34 00 +45 97 13 34 66	dantrim@dantrim.dk www.dantrim.com	Small scale (boilers for pellets and grain) + Large boilers (wood chips and pellets, <> 1MW)	
EURO THERM A/S	Søren Nymarksvej 25 A DK-8270 Højbjerg +45 86 299 299 +45 86 299 888	info@eurotherm.dk www.eurotherm.dk	Large boilers (wood chips, straw, pellets, <> 1MW)	
FLS Miljø A/S	Ramsingsvej 30 DK-2500 Valby +45 36 18 11 00 +45 36 18 34 26	info@flsmiljo.com www.flsmiljo.com	Large boilers (wood chips, straw, pellets, <> 1MW)	
Hollensen Ingeniør- og Kedelfirma ApS	Drejervej 22 DK-7451 Sunds +45 97 14 20 22 +45 97 14 26 86	hollensenkedler@post.tele.dk www.hollensen.dk	Large boiler systems	
Interforst K/S	Blåkildevej 8, Stubberup DK-5610 Assens +45 64 79 10 75 +45 64 79 11 75	interforst@post.tele.dk www.interforst.dk	Small scale and large boiler systems	
KEM A/S	Ådumvej 12 DK-6880 Tarm +45 97 37 21 00	mail@kem.dk www.kem.dk	Large boiler systems	
LIN-KA Maskinfabrik A/S	Nylandsvej 38 DK-6940 Lem +45 97 34 16 55 +45 97 34 20 17	linka@linka.dk www.linka.dk	Small scale and large boiler systems	

Company	**Address – Tel / Fax**	**E-mail / Web**	**Products**	
Passat Energi A/S	Vestergade 36, Ørum DK-8830 Tjele +45 86 65 21 00 +45 86 65 30 28	passat@passat.dk www.passat.dk	Small scale systems (boilers for pellets, grain and straw)	
REKA A/S	Vestvej 7 DK-9600 Års +45 98 62 40 11 +45 98 62 40 71	reka@reka.com www.reka.com	Small scale systems (pellets stoves, boilers for pellets, grain and straw) + Large boiler systems	
SKELTEK	Aalborgvej 74, Skellet DK-9280 Storvorde +45 98 31 16 26 +45 98 31 15 26	http://www.skeltek.dk/	Small scale systems (boilers for straw) + Large boiler systems	
Tjæreborg Industri A/S	Kærvej 19 DK-6731 Tjæreborg +45 75 17 52 44 +45 76 12 56 06	info@tji.dk www.tji.dk	Large boiler systems (wood chips, pellets <> 1MW)	
TWIN HEAT	Nørrevangen 7 DK-9631 Gedsted +45 98 64 52 22 +45 98 64 52 44	twinheat@twinheat.dk www.twinheat.dk	Small scale (boilers for pellets and grain)	
WEISS A/S	Plastvænget 13 DK-9560 Hadsund +45 96 52 04 44 +45 96 52 04 45	weiss@weiss-as.dk www.weiss-as.dk		
FINLAND				
HT Enerco Oy	Punojantie 1, FIN-42800 Haapamäki, Finland Tel. +358 10 7745 000 Fax +358 10 7745 095	Contact: Mika Anttila, Exports Manager E-mail: tulimax@htlaser.fi www.htlaser.fi	Pellet burners and boilers (20 – 100 kW) for private citizens, retail company chains. Biomass boilers (20-1000 kW) and burners (20-500 kW)	
Kaukora Oy	P.O.Box 21, Tuotekatu 11, FIN-21201 Raisio, Finland Tel. +358-2-437 4600 Fax. +358-2-437 4650	Contact: Engineer Raimo Arola Webmaster@kaukora.fi URL www.kaukora.fi	Jäspi-ECOPUU boiler. Boilers: Wood/chips: 15-50 kW, pellets 15-50 kW	
Säätötuli Oy	Keskustie 30 61850 KAUHAJOKI AS Finland Tel.: +358-207-299 300 Fax: +358-207-299 301	E-mail: info@saatotuli.fi http://www.saatotuli.fi/	Small- and medium scale pellet burners and furnaces	
Veljekset Ala-Talkkari Oy	Hellanmaantie 619 62130 HELLANMAA Tel.: +358-6-433 6333 Fax: +358-6-437 6363	asiakaspalvelu@ala-talkkari.fi http://www.ala-talkkari.fi/	Small- and medium scale pellet burners and furnaces Brand/Model: Veto	
FRANCE				
Compte R	ZI De Vaureil 63220 Arlanc France Tel: +33 4 73 95 01 91 Fax: +33 4 73 95 15 36	http://www.compte-r.com	Boilers for wood pellets and biomass in general (200-5,000 kW)	
ENERGIE SYSTEME	L'Espinglette RN 120 19430 SAINT-JULIEN-LE-PELERIN Tel: 05 55 28 70 41 Fax: 05 55 28 74 14	info@energiesysteme.fr http://www.energiesysteme.fr	Wood boilers (Auto 30-200: 30-200 kW)	
FRANCO-BELGE	2, rue Orphée Variscotte BP 11 59660 MERVILLE Tel: 03 28 43 43 43 Fax: 03 28 43 43 99	www.francobelge.com	Wood stoves (5.5 - 8 kW)	
Pagnod Industrie SARL	Les Servettes 74230 VIUZ-EN-SALLAZ Tél. 04 50 36 81 90 Fax. 04 50 36 97 44	pagnod-industrie-sarl@wanadoo.fr http://www.pagnodindustrie.com/	Pellet stoves (Mole 12 kW, Mont Jouan 12 kW)	
PERGE	RN 7 - BP 07 26800 PORTES-LES-VALENCE Tel: 04 75 57 19 11 Fax: 04 75 57 48 74	perge@perge.fr http://www.perge.fr	Wood / sawdust / wood-shavings boilers (Poncet serie A: 11 to 153 kW; Poncet serie S: 13 to 77 kW)	
GERMANY				
Buderus Heiztechnik GmbH	Sophienstrasse 30-32 D-355 76 WETZLAR Tel: +49-(0)6441/418-1472 (national) +49-(0)6441/418-1670 (international) Fax: +49-(0)6441/45602	info@heiztechnik.buderus.de (national) va@heiztechnik.buderus.de (international) http://www.heiztechnik.buderus.de/	Small-scale pellet furnaces Brand/Model: Logano	
Paradigma Deutschland Ritter Energie- und Umwelttechnik GmbH & Co. KG	Ettlinger Str. 30 D-763 07 KARLSBAD Tel.: +49-(0)7202/922-0 Fax: +49-(0)7202/922-100	info@paradigma.de http://www.paradigma.de/	Small-scale pellet furnaces Brand/Model: Pelletti	
Viessmann Werke GmbH & Co	Viessmannstr. 1 D-351 07 ALLENDORF (EDER) Tel.: +49-(0)6452/70-0 Fax: +49-(0)6452/70-2780	info-int@viessmann.com http://www.viessmann.de/	Small-scale pellet furnaces Brand/Model: Vitolig	
Wodtke GmbH	Rittweg 55-57 D-720 70 TÜBINGEN-HIRSCHAU Tel:+49-7071/70 03-0 Fax:+49-(0)7071/70 03 50	info@wodtke.com http://www.wodtke.com/	Pellet stoves Brand/Model: Topline, Smart, PE-Einsatz, CW 21	
ITALY				
Caminetti Montegrappa s.r.l.	Via A. da Bassano, 7/9 Pove del Grappa VICENZA Tel.: +39-0424-800500 Fax: +39-0424-800590	http://www.caminettimontegrappa.it/	Pellet stoves Brand/Model: Pellet Plus	

Company	**Address – Tel / Fax**	**E-mail / Web**	**Products**	
D'Alessandro Termomeccanica	C. da Cerreto, 25/B 66010 Miglianico (CH) Tel.: +39-0871-950329 Fax: +39-0871-950687	info@caldaiedalessandro.it http://www.caldaiedalessandro.it/	Small and medium-scale pellet furnaces Brand/Model: CS, CSA	
EdilKamin SpA	Via Mascagni, 7 20020 Lainate (MI) Tel.: +39-02-937621 Fax: +39-02-93762400	mail@edilkamin.com http://www.edilkamin.com/	Pellet stoves Brand/Model: Fox, Pellegg	
ITALVAS s.r.l.	Via Dell'Artigianato, 10 36030 Montecchio Precalcino VICENZA Tel.: +39-0445-864488 Fax: +39-0445-865243	info@extraflame.com http://www.extraflame.com/	Pellet stoves Brand/Model: Eco-Logica	
Palazzetti Lelio SpA	Via Roveredo, 103 33080 Porcia PORDENONE Tel: 800-018186 (toll-free) Tel:+39 0434 922-922/655 Fax:+39-0434-922355	info@palazzetti.it http://www.palazzetti.it/	Pellet stoves Brand/Model: Ecofire	
Piazzetta SpA	Via Montello, 22 31010 Casella d'Asolo (TREVISO) Tel.: +39-0423-5271 Fax: +39-0423-55178	infopiazzetta@piazzetta.it http://www.piazzetta.it/	Pellet stoves Brand/Model: P935, P940/1, P950	
Thermorossi SpA	Via Grumolo, 4 - Z.I. Arsiero 36011 VICENZA +390445741657 Tel: 800-276820 (toll-free)	thermorossi@keycomm.it http://www.thermorossi.com	Pellet stoves Brand/Model: Ecotherm 6000, 8000	
PORTUGAL				
Torres & Belo, S.A.	Ervosas – Apartado 14 3831 ÍLHAVO Codex Tel: + 351 234325011 Fax: + 351 325012	torbel@mail.telepac.pt http://www.torbel.pt	Torbel low-pressure boiler (Fuel: sawdust particles or bulk, automatic feeding, 350-4660 KW, 0,5 to 1 Bar)	
SPAIN				
Termisa	Rambla Badal, 98-102, esc A, entlo 7ª 08014 Barcelona Tel.: +34 93 331 55 12 Fax: +34 93 442 11 73	termisa@termisa.es www.termisa.es	Wood boilers	
Sugimat, S.L.	Colada d'Aragó s/n. Ctra. N-III, Madrid Valencia, km 331 - E-Apdo. de Correos 99. 46930 Quart de Poblet (Valencia) Tel.: +34 96 159 72 30 Fax: +34 96 192 00 26	sug4@sugimat.com www.sugimat.com	Wood boilers	
SWEDEN				
Altbergs Plåt AB	Älvbrinken 6 SE-828 94 EDSBYN Tel.: +46-(0)271-346 70 Fax: +46-(0)271-346 71	altbergsplat@zeta.telenordia.se http://www.altbergsplat.se/	Small-scale pellet burners Brand/Model: EP-Brännaren	
Ardeo Janfire AB	Box 194 SE-662 24 ÅMÅL Tel.: +46-(0)532-164 17 Fax: +46-(0)532-716 59	info@janfire.com http://www.janfire.com/	Small- and medium scale pellet burners Brand/Model: Janfire	
Bentone AB	Näsv. Box 309 SE-341 26 LJUNGBY Tel.: +46-(0)372-867 00 Fax: +46-(0)372-840 63	info@bentone.com http://www.bentone.se/	Small-scale pellet burners	
Biomatec	Grönahögsvägen 15 SE-523 30 ULRICEHAMN Tel.: +46-(0)321-153 10 Fax: +46-(0)321-153 12	bengtgoran.josefsson@biomatec.se http://www.biomatec.se/	Small-scale pellet burners Brand/Model: Infraheat	
Effecta-Pannan AB	Rågdal 6699 SE-434 96 KUNGSBACKA Tel.: +46-(0)300-223 20 Fax: +46-(0)300-223 95	effectapannan@swipnet.se http://www.effectapannan.se/	Small-scale pellet burners, furnaces Brand/Model: Effecta Pellets	
eKontroll AB	Skarvtjärn 1412 SE-820 75 HARMÅNGER Tel.0652-747800 Fax 0652 - 74 78 01	http://www.ekontroll.com/	Small-scale pellet burners Brand/Model: Katla	
Ekosystem AB	Björkevägen 84 SE-805 97 GÄVLE Tel.: +46-(0)26-16 10 50 Fax: +46-(0)26-16 01 50	info@ekosystem.se http://www.ekosystem.se/	Small-scale pellet burners Brand/Model: Eurofire	
Nordisk Miljöenergi AB	Ljungvägen 10 SE 944 72 PITEÅ Tel.: +46-(0)911-650 61 Fax: +46 (0)911-650 95	info@pitekaminen.com http://www.pitekaminen.com/	Pellet stoves Brand/Model: PiteKaminen	
Sahlins EcoTec AB	Box 2103 SE-511 02 SKENE Tel.: +46-(0)320-20-93-40 Fax: +46-(0)320-421 60	info@ecotec.net http://www.ecotec.net/	Small- and medium scale pellet burners, stoves Brand/Model: EcoTec	
Scand Pellet AB	Wismarsvägen 12 SE-393 54 KALMAR Tel.: +46-(0)480-49 10 80 Fax: +46-(0)480-49 10 95	info@scand-pellet.se http://www.pellx.com/	Small- and medium scale pellet burners, stoves Brand/Model: pellX	
Tellus Rör, Svets och Smide AB	Box 603 Sandåsavägen 1C, 572 36 Oskarshamn Tel1: +46 0491-199 33 Tel2: +46 0491-199 36 Fax. 0491- 199 10	info@tellusror.se www.tellusror.se		
Thermia Värme AB	Box 950 Snickargatan 1 SE-671 29 ARVIKA Tel.: +46-(0)570-813 00 Fax: +46-(0)570-176 16	info@thermia.se http://www.thermia.se/	Small-scale pellet burners, furnaces Brand/Model: BeQuem, Biomatic	

Company	**Address – Tel / Fax**	**E-mail / Web**	**Products**	
Torsby-Ugnen AB	Vinkelvägen 9 SE-685 34 TORSBY Tel.: +46-(0)560-68-99-60 Fax: +46-(0)560-148 28	info@torsbyugnen.se http://www.torsbyugnen.se/	Small-scale pellet burners Brand/Model: TB Mini	
TPS Termiska Processer AB	Studsvik SE-611 82 NYKÖPING Tel.: +46-(0)853-52-46-00 Fax: +46-(0)155-26 30 52	Contact: Mr Henrik Lundberg henrik.lundberg@tps.se http://www.tps.se/	Medium- and large-scale pellet burners Brand/Model: Bioswirl	
THE NETHERLANDS				
Kara Energy Systems	Postbus 570 7600 AN Almelo Tel.: +31 546 876580 Fax: +31 546 870525	Email: kara@introweb.nl www.kara.nl	The applied boiler to be chosen can vary from a hot water boiler to a steam boiler with a pressure of 20 bar. Higher operating pressures can also be delivered, after consultation with KARA	
UNITED KINGDOM				
Talbott's Ltd	Drummond Road Astonfields Ind. Estate STAFFORD ST16 3HJ Tel.: +44-(0)1785-213366 Fax: +44-(0)1785-256418	Contact: Mr Ben Talbott sales@talbotts.co.uk http://www.talbotts.co.uk/	Pellet furnaces Range of 40 different combustion systems at its factory with energy outputs ranging from 25kW to 4,000kW per hour	
CZECH REPUBLIC				
Atmos	Jaroslav Cankař & Syn Velenského 487 294 21 BĚLÁ POD BEZDĚZEM Tel.: +42-0326-70 14 04 Fax: +42-0326-70 14 92	http://www.atmos.cz/	Small-scale pellet furnaces	
HUNGARY				
IPARFEM Fémszerkezetgyártó Kft.	H*3104 Salgótarján, Hosök útja 49, Hungary Tel. +36 32/440-835, 36 32/441-100 Fax. +36 32/511-684	Contact: Mr. Nándor Fodor, Develop. Manager E-mail: iparfem@elender.hu	Fireplace and stove manufacturer (5 – 9 kW) Products, services	

2.3 Briquetting

In Africa, especially in its rural areas, biomass can be utilized by a way of directly burning in a traditional stove, the heat efficiency only 10%. The biomass energy is still playing an important role on the rural energy. Even if we can observe crop residues burnt directly in cultivated land in order to reduce works on transportation and stockpile of these residues.

Biomass briquetting technology can transform these lose biomass into dry, solid of regular shape, usually cylindrical with a diameter of 5-10 cm, which can be easily stored and transported. Use as a substitute for firewood helps to reduce deforestation. It will also help the rural women who spend considerable time and energy collecting firewood.

However, traditional stoves are not the best burners for briquettes. Improvements to stoves are also necessary for harnessing the full benefit of briquetting technology.

2.3.1 Characteristics

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

- piston press densification;
- screw press densification;
- roll press densification;
- pelletizing.

Products from the first three types of densification are large compared to pellets, and are normally called “Briquettes”.

Briquettes refer to the result of a compression process of materials as wood and agricultural residues. The compression process brings to a dramatic augment in the residues density; in fact the briquetting machines are able to press the biomass to obtain a compact cylindrical piece, characterized by a moisture content minor inferior to 15%.

The briquetting systems, according to the pressure applied, can be classified in systems with high, medium and low pressure. While the last two systems require to mix the biomasses with a binding substance, the high pressure systems can be applied to biomass in its actual form, because the binding effect develops as a consequences of the high pressure applied. In the high pressure systems, the most utilized technologies are:

- Screw pressing
- Piston ramming

In the screw pressing process the biomass comes extruded in continuation for effect of the spin of one or more cochlea inside one conic section room. The arranged effect of the high pressure and the temperature (the room comes heated during the process) improves the adhesion between particles. The partial carbonization of the external surface of and the presence of a hole in the centre of each briquette (typical of this system) improve the characteristics of ignition to the fire and combustion of the material.

The briquetting process with mechanical piston enables to compress the biomass for means of an alternative piston moved from an electric motor through a crank. The briquettes produced have an average diameter of 60 millimetres. The briquetting process with oildynamics circuit piston is based on a system with two pistons that compress the material in and that come sets in action through the oil maintained in pressure in a closed circuit.

The advantages and disadvantages of these two systems (screw and piston) are reassumed in the following table.

Characteristics	Piston ramming	Screw pressing
Optimal moisture of the biomass	10-15	8-9
Side's wear	low	high
Briquetting products	small block	continuous block
Average energetic consumption (kWh/t)	50	60
Briquette's specific weight (kg/m3)	1000-1200	1000-1400
Attitude to combustion	medium	good
External carbonization	absent	present
Briquette's omogeneity	low	good

The possibility to deal a biomass with greater moisture and the improved control of the applied pressure has rendered the process with mechanical piston the more utilized system.

The briquetting process primarily involves drying, grinding, sieving, compacting, and cooling operations.

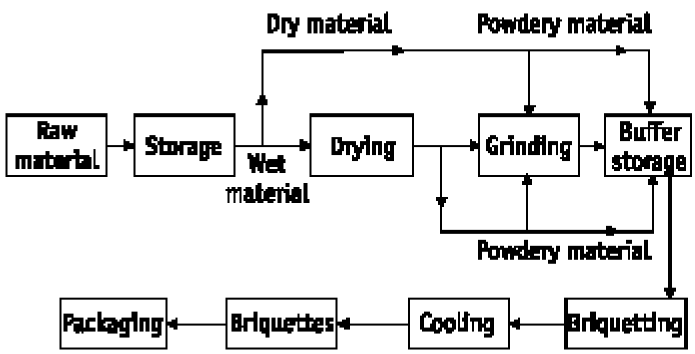


Fig. 18: Flow diagram of briquette production process Tripathi et al. 1998.

