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Final thesis

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The requirements for wood based biomass raw materials
in different bio energy processes and biomass properties and
logistics.

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CO-operating Company	Andritz Oy, Hollola
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Abstract

The work was done for Andritz wood processing division at Hollola. The subject was to find out what requirements different bio energy processes set for wood based biomass and clarify biomass properties and logistics. The purpose of the work solve out how Andritz portfolio suite for these processes.

The target for this thesis was to solve out what kind of raw material different bio energy processes use and what requirements these cause on wood processing. The following processes were clarified: Pelletizing, combustion, thermo mechanical conversion, biofuels and bioalcohols. Also wood based biomass properties and logistics were researched

The used sources were literature, www-pages, some final thesis and interviews. The practical experience on the subject is limited, so the information is mainly based on work experiments and studies. A research method was mainly qualitative.

The result of the thesis has shown quite well what kind of raw material different processes require. The logistics of biomass was clarified also and main properties were solved. The results can be used as an input in different bio energy processes wood processing equipment engineering.

Critical consideration of results is reasonable, because many of these processes were in pilot-scale and industry- scale plans are not exist. Scaling from pilot to industry-scale sets some challenges on wood processing and raw material requirements might change a little.

Keywords	Pelletizing, combustion, gasification, pyrolysis, wood based biomass
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Tiivistelmä

Työ tehtiin Andritzin puun käsittely divisioonalle Hollolaan. Työn aiheena oli selvittää mitä vaatimuksia erilaiset bioenergia prosessit asettavat puuperäiselle biomassalle sekä selvittää biomassan ominaisuuksia ja kuljetusmuotoja. Työn tavoitteena selvittää miten Andritzin nykyinen portfolio sopii näihin prosesseihin.

Työ tehtiin, jotta Andritz saisi selville millaista puuperäistä raaka-ainetta eri bioenergia prosessit haluavat ja mitä vaatimuksia ne aiheuttavat puun käsittelylle. Työssä selvitettiin seuraavien prosessien asettamat vaatimukset: Pelletointi, poltto, puun thermo mekaaninen jalostus, biopolttoaineet ja bioalkoholit. Lisäksi tutkittiin puuperäisen biomassan ominaisuuksia logistiikkaa.

Tietoa työhön hankittiin pääasiassa kirjallisuudesta, www-sivuilta, opinnäytetöistä sekä haastatteluiden avulla. Aiheesta oleva käytännön kokemus on hyvin rajoittunutta, joten tieto perustuu henkilöiden kokemuksiin tutkimuksissa. Työssä käytetty tutkimusmenetelmä oli pääasiassa kvalitatiivinen.

Työssä saatiin aika hyvin selville millaista puuperäistä raaka-ainetta erilaiset prosessit haluavat. Myös biomassan toimitusmuodot tehtaille saatiin hyvin selville. Työn tuloksia voidaan käyttää bionergiaprosessien puun käsittelyn laitesuunnittelun tukena.

Työn tuloksien kriittinen tarkastelu on järkevää, koska monet prosessit ovat vasta pilot-vaiheessa ja tehdasmittakaavaisia laitoksia ei ole olemassa. Tämä skaalaus voi aiheuttaa omat haasteensa puun käsittelylle ja halutun puuperäisen raaka-aineen vaatimukset voivat muuttua tietyiltä osin.

Avainsanat	Pelletointi, Poltto, Kaasutus, pyrolyysi, puuperäinen biomass
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Foreword

This work was for Andritz Oy wood processing division. Wood processing division headquarter is located at Hollola. Andritz Oy is one of biggest pulp mill supplier in the world. This work was very interesting and challenging for me, because my earlier knowledge of this subject was limited.

I would like to thank you Andritz Oy wood processing division employees for this opportunity. Especially I would like to thank you for my thesis supervisors at Hollola. Without their support and their knowledge this work would be lot more difficult to manage.

I learned a lot for bio energy processes during this work. This would not be possible without persons whom I interviewed during this final thesis so I would like to thank them.

DI Arto Nikkilä was a supervisor for my final thesis. I would like to thank to Arto for all his supports and feedbacks.

Hollola May 2010

Joni Väisänen

Table of Contents

1. Andritz's wood processing description.....	8
2. Pelletizing.....	10
2.1 Pelletizing process in general.....	10
2.2 Raw materials.....	12
2.3 Required raw material quality.....	13
3. Biomass combustion	16
3.1 Power plant process in general	16
3.2 Boiler types	18
3.2.1 Bubbling fluidized bed boiler	18
3.2.2 Grate boiler.....	20
3.3 Raw materials.....	22
3.4 Required raw material quality.....	23
4. Biomass thermo mechanical conversion.....	26
4.1 Processing in general	26
4.1.1 Gasification	26
4.1.2 Pyrolysis.....	32
4.2 end products	35
4.2.1 Gasification end products.....	35
4.2.2 Pyrolysis end products	37
4.3 Raw materials in thermo mechanical processes.....	38
4.4 Required raw material quality for gasification processes.....	39

4.5 Required raw material quality for pyrolysis processes	42
5. Biofuels	45
5.1 definitions of the biofuels	45
5.2 Fischer-Tropsch-synthesis method	45
5.3 Green pyrolysis diesel.....	46
5.4 Bio synthetic natural gas (Bio-SNG)	47
6. Bioalcohols.....	49
6.1 Bioethanol	49
6.2 Biomethanol.....	53
6.3 Raw materials for bioethanol production.....	54
6.4 Required raw material quality for bioethanol production.....	55
7. Wood biomass.....	57
7. 1 Wood structure and composition of wood.....	57
7.2. Moisture and heating values of different wood biomasses.....	60
7.3. Wood biomass transportation and handling.....	62
7.3.1 Small round wood (Thinning).....	62
7.3.2 Logging residues.....	64
7.3.3 Stumps.....	65
8. Summary	67
8.1. Pelletizing	67
8.2 Combustion.....	67
8.3 Thermo mechanical conversion	68
8.4 Biofuels.....	69

8.5 Bioalcohols	69
8.6 Wood biomass.....	70
References	71

1. Andritz's wood processing description

“The ‘Wood Processing’ Division engineers advanced wood, chip and bark processing plants and equipment for the pulp & paper, panel board and power industries worldwide. It is the world's leading supplier of systems, equipment and processes for all steps required in a wood yard - from the arrival of logs to their subsequent preparation into wood chips - for the production of chemical and mechanical pulps. The Andritz Wood Processing Companies also provide parts, repairs, and maintenance and modernization services throughout the world.” (Andritz Oy, Intranet.)

Product Range:

“KW’s product range includes wood yard portal cranes, PowerFeed™ conveyors, debarking drums, RotaBarker™ debarkers, chippers, chip screens, screw reclaimers, bark shredders, bark presses, presteaming bins, and grinder chargers.” (Andritz Oy, Intranet.)

Process Areas:

“Typical process areas of Andritz Wood Processing are:

1. Pulpwood processing in both cold and warm climates
2. Ground wood processing, completed with grinder charging system
3. Processing of random length logs in warm climate with special applications for short logs

4. Processing of eucalyptus and tropical mixed hardwood
5. Chip and bark processing including storage and pre-steaming
6. Wood processing for the panel board industry
7. Biomass processing and handling applications for power boilers, pelleting plants, biomass gasification plants etc.”

(Andritz Oy, Intranet.)

Organization:

“The ‘Wood Processing’ Division is headquartered in Hollola, Finland and has sites in the USA, Canada, China, Russia and Brazil. The companies employ 100 people worldwide and their average annual sales amount to 70 MEUR.”(Andritz Oy, Intranet.)

2. Pelletizing

Biomass pelletizing is an interesting alternative energy source. It decreases carbon emissions and reduces dependence of fossil fuels. Pellets are relatively cheap option to produce heat. Pellets have enormous growth potential in the future. In following chapters pelletizing process, raw materials and its handling systems are presented.

2.1 Pelletizing process in general

Pelletizing process includes the following process units: Raw material intake, crushing (not for sawdust), drying, fine grinding, pelletizing, cooling, sifting, bagging and truck loading. Raw materials and handling systems are presented in chapters 2.2 and 2.3. Pelletizing plant material flow is presented in figure 1. (Bloch 2010.)

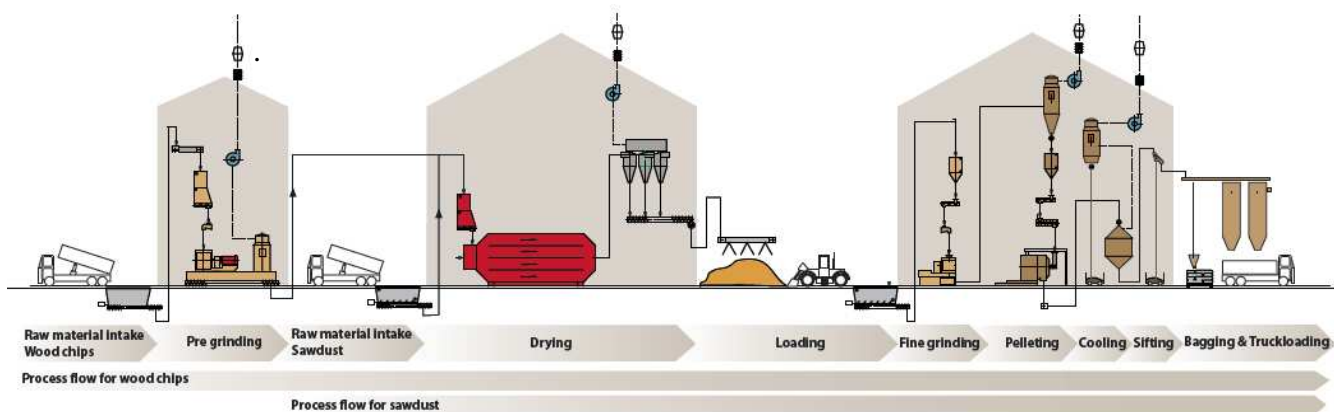


Figure 1. Pelletizing material flows. (Bloch 2010.)