- Storage: can be in an airy and repaired room (in parallel with natural drying), or in silos for biomass already dried and milled.
- Pre-treatment: involves grinding and sieving operations; these phases have the aim to obtain a biomass with the necessary physical and chemical characteristics.
- Feeding machine: by a tube maintained in depression or by a tape conveyor. The loading mouth of the briquetting unit can be provided of a vibrant riddle, for a further selection of the biomass to lower the stoppage risks.
- Compacting: transformation of the pre-treated biomass in briquettes.
- Final transformation of the briquettes: comprehends the phases of the eventual cutting, cooling, packaging and storing operations.
- System to deal with gaseous emissions: is required only for screw systems, when the high temperature causes the emission of volatile substances.

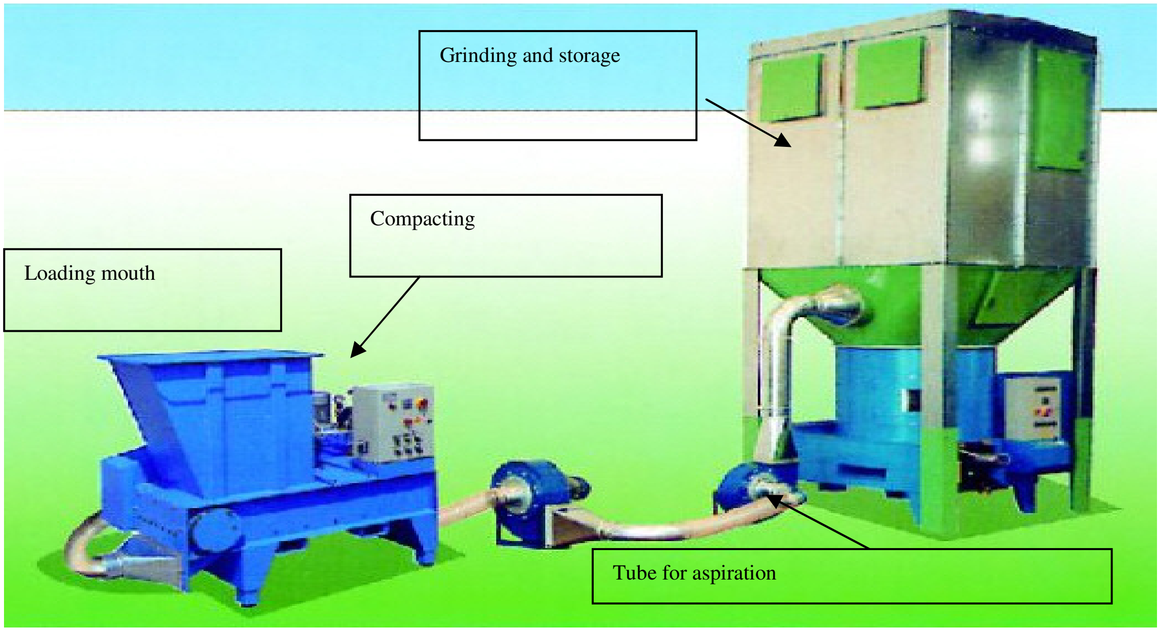


Fig. 19: Source: Punto Energia Brescia

The factors that mainly influence the selection of raw materials for briquetting are moisture content, ash content, flow characteristics, and particle size.

A moisture content in the range of 10% to 15% is preferred to enable proper grinding. Use of biomass with high moisture content makes grinding difficult and more energy is required for drying. The ash content of biomass affects its slugging behaviour together with the operating temperature and mineral composition.

Briquettes can be utilized for any application in substitution of firewood and coal, changing in the proper way the operative parameters, as the primary and secondary air distribution: in fact briquettes require a major quantity of primary air and a minor quantity of secondary air for the combustion.

Briquettes have a density doubled respect that of wood. Porosity is very low and so the ember produced during the combustion is denser than that of wood. Moreover, briquettes have a higher calorific power and maintain a higher temperature inside the furnace.

The more frequent utilizations for briquettes are:

- boilers for steam generation;
- in distilleries and vine companies as a fuel for the productive process;
- in the textile industries;
- in farmers and sawmills as a fuel for the productive process;
- in gasifier as fuel
- in domestic boilers for producing hot water;
- in stoves and fireplaces, because briquettes burn easily and have a combustion better than wood.

2.3.2 Economical aspects

Briquettes production from biomass is an operation that comprehends many phases, each with specific costs:

- Collection and transport of the biomass, from the field to the storage area.
- Transport of the biomass to the briquetting machines;
- Pre-treatment of the biomass: drying, grinding, refining;
- Briquetting: filling up of the biomass, pressing;
- Packaging;
- Transport of the briquettes to the sale point;

The realization of these operations involves investments costs that, in function of the size of the plant, vary from about 8 to 40 millions of euro.

The briquette's packaging is usually effectuated according to the following conditions:

- 50 bags per hour containing 5 kg;
- 12 bags per hour containing 20 kg;

The briquette's final cost varies in function of the potentiality of the machine, from 15€cent to 25€cent.

2.3.3 Pollutant emissions

With technical optimal conditions of combustion, wood can burn in its totality, and the combustion gases contain only carbon dioxide (CO_2), watery vapor (H_2O), nitrogen oxides (NO NO_2), nitrogen (N_2) and ashes particle, that represent the inorganic part of the dust. In practice, however, a perfect combustion can never be obtained in all the combustion phases; so, there is the formation of other substances, products of an incomplete combustion: gaseous carbon monoxide, hydrocarbons and liquids, beyond to tar and soot.

Incomplete combustion is caused by the fact that about the 70% of the organic components of the wood pass to the gas state before the combustion, and only the 30% remains in coal state.

It is important to consider that also the best available wood heating system will pollute if it is no utilized the proper a fuel with the proper characteristics. For this reason, briquettes mustn't contain chemical binding substances; the combustion of treated wood can create dioxin.

2.3.4 Main European briquetting machines manufacturers

Briquetting is a technology very interesting because, considerably reducing the residual density, enables to concentrate an high energetic value in a small volume.

The main manufacturers in Europe are listed in this paragraph with some comments on their products.

2.3.4.1 Welo SAS di Lochmann Karl & Co.

I-39011 Lana (BZ), Via Josef-Aigner 4
Tel. 0473 564984,
Fax 0473 565060
Mail: info@welo.it
Web: www.welo.it

Briquetting machine with shaving filter.

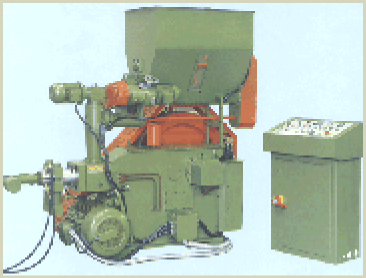
2.3.4.2 ASCOT S.r.l.

Via dell'Industria 38
36035 Marano Vicentino
VICENZA - ITALY
Tel. (+39) 0445 637330
Fax (+39) 0445 639210
E-mail: info@ascot-matic.com
Web: www.ascot-matic.com

ASCOT builds machines and complete plants for the production of briquettes and pellets from cellulose materials.

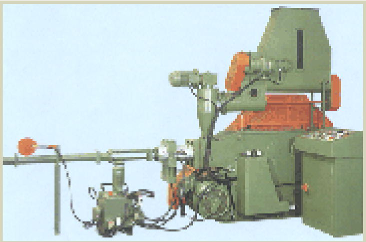
Manufacturing program machines							
Mod. BRICMATIC		**1-50/130**	**1-55/130**	**1-65/150**	**1-75/150**	**1-85/200**	**1-95/200**
Production capacity	kg/h	150 ÷ 200	200 ÷ 340	600	800	1200	1500
Briquette diameter	mm	52	56	67	77	87	98
Length of briquettes	mm	30 ÷ 250	30 ÷ 250	30 ÷ 300	30-300	30-300	30-300
Main motor power	kw	15	22	37	45	55	75
Flywheel diameter	mm	1000	1000	1250 x 1	1250 x 2	1250 x 2	1250 x 2
Weight approx	kg	2050	2280	4000	4800	6000	6300
With density of saw dust	kg/m^3	160 ÷ 180	160 ÷ 180	160 ÷ 180	160 ÷ 180	160 ÷ 180	160 ÷ 180
We reserve the right of technical modifications.Our machines are supplied with accident protections as required by international law.							

Bricmatic 1-50/130 1-55/130



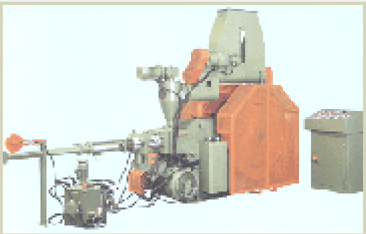
Automatic briquetting press			
Bricmatic		**1-50/130**	**1-55/130**
Production capacity	kg/h	150 ÷ 200	200 ÷ 340
Briquette diameter	mm	52	56
Length of briquettes	mm	30 ÷ 250	30 ÷ 250
Main motor power	kw	15	22
Flywheel diameter	mm	1000	1000
Weight approx	kg	2050	2280
We reserve the right of technical modifications.			

Bricmatic 1-65/150



Automatic briquetting press		
Production capacity	kg/h	600
Briquette diameter	mm	67
Length of briquettes	mm	30 ÷ 300
Main motor power	kw	37
Flywheel diameter	mm	1250 x 1
Weight approx	kg	4000
We reserve the right of technical modifications.		

Bricmatic 1-75/150



Automatic briquetting press		
Production capacity	kg/h	800
Briquette diameter	mm	77
Length of briquettes	mm	30 ÷ 300
Main motor power	kw	45
Flywheel diameter	mm	1250 x 2
Weight approx	kg	4800
We reserve the right of technical modifications.		

3 Conversion technologies

In this chapter a detailed survey of existing sectorial bioenergy E.U. technologies has been carried out mentioning the strong points and weakness. In particular the following ones of major interest for technological transfer and possible industrial cooperation have been identified:

3.1 Carbonisation and steam activation for activated coal production

3.1.1 Charcoal technology

Charcoal is the blackish residue consisting of impure carbon obtained by removing water and other volatile constituents from animal and vegetation substances. Charcoal is usually produced by slow pyrolysis, the heating of wood, sugar, bone char, or other substances in the absence of oxygen.

Firewood and charcoal for cooking and heating is actually used in a very wide way. For several hundred million of people, it is already impossible to get a sufficient supply of firewood because of the ruinous exploitation of forests. Here the modern charcoal technology high-grade energy recovery systems can find a new task. Tapping the vast waste reserves of the world, the charcoal industry can make one of its most important contributions to mankind by helping to provide for the energy needs of the future, especially in all developing countries.

3.1.1.1 Carbonization process

Carbonisation or dry distillation takes place when any organic matter is raised to a high temperature (i.e. above 180° C) under strict exclusion of oxygen or under controlled minimal air intake. Essentially the process of carbonisation follows a general temperature scheme:

- between 100° and 170° C all loosely bound water is evaporated from the raw material.
- between 170° and 270° C gases develop (off-gas), containing carbon monoxide (CO), carbon dioxide (CO_2), and condensable vapours, which form pyrolysis oil after scrubbing and chilling.
- between 270° and 280° an exothermic reaction starts, which can be detected by spontaneous generation of heat and the rising temperature. At the same time, the development of CO and CO_2 ceases but the quality of condensable vapours rises.

Once the carbonisation process has entered the exothermic phase, no more outside heating is required. The temperature in the retort will climb slowly until it comes to a standstill between 400° and 450° C.

Naturally, this scheme can be applied only if the carbonisation or dry distillation is conduced batch-wise. To achieve a higher terminal temperature, the process must be supported with extra heat from outside.

For the classification of charcoal equipment, the scheme shown in the figures here below is suggested for practical use. Presently, more than one hundred concepts and methods to make charcoal are known.

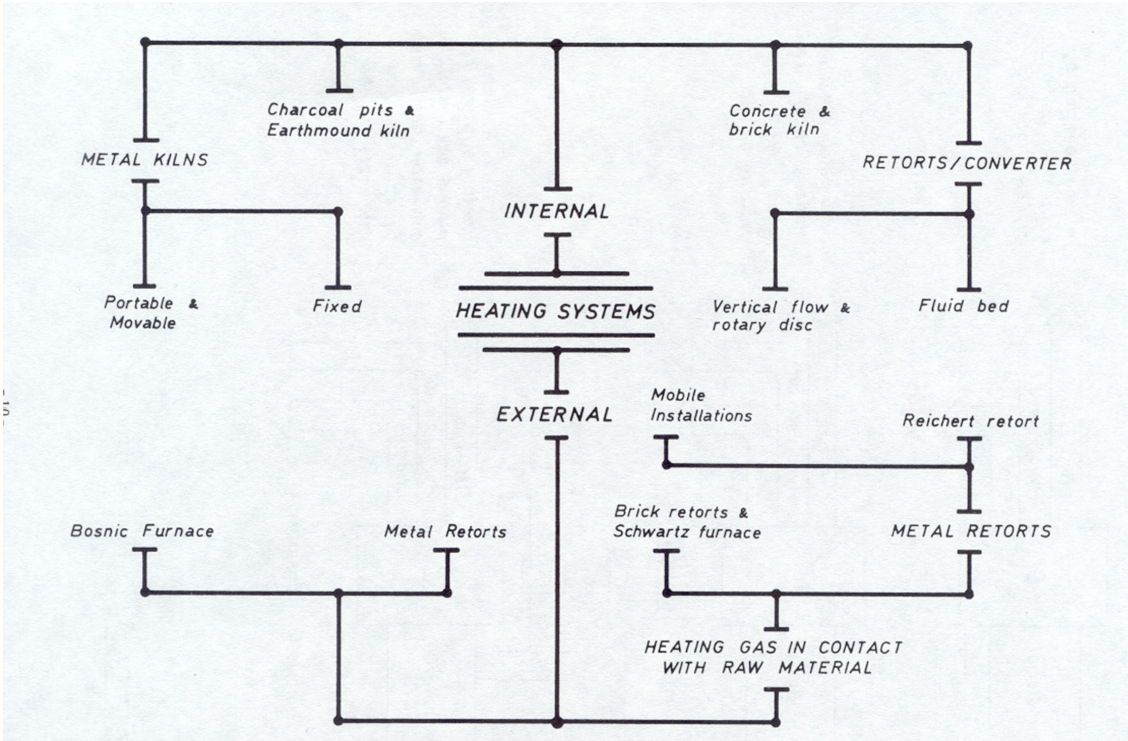


Fig. 20: classification of charcoal processes

To start up the carbonisation and to maintain higher temperatures, external heating is required. Many heating systems have been tried and only the three basics presented here below are generally used.

- Type A: most common system. Part of the raw material is burnt under controlled air inlet. The combustion heat provides the energy for maintenance of the process. Recommendable only in locations where raw material prices are low (waste material).

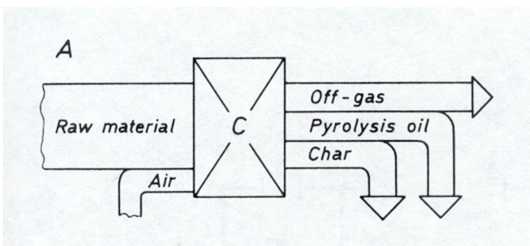


Fig. 21: Type A

- Type B: retort or converter heated from the outside under strict exclusion of oxygen. Fuel can be provided from the off-gases.

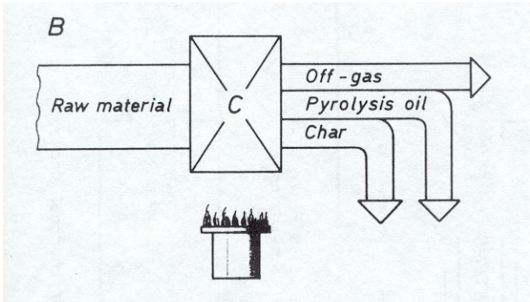


Fig. 22: Type B - external heating by combustion of firewood, fuel oil or natural gas.

- Type C: very expensive heating system. Raw material comes in direct contact with the hot gases. Charcoal and by-product yields are high. Recommendable for very large plant capacities only.

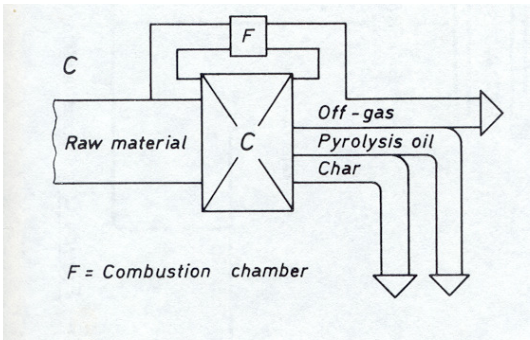


Fig. 23: Type C - heating with recirculated gas (retort or converter gas). Hot gases pass through raw material charge.

3.1.1.2 Raw materials for the process

Any type of biomass, containing organic carbon, may be used as a process raw material.

However, the choice of the raw material and the process conditions must be carried out as a function of the final properties of the charcoal to be produced.
For good results is suggested the utilisation of medium density resinous woods as the following: fir-tree, pine, and larch. It is possible, however, to obtain excellent and product by using biomasses as: beech, oak, chestnut tree, eucalyptus, olive wine tendrils, coconut shells, woody and herbaceous crops pellets.

The moisture of the biomass must not overcome 35% absolute by weight, and the suggested dimensions are those of pieces with 20 – 30 mm.

3.1.1.3 Modern charcoal equipment

Among others one should remind:

- ***The Retort Technology***

The term “retort technology” refers to carbonisation of pinewood or wood logs reduced in size to a minimum length of 30 cm and not exceeding 18 cm in diameter. Several types of retort plants are shown in the following schemes and figures:

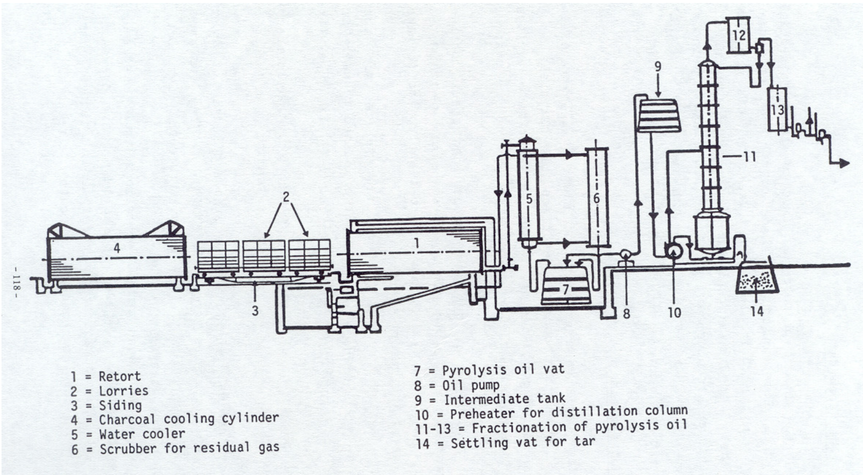


Fig. 24: The wagon retort plant

Retort dimensions: length 7.5 m / diameter 2.5 m
Retort capacity: ~ 35 m^3
Retort production: 9 t/m^3 per month
Raw-material: wood
Yield: 33% - 38% (charcoal Wt / wood weight)

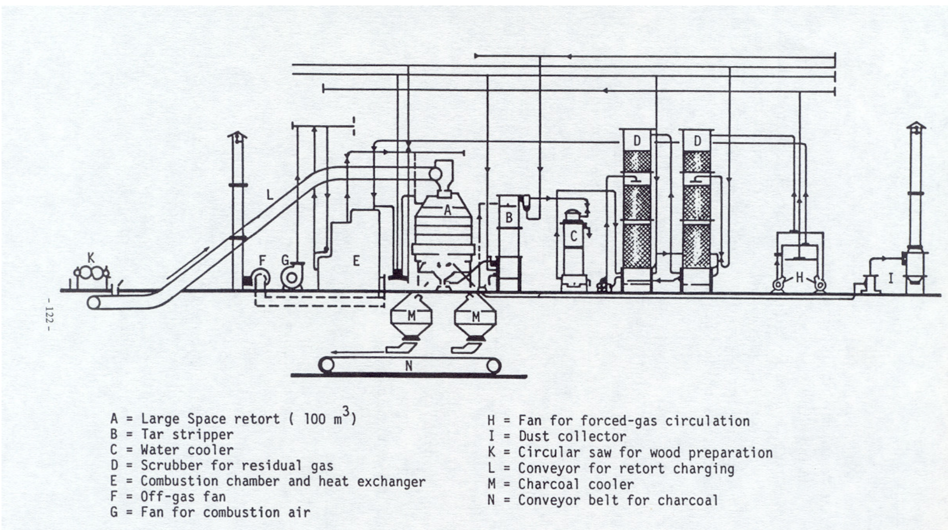


Fig. 25: the Reichert retort process

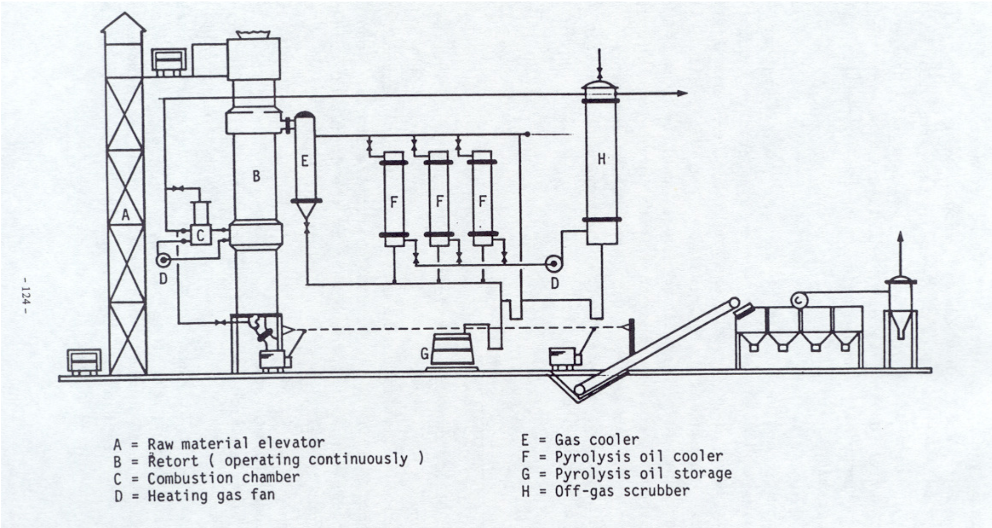


Fig. 26: the French SIFIC retort process

- ***The fluid bed carbonizer***

In this process the raw material (K) is directed to a bed of hot glowing charcoal in a closed chamber (D). This is maintained in a turbulent state by introducing an oxygen-containing gas under pressure into the bed.

The glowing charcoal quickly distils and gasifies the wood particles. The oxygen-containing gas and the evolved gases are present in such quantity that the charcoal and particle bed is maintained in a turbulent or "fluidised state" resulting in a uniformly high temperature throughout.

Charcoal is formed continuously in the process, and may be removed periodically (preferable continuously) and this is done by means of an overflow pipe (F).
Feed material: sawdust, nutshells, bagasse (max size 0.6 cm).
Yield: 18% - 25% (dry wt).

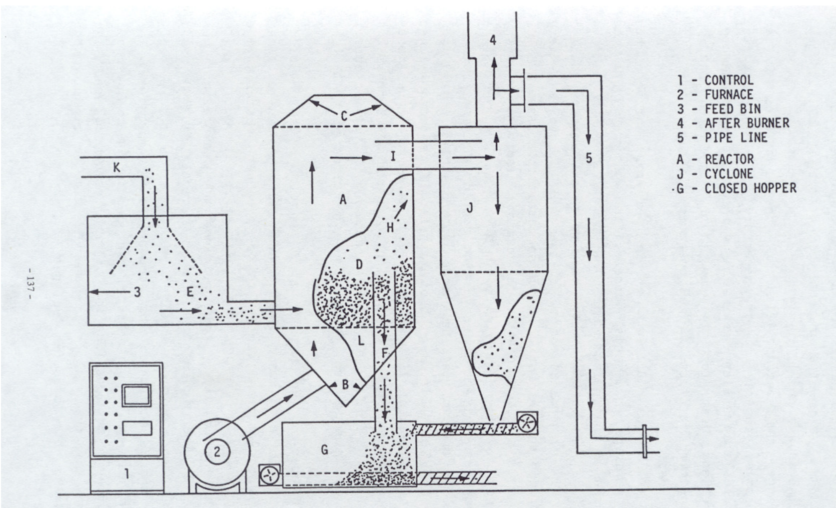


Fig. 27: the fluid bed carbonizer (generalised diagram).

➢ ***Mobile Carbonisation Plant***

This system is able to optimise the quantity and quality of the charcoal production. The dimensions of wood particles are smaller than 1.8 cm (23% moisture by wt). From 3 t of dry wood 1 t of charcoal and ½ t of pyrolysis-oil is obtained.

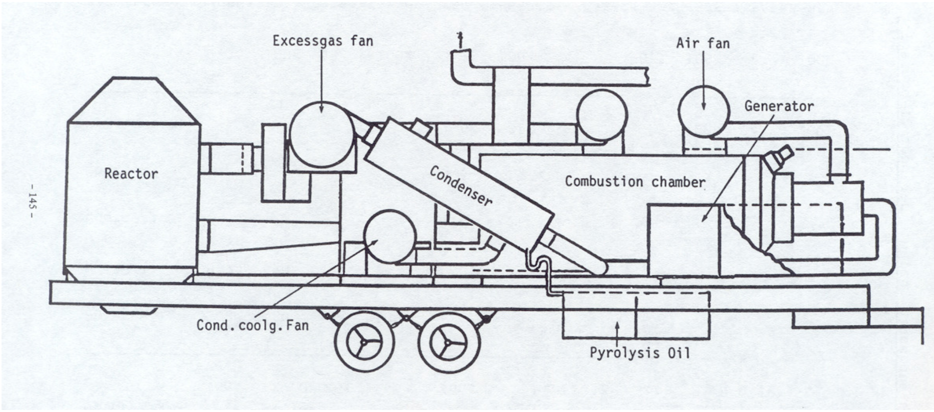


Fig. 28: the ENERCO Model 24 Pyrolyser (right side).

➢ ***Rotary Kiln***

This type of carbonisation units are the most efficient and pollution control technology.

Several industries in the E.U. manufacture this type of modern equipment as shown in figure here below.

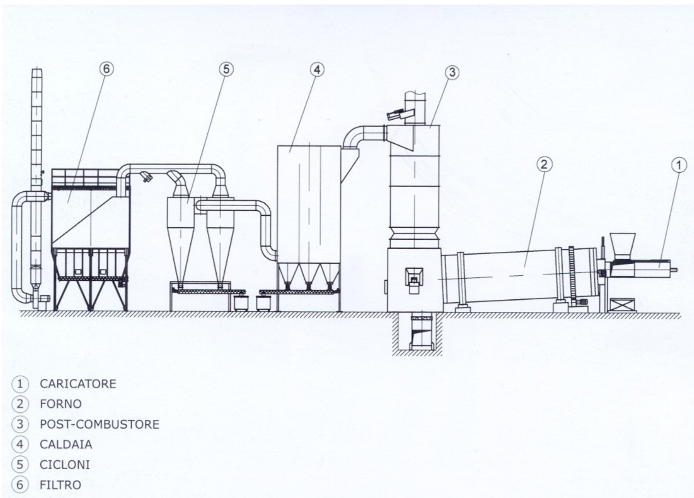


Fig. 29: Rotary kiln

3.1.1.4 Carbonisation products

Chemical and physical properties of charcoal are greatly influenced by three factors – raw material type, process characteristics, and after-treatment. The main properties of charcoal are determined by the following parameters:

Yield: expressed as weight of charcoal per unit weight of dry raw material, in percentage.

Specific Weight: refers to the density of charcoal, which varies according to the density of the raw material. The density of charcoal can be influenced within a narrow range by the course of the process temperature, in particular by the terminal temperature.

Hardness: a very important coefficient for industrial charcoal. Standard scales have been imposed in some countries; these are normally identical with the hardness degrees of bituminous coal.

Moisture: after the charcoal has left the converter, it vigorously absorbs water from the air up to 6% of its dry weight. In some continuous operations, the hot charcoal is cooled by a controlled water spray

Content of Volatiles: if charcoal is heated to 900° under confined conditions, it will lose weight because hydrocarbons and nitrogen are driven out. This weight loss is extremely important to industrial charcoal consumers when defining the utilisation properties. In general, the weight loss should not exceed 30%.

Fixed carbon content: the dry charcoal weight minus the content of volatiles and incombustible (ashes) is equivalent to the content of fixed carbon, which also determines its fuel value (C_{fix}).

Ash content: the ash is composed of the natural minerals contained in almost any organic matter and contamination. The quantity is related to the composition of the raw material mix, e.g. wood branches with a high proportion of bark will give high ash containing charcoal. Charcoal ashes are distinguished by their solubility in water and by chemical analysis.

Sulphur and phosphorus content: the low sum of these substances normally found in charcoals make them especially attractive for use in blast iron furnaces and for metallurgical purposes. The desired value for sulphur is usually below 0.05% and for phosphorus under 0.03%.

Heating or calorific value: this depends on the fixed carbon content and will be lowered only by high ash content. In general, heating values range between 6,500 and 7,200 kcal/kg (30,100 KJ/kg), comparable to bituminous coal.

Active or activated charcoal: the porosity or surface area can be enlarged by special activation processes. Industries use gas, steam or chemical activation. The largest surface area, which can be achieved in commercial plants, measures approximately 1,500 m^2/g, which is close to the area of a football field.

Agglomerated and briquetted charcoal: Known shapes and forms are spheres, cylinders, hexagonal, diamonds, bricks, oblong and pillow-shaped conglomerates and pellets. The constituent parts are: charcoal, binder, and additives.

3.1.1.5 Description of the continuous charcoal process of the woody biomasses in absence of oxygen

The available biomasses, if necessary are crumbled in a suitable crushing machine and continuously fed by a special screw conveyor and a cups elevator to the pre-heater.

The preheating process ventilators a cyclone, a recycling screw id made by utilising the stream of exhausted combustion fumes coming from the carbonisation rotary kiln throughout air pre-heater which will be discharged into the atmosphere at the outlet of the stack.

Then the woody biomass pellets are continuously transferred by screw and an elevator to the carbonisation rotary kiln which operates in absence of oxygen.
The kiln is constituted by:

- a rotating part comprising a cylindrical metallic shell, internally insulated for a certain thickness, and a concentric metallic pipe, joint with the cited shell to which is connected by some partitioning metallic wings, allocated in radial position and alongside the axis of the pipe.
- two fixed parts to the end sides of the rotating part, for the loading and the unloading of the solid or gaseous products. Some inert gas (i.e.: nitrogen) are injected between the rotating and the fixed parts to protect the feedstock from the air entering the reactor chamber.

The solid product (biomass and charcoal) flows on the external surface of the concentric pipe and over the cited wings which are at increasing temperature due to the fact that in the internal part of the pipe there is a continuous counter-currently passage of fumes at high temperature; they are not in contact with the solids in reaction.

The fumes are generated in a special combustor connected to one fixed part of the kiln.

The indicative temperatures (degrees centigrade) are:

- Fumes side: outlet 450 inlet 900
- Wood side: inlet 20 outlet 650

The outgoing fumes do preheat also the carburant air for the combustor throughout a heat exchanger.

The woody biomass is progressively heated by passing through up to the carbonisation temperature; it is submitted to a thermal degradation process which, together with the formation of the solid final charcoal, generates the emission of gaseous products – defined as pyrolytic vapours – which, at their final temperature at the outlet of the kiln have a good combustible characteristics.

The necessary heat for the system is obtained in the combustor by burning:

- during the start up – an external combustible (wood, methane, gpl a. s. o)
- in steady conditions – about 50% of the pyrolytic products
- of the stream of the vapours – generated from the reacting woody biomass -, which go out from the separator at a temperature between 550 and 600 degrees C and more, with a heating power of 2.000 – 2.500 Kcal/Kg.

A part of the pyrolytic product goes to the burner of the carbonisation combustor CC C, to which arrives in the same time the carburant air preheated in the fumes heat exchanger.

The exceeding part of the pyrolytic product is sent to burn in a special low emission combustor that can be used for heat production. The charcoal falling in the separator is normally directly fed – by a special screws system to the charcoal cooling and storage unit.

3.2 BioSynGas technology (from biomass pellets)

In several rural areas of Africa there is scarcity of cooking fuels and in particular a wide scarcity of clean modern fuels.
In general most of needs are satisfied by charcoal, agro-forestry residues, biogas and in smaller amount by GPL. Agro-forestry residues are utilised in very inefficient and traditional ways and generate great health risk for the high level of their noxious emissions, as e.g. CO – smoke – dust.

Modern, biomass derived, renewable clean fuels, like BioSynGas, biogas, bioethanol jelly, etc., could be of great importance for satisfying the vital cooking energy supply.

In rural villages or small towns, the production of BioSynGas, a medium heating value (M.H.V.) gas derived from lignocellulosic biomass residues could fill up the demand of cooking fuel gas which in many cases is partially provided by the biogas production. BioSynGas is in energy content similar to biogas; therefore these two types of gas could be mixed, before distribution in a local consumer network.

A cost-efficient process based on existing commercial technologies for the production of BioSynGas and BioHydrogen from low quality biomass (like agro-forestry residues) is described here below.

The production of BioSynGas from agro-forestry residues is obtained by the following “3-steps process”

- 1st Step: Biomass drying & pelletisation by an innovative technology (for avoid degradation of humid biomass)
- 2nd Step: Direct conversion of biomass pellets into charcoal-pellets (without binding compound)
- 3rd Step: Steam reforming of charcoal pellets at temperatures of ~ 900 °C to obtain BioSynGas consisting mainly of approx. 53% of H_2 and approx. 45% CO).

From one kg of biomass residues pellets with ~ 10% humidity, 0.6 kg of BioSynGas can be obtained with a Heating Value of approx. 4,000 kcal/kg (18.7 MJ/kg). Assuming a low cost of agro-forestry residues of ~ 35 $/d ton as in many developing countries, the estimated production cost of BioSynGas is 80 €/t (176 €/TOE) having often a selling value of ~ 160 €/t. Production plants of small-medium-large capacities can also be envisaged.

BioSynGas could be utilised also to feed a small microgas turbine cogeneration plant. Higher cost of biofuels can be compensated partially by power investment cost for the generator in the range of ~ 850 €/kWe.

3.2.1 Description of the process

The production of this MHV-gas is carried out by the following 3-steps:

3.2.1.1 Biomass drying & pelletisation.

Any type of agri-forestry residues and/or dedicated crops or mixtures with a humidity content of about 35-40% is simultaneously dried and palletised.

3.2.1.2 Conventional carbonisation

The biomass pellets are than submitted to a conventional carbonisation process to obtain charcoal-pellets.

A wide range of carbonisation systems in terms of efficiency, capacity, and emission control is available. Trials carried out by a small, charcoal producing unit have shown good results in converting sweet-sorghum bagasse pellets and corn stalks pellets into charcoal pellets without any need of binding element: good mechanical stability of the pellets, increased hardness, reduced diameter and good processing results have been obtained.

3.2.1.3 Steam reforming of charcoal pellets

Continuous or batch type reactors can be utilised with small-medium-large capacity ranges depending of needs. In the small generator under construction the charcoal pellets are heated at about 800/900 °C inside a rotating reactor and steam is injected producing gasification of charcoal to Bio-Syn-Gas, a mixture in the range of about 50 - 60% H_2 in volume and 35 to 45% of CO, with an heating value of about ~ 19 MJ/kg.

For the processing an important point is the absence of sulphur in the feedstock, eliminating thus the expensive step of gas desulphurisation. From 1 kg of biomass pellets with 10% of humidity approx. 0.6 kg of Bio-Syn-Gas can be obtained.

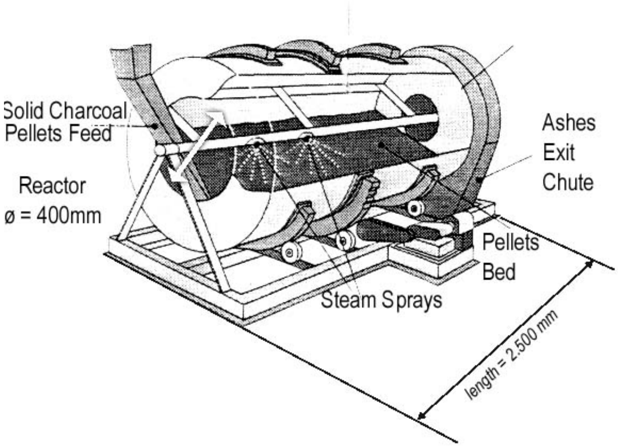


Fig. 3: Charcoal Steam Reforming Reactor

Fig. 4: cooking stove using medium heating value gas (bio-syn-gas).

In summary the concept of this process can be illustrated as follows:

Drying Pelletisation of biomass or mixture — Medium-large capacity

↓

Transformation of biomass pellets in Charcoal pellets — Small-medium-large capacity

↓

Steam Reforming of Charcoal pellets to obtain bio-syn-gas — Small-medium-large capacity

BioSynGas has a heating value of ~ ½ of that one of natural gas and can be utilised and burned efficiently in modern – conventional gas fuelled stoves.

3.3 Biogas plants

3.3.1 Biogas - Origin, Characteristics, Utilisation

3.3.1.1 Biochemical Bases of Biogasification

Biogas production is based on anaerobic digestion process of organic material. It is a metabolism product of bacteria taken part in this process. The digestion process can be divided in four stages, whereby for each dismantling process stage different bacteria strains are responsible.

- Hydrolysis: In the first stage enzymes are separated into the degradable substance by micro organisms, which are very present in animal excrements and sewage sludge. These enzymes decompose high-molecular substances such as proteins, fats, carbohydrates and cellulose into low-molecular connections. The products of the first stage are sugar, amino acids, fatty acids and water.
- Acidogenesis: In the second stage the products of the first stage are converted into provisional final products by acid-forming bacteria. Fatty acids will become acetic acid and hydrogen, amino acids will become acetic acids, ammonia and carbon dioxide.
- Acetogenesis: In the third stage acetate, carbon dioxide and hydrogen are formed by acetic acid from the provisional final products.
- Methanogenesis: These substances serve the bacteria of the fourth stage, the actual methane bacteria, as metabolism products. So the final products of the biogas process will be methane (CH_4), carbon dioxide (CO_2) and water.

During digestion about 50% of the organic carbon in the substrate will be diminished and converted to methane and carbon dioxide, which represent the main components of biogas.

The fertilisation value remains in the decomposed substrate since all of the plant nutrients like nitrogen are still contained. Also with the digestion process the etching action is reduced and the fluidity is improved by the dismantling of organic material. Therefore the decomposed manure flows off better from the sheets and penetrates more easily into the soil. Further the substrate is kind of sanatised, since with the digestion process pathogens and germs are partly killed.

Different kinds of bacteria are involved at the biogas process. In order to ensure the digestion process in the best possible way an adapted environment must be made available to the involved bacteria. Therefore different conditions for the expiration of the digestion process are to be kept:

- **Anaerobic process**

The biogas process runs under anaerobic conditions, this means without air. The bacteria strains involved react to oxygen in different ways. Some fail to increase and stop the biochemical reaction. Other strains are able to grow further with small amounts of oxygen. If solved oxygen is registered into the digestion process by fresh substrate, then it is used in the first digestion stage of aerob working bacteria (with air contact) [1;2;3].