In a pelletizing process, the crushed and dried raw material is fed into the pellet machine. Inside the pellet machine raw material forms a mat in front of pressing roll. Roll press raw materials through the die. During the compression, raw material temperature is rising and binding agents (lignin, resin or starch) start to soften. Pelletizing process consist many variables which affect on pelletizing process. Pressure,

temperature, compression and die material, die shaping, pressing rolls rotating speed and gap between the roll and die. Optimization of pelletizing process must be based on raw materials. Different raw materials need different parameters. Pelletizing process is presented in figure 2. (Kallio M, Kallio E, 13-19; Takalo 2010)

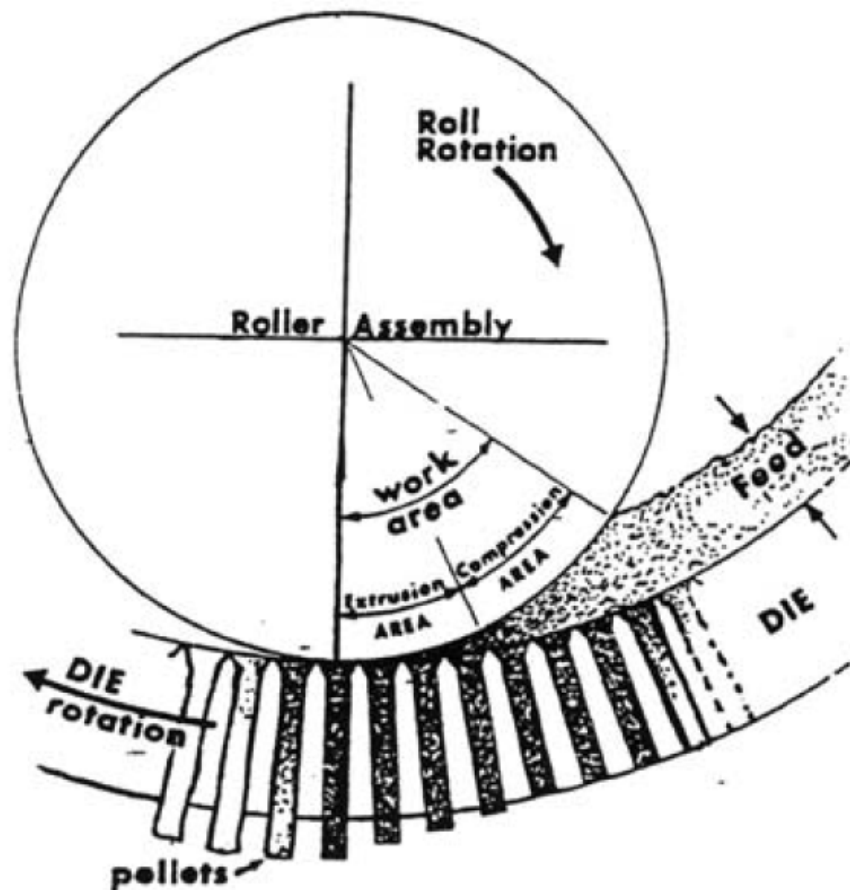


Figure 2. Pelletizing process. (Kallio M, Kallio E, 14.)

After the actual pelletizing process pellets are cooled, sifted and package and loaded to the trucks. The length of pellets varies depended on die design. The diameter for a households use is typically 6-8mm and for power plant industrial 8-10mm. Density of pellets is around 650kg/m^3 . Typical moisture content of pellets is between the 7-10%. Ash content is approximately 0,5%. Wood pellets heating value varies on 14-17,5 Mj/kg depending on pelletizing line and raw material. The moisture content is similar as coal (approximately 10%). The ash content is much lower compared with coal whose ash

content is 10-15%. Coal has a much higher heating value than pellet. Dry coal heating value varies on 20- 28Mj/kg, depending on coal type. (Takalo, 5-7; Takalo 2010.)

Pellets have many advantages compared to fossil fuels or solid biomass. Pellets are a renewable energy source and environmental friendly to use. Pellets using reduces carbon emissions compared to fossil fuels. A biomass power plant does not need to make large investments when starting to use pellets as a raw material. Pellets are easy to handle and transporting is easier and more efficient than other biomass because its density is so much higher. Pellets are homogenous material so fuel managing is easier compared to other biomass. (Bloch 2010; Takalo 2010.)

2.2 Raw materials

Used raw material can vary from wood to other biomass. In the past the raw material was mainly wood dust e.g. saw dust. In future pelletizing is based on round wood as a raw material. Saw dust is still an important raw material for pelletizing but due to limited availability round wood becomes more and more popular. Raw material sources are the following: timber industries, sawmills, paper industries, furniture industries, building industries, agricultural by products and forest residues. Main raw material source in future is going to be round wood or wood chips. Raw material can be wet or dry, logs or dust depending on a sources, raw material handling is different with different raw material. (Bloch 2010; Takalo 2010.)

Wood species affect the pellets properties e.g. heating value but all wood species are possible to pelletize on dense form. Different wood species behave differently in the pelletizing. Hardwood needs higher pressure and temperature in wood pelletizing process than softwood because the lignin content is lower in hardwood. Foreign wood species can be raw material for pelletizing but research has not yet been done in Finland. Bark is suitable for pelletizing so bark separation is not needed if the customer

does not want that. Bark might need some binding agent to achieve good pelletizing results. Stumps are a great raw material source if impurities separated totally, but it is very difficult to separate all impurities. In general it can be said that all wood based raw materials are possible to use as a raw material for pelletizing process but each raw material and each moisture level needs different process parameter. (Bloch 2010; Takalo 2010.)

2.3 Required raw material quality

Moisture

The most important raw material properties are moisture, particle size, ash content and amount of impurities. Raw material moisture level depends on the source. If raw material comes from forest and it is not dried moisture level is around 55%. In natural drying it is possible to achieve 20-25% moisture level. This is recommended because then external drying does not require so much energy. Raw materials which come from timber- or furniture industry have moisture level 5-10% so external drying before pelletizing is not required. In some cases moistening of raw material is needed because raw material might be too dry. Ideal moisture level for raw material before entering the pelletizing machine is around 10%. External drying can be done in many ways. Drum drying is the most common way to do that. Another used drying method is belt drying. Flash drying before the pelletizing is beneficial, it heats the wood and softens the lignin so pelletizing energy demand is lower than cold wood pelletizing. Particle size has crucial impact for drying efficiency. Particle size must be small and raw material must be homogenous to achieve equal drying. (Bloch 2010; Takalo 2010.)

Particle size

Another crucial property is the raw material particle size. Particle size has significant effect on drying and actual pelletizing process. In drying the size must be quite small and equal for each side. If thickness grows then drying result is not good. Particles become dryer on top of the particles than the middle of the particle. (Bloch 2010; Takalo 2010.)

For pelletizing process particle size is even more important than drying. Particle size depends on used holes diameter of die. The size must be around 60% of dies holes diameter, then good pellets are formed without increase of the energy consumption. Used dies depend of pellets end use destination. In private household consumption wood pellet diameter is 6-8mm and power plant industry pellet diameter is 8-10mm. If particle size is larger than diameter of die holes then energy efficiency of pelletizing machine increase and amount of the fines increasing. The reason for that is grinding roll must break the particles smaller to press them through the dies holes. End use might sets some specific requirements e.g. if pellets are used to replace coal to boilers and pellets are crushed before boiler then particle size has to be smaller. Pellets are easier to crush to dust if particle size is smaller. The form of the particles does not have a huge effect on the pelletizing process, the only criteria is that particles are smaller than dies holes diameter. (Bloch 2010; Takalo 2010.)

Impurities

Ash content depends on wood species and only debarking has an influence of ash content. Good debarking decreases ash content. Non wood impurities might increase the ash content so impurities separating must be done well. (Bloch 2010; Takalo 2010.)

One of the raw material quality factors is the amount of the impurities. Pelletizing process is strict for impurities. Impurities are all non wood particles e.g. metals, sand and rocks. Also too large wood particles are classified as an impurity, but with the fine crushing these are crushed to accept form. Non wood particles break the pelletizing machine. Metals and rocks have a consuming effect on grinding roll and dies. Maintenance cost increases and quality of the pellets decrease from impurities. Impurities also break down the wood processing equipment so separation of impurities is important. (Bloch 2010; Takalo 2010.)

Homogenous

All raw material flows must be homogenous. Homogenous is one crucial criterion for raw material quality. Uneven raw material flows affect problems in the pelletizing. Adjusting of process line is impossible if moisture level and particle size varies because adjustment is done for each raw material separately. In the worst case scenario die holes are plugged and whole pelletizing process must be stopped whilst the holes are opened. The drying process is not even if raw material flows are uneven, in the drying process same amount of heat is fed into dryer and if some points contain more raw material than other in these points drying is not so efficient. Two different raw materials e.g. chips and saw dust can be combined together if it is possible to guarantee the homogenous all the time. (Bloch 2010; Takalo 2010.)

3. Biomass combustion

Combustion is the oldest method to utilize biomass. Combustion generates heat and power. Wood biomass combustion can be done in many different ways from fireplace to power boiler system. Combustion is today the most common way to utilize biomass to bioenergy. Following chapters demonstrate common method of biomass combustion in industrial scale.

3.1 Power plant process in general

Boilers In power plant process can be divided according to the water circulation: natural circulation boiler, forced circulation boiler and straight through boiler. In natural circulation boiler water and steam move in piping because the density of water and steam density is different. Forced- and straight through boilers water and steam circulation created by pump formed pressure. (Prowledge 2010.)

Principle of power plant

Normal natural circulating power boiler is presented in the figure 3.

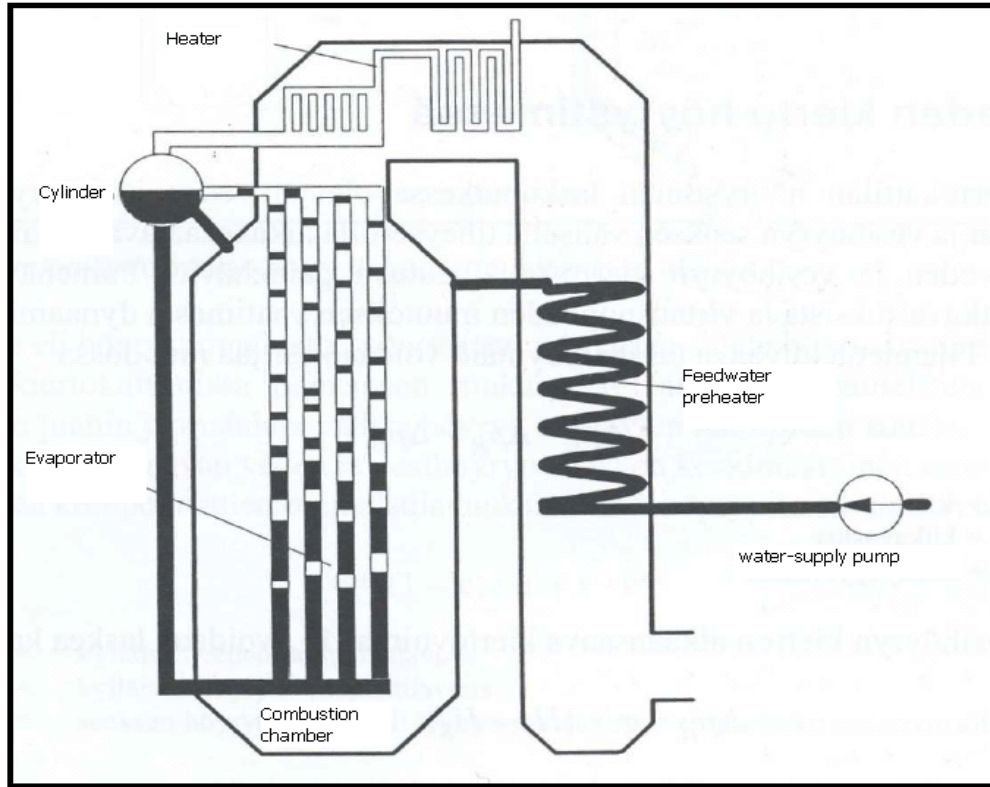


Figure 3. Principle of natural circulating boiler. (Lahtinen 2007, 10.)