- **Light**

Beam of light restrains the digestion process. However, the micro organisms are not killed [1].

- **Process temperature**

For the origin of biogas a process temperature between 0 and 75℃ in the septic tank is necessary. Since no heat of reaction is set free, the septic tank for middle and high process temperatures must be heated. Therefore with the rising of the temperature the heating requirement of the septic tank increases too. Advantage of a high process temperature is the higher biogas output and the faster decomposing of the substrate. Disadvantage is the higher portion of unwanted materials in the biogas, like carbon dioxide, water, ammonia and hydrogen sulfide.

Three typical ranges of process temperatures are differentiated:

- psychrophile range < 20℃
- mesophile range 20℃ - 38℃ optimum: 30℃ - 35℃
- thermophile range > 38℃ optimum: 55℃ - 60℃

In each temperature range lives a specific bacteria strain. Strong variations in temperature obstruct the growth of the bacterial cultures. Therefore the temperature is to be kept as constant as possible. Within the mesophile range daily variations in temperature of 2 - 3℃ can be tolerated, within the thermophile range the temperature is to be kept constant with variations of 1℃. Changing the temperature range of the process should take place during one period of several weeks.

- **pH-Value**

The optimum of the pH-Value lies in the weakly alkaline range with approx. 7,5. The pH-Value is in a stable range, if the biological dismantling stages of the digestion process is in an equilibrium. With to high (> 8) and to low (< 6) pH-Value methane production decreases. The pH-Value also decreases, if too much fresh biomass is added, since volatile carbonic acids are enriched. If too much easily degradable nitrogenous substances are supplied, the pH-Value increases, because the nitrogen is converted into basic working ammonia.

- **Nutrient supply**

Most of the micro organisms taken part in the biogas process need organic carbon and nitrogen, mineral materials and trace elements for growth and reproduction. Liquid manure and crap contain these materials in sufficient quantities and offer a good buffer for acids and bases. It also has to be ensured that the bacteria come in contact with fresh substrate by thorough mixing.

- **Solid content**

Solids in the substrate are necessary, in order to offer a settlement and/or a contact area to the bacteria. Since the bacteria need a damp environment for working and increasing, the maximum solid content is approximately 50 % related to dry substance. The optimum is reached, if sufficient settlement surface for the maximum number of producible bacteria is present. The solid concentration has to guarantee an effective mixing of substrate and also to give the bacteria the possibility to get in contact with fresh substrate. The optimum range of solid concentration lies between 2 to 9 % dry substance.

- **Comminution**

Substrates like bio garbage, straw and grass must be cut up, in order to offer the bacteria a large reaction area and to ensure an effective mixing.

- **Mixing**

The task of the agitator is the prevention of layer building, to secure the nutrient supply, the destruction of floating covers, the removal of biogas and bacteria metabolism products. Therefore the agitator should be equipped with large agitating sheets working slowly and constantly.

- **Restrictors**

Disinfectants, antibiotics and chemotherapeutic agents can restrain or completely stop the methane production during inappropriate handling. This can occur, if stables are disinfected or whole livestocks are treated at the same time.

- **Septic tank load**

The supply of too much fresh substrate into the septic tank can lead to stop the digestion process. The acid-producing bacteria strongly increase due to the high nutrient offer, so the acid concentration in the septic tank grows and after exceeding the limit value the methane bacteria will stop their metabolic activity. The daily supply load of organic material must remain in a certain framework in order to prevent the acidification by sufficient nutrient supply for the micro organisms. In order to avoid occasional high loads in the feeding zone of the septic tank, the substrate should be supplied as continuously as possible.

- **Degassing**

In order to ensure a high dismantling achievement of the substrate the biogas should be constantly taken out of the septic tank, otherwise the gas production decreases.

3.3.1.2 Composition and Characteristics of Biogas

As a metabolism product of micro organisms biogas mainly consists of methane and carbon dioxide. Fresh biogas is saturated with water vapour. The following table shows the typical values of the respective materials for biogas and compares several information out of different literature sources (see bibliography).

Bibliography	[1]	[2]	[3]	[4]	[5]
Methane CH_4 [vol. %]	65 (59,2 – 72,8)	65	(55 – 70)	65 (51,8 – 85,2)	(40 – 75)
Carbon dioxide CO_2 [vol. %]	34 (27 – 40)	34	(27 – 44)	34,8 (14 – 48)	(25 –55)
Hydrogen sulfide H_2S [vol. %]	(0 – 1)	-	< 3	0,2 (0,08 – 5,7)	(0 – 1)
Hydrogen H_2 [vol. %]	traces	-	< 1	traces (0 – 5)	(0 – 1)
Carbon dioxide CO [vol. %]	-	-	-	traces (0 – 2,1)	-
Nitrogen N_2 [vol. %]	traces	-	-	traces (0,6 – 7,5)	(0 – 5)
Oxygen O_2 [vol. %]	traces	-	-	traces (0 – 1)	(0 – 2)
Ammonia NH_3 [vol. %]	traces	-	-	-	(0 – 1)
Water vapour H_2O [vol. %]	saturation zu 100%	-	-	-	(0 – 10)

Fig. 32: Composition of biogas

Biogas is inflammable, if the methane content lies over 50 vol.%. The heat value of biogas is determined mainly by the methane portion. Methane has a heat value of 9,94 kW/h/m_N^3. With methane concentrations of 60 to 65 % in the biogas a heat value of 6 to 6,5 kW/h/m_N^3 is typical. The density of biogas amounts around 1,2 kg/m^3. The ignition temperature amounts to approximately 700 °C, the ignition border in air is at 6 to 12 vol.% [1].

Hydrogen sulfide is responsible for the toxic effect of biogas. It works at approx. 400 mg/m^3 toxically and starting from 1.200 mg/m^3 deadly. The usual sulfur portion of 0,2 vol.% corresponds to a hydrogen sulfide concentration of 3.060 mg/m^3! Carbon dioxide in biogas leads to breath paralyses, cramps, unconsciousness and blood pressure drop. Starting from concentrations of 177.000 mg/m^3 it works deadly. 35 vol.% of CO_2/m^3 correspond to 687.600 mg/m^3!

3.3.1.3 Utilisation of Biogas

- **Thermal utilisation**

Biogas can be burned in atmospheric heaters. Whereby the heat is partly needed for keeping the temperature level in the septic tank. Depending upon design and isolation 20 to 50 % of the energy contained in the biogas are necessary. The remaining heat energy can be used for heating of buildings and stables, heating of industrial water and drying process for straw, wood, grain, etc..

- **Utilisation in Combined Heat and Power (CHP)**

The utilisation of biogas in CHP-plants is more economical and ecologically, since heat and electricity are made available with a better total efficiency. Beside heating the septic tank the developed heat can be used in absorption climate devices for cooling processes and of course on other consumers stated above.

3.3.1.4 Biogas sources

Relevant sources for the energetic use of biogas are excrements of humans and animals, as well as vegetable materials and biological wastes. Some sources which are present in Africa are shown in detail:

- **Cattle, pigs, chickens**

Due to the open land livestock husbandry not all excrements are avaiable for the processing in a biogas plant. Most important for the biogasification is liquid manure, since it is easier to agitate and pumpable with less technical expenditure than the digestion of solid crap. For this reason liquid manure is processed predominantly in biogas plants.

- **Sheep**

The majority of the resulting excrements of sheep husbandry can not be used due to the pasture management. So from the sheep husbandry no considerable biogas potential is given.

- **Poultry**

The number of geese and ducks vary seasonally due to slaughtering and therefore vary the avaiability of excrements accordingly. Beyond that the animal numbers per owner are often not large enough, in order to make a biogas plant economically work.

- **Grain**

Grain has a very high dry substance content (85%) and is very fibrous so it can only used as a co-substrate in a biogas plant. Grain should also be cut up, since at short retention times no dismantling takes place. The grain digestion is only meaningful if it is too wet for burning purposes, which is energetically more favorable.

- **Corn**

Corn straw is not suitable for the usage in a biogas plant because of its thickness and fibrousness problems with pumps and agitator can occur.

However corn silage is good to degradable and suitable for storage.

- **Fruits and vegetables**

Fruits and vegetables are good degradable and provide also a good biogas output. The danger of acidification exists if large quantities are supplied.

The following table gives an overview to the biogas and energy output :

	m^3 Biogas per kg	Biogas output		Energy output	
		Fresh substrate	Acreage	Fresh substrate	Acreage
	Organic Dry Substrate	[m^3/t]	[m^3/ha]	[kWh/t]	[kWh/ha]
Cow manure	0,2 - 0,48	22,1	-	135,1	-
Pig manure	0,36	22,1	-	135,3	-
Grain straw	0,3 - 0,6	217 - 481	1.084 - 2.403	1.410 - 3.127	9.165 - 20.326
Chicken excrements	0,5	160	-	1.040	-
Corn silage	0,6	151	5.600	982	36.400
Cow dung	0,2 - 0,3	20 - 50	-	130 - 350	-

Fig. 33: Output overview

3.3.2 Identification of European Biogas Plant Manufacturers

This paragraph propose the selection of companies providing complete equipment manufacturer, since planning, project engineering, building and operating services. Nevertheless information of other fields of business is also mentioned if available. Another criteria is the internet presence of the company, which may be a key factor for foreign customers to get appropriate information quick and also an easy manageable option to get in contact with the company.

Company	Country	Comment
Anlagen- und Apparatebau Lüthe GmbH	Heide,Germany	Biogas-Komplettanlagen (Planung schlüsselfertiger Anlagen, Komplettbau, Lieferung von Komponenten)
AgrEnviCon GmbH	Ockensfeld,Germany	
Agrikomp GmbH	Weidenbach,Germany	
AQUA - TEK Biotechnologie und Anlagenbau GmbH	Berlin,Germany	Biomass anaerobic digestion, CHP 5kW-15kW, reed bed water purification
ARCHEA GmbH Gesellschaft für umweltschonende Technologien	Hessisch Oldendorf, Germany	Biogas plants
BEKON GmbH	Landshut, Germany	Digestion of moisturous, solid and liquid biomass, gas utilisation in CHP
BINOWA Umweltverfahrenstechnik	Weischütz, Germany	
Bio System GmbH	Konstanz, Germany	Conception of biogas plants
Biogas Nord GmbH	Bielefeld, Germany	Design, planning and manufacture of biogas plants
Biomass technology Group BV - BTG	Enschede, Netherlands	
BIOPHIL - Gesellschaft für Biotechnologie, Energie- und Umwelttechnik mbH	Berlin, Germany	
Bioscan GmbH	Osnabrück, Germany	

Company	Country	Comment
Bioteg GmbH	Kulmbach, Germany	Bio filter
Bi - Utec	Hirschfelde, Germany	
BTA Biotechnische Abfallverwertung GmbH & Co. KG	München, Germany	
Buehler AG	Hannover, Germany	vegetal biomass utilisation - digestion, composting
Consentis Energie & Umwelt	Wietmarschen, Germany	Biogas - complete conversion and gas utilisation units
Dansk Biogas A/S	Hasselager, Denmark	
ECB Enviro Berlin AG	Berlin, Germany	Biogas plants
ECONS SA	Bioggio, Switzerland	Biogas from waste
Ecotop BV	Overdinkel, Netherlands	
energie + konzept	Hamburg, Germany	Design of Biogas plants
ENTEC - Umwelttechnik GmbH	Nauen Fussach, Germany	Biogas plants
Environmental Biotechnology Ltd - EBL	Bridgwater, United Kingdom	Anaerobic digestion of wastes, composting
EnviTec - Mall	Saerbeck, Germany	Biogas plants
EWO Energietechnologie GmbH	Lichtenau, Germany	Biogas plants for farmers
Farmatic Anlagenbau GmbH	Nortorf, Germany	complete biogas units - conception, manufacture, start-up and operation
FLS Miljoe a/s - BS Incineration Technology Centre	Valby, Denmark	solid waste management and biogas utilisation
GBU mbH Biogas & Umwelttechnik Büro Nord	Hechthausen, Germany	Biogas plants
Henze HARVESTORE GmbH	Unna Königsborn, Germany	
Ing.-Büro C. Rückert	Neukirchen bSR, Germany	complete biogas units - conception, set-up
INNOVAS	München, Germany	… related to energie + konzept
Linde-KCA-Dresden GmbH - Environmental Technology Processes	Dresden, Germany	Digestion of organic waste, sludges, manure, wastewater and biogas use
LIPP GmbH	Tannhausen, Germany	Biogas plants
MAT Müll- und Abfalltechnik GmbH	Waiblingen, Germany	Biogas - complete plants (design, manufacture, set-up and operation)
Meixner Gülletechnik	Buchen-Hollerbach, Germany	Biogas plants, pumps technology, transportation, stirring and comminution technology
OSMO - Anlagenbau GmbH & Co. KG	Georgsmarienhütte, Germany	Biogas plants
Rosinger Anlagentechnik GmbH & Co.	Attnang Puchheim, Austria	Biogas complete units, vegetable oil - and esterification), waste-to-energy units
Schmack Biogas GmbH	Burglengfeld, Germany	Biogas- full systems (planning, multiple fermenter technology, gas storage, analytical service)

Company	Country	Comment
SEF Energietechnik GmbH	Zwickau, Germany	Biogas-whole conversion units, CHP for biogas, lanfill gas utilisation
SITA BFI	Oosterbeek,, Nertherlands	
U.T.S. Umwelt - Technik - Süd	Obertaufkirchen, Germany	Biogas- complete plants (conception, manufacture, consultation)
UWAS Umwelttechnik und Anlagenbau	München, Germany	manufacturing of Two-stage-fermenters
Valorga International SAS	Montpellier, France	Biological household waste treatment, biogas use, turnkey plants
WELtec BioPower GmbH	Lutten, Germany	Biogas- complete plants (conception, manufacture, consultation)

Fig. 34: list of biogas plant manufacturers

3.4 Microdistilleries

3.4.1 Introduction to the microdistillery concept

The most relevant motivations that make bioethanol microdistillery an interesting opportunity for Arid and semi-arid rural areas are:

- It is now possible to supply modern bioenergy complexes for remote rural villages based on different crops able beyond the satisfaction on the essential needs of the population (food, animal feed, energy), to produce an extra income from the surpluses sale for an economic sustainable activity
- The comprehensive utilisation and processing of the biomass resource in integrated complexes with the simultaneous production of several high value commodities is essential for the improvement of the economic activity and for a large scale sustainable deployment of these bioenergy complexes
- These Integrated Complexes could provide a vital contribution for a general rural socio-economic development and for considerably increasing the Index of Human development of the population (60-70%). It seems that a specific investment of 500$ - 1500$ are sufficient tin very poor situations to change the life of one person forever
- Significant effort to expand the availability and local manufacture of commercial small size technologies, for technical assistance and for education & training - especially for a sustainable biomass production - must be envisaged as vital measure to ensure a viable and durable operation

Considering the production by small plants in general, the economics of decentralised bioethanol production in microdistilleries at capacities of 5-10 tons/day is penalised for the scale-effect expressed by the “Capacity 0.6 exponential factor”. This negative effect can be compensated by:

- Large number repetition of standard optimised microdistilleries (production in series as indicated below).
- Adoption of small-scale bioenergy integrated complexes for the production of several coproducts from well selected dedicated crops, to maintain the price of bioethanol at a preferential level

It is estimated that in this way production costs of about 250 $/liter can be obtained also by small plants offering thus the opportunity to increase considerably the supply of bioethanol at world-scale and facilitating for developing countries the possibility of becoming large high value energy producers, generating with significant impact on their rural development and increase of the general Index of Human Development, this being so much related to the energy availability and use .

The most important fields in which bioethanol can be used are:

- **Heat market** (Cooking Fuel, ETOH jelly): Space heating – Cooling
- **Cogeneration** (microturbines, external combustion engines): Power + water and space heating + space cooling + food freezing (for hospitals, hotels, shopping centres, public and private buildings, schools)

- **Trigeneration** (microturbines + engines + absorption refrigeration systems): Power + water/space heating + space cooling + food freezing (hospital + hotel + shopping centres + schools)
- **Transport**: Low-grade (95°) bioethanol as additive for Diesel and gasoline, low-grade bioethanol for external combustion power generators (hybrid – cars)
- **Chemicals**: ETOH for hydrogen production

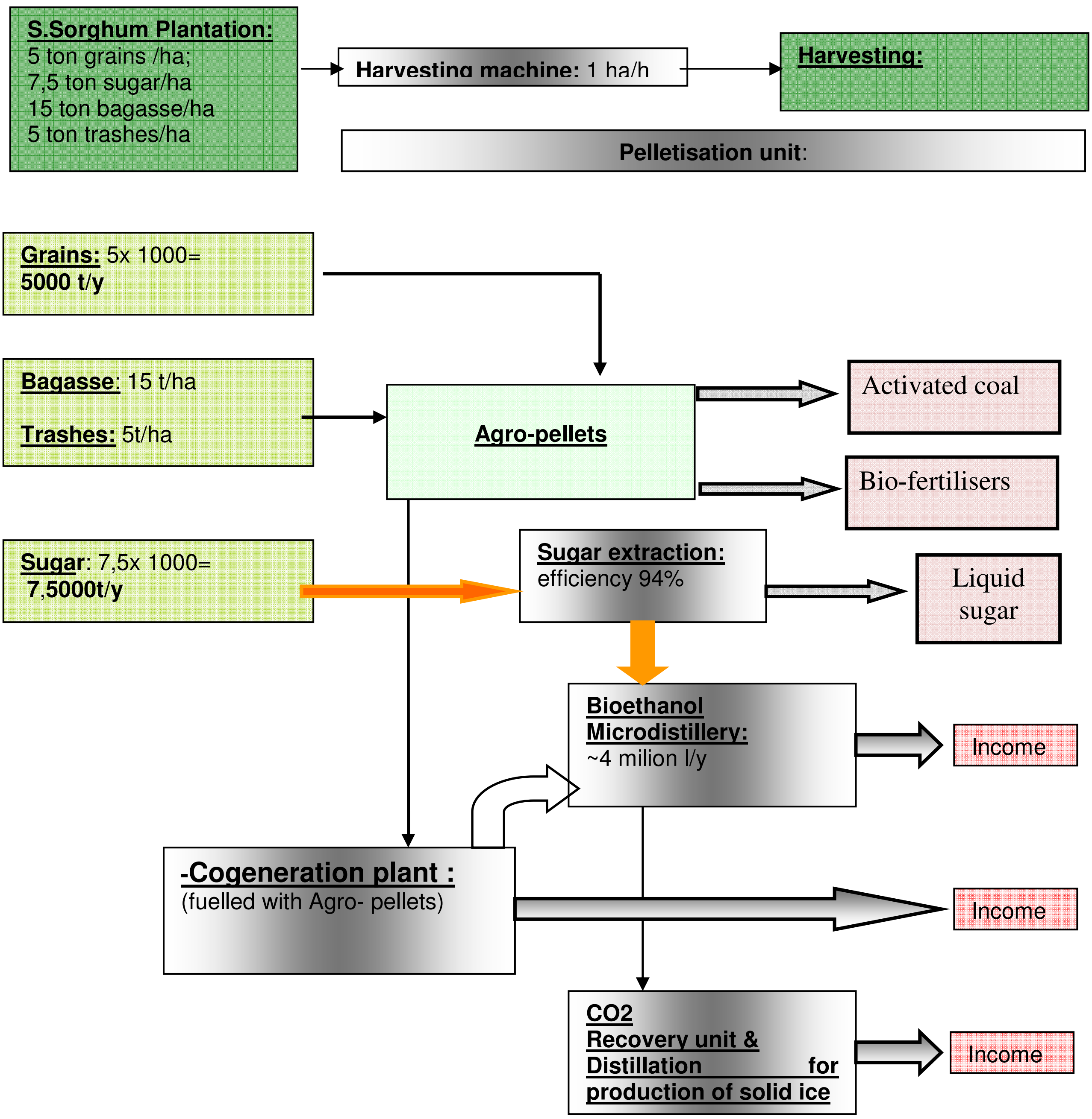


Fig. 35: Scheme of Sweet sorghum Bioenergy Complex.