The purpose of power plant is to warm water and generate heat and electricity with turbine. Water is fed into boiler with feeding pump to increase the pressure up to 90 bar and the water temperature is between 120-140 °C. Feed water is heated with preheater near to boiling point. The pressure is 90 bar and temperature is 290 °C. Heating is done with the exhaust gas from boiler. Incoming gas temperature is typically 600-800 °C and outgoing temperature is 250-450 °C. (Andritz Oy 2010, presentation; Hulkkonen 2010; Lahtinen 2007, 4-12; Prowledge 2010.)

After preheating injection water goes to cylinder where water and steam is separated. Water flows down by gravity into boiling surface. The heat is transferred into the water from combustion chamber and water partially vaporizes. The temperature increases only a little because energy goes mainly into vaporizing. Boiling water is lighter than descent pipe water and it flows up into the cylinder. The water temperature is around 300 °C. (Andritz Oy 2010, presentation; Hulkkonen 2010; Lahtinen 2007, 4-12; Prowledge 2010.)

In the cylinder steam separating based on density difference and steam is led into the superheater where steam temperature is increased without increasing the pressure. Temperature after the superheater is around 500 °C. The purpose of the super heater is to increase the steam temperature so it contains more kinetic energy. Finally steam is led into the turbine. The forced boiler principle is similar, only difference is a water circulating system which is done by pump. Straight through boiler can be demonstrated as a single pipe where water is fed into one end and steam come out from another end. Cylinder where water and steam are separated is not used in these boiler types. (Prowledge, 2010.)

3.2 Boiler types

3.2.1 Bubbling fluidized bed boiler

BFB-boilers range is 30–300 MWth. BFB-boilers are natural circulating steam boiler. BFB-boilers are the best option for biomass burning. Bubbling fluidized bed boiler (BFB) has about 1m thick bed layer, bed layer material is usually sand. Fuel is fed above of the bed and air is blown through the bed. The combustion is based on drying and gasifying the high volatile content fuel in and above the fluidized bed and combustion of the volatiles in the freeboard section of the furnace. Secondary and tertiary air is fed above the bed to achieve total combustion. BFB- boiler is presented in the figure 4.

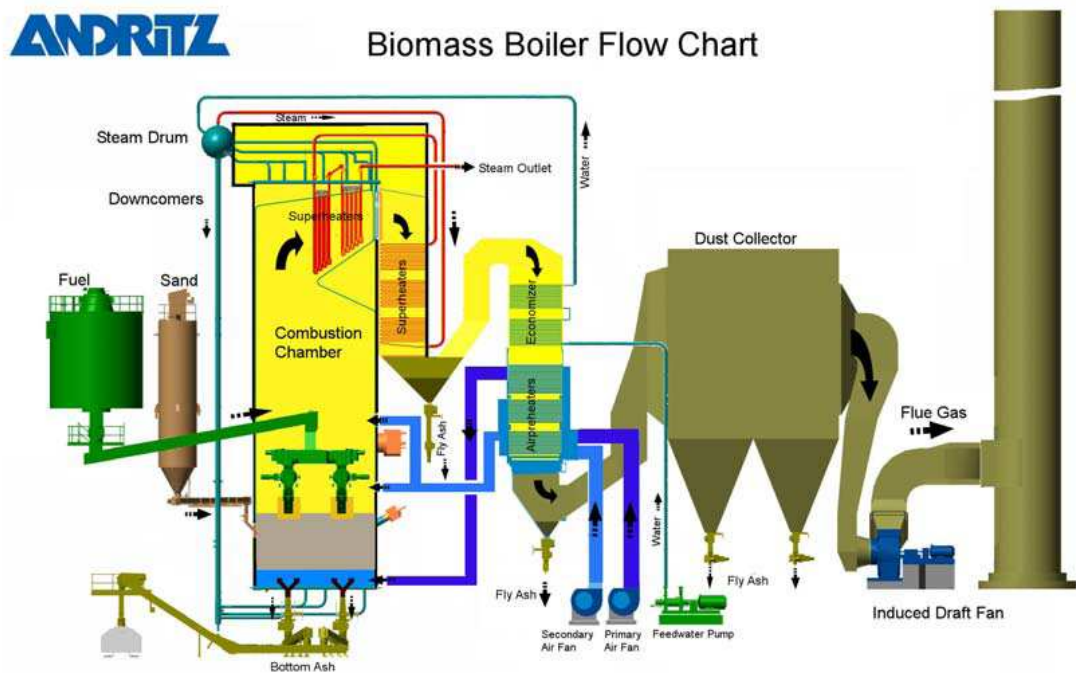


Figure 4. BFB-boiler system. (Andritz Oy 2010.)

Variables which affect BFB- combustion process are following: Pressure, amount of air and its temperature, fuel, bed material and its temperature. Pressure is typically approximately 50-110bar. Steam temperature before the super heater is relatively low, temperature is approximately 450 °C. Bed material is usually sand and height is 1m. Bed temperature is maintained between 800 – 900 °C. (Andritz Oy 2010; Hulkkonen 2010.)

Bubbling fluidized bed- boiler has good mixing between the air and fuel. Residence time in boiler is long so fuel burns totally in bed. Amount of the unburned carbon in ash is low and CO-emissions are low. Low NO_x-emissions are possible to achieve with air staging. The boiler construction is simple so boiler does not need much maintenance and it is reliable. BFB-boiler is suitable for many fuels and fuels can be burned in wet also. The particle size of fuels is not so critical, larger particles burn also because of the long residence time. These reduce wood handling costs, because crushing and screening do not have to be so crucial. Gas is heated with the super heater in temperature up to

900 °C. Outgoing steam is led into turbine to produce electricity (Andritz Oy 2010; Hulkkonen 2010.)

Boiler ash contains both some bed material and ash and impurities brought to the boiler with the fuel. Ash handling system is divided into two systems: Bottom ash and fly ash. Bed ash and coarse material is removed from the bed in dry phase. When fuel is burned the ash is in practice converted totally into fine dust, which escapes from the furnace with the flue gas flow. Stones and other coarse material remain at the bottom and are removed when necessary by the bottom ash removal system. Fly ashes are collected from second and third pass conical ash hoppers. (Andritz Oy 2010; Hulkkonen 2010.)

3.2.2 Grate boiler

Grate boiler is the oldest method for solid raw material burning. Grate boilers are suitable for small power production. Typical range is 1-80MW, but in upper part of scale fluidized bed boilers have partially replaced grate boilers. Grate boiler's investment costs are lower than BFB-boiler's, because BFB-boilers are tailored for customers. Coefficient of efficiency of grate boiler is usually lower than BFB-boilers. There are many different grate types, stationary grate, mechanical grate and vibrating grate are the most common grate types. Also manufacturers might have own solutions. (FSWA; Venäläinen 2010.)

The principle of grate boiler is presented at the figure 5.

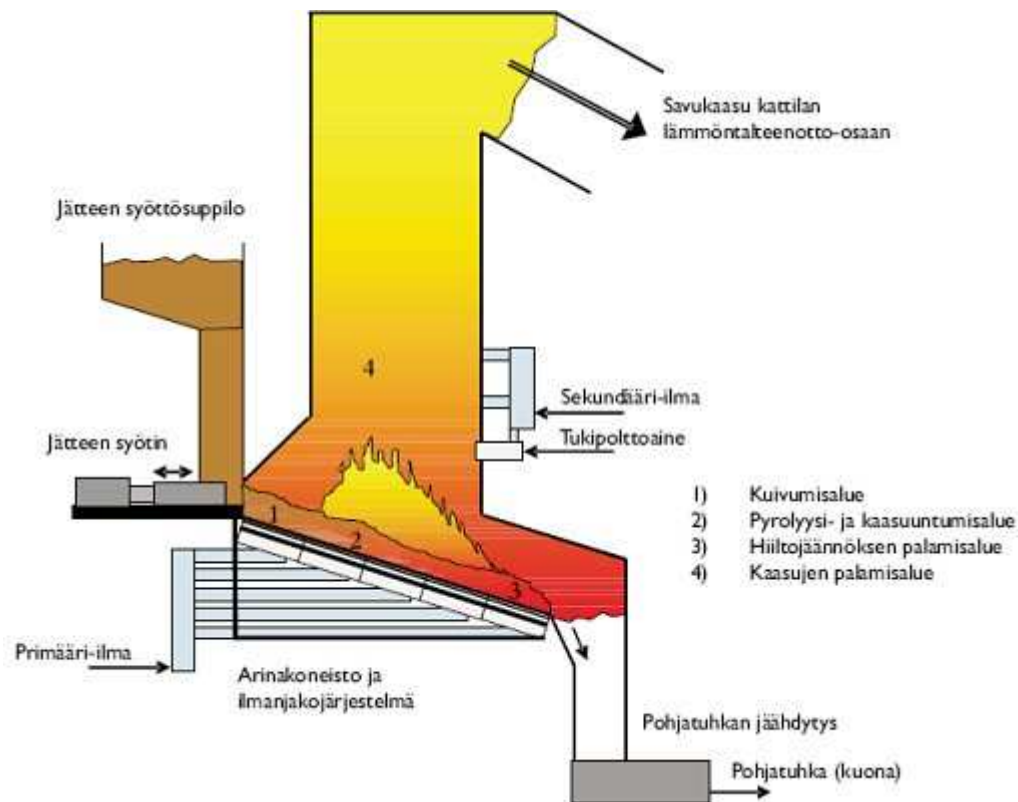


Figure 5. Principle of grate boiler. (FSWA.)

Grate boiler is suitable for many different solid raw materials. It tolerates very well different raw materials. The of pre treatment Raw material is quite simple. The big particles must be crushed and metal particles must be taken away. Drying is not needed. Raw material is fed into the boiler with hydraulic pusher. The combustion chamber has all moist raw material phases: drying, pyrolysis, burning and char burning area. Primary burning air is fed from below of the grate and secondary burning air is fed in from the top of the grate. Burning air can be adjusted in different phases. Grate boilers try to make so that combustion gases mix together well and gases are led into the heat recovery system. Bottom ash is taken away from bottom of the grate boiler. (FSWA; Venäläinen 2010)

3.3 Raw materials

Bubbling fluidized bed combustion can use raw materials which contain lot of volatile material. Biomass, sludge etc. are suitable raw materials. Wood can be used in many forms. Trunks of wood, bark and branches are allowed. Stumps are difficult because they contain a lot of the impurities and heating value is high. High heating value raw materials are not good raw materials because they burn in too high temperature. It sets a limit for stumps. All wood species are suitable raw material for BFB- combustion. Process designer must just know the incoming wood species for boiler optimization. (Andritz Oy 2010; Hulkkonen 2010.)

Saw dust is one option for a BFB-combustion raw material. Saw dust can be fed together with the pre processed wood the saw dust content can not be over 50% because then small particles might rise up without burning. Sander dust is too small to be fed together with the other feed material. It has to be blown straight to the bed because otherwise it rises up without burning, if it is fed as a larger raw material. Sander dust is good raw material for BFB-combustion it just has to install with independent blow nozzle for sander dust. Pellets have too high heating value (4,6-4,9 kWh/kg). (Andritz Oy 2010; Hulkkonen 2010; Takalo 2010.)

Short rotation crops (Eucalyptus, willow, etc) are a big raw material source in subtropical countries but high alkali content need to be taken into account in boiler design and gas cleaning. BFB-combustion ideal raw materials have low heating value (1,6-2,5 kWh/kg) but raw materials which have higher heating value are suitable as a partial fuel. Raw material with higher heating values raw material burn in too high temperature and it causes some problems in process handling and the bed material might start sinter. Also emissions are hard to handle if material's energy value increases rapidly. BFB-boilers raw materials are mainly wet because of the heating value range. Moisture level is 30-60%. (Andritz Oy 2010; Hulkkonen 2010.)

Grate boiler's raw materials can vary a lot. Mainly same raw materials which suite for BFB-combustion, are also suitable for grate boilers. Sludge is difficult raw material for grate boilers. If sludge is used as a fuel, it must be mixed with bark. Stumps are suitable raw materials for grate boilers if they are crushed in right size. Saw dust is too fine raw material so amount of it must be controlled. (Venäläinen 2010.)

3.4 Required raw material quality

Moisture

Moisture level is usually 30-60 % depending on the source and season. Moisture has impact on heating value. BFB-boilers are designed for moist material. Drying is not required before the boiler. Forest residues can be dried with the natural drying if it is possible but then heating value increases and it has to be taken into account in boiler design. External drying might be reasonable both economically and technologically if free heat source is available. Grate boilers are designed for moist raw material also so pre-drying or external drying is not needed. (Andritz Oy 2010; Hulkkonen 2010; Venäläinen 2010.)

Particle size

Particle size is not crucial, large and small particles both burn in boiler but there are some limitations. Fine particles are not preferred because if those are fed together with normal feed then fine particles rise up as an unburned material before they drop down into the boiler bed. Independent blow nozzle for fine particles is needed and this increases expenses. Below 1mm particles are defined as fine in BFB-combustion. Large particles are suitable for BFB-combustion because residence time in bed is long and heat transferring is efficient so danger that large particle does not have enough time to

burn is minimal. Particles which size is over p100 classification are defined as large particles. (Andritz Oy 2010; Hulkkonen 2010.)

Standardization is used in raw material classification. Wanted raw material particle size is p63, but p100 is suitable also if p63 is not easy to achieve. According to Andritz Oy “match box sized particles are best for BFB-combustion” (Andritz 2010), (translation by J. Väisänen). The form of the particle is not so exact, it can vary a lot but size must fit into wanted standard. In general it can be said that BFB-boilers tolerate different particle sizes well. (Andritz Oy 2010; Hulkkonen 2010.)

Grate boilers sets quite strict limits for particle size. Grate boilers do not stand fine material at all. Milled peat is too fine for grate boilers and it can be used only with bark. Also saw dust alone is not suitable for grate boilers, because it is too fine and it might vault or drop through the grate. Smaller than 5mm particles are too small for grate boilers, but small amount of those are possible to be fed into the boiler with bigger particles. Residence time sets upper limit for particle size. Particles can not be too big so that they do not have enough time to burn totally. Particle size's upper limit depends very much on used grate types. (Venäläinen 2010.)

Impurities

All non wood materials are impurities. Bed material is sand so external sand which comes from feed is not crucial but sand can not contain any salt. Incoming sand just only increases bottom ash outflow. Rocks must be taken out from the feed because big rocks might break the equipment and affect jams for the boiler. Also if big rocks go through the feeding system they must be taken out from the boiler and bottom ash outflow increases again. This decreases amount of bed material and bed fluiding properties become poorer and efficiency of the boiler decreases. All metals are very bad. Heavy metals cause corrosion and maintenance costs increase. Aluminium burns in

high temperature which is not wanted for BFB-combustion. In ideal situation all rocks, sand and metal are taken out from the feed. (Andritz Oy 2010; Hulkkonen 2010.)

Grate boilers tolerate impurities very well and it is a big advantage compared to other combustion method. Bark suites for grate boilers very well. (Venäläinen 2010.)

Homogenous

Even material flow of the feed is very important. If feed swings a lot, an emission starts to increase. Boilers have strict limits for emissions. Raw material quality can vary only, not an abrupt. Raw material flow can combine but the mixing must be very good to avoid uneven flow. Homogeneity of the feed has a crucial effect on the distributing chamber. Distributing chamber is located just before boiler and screws feed raw material into the boiler just above bed. The purpose of the distributing chamber is to even the pressure and secure stable feed into the boiler. These are very problematic things because different raw material behaves different. Feed must form a loaf to stabilize the feed and discharge is done underneath the loaf. Screw conveyors are the best option for loaf discharge (Andritz Oy 2010; Hulkkonen 2010.)

In grate boilers feed particle size can not vary at all, because otherwise control of the burning becomes more difficult. Raw material must be fed equal on every part of the grate (in cross direction), otherwise thickness of raw material bed is not equal so burning air “escape” there where thickness is lower and controlling become more difficult. Particle size must stand same all the time, but grate boilers allows more impurities than fluidized bed boiler. In general grate boilers are more sensitive particle size variance than BFB-boilers but these stand more impurities. (Venäläinen 2010.)

4. Biomass thermo mechanical conversion

The purpose of the biomass thermo mechanical conversion is to change biomass into valuable gases or oils, which can be used to produce different biofuels e.g. Bio-oil. To produce these valuable gases or oils there are many different processes but two most common ones are pyrolysis and gasification. (Higman 2003, 1-7)

These processes have two common things both processes are executed in high temperature and in absence of oxygen or significantly less oxygen is present during the process. If there is too much oxygen then biomass will burn totally and it just creates carbon monoxide and heat which is not the purpose of the process (Higman 2003,1-7; Demirbas 2009, 261- 270).

4.1 Processing in general

In the following chapters is explained and demonstrated biomass thermo mechanical processing, gasification and pyrolysis.

4.1.1 Gasification

Principle of gasification is to convert solid carbon fuels into the gas which contains mainly carbon monoxide and hydrogen. The feedstock can vary from coal to biomass. Gasification process needs gasification agent to work properly, gasification agent can be air, oxygen or steam depending on process pressure and wanted gas composition. Gasification is an endothermic reaction. Gasification can be done in different reactor types. The reactor types are explained below. (Demirbas 2009, 283- 287.)

Fluidized bed gasification

“Fluidized bed gasification is divided into bubbling fluidized bed (BFB) and circulating fluidized bed gasifier”. (Pietarinen 2007, 4-23.) Principles of fluidized bed gasifiers are presented at the figures 6 and 7.

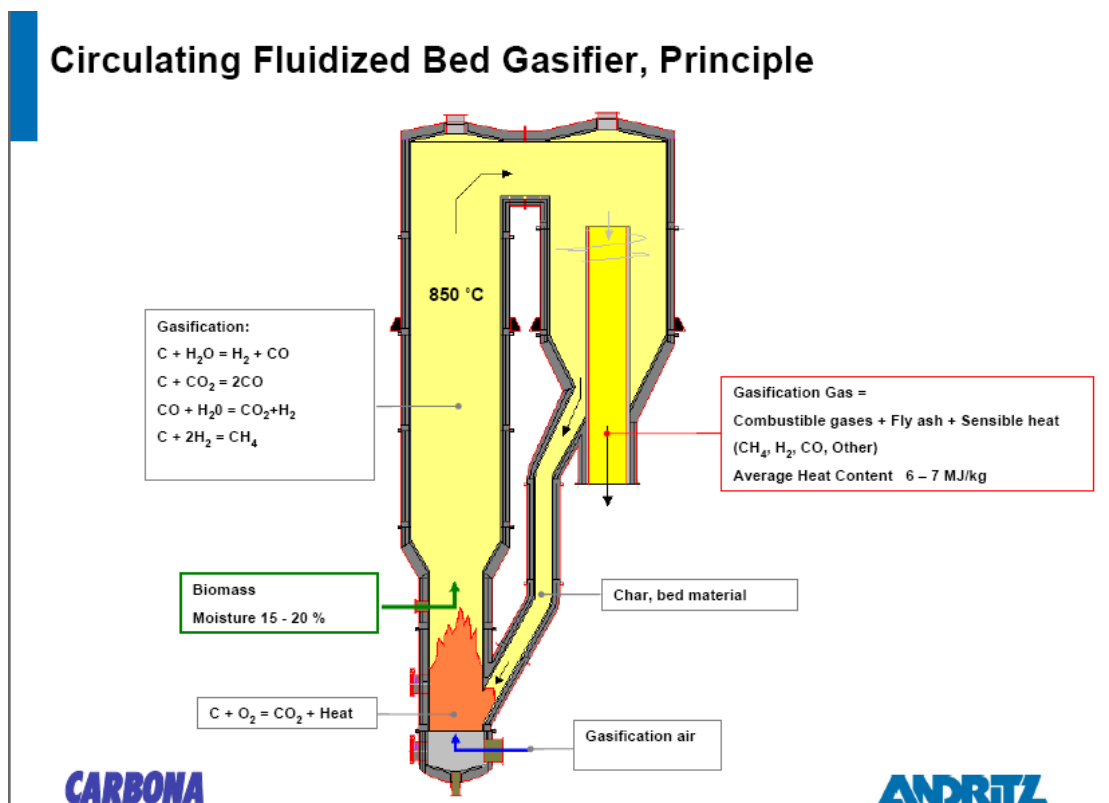
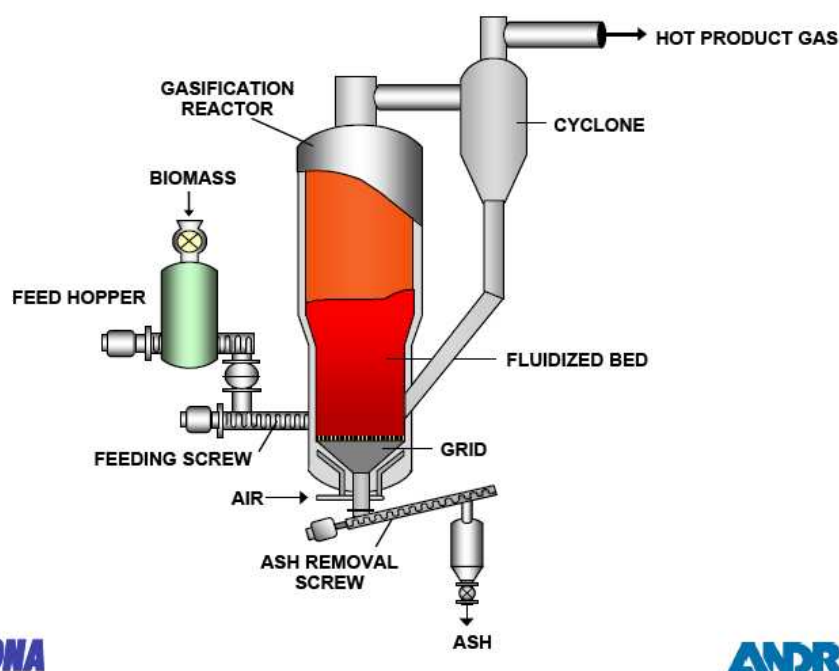


Figure 6. Circulating fluidized bed gasifier. (Carbona Oy 2010.)