3.4.2 Technology overview

The production of ethanol or ethyl alcohol from starch or sugar-based feedstocks is among man's earliest ventures into value-added processing. While the basic steps remain the same, the process has been considerably refined in recent years, leading to a very efficient process. There are two production processes: wet milling and dry milling. The main difference between the two is in the initial treatment of the grain. In dry milling, the entire corn kernel or other starchy grain is first ground into flour, which is referred to in the industry as "meal" and processed without separating out the various component parts of the grain. The meal is slurried with water to form a "mash." Enzymes are added to the mash to convert the starch to dextrose, a simple sugar. Ammonia is added for pH control and as a nutrient to the yeast.

The mash is processed in a high-temperature cooker to reduce bacteria levels ahead of fermentation. The mash is cooled and transferred to fermenters where yeast is added and the conversion of sugar to ethanol and carbon dioxide (CO2) begins. The fermentation process generally takes about 40 to 50 hours. During this part of the process, the mash is agitated and kept cool to facilitate the activity of the yeast. After fermentation, the resulting "beer" is transferred to distillation columns where the ethanol is separated from the remaining "stillage." The ethanol is concentrated to 190 proof using conventional distillation and then is dehydrated to approximately 200 proof in a molecular sieve system. The anhydrous ethanol is then blended with about 5% denaturant (such as natural gasoline) to render it undrinkable and thus not subject to beverage alcohol tax. It is then ready for shipment to gasoline terminals or retailers.

The stillage is sent through a centrifuge that separates the coarse grain from the soluble fractions. The soluble fractions are then concentrated to about 30% solids by evaporation, resulting in Condensed Distillers Solubles (CDS) or "syrup." The coarse grain and the syrup are then dried together to produce 'Dried Distillers Grains' (DDGs) with the soluble parts, a high quality, nutritious livestock feed. The CO_2 released during fermentation is captured and sold for use in carbonating soft drinks and beverages and the manufacture of dry ice.

In wet milling, the grain is soaked or "steeped" in water and diluted in sulphurous acid for 24 to 48 hours. This steeping facilitates the separation of the grain into its many component parts. After steeping, the corn slurry is processed through a series of grinders to separate the corn germ. The corn oil from the germ is either extracted on-site or sold to crushers who extract the corn oil. The remaining fibre, gluten and starch components are further segregated using centrifugal, screen and hydroclone separators. The steeping liquor is concentrated in an evaporator. This concentrated product, heavy steep water, is co-dried with the fibre component and is then sold as corn gluten feed to the livestock industry. Heavy steep water is also sold by itself as a feed ingredient and is used as a component in Ice Ban, an environmentally friendly alternative to salt for removing ice from roads. The gluten component (protein) is filtered and dried to produce the corn gluten meal co-product. This product is highly sought after as a feed ingredient in poultry broiler operations. The starch and any remaining water from the mash can then be processed in one of three ways: fermented into ethanol, dried and sold as dried or modified corn starch, or processed into corn syrup. The fermentation process for ethanol is very similar to the dry mill process described above.

This process flow diagram shows the basic steps in production of ethanol from cellulosic biomass. Note that there are a variety of options for pre-treatment and other steps in the process and that several technologies combine two or all three of the hydrolysis and fermentation steps within the shaded box. (Chart courtesy of the National Renewable Energy Lab.)

Sweet sorghum is a very promising energy crop with high yields of grains, sugar and bagasse. Sweet Sorghum in some special varieties has been selected mainly for economic reasons: it is a highly competitive energy crop, as for some varieties, it has been estimated that the sale of grains (yield 5-8 t/ha) could cover the cost of crop production and consequently, the other components, for instance, sugar and lignocellulosic bagasse, can bring in good profits and the sales can provide the farmers surplus income. Demonstration projects at a scale of 800- 1000 ha could be sufficient for assessing and demonstrating the feasibility, the economic viability and sustainability for large-scale integrated complexes.

For the production of bio-ethanol sweet-sorghum seems the most promising feedstock because:

- It is world-wide applicable. It can be grown in temperate and tropical regions and on low-quality soils, therefore it can be valuable for all the continents.
- It is a C-4 crop with a short growing cycle of 4-5 months and produces high yields of multiple components such as starch, sugar and lignocellulosics.
- It requires little water -1/3 of the water required for sugar cane and ½ of that for corn- and fertilizers inputs.
- Plantation needs a lower amount of seeds: 10 kg/ha compared to corn with: 40 kg/ha and wheat: 150 kg/ha.
- It can provide many valuable food-animal feed-energy products, i.e. grains-sugar/grains-leaves-bagasse/power-heat-bioethanol-charcoal, etc.
- The positive energy output/input ratio for the production processing routes to obtain bio-ethanol , DDG and co-generation fuels, which is 2 : 5.

The integrated bioenergy complex, based on the exploitation of sweet sorghum for the production of bio-ethanol and other energy/industrial commodities, after its high economic viability has been demonstrated, offers a new sustainable path for production of bio-ethanol, which is considered a strategic fuel for the transport sector. Such a project may be implemented in Africa and other regions on a large scale, as past studies have shown the high yields of this crop in terms of grains, sugar and bagasse in several different climatic belts.

This “integrated” project, once implemented on a large-scale, or in a repetitive way, can have important impacts on the economics of such complex in terms of reducing the production costs of ethanol. Utilisation of particular varieties of Sweet Sorghum as dedicated energy crops is, in this respect, of great importance because the process “integration” comes from the opportunity of converting the several components of the plant: starch, sugar and lignocellulosic. This very important feature distinguishes Sweet Sorghum from other grain crops as i.e. corn, wheat, barley, currently utilised for bio-ethanol production in other climatic areas. In fact, well-known bioethanol crops (i.e. sugar beet- corn-sugar cane) are cultivated only to produce alcohol. Sweet sorghum plant, on the contrary, can provide not only sugar and grains which can be used for bioethanol production, but also large amounts of bagasse, which can be used as fuel to generate steam, electricity necessary for the bio-ethanol production process, syngas, hydrogen, etc., thus providing an energetic surplus for sale.

A 'Small bioenergy complex' based on a plantation of 1000 ha with good Sweet Sorghum seeds, could satisfy the essential needs of a rural village with a population of about 5,000 people, and provide additional energy for comfort and production activities.

3.4.3 Bio-ethanol/DDG plants

3.4.3.1 Ethanol Production

Sugar juice after extraction can be converted into ethanol by fermentation (resulting in a beer with alcohol percentage of about 7%) that is consequently upgraded to high-grade ethanol (alcohol percentage 99.8-99.9%). Grains can be converted into ethanol as well. However, since in grains sugar is only available as complex sugars/starch, the grains have to be mashed and saccharified first to convert the complex sugars/starch into simple fermentable sugars. The process steps following this mash preparation and saccharification are similar as for sugar juice to ethanol (fermentation followed by distillation). However, when converting grains into ethanol a non-fermentable residue remains, i.e. distillers' dried grains (DDG) that is a high value protein rich animal feed. This so called stillage is processed separately from the fermentation and distillation processes.

A commercial technology is utilized all over the world for ethanol plants of different capacities (from few litres per day of product to huge industrial production) and treating different raw materials as cane and beet molasses, fruits, potatoes, grain.
The process scheme for a plant designed in accordance with the European technology to produce about 1,000 liters of alcohol per day includes:

Fermentation unit (batch system) completed with one mash buffer tank, two small yeast propagation tanks, two fermentation tanks and ancillaries such as pump, air compressor, piping. In this plant a side stream of mash is fed to the yeast propagation tank and mixed with fresh yeast available on the market (Baker's yeast or similar), nutrients, and process water, to produce sufficient yeast cells to balance process losses. The enriched yeast suspension is then pumped to the fermentation tanks along with the mash main stream. The fermentation tanks are maintained in anaerobic condition in order to maximise the production of alcohol.

Batch (or continuous) distillation plant complete with one column (or a pot still) to strip alcohol from the fermented mash and to concentrate alcohol to the required level and with all ancillaries such as condensers, coolers and piping. This process uses a special technique to recover most of the residual ethanol remaining in the whole stillage (or slops) when it leaves the column as waste, preventing valuable ethanol from being either blown into the atmosphere as polluting VOCs (volatile organic compounds) or discharged in the water.

The plant is normally designed, in consideration of the low output, for indoor installation inside a building of ± 8.00 x 6.50 x 9.00 meters high.

The investment cost for this fermentation/distillation/storage unit is in the region of 250,000 Euro.

3.4.3.2 Process steps grains to DDG

After the process steps described above the stillage from grain fermentation is processed further into DDG. Process steps are:

- Stillage separation: separates solids contained in the stillage water from the water.
- Stillage evaporation.
- DDG's drying.

3.4.3.3 Description of the fermentation process

The components in this system are: carbon dioxide supply, circulation system, juice flowing and filing system, cooling and warming system and measuring meter system.

The carbon dioxide circulation system includes foam collector, gas-liquid separator, cooling and purifying tank. No.1 Luechi gas circulator, gas storage bag, No.2 Luechi gas circulator, constant pressure gas storage tank, gas volume of flow meter, and gas chamber at the lower end of biological reactor.

The juice flowing and filling system is composed of a juice storage tank, juice pump, flowmeter of juice and biological reactor. The beer removing system comprises beer storage chamber, solid liquid separator, and beer discharge. In order to make the reactor cool or warm, a loop pipe is used for circulating cold water or hot water.

Before normal operation of this fermentation system, the fixed-yeast cells must be reproduced. Firstly, the prepared fixed-yeast particles must be supplied into the reactor, secondly, afterward diluted juice of sweet sorghum must beaded to the reactor until the reactor is completely filled, at the same time, some aseptic gas were flowed into to this one, up to when the number of fixed-yeast cells reach the standard desired level; the normal operation starts. During the normal operation, several actions are required: First of all, the carbon dioxide circulation system and the juice flowing and filling system must be activated. In this stage firstly the No.1 Luechi compressor injects the carbon dioxide (available inside the gas storage bag) into the constant pressure gas storage tank and then, the carbon dioxide is led to the gas chamber at the lower end of the multi-stage biological reactor. Where the fixed yeast particles react, at the same time, the juice of sweet sorghum inside high position tank is injected into the reactor along two tangential holes of the reactor (under the pressure) resulting in a circular movement of liquid inside the reactor. Because of this movement, the carbon dioxide adhered to the surface of fixed-yeast particles can be released easily at any time. Beside, the particles can remain sufficiently in contact with the fermentation liquid generating vigorous reaction momentum throughout the operation and an increase of the velocity of reaction. Finally, with the gradual rise of fermentation liquid inside the reactor from the first unit to the beer storage chamber the sugar is converted into alcohol and carbon dioxide within 9 hours. The conversion rate can reach up to 90%.

The beer is separated into two parts: liquid and broken yeast particles by the solid-liquid separator.

The carbon dioxide is accumulated into the gas storage bag, through the beer storage chamber, foam collector, gas-liquid separator, and cooling and purifying tank under the negative pressure of the Luechi gas circulator.

In summary the most interesting point of this processes the fast conversion of sucrose into ethanol (~9 hr), with the utilisation of immobile cells carrier (in replacement of traditional ferment technology) which shows a faster conversion rate, higher productivity and efficiency.

To obtain bioethanol-96 (or bioethanol-92) a conventional but efficient distillation technology is enclosed. Steam derived from the power cogeneration plant operating with a conventional steam engine and/or a small steam-turbine will be utilized for supplying the required process heat.

3.4.4 European actors and Manufacturers

European manufacturers of bio-ethanol plants are for example:

- Ferrostaal AG – Division Kirchfeld Food Technology, Essen, Germany
- Frings Austria Ges.m.b.H, Graz, Austria
- Chema Anlagenbau GmbH, Rudisleben, Germany
- Maschinen- und Anlagenbau Grimma GmbH, Grimma, Germany
- Vogelbusch GmbH, Wien, Austria
- Frilli, Italy

4 Technologies of biomass to bioenergy valorisation

4.1 Small biomass cogeneration plants (gasifier – engine generator)

4.1.1 Generalities

In both the industrial world and developing countries there is a steady and continuing interest in biomass gasification that has not yet been satisfied by the emergence of either a sufficiently reliable or a sufficiently cost effective technology.

Biomass gasification can either be taken in a general sense to mean a process to produce gas through a thermal process in which a limited supply of gasifying agent such as air oxygen is reacted with biomass at high temperature.

There are three basic thermochemical conversion processes:

- Gasification
- Pyrolysis
- Hydrolysis

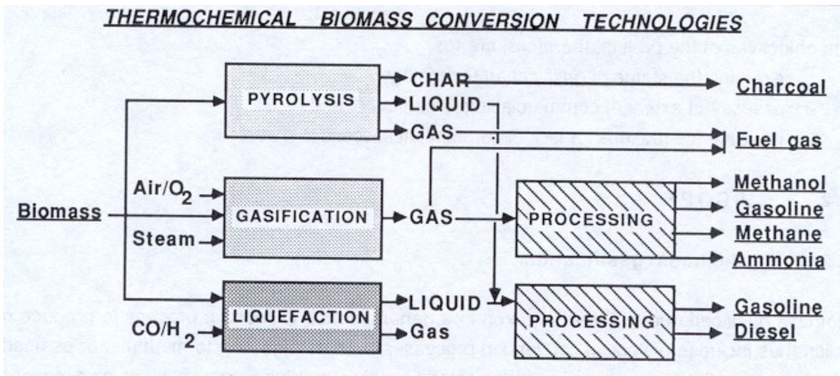


Fig. 36: The three main conversion processes and secondary products

4.1.1.1 Gasification

Through the process of *gasification*, solid biomass can be converted into a fuel gas or biogas. Biomass gasifiers operate by heating biomass in an oxygen-free, high temperature environment that breaks it down to release a flammable, energy-rich synthesis gas or 'syngas'.14 This gas can be burned in a conventional boiler, or used instead of natural gas in a gas turbine to turn electric generators. Biogas formed through gasification can be filtered to remove unwanted chemical compound and can be used in efficient power generation systems known as 'combined-cycles', which can combine steam and gas turbines for electricity generation and can yield up to 60 percent efficiency of coal-fired plants.15 The first integrated gasification combined cycle (IGCC) plant fuelled by 100 percent biomass (from straw) was successfully demonstrated in Sweden from 1996 to 200016. IGCC plants elsewhere could become economically competitive using black-liquor from the pulp and paper industry as a feedstock, but further analysis is required.17

4.1.1.2 Pyrolysis

This is a process that heats biomass in anoxic conditions, although well-established in small plants, has yet to be used on a large scale. Pyrolysis can be classified as conventional, fast or flash depending on the temperature, heating rate, particle size and solid residence time of the process. Fast pyrolysis of biomass yields a liquid product called pyrolysis oil or bio-oil that can readily transported and stored. Most forms of cellulosic biomass maybe used as pyrolysis input. In laboratory conditions, nearly 100 types of plant biomass have been tested such as agricultural wastes (straw), olive pits, nut shells, forestry wastes such as bark and thinnings.36

However, large scale pyrolysis facilities are yet to be developed and in most instances, it may be desirable to use a combination of different conversion methods for different types of biomass in one production facility in order to optimize and regulate the amount of required process energy.

4.1.1.3 Hydrolysis

This is a form of biochemical conversion for transforming biomass into liquid fuel. Hydrolysis can convert biomass to bioethanol by using acids that break the bonds of the larger cellulose molecule to form smaller sugar molecules ready for fermentation. The process is currently expensive and a drawback of using it for cellulosic feedstock is the low fuel yield. caused by the over-disintegration of the hemicellulose sugar before fermentation. Hydrolysis using enzymes and microbial digestion is also currently being developed that look to optimise sugar extraction from cellulose and hemicellulose.35

Biomass gasification can be viewed as a sequence of physical and chemical steps as represented schematically in figure below:

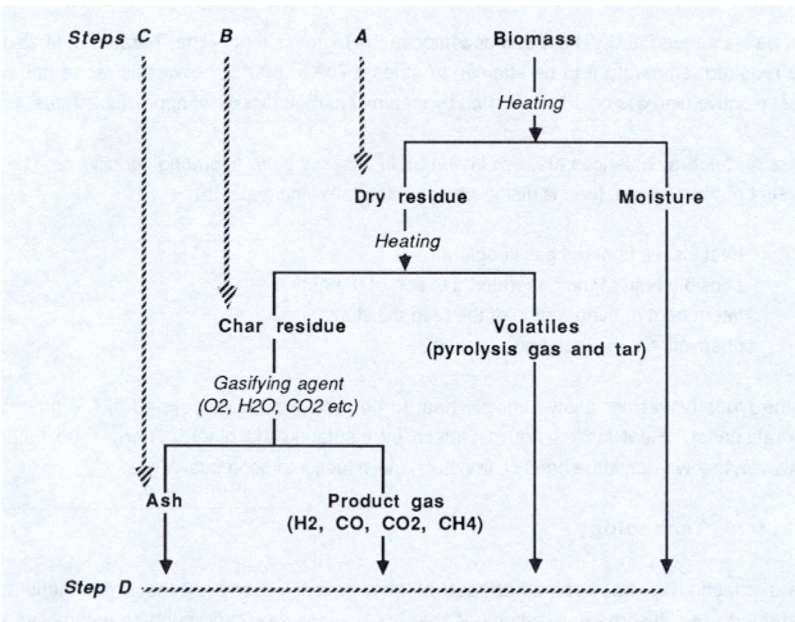


Fig. 37: schematic representation of gasification as a series of consecutive and interactive processes A to D

Drying, pyrolysis and gasification proceed sequentially, but with numerous interactions, the nature and extent of which depend on the gasification technology used.

Gasification may also be regarded as a form of incomplete combustion. The heat of combustion thereby provides the required driving force to the entire process.

Hot gas is needed to dry, heat and decompose the biomass feed. The liberated heat also allows the required temperature to be attained of at least 700 to 800°C; below this range not even the most reactive biomass char is converted by steam or carbon dioxide at appreciable rates.

Mass and energy balances are also important in assessing the operating conditions. The energy content of the biomass feed is distributed over the following aspects:

- heat losses from the gasifier plant
- sensible heat of the generated gas and of the ash
- latent heat of evaporation of the feed moisture
- chemical energy in the gas

Some types of gasifier allow sensible heat to be recovered and recycled to the process (e.g. updraft units). Heat losses are minimised by insulating the plant. There is no technology, however, that will convert a barely flammable, moist fuel, into good quality gas.

4.1.2 Modern type of gasifiers

Gasifier technology has been a basic tool of the chemical industry. The first commercially used gasifier was built by Bischof in 1840 for the iron works of Audincourt, France. From then on several improvements were made to the technology until 1861 when Siemens introduced his gasifier, which can be considered as the first successful commercial unit.
The widespread industrial use of coal also made possible the large-scale use of producer gas. Gasifiers can be classified according to two criteria, namely:

- the relative motion between solid and gas
- the bulk density of the solid phase in the reactor.

Dense phase gasifiers are characterised by a relatively large amount of fuel in slow motion and exposed to a limited amount of reactive gas. In lean phase reactors such as entrained flow, circulating and bubbling fluidised beds, a relatively small amount of finely divided solids are reacted while in vigorous motion in a gas stream.