Principle of Carbona Bubbling Bed Gasifier

High or Low Pressure



CARBONA

ANDRITZ

Figure 7. Bubbling fluidized bed gasifier. (Carbona Oy 2010.)

In both fluidized bed gasifier type's fuel is fed into bottom of the gasifier reactor. Gasification agent is fed on the bottom of the reactor. Gasification agent varies on depended end product or reactor process pressure. In bubbling fluidized bed gasifiers non-volatile compounds stays in the bed and volatile compounds are gasified into the gas. The gas goes up to reactor and gets out from gasifier to gas cleaning system. In circulating bed gasifier non-volatile particle stays in bed but some smaller non-volatile particles may leave to circulate into the reactor. These particles are returned into bed when gas gets out from the reactor to gas cleaning. (Hedman 2007, 4-26; Liukkonen 2010; Pietarinen 2007, 4-23.)

Fluidized bed gasifiers have many advantages, for example good mixing and uniform conditions during gasification process compared to fixed bed gasifier. Fluidized bed gasifier feed can vary more compared to other gasification methods. The process temperature varies depending on feedstock material. Temperature range is between 800 and 1100 °C. This range is higher than in fixed bed gasifier so existing gas is in higher

temperature and tar formation is a problem. (Hedman 2007, 4-26; Higman 20003, 98-108; Liukkonen 2010; Pietarinen 2010; Pietarinen 2007, 4-23.)

Entrained flow gasification

Entrained flow gasification is the most common gasification method for coal. Biomass can be used as a raw material but wood's pre-treatment is important. Some developing has been done for biomass gasification with entrained flow gasification. Raw material must be converted into very small particles, smaller than 0,5mm dust. One option is that first biomass is charred. Charred wood is crushed 0,5mm particle size and fed into entrained flow gasification process. Fines are not wanted because fines go along the gases and bigger gas cleaning systems are then required. Another option is to make pyrolysis oil first and use that as a feed for entrained gasification process. Pyrolysis oil has low heating value and this is a disadvantage for entrained flow gasification process. (Higman 2003, 109-127; Kurkela 2010.)

Raw material and gasification agent is fed on the top of the boiler. Residence time is couple of seconds and temperature is higher than in other gasification processes (1300-1500 °C). The principle of the entrained flow gasification is presented at the figure 8. (Higman 2003, 109-127)

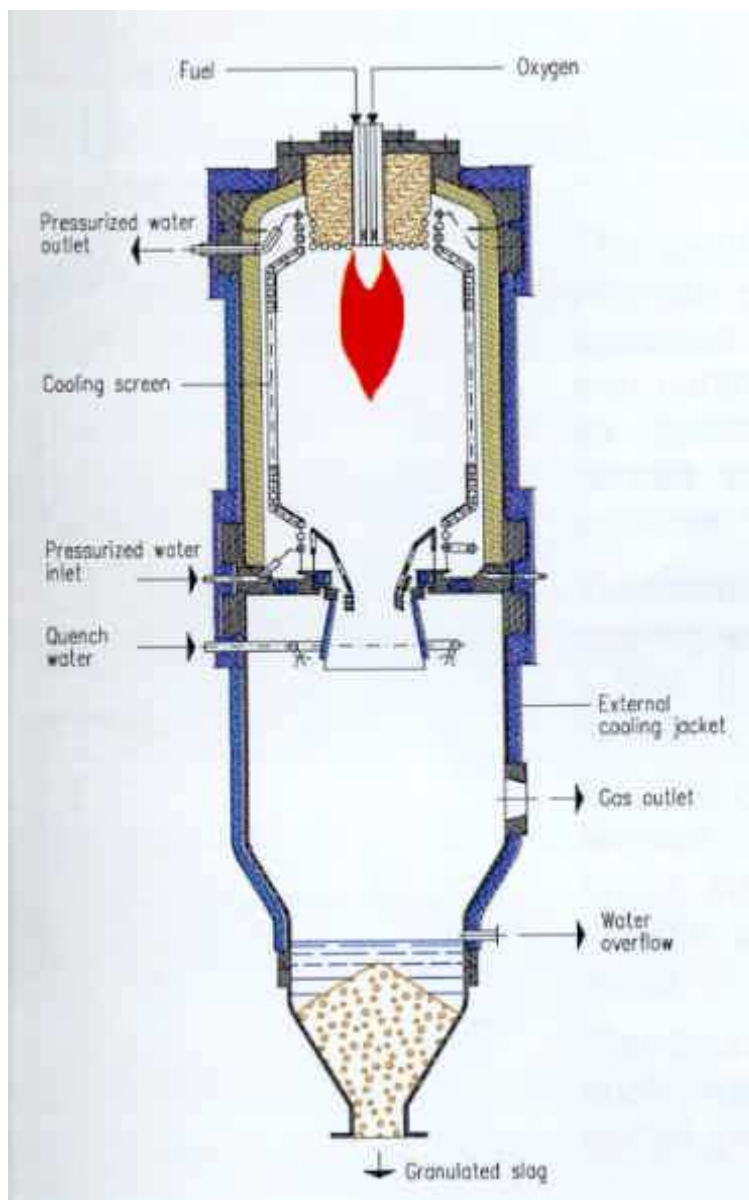


Figure 8. Entrained flow gasifier. (Van Der Drift 2004, 42.)

The pressure depends on used gasification agent. Mainly air gasification process works in atmospheric and oxygen gasification work in pressurized conditions. Also steam can be used as a gasification agent. Entrained flow gasification process is a good method to produce syngas but it requires lot of pre-treatment which decreases efficiency of the producing. Raw material quality requirements set limits for different wood based biomasses. Stem wood is the most interesting option. Biomass entrained flow gasification studies have been done with stem wood. (Higman 2003, 109-127; Kurkela 2010; Van Der Drift 2004, 41-43.)

Fixed bed gasification

Fixed bed gasifiers are sorted out in two methods: updraft gasification and downdraft gasification. Fixed bed gasifiers principle is shown at the figure 9. (Hedman 2007, 4-26.)

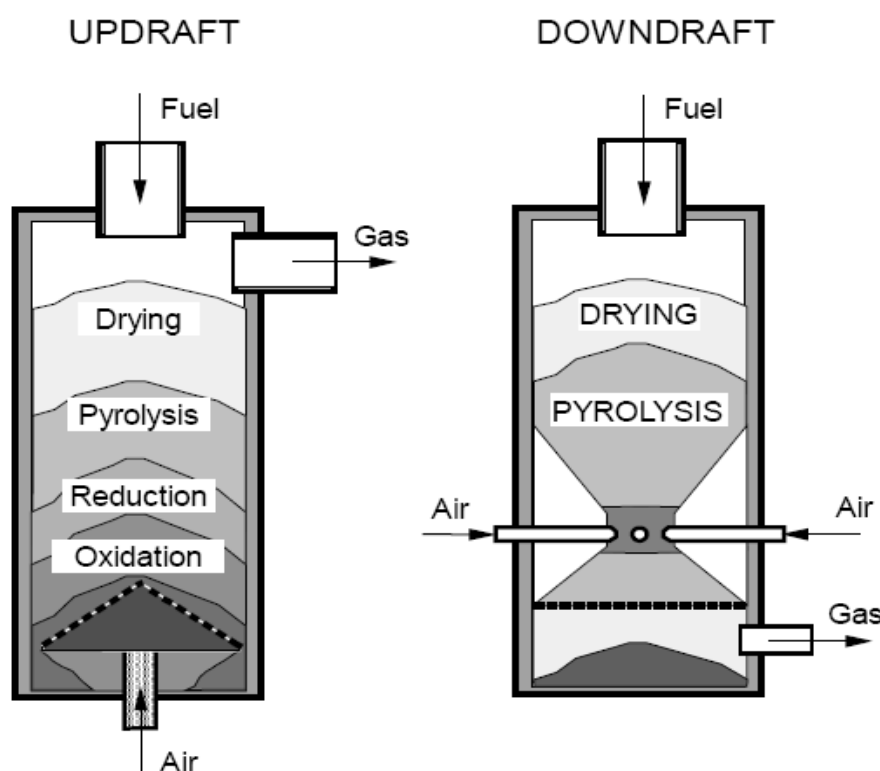


Figure 9. Fixed bed gasifiers. (Ohlström, Mäkinen, Laurikko, Pipatti 2001, 19)

Updraft gasifier is also called counter-current gasifier. The name comes from the gasifier principle, fuel and gasification agent is moving in opposite direction. In updraft gasifier fuel is fed into the top of the gasifier and gasification agent is fed from the bottom of the gasifier. The produced gas exits on the top of the reactor. In downdraft gasifier fuel and gasification agent is moving same direction, fuel is fed from the top of the gasifier and gasification agent is fed into the middle of the gasifier and produced gas exits from bottom of the reactor. Temperature of produced gas is 300-450°C (updraft gasifier) and 400-600°C (downdraft gasifier). (Hedman 20074-26; Higman 2003, 87-97; Lassi 2010.)

Updraft gasifier works properly if feedstock moisture is 50% or lower but downdraft gasifier needs lower moisture content (20-30%). Fixed bed gasifier's disadvantage is the high tar content of the product gas, quality compared to other gasification methods is not good. (Hedman 20074-26; Higman 2003, 87-97; Lassi 2010.)

4.1.2 Pyrolysis

“Pyrolysis is the decomposition of organic matter occurring in the absence of oxygen or significantly less oxygen is present than required for complete combustion.” (Demirbas 2009, 277.) Typical temperature of pyrolysis is between 200-900°C. Initially pyrolysis is an endothermic reaction so heat is transferred from an outer heat source. Pyrolysis is same kind process than gasification but it is optimized to produce fuel liquids (bio-oil) which can be used straight as a fuel or it can be refined to produce higher quality fuels. Raw material ranges which can be used in pyrolysis vary a lot, biomass, agricultural wastes and coal to mention a few. (Demirbas 2009, 277-281.)

Variables which affect to pyrolysis are the following: temperature, heating rate, residence time, pressure, used catalyst and feedstock particle size. The catalysts are used sometimes if reaction needs them but then pyrolysis is not the right name for the reaction anymore. Wood thermal conversion can be divided into three categories, which are presented at the table 1. (Demirbas 2009, 277-.281.)

Table 1. Typical product yields [dry wood basis] obtained by different modes of pyrolysis of wood. (Bridgewater 2002, 11.)

		Liquid	Char	Gas
Fast pyrolysis	Moderate temperature, short residence time particularly vapour	75 %	12 %	13 %
Carbonisation	Low temperature, very long residence time	30 %	35 %	35 %
Gasification	High temperature, long residence times	5 %	10 %	85 %

As table 1 presents fast pyrolysis is the best way to produce bio-oil. Other thermo mechanical processes are more suitable on different purposes.