Dense phase gasifiers can be subdivided into updraft or counter current; and downdraft or concurrent units. Cross draft units were formerly used in automotive applications, and still have some applications. Dense phase gasifiers normally rely upon gravity for the (vertical) movement of the feedstock, characterised by feeding at the top with ash extraction at the bottom. It is possible, however, to organise the solis' movement in other ways, e.g. by means of a rotary kiln, an angle conveyor, a mechanical grate, a stirrer, an auger, or rabble arms as in multiple hearth units.

Mechanical auxiliaries, however, are not in widespread use, unless are essential in solving specific feed or ash handling problems. Mechanical extraction of ash, for instance, by means of a slow moving rotary grate has been widely used.

Provision is often made to cool the hottest part of the gasifier to avoid slugging and loss of construction materials, for example with a water jacket. This option, however, extracts heat where it is most useful, i.e. in the hearth.

Many devices have been designed in order to:

- promote an even and regular flow of biomass fuels that have a tendency to bridge, choke, or form channels
- organise the flow of condensable vapours and tars, e.g. two-stage gasoliers
- concentrate the high temperature zone at a specific and suitable location
- transfer sensible heat from the generated gas to the incoming feed

4.1.3 Utilisation of producer gas in diesel engines

4.1.3.1 Mixed and pilot injection

Diesel engines can be used with both diesel oil and generator gas as a fuel. In the latter case the gas mixed with the intake air and the diesel injection system is equally readjusted.

4.1.3.2 Carburation of producer gas in Diesel engines

In general, the carburation of producer gas in a diesel engine is the same as the one in an Otto engine. The regulating system has to control not the quantity of mixture but the quantity of gas. When using a stationary engine, the quantity of gas supplied to the engine can be controlled by a second all speed governing system, depending on engine load.

4.1.3.3 Injectors

Apart from readjustment of governing systems etc. one has to pay special attention to the injectors. The diesel oil does not only have the ability of generating mechanical energy but acts as a coolant for injectors.

4.1.4 Main constraints

4.1.4.1 Problems in gasifiers

Generally there is an interaction between problems in the gasifier and those in the engine. For this reason these problems are summed up in general terms.

The most important problem, with the application of gasifiers for fuelling engines, is the variable gas quality (heating value and the amount of dirt), dependent on the solid fuel feedstock and operating parameters. These may vary particularly in respect of water content, ash content and chip size. Irregularities in feeding, in fuel flow and in hearth position and temperature also affect gas quality.

4.1.4.2 Tar content of fuel

Tar formation is the most general problem, which can result in rapid engine failure when it is not filtered out.

4.1.4.3 Ash content of the fuel

When the ash content of the fuel exceeds a certain value there is a possibility of ash slagging in the reactor.

4.1.4.4 Feedstock size

Generally the feedstock size has to be adapted to the reactor design. Sometimes it is necessary to reduce the particle size. This is labour and mechanical consuming.

4.1.4.5 General problems in engines

The most common problem with the application of producer gas in combustion engines is the lifetime of the engine. This is quite a general complaint although documented cases are known of very good lifetime combined with good gas cleaning.
Engine wear is a result of unwanted components such as dust, tar and corrosive components in the gas. This is strongly dependent on the proper operation of the gas cleaning system.

4.1.4.6 Dust

Soot, carbon and ash particles are produced in the reactor and carried with the gas. In case the gas cleaning is inadequate, this material comes into the engine cylinders and creates wear of the cylinder wall and piston rings.

4.1.4.7 Tar

Tar is formed during the gasification process. Although some manufacturers of gasifiers claim that no tar is formed it is noticed that tar is always present sometimes as small droplets. Tar as such does not create abrasive wear but can settle down on valves, piston rings, etc. and thereby obstruct the operation. Sometimes tar becomes bituminous, which can create problems particularly during start-up of a cold engine.

4.1.5 Full Systems Biomass Gasifier

Biomass gasifiers are process reactor to transform solid biomass in an operating gaseous fuel. Depending of the sectorial market needs we get the following systems:

- **Heat production market:** gasifier + boiler

Several commercial technologies are available. In gasifier systems for industrial thermal purposes the energy content of producer gas is usually far less than that of natural gas but the economics of gasification were attractive enough since the early 1980's for industrial and commercial process heat applications to become common in the U.S.A. and developing countries such as China, Brazil, Indonesia, Malaysia. Heat gasifiers, primarily large system replacing fuel oil in industrial applications, are commonly located in urban or peri-urban areas. Conversely, many rural applications are found for power gasifiers that burn the gas in internal combustion engines. These applications primarily replace diesel oil in small engines used to generate electricity, pump water, or mill grain.

Biomass heat gasifiers are presently used to provide process heat in a wide variety of applications including: tea, grain, and lumber drying: glass, tile, and brick manufacturing: cement production, food processing, and greenhouse heating. Heat gasifier systems, consisting essentially of a fuel feed system, reactor chamber, and gas burner, are commercially available in sizes from 100 kWth to 10 MWth. The smaller, manually batch fed, systems are commonly used for crop drying, baking or other similar applications. The larger systems are automatically fed and are used to provide heat for industrial kilns, boilers, dryers and furnaces. As heat gasifiers can usually be retrofitted to existing oil or natural gas burning equipment, the potential number of applications is extremely large. The primary economic benefits come from being relatively simpler than power gasifiers and their financial and economic attractiveness are more favourable due to low capital costs and higher utilisation factors associated with the technology.

- **Cogeneration market**: gasifier + diesel generator (adapted), gasifier + turbine

As explained in more details in the following chapter, very few technologies are at commercial or demonstration stage. These cogeneration systems able to supply simultaneously heat and electricity present better economic perspectives.

- **Transport market**: gasifier + otto engine

At present there are no more applications, but in the past there was a wide use of gasifiers to propel vehicles as shown in the following table;

- **Chemical market**: special gasification with oxygen with nitrogen largely eliminated.

MHV gas is mainly generated for its high concentration of hydrogen and carbon monoxide, which form the basis of synthesis gas. It can be used as a raw material in chemical synthesis. The following are the most common synthesis routes:

4.1.6 Application of Biomass Gasifiers for decentralised power generation (or cogeneration)

Historically, steam cycles and internal combustion engines have been the common routes to the generation of electric power from producer gas. In recent times however, the use of gas turbines is receiving considerable interest. Much of the interest in the 1980s was on small/medium sized fixed bed gasifier systems. In the beginning of this period, at least 10 (mainly European) manufacturers were offering small-scale wood and charcoal fired power plants of up to 300 kWe. At least four developing countries - Philippines, Brazil, Indonesia, India - started to introduce both power gasifiers and implementation programmes based on locally developed and manufactured technology. Also a number of donor organisations were involved in power biomass gasification programs, sometimes by financing foreign made equipment, in other cases through technical assistance in the development of local technology. As results of this activity, hundreds of biomass gasifiers were installed in a large number of developing countries.

It has become clear that biomass gasification for power generating purposes is not a technology that can be easily implemented in a dispersed and small-scale manner. On the contrary, widespread dissemination of the technology is obviously dependant on a number of institutional pre-requisites being put into place.
Important factors to be addressed are:

- Extensive user information;
- Standardisation and certification of commercial systems;
- Institutional training systems for operating personnel.

From the economic viewpoint, it is clear that biomass gasification is not a technology that can produce power now at a lower cost than petroleum fuelled alternative systems. Commercialisation of the technology in developed or developing countries has not take place.

The present situation is that almost no small/medium power gasification systems are commercially operating in developed countries. The majority of the power systems installed in developing countries suffer from technical problems that have led to only intermittent operation and sometimes to complete abandonment of the project. A few installations, however, show a reasonable operational record and work to the satisfaction of the user.

Almost all European manufacturers of small/medium sized power systems have stopped production, due to the lack of a home market and high capital cost of their systems.

In the following figures is shown the general scheme of a typical plant.

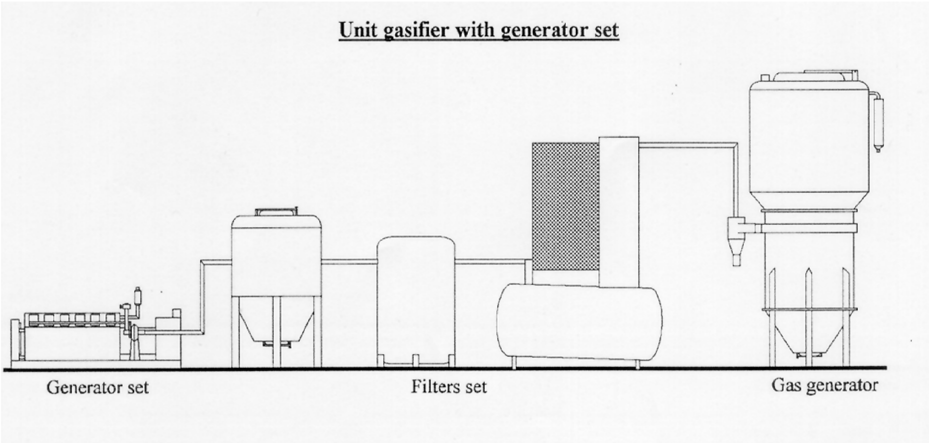


Fig. 48: Martezo electric and thermic power plant

4.1.6.1 Main characteristics of the generator

Electricity generation from this biomass gasification plant is achieved by coupling the following systems: a gas generation unit and a gas generator set consisting of a combustion engine driving an alternator and some heat exchangers for heat recovery. Together, these systems are called a **gasifier-based cogeneration power plant**.

The gasifier (down-draft) can operate on wood or agricultural wastes (in briquettes) and consists of:

- a counter current gas generator, whose firebox is made of highly resistant refractory material to sustain high temperatures and thermal shocks
- a pyroligneous liquid collector that eliminates most of the tars and oil produced during the gasification
- a vapour condenser which collects most of the moisture contained in the gas prior to end use
- a set of high-performance filters for the fuel gas

The downdraft gasifier is the most common type of reactor. The vessel is equipped by a throat, above which the gassifying agent is introduced. In this region the oxidation reactions create an high temperature zone sufficient for pyrolysis of biomass to occur and for drying the mass above the throat. In the downstream section there is the reduction zone where the remaining char is gasified.

4.1.7 Types of biomass feedstock

Feedstock characteristics: wood, agricultural wastes and agricultural wastes requiring densification

As already underlined, the Martezo gas generator can use hard wood or soft wood, barked or not. The dimension varies according to the power plant type.

The moisture of the solid fuel content must not exceed the 20 %, in order to obtain a gas with a sufficient calorific value.

As an indication, at the cutting, the moisture of the wood content is about 85%. The weathering is achieved after 3/6 months of air storage according to the site and dimensions, or it can be executed in a drier at the pre-treatment phase for proper utilization.

In many cases, briquetting of agricultural and wood waste constitutes in general an interesting solution.

4.1.8 Environment

Biomass gasification systems produce solid, liquid and gaseous wastes, which, if not adequately controlled, could lead to detrimental impacts for the environment.

Solid wastes are primarily residue ash. The amount produced may vary between one and twenty percent, depending on the biomass fuel. In most cases disposal of this ash is not a problem, and in some cases the ash has even a positive value when used by steel or cement industries.

Particulate emissions are also low, primarily due to the low ash content of wood, which is typically between one-twentieth and one-tenth of the ash content of coal. Gaseous emissions from biomass gasifiers are also not a significant factor.

Biomass fuels have the potential to be neutral in terms of carbon dioxide (no net CO_2 emissions), because the level of CO_2 emitted in the combustion process is essentially equivalent to that absorbed by the fast growing herbaceous and tree crops.

In comparison to other alternatives, especially fossil fuel based systems, biomass gasifiers are relative benign in their environmental emissions producing no sulphur oxides and low levels of particulate. The level of SO_2 released by wood are even lower than those released by other biomass fuels. Clean wood contains only about one-fourth the nitrogen of an average coal, and conventional wood-fed plants generally emit 45 % less NO_x than coal-fired units. Therefore SO_2 emission are almost unmeasurable, being far below the levels set by air quality regulations.

The situation is not as encouraging when large quantities of liquid effluents are produced, as in the case of up-draft power gasifiers. Fortunately downdraft and cross-draft power gasifiers can be equipped with dry gas clean-up systems, which drastically reduce the quantity of liquid effluent produced to be disposed. The design of the gasifier hearth was optimised to recuperate the pyrolineous liquid containing an important proportion of noxious substances (certain woods contain 100 different chemical products) and to condense the water steam from the combustion to reach a fuel gas high quality.

Gasification combined with the gas utilisation in an internal combustion engine is the most efficient way of converting solid fuels into shaft power or electricity and steam.

Small-scale biomass gasification allows the use of biomass instead of petroleum derivates in small internal combustion engines. Gasifiers use a renewable energy resource, that is or can be made available almost everywhere in one form or another. Therefore biomass gasification presents local fuel alternatives in locations where the supply of fossil fuel resources are difficult.

Providing that it is grown on a sustainable basis, the use of biomass does not increase the amount of so called “greenhouse gas” (CO_2) in the atmosphere. The technology may find application on sites where petroleum fuels are either unavailable or where the cost of power from engines fuelled by producer gas is lower than such from diesel or gasoline fuelled engines.

Further project benefits are in term of local rural development, employment (as a result of the implementation of new activities in bioenergy sector), environment (in terms of reduction in air pollution, land recovery, and use of energy efficient technologies), and market (through the creation of new commercial opportunities).

Finally, the proposed plant will be a useful base for the installation and subsequently implementation of small-size biomass powered cogeneration schemes.

4.2 Large scale power plants (Cofiring)

The main reasons for the growing international interest in utilising renewable biomass fuels is the new challenges to power producers to decrease the noxious emissions level in general (especially the greenhouse gas emissions) and the attractive future emission trading allowance possibility. Coal which is a very polluting fuel is at present the major energy resource utilised for power generation world-wide (6,000 tWh/y are produced from coal in comparison of a total supply of ~ 14,000 tWh/y).

Biomass is a very clean energy resource, but because it is a dispersed resource it is not realistic to envisage the possibility of implementing very large plants of capacity similar to those fuelled with coal, natural gas and/or oil (~ 650 MWe to 1,300 MWe).

In North Europe, e.g. Finland, Sweden, Denmark many examples of full biomass power plants are available but always in the range of 10 - 100 MWe as shown in figures below. The main reason for this limited size is the economics of transporting large biomass quantities on distances of more than approx. 100 km.

Fig. 39: Co firing power plant (UK)

4.2.1 Biomass Cofiring

Cofiring refers to the practice of introducing biomass as a partial substitute fuel in high-efficiency coal boilers. This is the nearest term low-cost option for the efficient conversion of biomass to electricity. Cofiring has been practiced, tested, and evaluated for a variety of boiler technologies. After "tuning" the boiler's combustion output, there is little or no loss in total efficiency, implying that the biomass combustion efficiency to electricity would be close to the 33% - 37% range.

In North Europe extensive demonstrations and trials have shown that effective substitutions of biomass energy can be made up to about 15% of the total energy input with little more that burner and feed intake system modifications to existing stations. In addition to CO_2 emission benefits, biomass in general contains significantly less sulphur than coal, so there is an SO_2 benefit as well. Early test results also suggest that there is a NO_x reduction potential of up to 30% with wood biomass.

In Europe exists already a significant specific expertise (in different competitive enterprises) in co-firing technology and biomass power plants.

4.2.2 Grate combustion for solid fuels

Grate boilers have been traditionally used for solid fuel combustion. The size range is broad; grate boiler technology is available from 15 kW up to 150 MW. Grate boilers are suitable for many types of fuels: coal, wood fuels, waste fuels, peat and even straw. Even fairly moist fuels can be used if this is taken into account in boiler design.

Co-firing of recycled fuels in power plants is relatively safe as the steam temperature is usually lower than 400 °C and there is no risk of hot corrosion. Nevertheless, special attention must be paid to flue gas cleaning. Most plants are now equipped with cyclone or electrostatic precipitators, sometimes even with gas scrubbers. Variation in fuel quality also poses challenges to fuel handling and feeding.

The key issues in grate firing are homogeneous fuel particle size and quality, proper sizing of the combustion chamber and efficient mixing of the combustion air.

4.2.3 Pulverised combustion for co-firing in existing coal-fired boilers

The main motivation to use biofuels in coal-fired pulverised fuel boilers is the need to reduce emissions and to exploit available local biomass resources. Using biomass in existing pulverised fuel boilers can be more profitable than building a new biomass plant using 100% biomass. On the other hand, the amount of available biomass may be a restricting factor.

There are basically four options for direct combustion in a pulverised fuel boiler.

- When the proportion of biofuel is rather low, it can be fed together with coal to coal mills and then be burned together with coal through coal burners.

- The second option involves separate handling, metering and comminution of the biofuel and injection into the pulverised fuel upstream of the burners or at the burners.
- The third option involves the separate handling and comminution of the biofuel with combustion through a number of specifically dedicated burners.
- The final option involves the use of biofuel as a reburn fuel for NO_x emission control.

4.2.4 Fluidised bed combustion

Fluidised bed boilers can be designed to combust almost any solid, semi-solid, or liquid fuel. They achieve high fuel-to-steam efficiency, typically over 90%, even with challenging, low-grade fuels.

Coal contains large portion of fixed carbon which burns in the bed and freeboard or riser and the gas temperature is clearly lower than the bed temperature. With a higher amount of wood, the freeboard temperature increases. Wood contains large amounts of volatile matter, which burns mostly in the freeboard area, thus causing the temperature to rise.
The new enhanced CFB designs can be a competitive alternative even in smaller biomass fired plants.

One example of this type of modern technologies are shown in the figures here below.

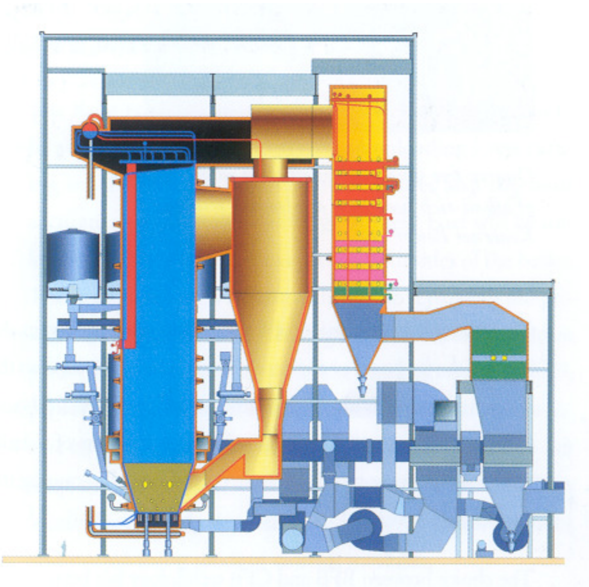


Fig. 40: circulating fluidised bed combustion. Kvaerner Power.

4.3 Pellet combustion technologies

4.3.1 Introduction

Biomass combustion is a complex process that consists of consecutive steps: drying, devolatilisation, gasification, char combustion, and gas phase oxidation .The time used for each reaction depends on the fuel size and properties, on temperature, and combustion conditions. During the first phase, free water vaporises. During gasification combustible gases are produced depending on the temperature. There will always be a certain content of carbon monoxide (CO), hydrogen (H_2), methane (CH_4), and other hydrocarbons. Then combustion of gases takes place. If sufficient oxygen is supplied, a complete combustion occurs where the residual products are carbon dioxide (CO_2) and water. Where the oxygen supply is insufficient, carbon monoxide (CO), soot (finely divided carbon), tar, and unburned hydrocarbons (UHC) are produced. Finally, the charcoal burns. At the end of the process, there only remains ash, which consists of incombustible inorganic matter. If combustion is incomplete, the ash may contain unburned organic matter. In all cases, as a result of the combustion process, different types of pollutants can be distinguished:

- Unburnt pollutants such as carbon monoxide (CO), unburned hydrocarbon (UHC; CxHy in gaseous phase), polycyclic aromatic hydrocarbon (PAH), tar, soot, hydrogen (H_2), HCN, NH_3, and nitrous oxide (N_2O),
- Pollutants from complete combustion such as nitrogen oxides (NOx: NO and NO_2), carbon dioxide (CO_2)
- Ash and contaminants such as ash particles (KCl, etc.), SO_2, HCl, PCDD/F, Cu, Pb, Zn, Cd etc.

A high combustion quality, in terms of maximal combustion of the burning gases, is therefore very important for low emission level. It will mainly depend on the combustion chamber temperature, the turbulence of the burning gases, residence time and the oxygen excess. These parameters are governed by a series of technical details such as:

- Combustion technology (e.g. combustion chamber design, process control technology),
- Settings of the combustion (e.g. primary and secondary air ratio, distribution of the air nozzles),
- Load condition (full- or part-load),
- Fuel characteristics (shape, size distribution, moisture content, ash content, ash melting behaviour). From that point of view, wood pellets are very interesting, because they have a low ash content, a somewhat high melting ash point, and a shape facilitating automatic operations.

4.3.2 Environmental aspects

One of the main advantages related to biomass fuel is their net CO2 neutrality with respect to the carbon cycle, assuming that the CO2 released from combustion is re-incorporated in the vegetal cycle during plant growth. But biomass combustion also results in other emissions. Results from the first table below underline the relation existing between the fuel content and the emissions it originates. Wood pellets trigger relatively low emissions, which generally meet the national and European standards (although there is obviously a wide variation of emissions according to the combustion devices used). In contrast, a typical feature of agricultural residues in comparison with wood residues is their higher content in nitrogen (N), sulphur (S), chlorine (Cl) and potassium (K), increased by the use of fertilisers, pesticides and herbicides in agriculture. The presence of those elements leads to higher emissions of NOx, SOx, and HCl than for wood pellets (see the second table below). In addition to those emission problems, potassium (K) influence both particulates emission and slagging (by lowering the softening temperature of the fuel) of an increased ash volume (5% for straw – 0.5% for sawdust). Finally, a high chlorine (Cl) content result both in corrosion problems on boiler's surfaces and in formation of dioxins.

Typical environmental impact (emissions in mg/MJ) of produced heat from different fuels (data for a heating plant):

	Coal	Fuel oil	Natural gas	Wood pellets	Straw	Forestry residues
CO2	106,000	87,000	58,000	-	99,000	-
NOx	78	130	64	62	90	93
SOx	79	210	0.22	40	130	40
CO	46	19	12	290	600	300
N2O	13	0.58	0.53	4.7	n.a.	4.7
CH4	1200	2.9	2.8	5.2	n.a.	4.7
Particles	29	0.4	0.02	0.94	40	3.7
NH3	1.9	0.66	0	2.4	n.a.	2.4
VOC	2.3	47	2.8	19	n.a.	23
Residues [mg]	n.a.	12	20	n.a.	n.a.	1600

NOx, SOx and HCl emissions from wood chips, straw and whole crops:

	Wood chips	Straw	Whole crops
Fuel content of (in mg/kg):			
Nitrogen (N)	670	1750	13500
Sulphur (S)	40	470	970
Chlorine (Cl)	44	1400	3000
Emissions of (mg/Nm3):			
NOx	140	260	250
SOx	10	100	145
HCl	0.6	36	78

Environmental impact as well as current state-of-the-art of combustion technologies indicate that pellets made from agricultural residues (and in general other ash-, N-, K- and Cl-rich fuels) should be used primarily in controlled large scale combustion plants equipped with sophisticated combustion control systems and flue gas cleaning systems, whereas wood pellets can be used with practically any combustion unit, but might be preferred for residential heating to let agricultural residues orientated towards big energy plants.

4.3.3 Technology overview

The devices used for direct combustion of wood pellets range from small domestic stoves (1 to 10 kw) to the largest boilers used in power and CHP plants (>5 MW). Intermediate devices cover small boilers (10 to 50 kW) used in single family houses heating, medium-sized boilers (50 to 150 kW) used for multi-family house or building heating and large boilers (150 to over 1 MW) used for district heating.

4.3.3.1 Modern pellet stoves

Nowadays, modern pellet stoves are efficient heating appliances. While a conventional fireplace is less than 10% efficient at delivering heat to a home, an average modern pellet stove achieve efficiencies between 80 and 90%. Typically small combustion units (stoves and small boilers) have higher emissions of unburned components than larger units where possibilities for combustion control are better. But even small combustion units can greatly enhance their combustion efficiency and reduce the emissions levels of unburned components by introducing new techniques as catalytic combustors and staged air combustion, or simply by better insulation of the combustion chamber and preheating of the inlet air. Pellets, by their small size and low moisture content contribute to a reduction of emissions, whenever air supply is sufficient.

4.3.3.2 Small scale boilers

Most of the small scale boilers for household use were filled batch-wise and had water cooled furnace walls, resulting in low flame temperatures causing low efficiencies and high emissions. In addition, they had traditionally been fired according to demand (direct firing), where the amount of combustion air had been used to control the heat output. This type of combustion control leads to very high emissions of many harmful products of incomplete combustion, such as carbon monoxide (CO), volatile organic compounds (VOC) and tars. Today, many of the small boilers available on the market use two stage combustion systems equipped with ceramic refractory lining and are combined with a suitable hot water tank for heat recovery. In this configuration, the boiler can then be operated at optimal load with sufficient air and high process temperatures independently from the heating demand. This leads to relatively low emissions of all products of incomplete combustion. With this, over the last ten years, boilers thermal efficiencies have improved from an average of 60 to 80-90%, while the emissions of VOC and tars have been reduced 100 fold.

4.3.3.3 Burners

One common low-cost solution when changing from heating oil to pellets in small houses is retrofitting the old oil-fired furnace with a new burner designed for pellets. Several pellet burners convenient for substitution for oil burners are already available on the market. These are relatively simple but functional devices that in general give lower emissions than the best firewood boilers. Oil furnaces, however, are not designed for fuels that leave some amounts of bottom ash like wood pellets. Therefore a frequent emptying of ash is necessary to prevent the efficiency from decreasing or even the combustion chamber from filling with ash. This can be taken care of with simple equipment with intervals depending on the season and what kind of pellets that are used.

4.3.3.4 Medium and large scale technologies for biomass combustion

The major types of large scale biomass boilers use one of the following technologies: grate combustion systems (stationary or travelling), pulverised fuel (PF) systems or fluidised bed combustion (FBC) systems.

- *Grate combustors*

With the techniques based on grates, the fuel is usually fed automatically onto the grate by gravity. As the fuel bed moves, moisture is driven off initially, followed by ignition, burning and finally cooling when the ash is removed. The air supply below the grate is often sectioned so that the flow rates and pressures of the primary combustion air to each section can be independently controlled. Those systems also require a fairly high proportion of the air supplied above the grate as secondary air. Measurements of the temperature within the bed and furnace have shown relatively homogeneous profiles with maximum temperatures of 900-1100℃ in the burning area of the bed, but as low as 200-500℃ in the drying and ashing zone. Temperatures above the bed and in the freeboard normally range between 800 and 1000℃. In the stationary grate design, ashes fall into a pit for collection. In contrast, a travelling grate system drops the ash into a hopper.

- *Stokers*

Spreader stokers, which feed the fuel by distributing it on the top of the bed throughout the furnace, and retort (underfeed) stokers are less common for biomass fuels in Sweden, but successfully used in some boilers that have been converted from coal firing.

- *Pulverised fuel systems*

Wood and agricultural residues powder is attractive for larger plants, since it allows conversion to biomass fuels with minimal investment for boiler conversion. Burners for wood powder are available in the range of 1 to 30 MW. In pulverised fuel combustion, the fuel is introduced with air in burners similar to those used for oil or coal burners. The particle size must be small (generally below 1 mm) to complete a rapid combustion. Boilers equipped with oil burners or coal powder burners can be converted to use biomass powder fuel, or blends of biomass and fossil fuels. The PF process is somewhat difficult to control and may suffer from too high combustion temperatures (>1200℃) which may result in high emissions of nitrogen oxides (NOx). The high process temperature may also lead to severe slagging and fouling problems. In the pulverised combustion system, the fibrous structure of straw makes it very hard to grind into reasonably isometric particles. Thus, feeding of pulverised biofuels poses problems unheard of in coal-powder feeding. Therefore, the use of straw pellets, with a controlled moisture content and a particle size already reduced could offer an interesting opportunity.

- *Fluidised bed systems*

Fluidized bed boilers are well known for their inherent fuel flexibility which is unmatched by any other combustion technology. Fluidized bed boilers can burn fuels with a wide range of calorific values, ash and moisture content. The fluidized bed combustion process has been in use for more than 25 years and is now established as an efficient and environmentally friendly technique.

Fluidised-bed combustors (FBC) burn biomass fuel in a hot bed of granular material, such as sand. The primary air keeps fluidised the bed of sand (making it resembling a boiling liquid), while secondary air, and in some cases tertiary air, may be introduced higher up in the furnace to achieve a staged and more complete combustion. The bed is normally operated at 750-950℃, which are considerably lower temperatures than for grate and pulverised systems. The lower temperatures inhibit the formation of nitrogen oxides (NOx) from the combustion air and allow fuels with lower ash melting temperatures to be fired. These systems also permit the removal of sulphur dioxide (SO_2) from combustion of high-sulphur fuels simply by addition of sulphur absorbents such as limestone or dolomite in the bed. Besides many different coals, wood, other biomasses and also waste derived fuels have been successfully demonstrated in a number of FBC installations around the world. As this technology allows handling high-ash fuels, it is therefore a very suitable conversion technology for a large variety of agricultural biomass residue.

Two types of FBC are commercially available: the stationary fluidised bed (SFB) and the circulating fluidised bed (CFB). The CFB system process provides excellent conditions for the burning of several different fuels in the same boiler – this has been almost impossible in earlier technologies. Bed material circulation and high turbulence in the combustor ensures good mixing of fuel and combustion air, and also efficient heat transfer to the heat surfaces inside the furnace. An efficient particle separator, cyclone, is the heart of the process and differentiate it from SFB units. The cyclone separates out all particles larger than a certain size from entering flue gas and returns back to the bottom part of the furnace via the loop-seal located in the bottom part of the cyclone. The CFB process is shown in figure below. The duty of the cyclone is to separate unburned fuel particles and return them to the furnace, as well as to give the limestone particles used for sulphur removal more time react.

Picture: Profile of a circulating fluidised bed (CFB).

Comparison between BFB and CFB

	Stationary fluidised bed	Circulating fluidised bed
Fuels	Good for biofuels (w<63%) Limited with coal proportion (max. 30%) Full capacity on oil and gas	Limited with biofuel moisture (w<58%) Full coal capability Limited capacity on oil and gas (max. 40 %)
Process	Coarse bed material Low fluidizing velocity	Fine bed material High fluidizing velocity
Operation	Low power consumption Low erosion Low maintenance	Higher power consumption Possibility for erosion More refractory => more maintenance
Performance	Good efficiency Low NOx Low N2O Limited SO2 removal with limestone	Good efficiency Very low NOx Higher N2O Efficient SO2 removal with limestone

4.3.3.5 Conclusions

To recap, thanks to the well-defined fuel at low water content, pellet furnaces can easily achieve high combustion quality and efficiency (>90%). They are applied both as stoves and as boilers. Until now, they have been exclusively designed for wood pellets, which present a low-ash content and a high ash melting point, unlike straw. Understoker furnaces are mostly used for wood chips and similar fuel with relatively low ash content, while grate furnaces can also be applied for high ash and water content. Stationary or bubbling fluidised bed (SFB) as well as circulating fluidised bed (CFB) boilers are applied for large-scale applications and often used for waste wood or mixtures of wood and industrial wastes e.g. from the pulp and paper industry. In fluidised bed boilers, nearly homogeneous conditions of temperature and concentrations can be ascertained thus enabling high burnout quality at low excess air.

The choice of different bed materials in CFB offers additional opportunities of catalytic effects. Further, the option of heat removal from the bed allows controlling the combustion temperature and hence enables an operation at low excess air without excessive ash sintering. Since similar conditions for nitrogen conversion as by air and fuel staging are attained, relatively low NOx emissions are achieved. Regarding pulverised fuel technology, biomass can be co-fired with coal, in particular to reduce SO_2 emissions.

The table below recaps the main furnace types, which are or could be used for straw pellet combustion.

Types of furnaces with typical applications and fuels

Application	Type	Typical size range	Current used fuels	Water content
Small scale	Pellet stoves	1 kW – 10 kW	Wood pellets	8 – 10%
	Pellets boilers	10 kW – 50 kW	Wood pellets	8 – 10%
Medium to large scale	Boiler	50 kW – 150 kW	Wood pellets, other biomass	5 – 50%
	Stoker furnaces	20 kW – 2.5 MW	Wood chips, wood residues	5 – 50%
	Grate furnaces	150 kW – 15 MW	All wood fuels and most biomass	5 – 60%
	Stationary fluidised bed	5 MW – 15 MW	Various biomass, diameter < 10 mm	5 – 60%
	Circulating fluidised bed	15 MW – 100 MW	Various biomass, diameter < 10 mm	5 – 60%
	Pulverised combustor	1 MW – 30 MW	Various biomass, diameter < 5 mm	< 20%
Co-firing*	Stationary fluidised bed	50 MW – 150 MW	Various biomass, diameter < 10 mm	5 – 50%
	Circulating fluidised bed	100 MW – 300 MW	Various biomass, diameter < 10 mm	5 – 60%
	Pulverised combustor (coal boiler)	100 MW – 1 GW	Various biomass, diameter < 2-5 mm	< 20%

*: biomass covers typically less than 10%of the fuel input

4.3.4 European manufacturers of pellet appliances

In Europe most of the wood fuel is utilised in domestic boilers and stoves or in boilers for community heating systems (<10 MW). Biomass boiler and stove manufacturers are usually small and medium enterprises operating mainly in domestic markets or neighbouring countries. In that section, we will focus on small and medium scale combustion devices, i.e. stoves (for family use) and small and medium boilers for individual and/or industrial uses. Some European manufacturers are listed below in alphabetical order.

4.3.4.1 Baxi A/S

Smedevej DK-6880 Tarm, Denmark
Tel.: +45-97-37 15 11, Fax: +45-97-37 24 34
Web: www.baxi.dk/

Baxi A/S develops and manufactures central heating boilers for domestic use of up to 100 kW. They are one of the Scandinavian's largest and leading producers of central heating installations for individual home heating and domestic hot water supply. They produce boilers for such different fuels as oil/(gas), solid fuel and biomass, which can be wood pellets, grain/corn and wood chips. The technology offered in the biomass boilers is a stoker principle. Primary and secondary air are added to the combustion in the right amount and the combustion process allows us to obtain approx. 90% efficiency. Stoker biomass boilers are very compact and low noise. It has a sophisticated yet very user-friendly control panel, which allows for a high degree of automatisation. Among the boilers commercialised, the MultiHeat range offers output power of 15, 25 and 43 kW.

4.3.4.2 Compte R

ZI de Vaureil 63220 Arlanc, France
Tel: +33 4 73 95 01 91, Fax: +33 4 73 95 15 36
Web: www.compte-r.com

Small-sized boilers Compact, with output power from 200 to 1,200 kW which can be fuelled with dry biomass such as waste wood or wood pellets. Other types are specially designed for wet biomass, with sowehow lower power ranges (150 to 900 kW). In the upper range, Standard boilers accept the same dry biomass fuels for a 2,000-5,000 kW power, and units for wet biomass fuels are 1,500-4,000 kW sized.

4.3.4.3 Danstoker A/S

Industrivej Nord 13 DK-7400 Herning, Denmark
Tel: +45 99 28 71 00, Fax: +45 99 28 71 00
Web: www.danstoker.dk

With a ballast of more than 65 years of experience, Danstoker has specialised in manufacturing horizontal and vertical bio-fuel boilers ranging from 70 kW to 15,000 kW (or

15 kg/h steam). The boilers are of the fire-tube design - with the option of having a combined fire-tube-water-tube design in operating pressures up to 30 bars. In the Danstoker solid-fuel boilers all traditional fuels as well as biomass fuels may be burnt.
The range of their products covers hot water, high-pressure hot water and steam boilers, specifically designed to exploit solid fuels with a moisture content up to 60%. The boilers are according to the norms applicable in the country of installation, and the design may be customised to meet individual requirements. Here are some products examples:

Hot water boiler	**High pressure hot water boilers**	**Steam Boilers**
Capacities from 800 to 2000 kW Design pressure : 6 and 10 bar-g Type OMNIMAT 16.1 PG Reverse flame boiler Large water capacity	Capacities from 1,000 to 20,000 kW Design pressure: 8 to 16 bar-g Type Global-H 3-pass wet-back boilers Low heating surface load Super-insulated.	Low pressure steam boiler Ratings from 700 to 4000 kg/h Design pressure: 1,0 bar-g Type TDL 3-pass boiler Low heating surface load Super-insulated.
Capacities from 1,000 to 10,000 kW Design pressure: 4, 6 or 10 bar-g Type GLOBAL 3-pass wet-back boiler Low heating surface load Super-insulated.	Capacities up to 33,400 kW Design pressure: up to 20 bar-g Type TVB-H Twin-furnace 3-pass wet-back boilers Low heating surface load Super-insulated.	High pressure steam boiler Ratings from 300 to 2,000 kg/h Design pressure: 6 to 20 bar-g Type OMNIMAT 33 HD Reverse flame
Capacities from 10,000 to 25,000 kW Design pressure: 4, 6 and 10 bar-g Type TVB 3-pass wet-back boiler Low heating surface load Super-insulated	Type: DHF og HHF / High pressure hot water 3-pass open bottom boiler Fuel: all bio-fuels Steam capacity 1,000 - 10,500 kg/h Heat capacity 525 - 6,800 kW Working pressure max. 16 bars	High pressure steam boiler Ratings from 1,000 to 25,000 kg/h Design pressure: 8.3 – 12,3 – 18,3 – up to 32 bar-g Type TDC 3-pass boiler Low heating surface load Super-insulated.
Capacities up to 33.400 kW Design pressure: up to 10 barg-g Type TVB Twin-furnace 3-pass wet-back boiler Low heating surface load Super-insulated	Capacities up to 50,000 kW Design pressure: Up to 32 bar-g Type COMBO-H 3-pass combined water-tube and fire-tube boiler	High pressure steam boiler Ratings up to 35,000 kg/h Design pressure: 8,3 – 12,3 – 18,3 – up to 32 bar-g Type TDB Twin-furnace 3-pass boiler Low heating surface load Super-insulated.
Special boilers Horizontal or vertical Special designs acc. to specific plant parameters	Special boilers Horizontal or vertical Special designs acc. to specific plant parameters	High pressure steam boiler Ratings up to 35,000 kg/h Design pressure: Up to 32 bar-g 3-pass combined water-tube and fire-tube boiler
		Special boilers Horizontal or vertical Special designs acc. to specific plant parameters

4.3.4.4 FRÖLING Heizkessel- und Behälterbau GmbH

Industriestraße 12 A-4710 Grieskirchen, Austria
Tel.: +43 (7248) 606, Fax: +43 (7248) 62387
Web: www.froeling.com/en/

Fröling manufactures several combustion devices for wood pellets, all products being tested by test authorities:

- The Pelletherm P2, with power output of 4.4-14.9 kW or 7.5-25 kW. One advantage is a comfortable ash removal of the entire combustion residues by means of a conveyor worm screw to an ash container on wheels
- The Turbomatic pellet boilers serie, ranging 28 to 55 kW output power (see picture). Fuels with a water content of up to 40% can be used without difficulties (from dry pellets to damp chippings). It is also possible to use split logs. Its optimum

combustion control (Lambda/vacuum control) guarantee an efficiency of up to 92% over the whole output range.