Fast pyrolysis is advanced process compared to carbonization, with carefully controlled parameters to give high yields of liquids. Fast pyrolysis typical reaction temperature is around 500 °C and temperature in vapors phase is 400-450 °C. Fast pyrolysis process has high heating and heat transfer rate. To achieve these, small particle size is required. Residence time is typically short (less than 2 seconds). Cooling must be done rapidly to achieve high yield of bio-oil product. With fast pyrolysis it is possible to achieve 75% of yield on dry feed basis. Fast pyrolysis can be done with many different reactors types. Reactor types are the following: bubbling fluidized bed-, circulating fluidized bed-, ablative -, rotating pyrolysis - and entrained flow reactor. Reactors are presented below (Figure 10 & 11). (Bridgewater 2002, 10-13.)

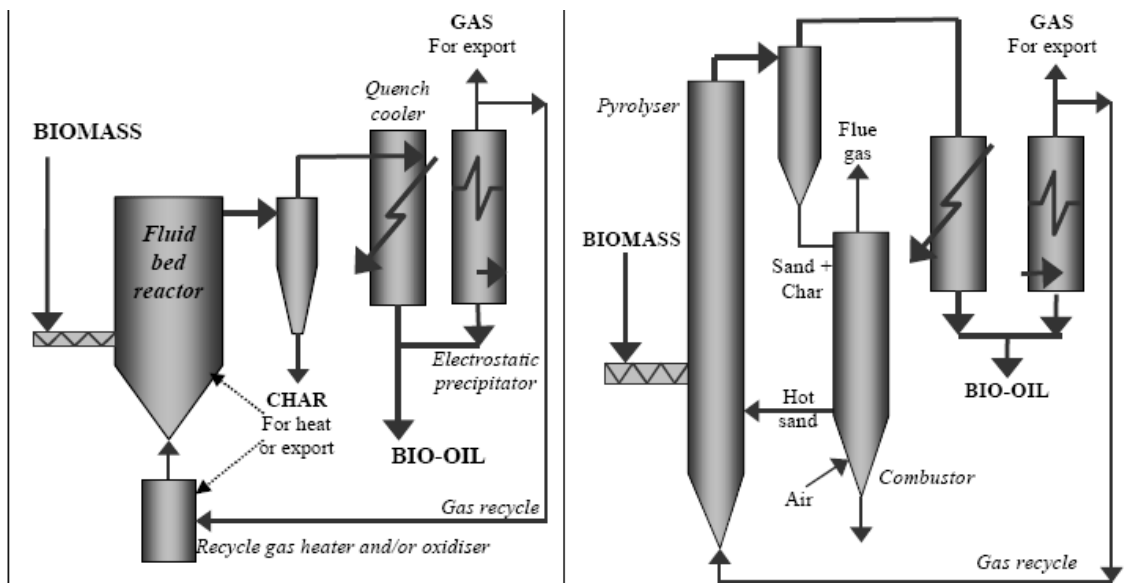


Figure 10. Bubbling fluidized bed (left) and circulating fluidized bed (right). (Bridgewater 2002, 13.)

Bubbling fluidized bed and circulating fluidized bed are well know technologies. Both of these technologies have good heat transfer and temperature control can be achieved. Heat transfer is proved in large scale. Residence time of the char is almost same as in gas or liquid. CFB reactor is suitable for large throughputs. These technologies require small particles (2-3mm). Gas is cooled rapidly and bio-oil is separated in that phase. Fuel gas can use either for gas recycling or for export. (Bridgewater 2002, 11-19; Brown 2006, 1-30.)

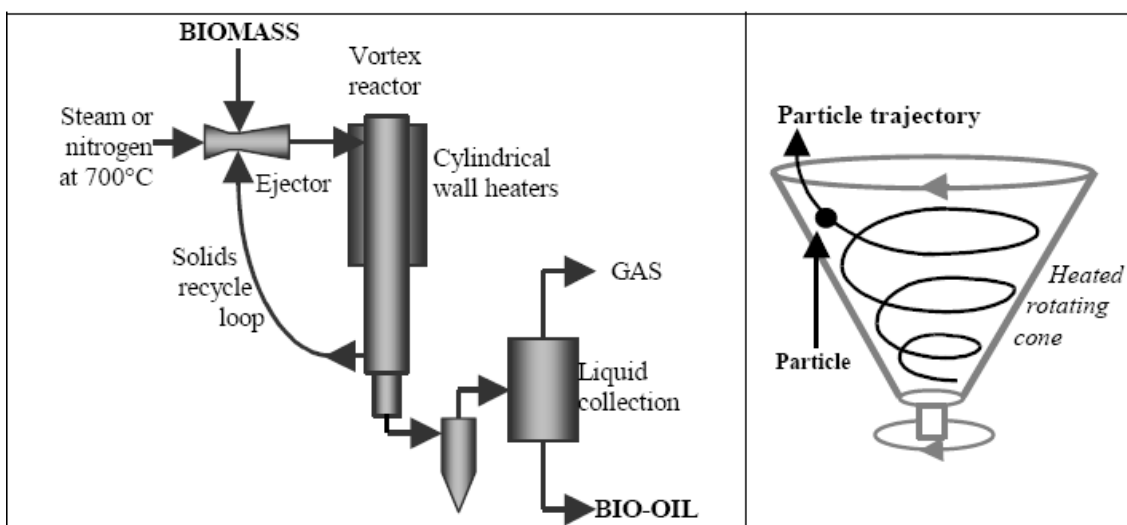


Figure 11. NREL Vortex ablative reactor (Left) and rotating cone pyrolysis reactor (right). (Bridgewater 2002, 14.)

In ablative reactor wall temperature should be less than 600 °C. The feed is pressed against reactor wall, achieved due to centrifugal or mechanical forces. Large particles can be used. Ablative reactor is quite complex and does not scale well. Rotating cone pyrolysis reactor requires very small feed particles and its yield is little bit lower than in other pyrolysis reactors. The structure of rotating cone is quite compact. Scaling is difficult and expensive. In general it can be said that BFB- and CFB reactors are well known and they more suitable for pyrolysis processes. (Bridgewater 2002, 11-19; Brown 2006, 1-30.)

4.2 end products

Following two chapters show gasification and pyrolysis end products and their field of applications.

4.2.1 Gasification end products

Synthesis gas utilization can be divided into two categories: Chemical utilization and heat and power utilization. Chemical utilization contains F-T- synthesis, methanol production, ammonia production and other chemical applications. Synthesis gas can be used to produce heat and power with many different applications e.g. Lime kiln heat production. With developed gasification technologies synthesis gas can be converted into heat and power (IGCC-technologies). In the past and now heat and power production has been the main applications of synthesis gas but in the future chemical applications will more and more important. (Kurkela 2010; Lassi 2010; Liukkonen 2010; Pietarinen 2010.)

In chemical utilization synthesis gas must be more pure than heat and power production. Amount of the H₂ and CO must be maximized in chemical utilization and content of

impurities should be as low as possible. This requires better gas cleaning system which can be done in both cold – and hot gas cleaning. Chemical utilization products and their production methods are demonstrated in chapters 5 and 6. (Kurkela 2010; Liukkonen 2010; Pietarinen 2010.)

In power and heat production purify of gas is not so important because gasification impurities burn in power and heat production. Heat and power process is presented at the figure 12.

CFB Gasifier – Lime Kiln Concept

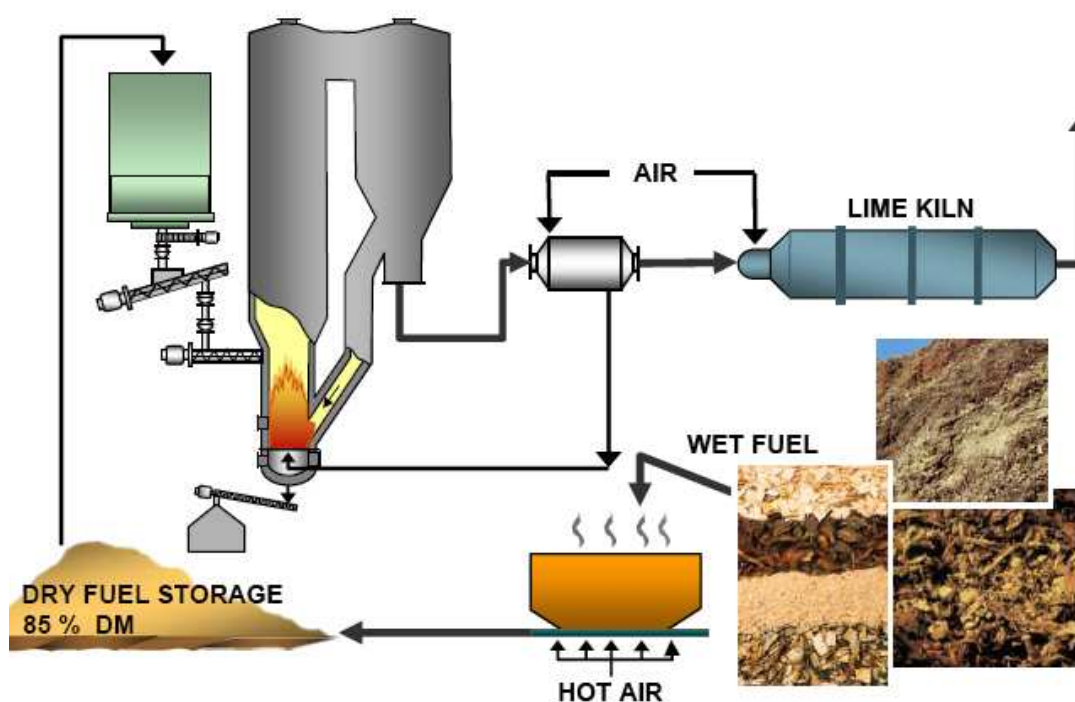


Figure 12. CFB-lime kiln concept. (Carbona 2010)

Synthesis gas can be used to produce heat in the lime kiln or to replace fossil fuels in boiler technologies. In IGCC-technologies gasification gas is transported into gas turbines to produce power and heat. The simplified IGCC-technology is presented at the figure 13. (Liukkonen 2010; Pietarinen 2010.)

Carbona BFB-Gasifier – Simplified IGCC Process

High Pressure Air Gasification

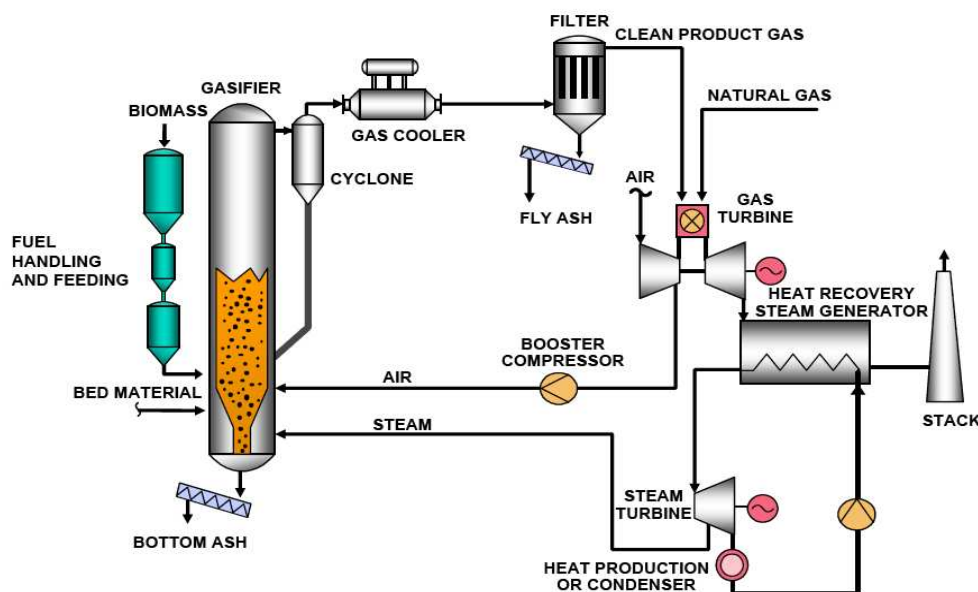


Figure 13. IGCC-process. (Carbona 2010.)

4.2.2 Pyrolysis end products

End products of biomass pyrolysis reaction have high heating value so most of those are used in fuels. Typical end products can be gaseous, liquid and/or solid depending on what is wanted. Gaseous end products are called pyrolysis gases and they can be used to produce heat. Also pyrolysis gas can be used as a fuel. Solid material from wood pyrolysis is mostly char. The char is used as gasification raw material. Also char can be burned to produce heat or used as a raw material in different products. (Higman 2003, 73-74; Demirbas 2007, 39-60; Demirbas 2009, 261-302.)

Pyrolysis oil is the main end product of pyrolysis. Pyrolysis oil is also called bio-oil. Bio-oil is produced mainly by fast pyrolysis process. It is used straight as a fuel or refined for higher quality uses such as engine fuels, chemicals, adhesives and other products. Also one end use target is to use bio-oil as a raw material for gasification. (Higman 2003, 73-74; Demirbas 2007, 39-60; Demirbas 2009, 261-302.)

The reason to produce bio-oil with the pyrolysis method is that first biomass must be converted into transportable form. Energy density of bio-oil is same as methanol (20GJ/m³ bulk density) and heating value is 16-18MJ/kg. A bio-oil's disadvantage is that it is corrosive material due to the presence of organic acids. (Higman 2003, 73-74; Demirbas 2007, 39-60; Demirbas 2009, 261-302.)

4.3 Raw materials in thermo mechanical processes

Thermo mechanical conversion processes (pyrolysis and gasification) are suitable for different raw materials. Biomass, coal and other carbonaceous feedstock are suitable for these processes. (Kurkela 2010; Liukkonen 2010; Pietarinen 2010.)

Forest residues, stumps, logs, pellets, sawdust, chips and fuel wood are the main wood biomass raw materials. All wood species are suitable because they contain carbon, oxygen and nitrogen which are the main components for synthetic gas. Eucalyptus can be used also as a raw material for gasification and pyrolysis. Sawdust is not usually used because there is not so much of it available, because it is mainly utilized to pellets. Wood raw material must be manipulated into smaller chips before the gasification. Wood raw materials contain around 85 % of volatile compounds which settles some specific requirements for thermo mechanical conversion processes. (Alakangas 2001, 37-47; Liukkonen 2010; Pietarinen 2010.)

Raw material sources can come from different sources. First source is forest. Forest residues, stumps, logs and fuel wood come from there. Another big source is forest industry. Gasification's raw materials are industry by-products or waste e.g. saw dust. Plants can be installed near forest industry plant, then raw material sources are near and plants have infrastructure to receive and handle raw materials. (Alakangas 2001, 48; Liukkonen 2010; Pietarinen 2010.)

Raw material comes mainly in chips. Other forms must be converted into chips before gasification. Gasification plant wants standardized chips, usually p100 is used. This helps in receiving and paying the right amount for the raw material. Moisture content of the incoming raw material is around 55% depending on wood species and seasons. Raw material can also come in different form than chips but then amount of the pretreatment is higher. For example crushers are needed in stumps handling. Ideal situation is where all incoming raw materials are in similar or standardized form. Quality determination is based on the quality specification. Quality specification specify the methods how to determine wood raw material quality. Quality specification is basis on the wood trading. (Kurkela 2010; Liukkonen 2010; Pietarinen 2010)

4.4 Required raw material quality for gasification processes

Moisture

Drying is the most important pretreatment in wood handling process before gasification. Variances in the moisture level cause big problems in the gasification process. Raw material moisture content must be equal all the time because otherwise gasification process optimization becomes difficult. If gasification process product gas is going to be used to produce synthesis gas, raw material homogenous becomes even more important. Raw material moisture level must be below 20 % for every gasification processes. Entrained flow gasification requires lower moisture level (15 %) because raw material residence time in gasification process is short and raw material is like dust. In fluidized bed gasification process 20 % moisture level is allowed but higher moisture level will increase gasification process energy efficiency. Higher moisture level will increase amount of the needed gasification agent. E.g. oxygen is an expensive agent. Water also contain nitrogen so better and expensive gas cleaning system is required if moisture level increases. In pyrolysis process moisture must be even lower than in gasification. Moisture in pyrolysis is around 10 %. (Kurkela 2010; Liukkonen 2010; Pietarinen 2010.)

Now days there are couple different drying systems available. Wire drying and drum drying are most common systems. There has been some developing about the steam drying system. According to VTT steam drying system might be an interesting drying method. Steam drying system requires smaller particle size than traditional systems. Choosing the right drying method depends a lot on available heat sources. If gasification plant is installed near the pulp- or paper mill then low drying equipment must be able to use low heating value energy sources. (Kurkela 2010; Liukkonen 2010; Pietarinen 2010.)

Particle size

Particle size is very dependent on gasification process, but processes have some requirements what comes to raw material particle size. First the incoming raw material flow must be homogenous and distribution narrow. Particle shape does not have effect on gasification process. (Kurkela 2010; Liukkonen 2010; Pietarinen 2010.)

Entrained flow gasification sets high requirements for raw material handling and quality. Entrained flow gasification is designed for coal gasification so raw material must be similar to coal. Accepted particle size is lower than 0,5mm. Raw material is like dust. It is hard to crush as small as entrained flow gasification requires so one method for that is first to coke the wood and crush formed wood coal into 0,5mm or smaller particles. Raw material requirement for coking is similar than in fluidized bed gasification process. Particles must fit in p35 standard and raw material must be homogenous. Oversized particles are not big problem, because charred wood is crushed into dust after the coking. Fine material is not wanted because it goes with the gas to the entrained flow gasification process but small amount of fines is not a problem. Distribution must be very narrow because residence time is short so larger than 0,5mm particles may have problems in gasification. Uniform quality is important because

variance of quality causes many problems during and after gasification especially in oxygen gasification. (Kurkela 2010; Liukkonen 2010; Pietarinen 2010.)

Fluidized bed gasification processes tolerate changes of raw material quality better than entrained flow gasification. Also these processes are more suitable in larger particle sizes. Needed particle size for fluidized bed gasification processes is below 50mm. Bubbling fluidized bed gasification is more accurate for incoming raw material than circulating fluidized bed gasification. Wanted particle size for BFB-gasification is p35 standard so 85 % of all particle sizes is smaller than 35 mm. CFB-gasification can handle rougher raw material but most of the particles must be below 50 mm. Oversized particles are not big problem because fluidized bed gasification has good mixing between the raw material and bed material and residence time is long so raw material has enough time to gasify even it is bigger than wanted. Amount of these big particles is more important than size. If there is a lot of big particles bed material might start to sinter especially in oxygen gasification. Fine particles are not allowed because tar amount increases and it creates form which can seal the cooler and heat exchanger filters. In circulating fluidized gasification fines are not a problem. BFB-gasification is more sense for fines because fines rise out from the bed and form tar in the top of the gasification boiler. Uniform quality is important because variance of quality causes many problems during and after gasification especially in oxygen gasification. (Kurkela 2010; Liukkonen 2010; Pietarinen 2010.)

Impurities

All gasification processes have same impurities. All non-wood particles are classified impurities. Sand, rocks and metals are the worst because they might cause jams into the screws or conveyors. Fine material is unwanted raw material for BFB-gasification because it might form tar in the process. Large wood particles can be understood as impurities but in further processing these can turn into accepted raw material. FB-gasification tolerates small amount of impurities but they might cause some problems in flow control. FB-gasification bed material is usually sand, so sand is mixed well with

bed material and those are taken out of the process with the bottom ash. Metals cause corrosion in the boiler and cause sintering of the bed material. Soil is also classified as an impurity, it can come into the process with stumps or other forest residues. Soil is an unburned material, it causes same problems as sand or rocks. In Entrained flow gasification large wood particles are impurities and these must be taken away from the process. Big rocks and big metal particles also jam the screws and conveyor and affect on that way on the process. (Kurkela 2010; Liukkonen 2010; Pietarinen 2010.)

Homogenous

Incoming raw material must be homogenous in every way. Raw materials can not change in abrupt. Moisture level must be adjusted in wanted level and kept on that level, because changes in moisture level affect on consumption of gasification agent and utilizing processes are very sensitive for changes. Particle size homogeneity is very important especially in entrained flow gasification process because this process does not stand large particles (over 0,5mm) at all. This all has a huge affect on process optimization. Changes in raw material flow must be controlled. (Kurkela 2010; Liukkonen 2010; Pietarinen 2010.)

4.5 Required raw material quality for pyrolysis processes

Moisture

Fast pyrolysis sets strict limits for raw material. Moisture level must be on a certain level and variation is not allowed. Moisture must be below 10 %, because residence time is low. High raw material moisture content also affect on water content of product liquid, which is one quality parameter for bio-oil. Variance of moisture content causes problems on process optimization. Moisture content must be below 10 % at all different

pyrolysis processes. (Brown 2006, 1-30; Bridgewater 2002, 11-19; ; Oasmaa, Elliot, Muller 2009, 1-6; Oasmaa, Solantausta, Arpiainen, Kuoppala, Sipilä 2009, 1-9.)

Particle size

Another important factor in fast pyrolysis processes is the particle size. In general particle size must be below 3 mm. Bubbling fluidized bed pyrolysis process requires small particles (<3 mm) and rotating cone requires even smaller particles, because otherwise mixing between the sand and raw material is not equal or uniform. Ablative pyrolysis process stands large particle size, because raw material is pressed against the rotating disc. In processes which require small particles size variance must be minimized, because variance causes problems in process controlling. Particle size must be small to achieve high heating rate between raw material and heat. (Brown 2006, 1-30; Bridgewater 2002, 11-19.)

Impurities

Pyrolysis process does not stand impurities. All metals and rocks must be separated before actual pyrolysis process. Big wood particles are also classified as an impurity, because residence time of pyrolysis reactor is short so large particles do not have enough time for liquefaction, yield stay lower and bio-oil quality is not so good. Amount of extractives affect on yield negatively. Used raw material quality for laboratory scale pyrolysis reactor is good and does not contain any impurities mainly, so how impurities affect on large scale process is not clarified totally yet. (Brown 2006, 1-30; Bridgewater 2002, 11-19; Oasmaa etc. 2009, 1-6; Oasmaa etc. 2009, 1-9.)