- The Lambdamat range corresponds to medium-sized boiler, with power output from 150 to 1000 kW, with intermediate levels: 220, 320, 500 and 750 kW.

Turbomatic specifications		**28**	**35**	**48**	**55**
Output	kW	15-28	15-35	20-48	20-55
Permitted operating pressure	bar	3	3	3	3
Permitted feed flow temperature	°C	95	95	95	95
Min. return flow temperature	°C	55	55	55	55
Boiled capacity (water)	Liter	114	114	185	185
Boiler weight	kg	420	425	500	505
Water-side resistance	Pa	650	750	1700	1900

4.3.4.5 Herz Feuerungstechnik GesmbH

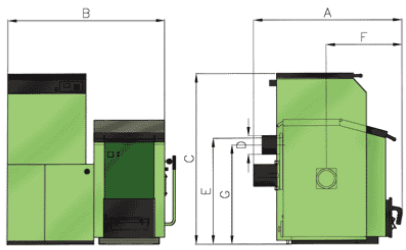
Sebersdorf 138 A-8272 Sebersdorf, Austria
Tel.: +43 (3333) 2411 0, Fax: +43 (3333) 2411 73
Web: www.herz-feuerung.com

The Herz Feuerungstechnik biomass heating systems, fuelled by pellets, wood chips or billets meet the requirements of modern, environmentally sound, low cost heating. Many satisfied HERZ customers are enthusiastic about the wide range of possibilities offered by the new technologies. all products are tested either TGM Wien, Institut für Brandschutztechnik und Sicherheitsforschung, TÜV Bayern, TÜV Hannover, EMPA or Prüfanstalt Wieselburg. Herz pellet-systems include the Pelletstar range (pellet systems from 3 to 25 kW) and the Pelletfire range (in possible combination with billets) with 5–34 kW output.

Pelletfire specifications

Technical data	15	25	35
Output power kW	5-17	7-24	10-34
Behälterinhalt Autom. ca. Liter	150	150	150
Behälterinhalt Kompakt ca. Liter	150	150	150
Weight (Brenner) kg	325 (250)	325 (250)	584 (250)

Dimensions (mm)	15	25	35
A	1260	1260	1560
B	1310	1310	1450
C	1450	1450	1450
D	160	160	180
E	910	910	1170
F	505	505	790
G	840	840	1275



Pelletstar specifications

Technical data	15	25
Output power kW	3-15	8-25
Inhalt Zwischenbehälter l	350	350
Elektrischer Anschluss	230 V, 50 Hz	230 V, 50 Hz
Wasserinhalt l	55	75
Max, water pressure (bar)	3,0	3,0
Max. water temperature (°C)	90	90
Weight (kg)	340	340

4.3.4.6 Kaukora Oy

P.O.Box 21, Tuotekatu 11, FIN-21201 Raisio, Finland
Tel. +35 8-2-437 4600, Fax. +35 8-2-437 4650
http://www.kaukora.fi/fi/

Kaukora Oy is one of the leading device manufacturers in its field in Finland. The main products of the company are JÄSPI hot water heaters, central heating boilers (operating on oil / gas, electricity, wood, pellet) heat exchangers and thermo-technical special products.

4.3.4.7 KWB - Kraft und Wärme aus Biomasse

Raab 235 A-8321 St. Margarethen, Austria
Tel.: +43 (3115) 6116 0, Fax: +43 (3115) 6116 4
Web: www.kwb.at/

KWB activities cover R&D, manufacturing, assembling, sales and after sales service of fully automatic wood pellets and wood chips boilers and fuel handling equipment. They have about 150 sales partners (most of them are plumbers) all over Europe (Austria, Germany, Italy, Switzerland, Slovenia). Their pellet-related products are pellet stoves of 10-30 kW and boilers from <50 -100 kW, both for wood pellets and wood chips. Their manufacturing complies with ISO 9001 and Ökoaudit (EMAS). Following comes a link toward one of their very complete technical data sheet about pellet small-boilers USP (10-30 kW): http://www.kwb.at/PDF/pellets/techn_daten/usp_10-30kw.pdf. They have the approval of Bundesanstalt für Landtechnik Wieselburg. Picture: pellet stove USP (10–30 kW) with efficiencies between 88 and 90%.

4.3.4.8 LIN-KA Maskinfabrik A/S

Nylandsvej 38 DK-6940 Lem
Tel +45 97 34 16 55, Fax: +45 97 34 20 17
Web: www.linka.dk
In Denmark LIN-KA Maskinfabrik A/S is one of the leading suppliers of medium-sized wood pellet systems for companies, institutions, schools etc. The size of the system is typically between 400 kW and 1500 kW. Wood pellet firing is a very convenient and efficient method of producing heat, when speaking of solid biofuel. The system is established with either an external glass fibre silo or container, or an internal silo (see picture). The company has specialized in the production of fully automatic firing systems in all sizes (from 25 kW to about 10 MW) for agriculture, industry and district heating plants. All systems are based on the use of straw, wood chips and pellets. They have delivered more than 1500 biofuel firing systems for the Danish and European markets since 1978.

Technical specifications for several Lin-ka small and medium boilers

Wood pellet boilers	Nominal capacity kW	Efficiency %	Wood pellet consumption kg/h
P 30	25	92,2	5,5
P 40	41	91,0	9,2
F 120	131	90,3	29,0
P 200	235	93,4	52,0
P 250	258	95,1	56,6
Wood chips boilers	**Nominal capacity kW**	**Efficiency %**	**Wood chips consumption kg/h**
F 120	118	89,8	33,0
Multimiser 10	180	86,0	65,0
F 200	232	91,1	65,8

4.3.4.9 ÖkoFEN Forschungs- und Entwicklungs Ges.m.b.H.

Mühlgasse 9 A-4132 Lembach i. M., Austria
Tel.: +43 (7286) 7450, Fax: +43 (7286) 7450 10
Web: www.pelletsheizung.at/

With more than ten years experience Ökofen is a pioneer in the production of pellet heating systems for small capacities up to 32 kW. Burner manufacturer: Underfeed burner with electrical ignition and automatic ash removal. Automatic pellet heating systems are suitable for all low temperature heating systems (e.g. floor, wall, radiator heating as well as heating coil stoves).

4.3.4.10 Passat Energi A/S

Vestergade 36, Ørum DK-8830 Tjele, Denmark
Tel.: +45-8665 2100, Fax: +45-8662 3028
Web: www.passat.dk

Passat Energi A/S has almost 30 years' experience in the development and production of biomass boilers. They have sld more than 50,000 units in Denmark alone. They commercialise the compact series, which are boiler models whose power output are respectively 11, 23, 42, 70, 93, 130 and 185 kW. They can fuelled with wood pellets, wood chips, grain or similar biomass fuels. Main features are: a thermal efficiency of 90%, advanced P L C controls, stainless steel combustion chamber, unique fuel scraper system for reliable, flexible and precise feeding of fuel, large ash pan, ceramic hearth for high temperature combustion. Pellets hoppers have a capacity between 240and 600 kg, but boilers can additionnally be fed automatically from a silo. Picture: Compact serie (11 to 42 kW)

4.3.4.11 Prosessiputkitus Oy

Address P.O.Box 430, FIN-33101 Tampere, Finland
Tel. +358-3-347 3600, Fax. +358-3-347 3657
E-mail: markku.makela@prosessiputkitus.fi
prosessi@sgic.fi

Equipment manufacturer, product development, testing, Construction and implementation of boilers andì boiler components. Boiler reparations 24 h/d.
Prefabrication and installation of pressurized pipings. ISA 9002 quality system. Products: manufacture of pellet-fired heating boilers and heating plants for residential and public buildings. Power range 30 – 500 kW.

4.3.4.12 REKA A/S

Vestvej 7 DK-9600 Års, Denmark
Tel.: +45 98 62 40 11, Fax: +45 98 62 40 71
Web: www.reka.com

Boilers with power output between 10-60 kW, and between 100-3,500 kW. Their products comply with the current European legislative framework, i.e. European norm EN 303-5 up to 300 kW or directive EN 2000/76 for higher power.

A screw feeder feeds boilers automatically, and the fuel is burnt on a small moving grate. Those boilers can be fuelled with wood chips, wood pellets, shavings, briquettes and also straw, grains etc. Practically all kind of biomass wastes (in small pieces) with a moisture content between 0% and 30 % or between 30% and 50% can be used. A fast adjustment program electronically controls boilers. Thermal efficiencies are generally over 90%. As an example, the 100 kW boiler produce hot water at 110℃ and at 3.5 bars maximum.

4.3.4.13 Sahlins EcoTec AB

P.O. Box 2103, SE-511 02 Skene, Sweden
Tel. +46 320 20 93 40, Fax. +46 320 421 60
Web: www.ecotec.net/

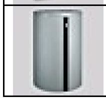
Sahlins EcoTec AB manufactures pellet burners in various sizes for both private homes and the heating of larger properties and industries. They also manufacture pellet stoves (7 kW) and storage and feeder systems. EcoTec pellets burners can be mounted on almost every existing boiler, and present power outputs of 14, 25, 50, 75, 140 and 300 kW. Automatic pellets heating with EcoTec pellets system is as simple as oil heating. The pellets store does not require more floor space than the old oil tank and does not have to be in close connection to the burner. A bulk truck that will blow the pellets into the store by means of compressed air makes delivery to the store.

4.3.4.14 Viessmann Werke GmbH & Co

Viessmann str. 1 D-351 07 Allendorf (Eder)
Tel.: +49-(0) 6452/70-0, Fax: +49-(0)6452/70-2780
Web: www.viessmann.de/

The Viessmann group is one of the most important manufacturers of heating technology products. Viessmann produces heating equipment in ten factories, both in Germany and abroad. Their sales organisation comprises a total of 106 sales offices based in Germany and in 33 other countries. The product range comprises boilers for operation with oil, gas and solid fuels ranging from 4 to 15 000 kW output, as well as all modular components designed for this product range.

Short description of Viessmann's solid fuel-fired boilers

	Vitolig 100	Solid-fuel-fired boiler, 12.7 to 14.8 kW
	Vitolig 200	Wood gasification boiler with stainless steel filling space for billets, 13 to 40 kW.
	Vitolig 300	Wood pellet-fired heating system whose output may be modulated over the range 5 to 26 kW.
	Vitocell 050	Type SVP. Hot water storage cylinder constructed from steel. Capacity: 600 and 900 litres.

4.3.4.15 WEISS A/S

Plastvænget 13 DK-9560 Hadsund, Denmark
Tel: +45 96 52 04 44, Fax +45 96 52 04 45
Web: www.weiss-as.dk

Weiss A/S is a very internationally orientated company, exporting about 80% of its production. The company has agents in Austria, England, Finland, France, Hungary, Poland, the Czech Republic and Sweden. During the last years the company export to East European countries has grown considerably. Weiss designs, manufactures, and installs boilers for all types of bio mass in the range 0.2 MW up to 20 MW. Plants up to 10 MW are built from standardised components, which are especially designed for burning all types of biomass, and each plant is built to suit customer wishes.

Weiss boilers range from 0.2 to 40 MW with an operation pressure of up to 42 bar. The following heating mediums can be used: hot water, saturated steam or superheated steam with temperatures up to 450 C°. Depending on the heating principle used semi- or fully automatic ash outfeeding systems are supplied. Demands on flue gas cleanliness are constantly increased, and the allowed emission values are constantly tightened. Weiss offers a combustion quality with minimum emissions of CO, NOx, and unburned organic matter. Fly ash is separated by means of cyclones, electrostatic precipitators or textile filters to the required marginal value. Flue gas condensing If the fuel has a high water content and the return temperature to the plant is sufficiently low, the condensed heat in the flue gas water steam can be utilised in a Weiss flue gas condensing system. In this way plant efficiency is improved by 15-20%. Weiss delivers both simple relay, and advanced programmable control and monitoring systems. The possibilities to - via the oxygen percentage - constantly run the heating plant with the absolutely best operation economy from a PC are today fully exploited.

4.3.4.16 Wodtke GmbH

Rittweg 55-57 D-720 70 Tubingen-Hirschau
Tel: +49-(0)7071/70 03-0, Fax:+49-(0)7071/70 03 50
Web: http://www.wodtke.com/

Wodtke manufactures a range of design pellet stoves (Topline, Smart, PE-Einsatz, CW-21), between 2 and 8 kW, conceived for space heating. Technical data for Topline and CW-21 stoves are presented below.

Pellet stoves specifications

	**Topline** Thermal power: 2 - 8 kW Dimensions: 660 x 1132 x 585 mm Weight: 180-250 kg		**CW-21** Thermal power: 2 - 6 kW Dimensions: 790 x1000 x 560 mm Weight: 110 kg

4.4 Jelly ethanol stoves

Jelly ethanol cartridges can easily replace the coal fuel in existing little cooking devices that are in use in Africa. This gives much less emissions and are much less dangerous (stocking and transport) than normal ethanol. Moreover, it causes less in-door pollution.

The RPES project of the World Bank focused on this fuel for the solution to several problems in sub Saharian African countries. The name of the developed fuel was Millennium Gelfuel (Ethanol Based Fuel Produced from Agricultural Crops). RPTES states also other interesting facts, for different African countries :

- The cost of this fuel is about half to one fifth of LPG,;
- The combustion is efficient, clean and safe;
- The emissions are typically tens of percents lower than of other fuels, which are used with improved methods, or even two or three times better than of traditionally burned fuels. Among these, particularly fuelwood and charcoal give high emissions.

In Africa, population has very limited access to cooking fuel, this is also a threat for health. Therefore, technologies to convert local biomass into gelfuel are likely to create successful partnerships between Europe and Africa.

4.4.1 The Greenheat Group

The Greenheat Group of companies were established to develop and commercialise a family of non-petroleum, renewable energy, flammable products to sell into traditional areas such as Barbecue and Fire Lighting, Camping, Catering and Gardening.

Over ten years research and development has gone into producing over twenty five unique organic products all with the same minimal environmental footprint. Not surprisingly, organisations such as the World Wide Fund for Nature (WWF) and the World Bank are keen to work with Greenheat to ensure the success of this new, revolutionary, organic fuel.

The demonstrated superiority of Greenheat Products from both environmental and performance perspectives, significantly distinguishes them from other existing chemical or petroleum based products. With a clear advantage, the Greenheat Group intends to actively market its superior range of products, at competitive prices, in established retail categories as a replacement for the existing non-environmentally products.

Source: Greenheat, UK

4.5 Absorption refrigeration units for space cooling / food preservation

Thermal Energy can be used in Absorption Refrigeration Plants (ARP) to produce cold with temperatures down to – 60 °C (Source: ww.thermeq.nl). A conventional Compression Refrigeration Plant (CRP) uses electricity to produce cold, while an ARP can be driven by Hot Water, Low Pressure Steam, Exhaust Gases or other residual heat sources.

The Tri-Generation concept gives the opportunity to generate Power, Heat and Cold at the same time, being independent from the grid. In this concept residual heat from the CHP is used as prime driver for the ARP. This results in significant savings in power consumption, increase in total plant efficiency and contributes to the reduction in CO2 emission.

An expired patent of General Electric that had much success in the early part of the last century is an absorption system that circulates its fluid via natural convection rather than with an electric pump. This type of system needs no electricity at all. The problem is that the natural convection does not function if the unit is not very level, or if it is being moved. Therefore, it is not very suitable for transportation. This has not to be a problem, because in this case a compression or pump driven absorption unit can be used.

Dometic in Sweden makes the World-Fridge (see http://www.dometic.com) that works on bottle Gas and Electricity, Kerosene and Electricity – whatever is available. The concept of multi-energy input is interesting for reliability of cooling and also applicable for biomass and solar energy. The enterprise uses an absorption unit in its small portable refrigerator, too.

Extensive work has also been carried out at Asian Institute of Technology (AIT, www.ait.ac.th) with the aim to produce ice or cool storage in rural areas. The figure below shows a diagram of a solar-operated absorption refrigeration system. The solar collector can clearly be substituted by any other low temperature heat source, for example based on biomass. The above mentioned concept of tri-generation can be applied in an infinite number of configuration, generating heat, cold and electricity from biomass, solar energy and other (renewable) energy sources.

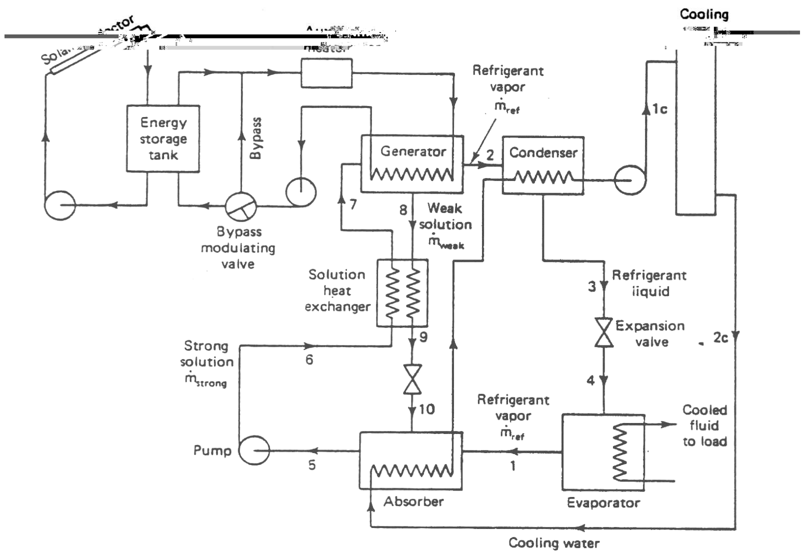


Fig. 41: Schematic diagram of a solar-operated absorbtion refrigeration system. Source: www.courses.ait.ac.th

The meaning for arid and semi arid area is clear: the flexibility of tri-generation with absorption refrigeration systems gives a development tool for rural areas. This flexibility creates at the same time the need for development of the most economical, reliable and energy efficient configurations.

CONCLUSIONS

This study shows the value of a co-operation between Arid and Semi Arid Area of Africa and European Small and Medium Enterprises. These regions are in great need for development and great opportunities in regard to economic co-operation, land use for crops plantation, biomass based energy production, etc..

Biomass resources, most agriculture residues, but also forestry residues for energy utilisation in those regions are available.

This large amount of biofuel is able to satisfy significant rural energy needs. In particular major interest appears in:

- **Heat production** using solid biomass pellets in high efficiency stoves;
- **Cooking biofuels production**, in particular:
  - Charcoal pellets
  - BioSynGas
  - Bioethanol (95°)
  - Biogas
- **Power (cogeneration) production**, by:
  - Gasifier - engine generator fuelled with biomass briquettes
  - Microgas turbines fuelled with low-grade bioethanol or bio-syn-gas
- **Activated coal production** seems of great environmental interest for its high capacity of drinking water purification.
- **Production of animal feed** and therefore also food (meet, milk and derived products) for the population.

A supplementary amount of liquid and solid biofuels could be available using sweet sorghum plantations because of the high productivity of best selected crop varieties.

This volume of biofuels could thus be able to provide a significant amount of the heating, cooking energy, electricity and nutritional needs of rural population of those areas.

The viable local production of these valuable biofuels requires a wide spectrum of modern, efficient technologies that are available in the European Union but mostly too expensive for the African market. Therefore the only way to penetrate the local conventional fuel / electricity markets is by implementing a technological and know-how transfer and by establishing joint-ventures for a common business.

It is expected that the available potential bioenergy activity will have significant rural development impact and important environmental benefits in Africa. Moreover, it will improve the economic self-sufficiency and therefore the balance and distribution of prosperity in the country.

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COMPETE is co-funded by the European Commission in the 6th Framework Programme – Specific Measures in Support of International Cooperation (INCO-CT-2006-032448).