Homogeneous

Feed must be as fluent as possible. Particle size can not vary at all. Also moisture content must be all the time below 10 %. Impurities must be taken away as mentioned earlier. All these have effect on process optimization, which becomes difficult if the feed is not homogenous. Quality of product yield might decrease if feed properties vary. Moisture content variety causes higher amount of water in product yield, which is not wanted. (Brown 2006, 1-30; Bridgewater 2002, 11-19; Oasmaa etc. 2009, 1-6; Oasmaa etc. 2009, 1-9.)

5. Biofuels

5.1 definitions of the biofuels

In the World there are many different definitions for a biofuels. The most common definition is following: 1st generation biofuels are made from sugar, starch, vegetable oils or animal fats using conventional technology. The conventional method is fermentation. 2nd generation biofuels also are called advanced biofuels and 2nd generation biofuels are made from non-food crops, wheat straw, corn, wood and energy crops using advanced technology. Fischer-Tropsch method is the most common and most usability advanced technology. (Demirbas 2009, 87-90).

5.2 Fischer-Tropsch-synthesis method

F-T-synthesis was developed in Germany in the 1920s. F-T-synthesis transforms synthetic gas into straight-chain hydrocarbons: parafines and olefins. Synthesis works in presence of catalysts. Used catalysts are made from iron or cobalt. F-T-synthesis temperature is 470-570 °C and pressure is 10-37 bar depending on desired products. F-T-synthesis process is strongly exothermic and release lot of heat so good heat transfer out from the process is required. All material which contain carbon is possible to be used as a raw material. Wood biomass converting is more difficult than oil but it is environmental friendly. F-T-synthesis process flow is presented at the figure 14. (Lohi 28-30; Russo 2006, 9-10.)

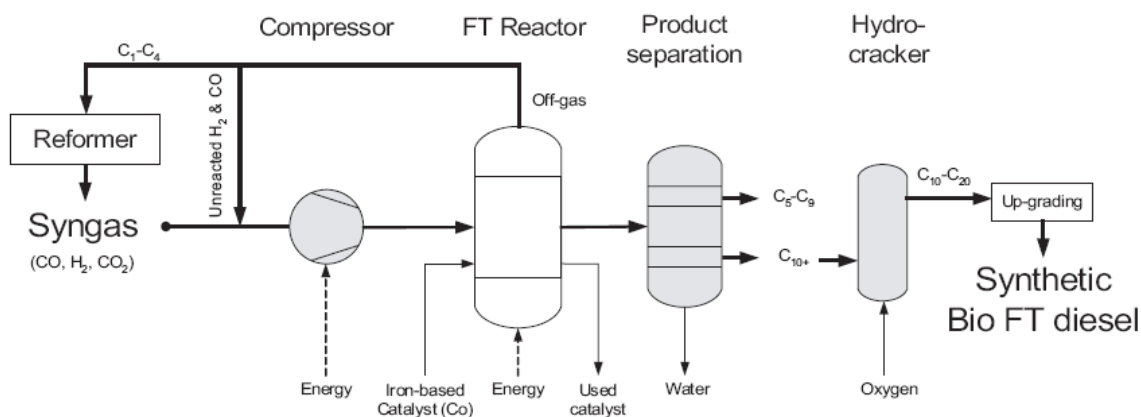


Figure 14. F-T-synthesis process. (Russo 2006, 10)

Synthetic gas can be produced in different gasification types. Fluidized bed- and entrained flow gasification are the most suitable for biomass gasification so those are used in biomass F-T-synthesis process. Syngas has to be cleaner in F-T-synthesis than in combustion process. (Lohi 28-30; Russo 2006, 9-10.)

5.3 Green pyrolysis diesel

Green pyrolysis diesel is derived from bio-oil, end product of pyrolysis. Pyrolysis oil goes through the cyclone and char is separated. Char can be burned to energy. Off-gas, gas which is not converted into bio-oil can be burned as a fuel. Bio-oil upgrading can be done in many ways, two different upgrading are presented at the figure 15. The upgrading is needed, because bio-oil does not suite in diesel engines without upgrading. Hydrodeoxygenation need high pressure hydrogen which makes this process more expensive than zeolite upgrading where yield is poorer. Raw material requirements are based on pyrolysis. At 2006 green pyrolysis diesel development stage was in pilot plant. (Russo 2006, 12.)

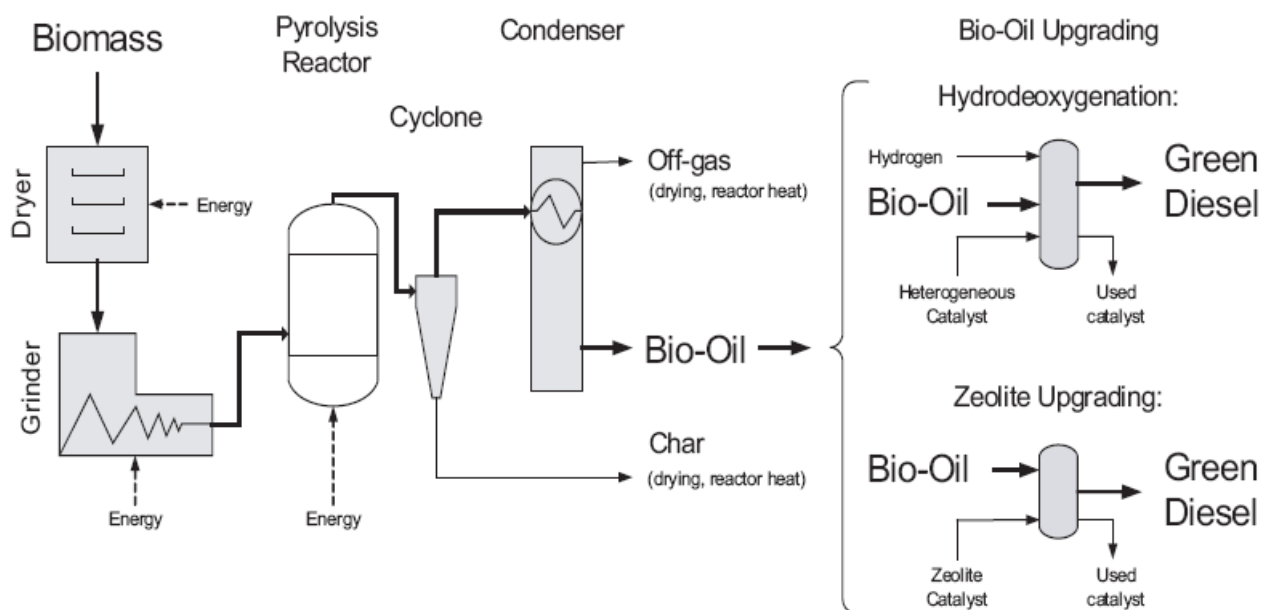


Figure 15. Green pyrolysis process description. (Russo 2006, 12.)

5.4 Bio synthetic natural gas (Bio-SNG)

Bio synthetic natural gas (Bio-SNG) is natural gas derived from biomass via gasification. Bio-SNG contains mainly methane, but also small amounts of hydrogen, carbon dioxide and nitrogen. Bio-SNG can also be called upgraded synthetic gas. Bio-SNG can be produced either stand alone or in co-production of Bio-SNG and F-T diesel (Figure 16). (Russo 2006, 11-12.)

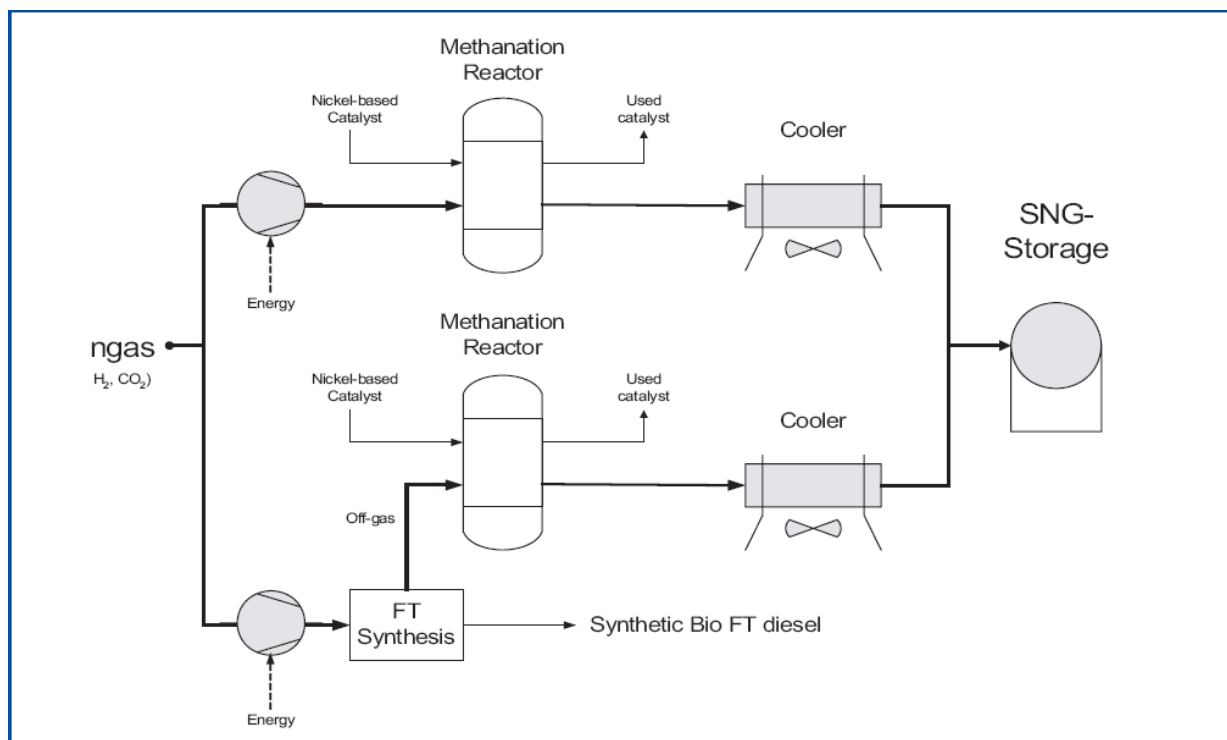


Figure 16. Process flow diagram for co-production of bio-SNG and synthetic bio F-T-diesel. (Russo 2006, 11.)

During methanation, CO and CO₂ react with H₂ to produce methane (CH₄) and water. Catalyst is nickel-based. Cooling is needed after methanation reaction because methanation process is an exothermic process. Syngas cleaning is a major challenge for methanation production because methanation catalysts are very sensitive for impurities. Bio-SNG raw material requirements are similar in methanol production. Syngas can be produced in different types of gasifiers which all have detailed raw material requirements. These requirements are presented in chapter 4.4. (Russo 2006, 11-12.)

6. Bioalcohols

6.1 Bioethanol

Ethanol is mainly produced via fermentation from starch or grain. Ethanol production from grain is well known technology and it is used e.g. in Brazil to ethanol production mills. Producing ethanol from wood, first wanted particles (cellulose or hemicellulose) must be separated out. Then cellulose or hemicellulose sugars are taken out and reprocessed to ethanol. Producing ethanol from woods is more difficult than producing from it from grain or starch. Wood contains more different sugars than grain and mainly the structure of sugars is more complex. Ethanol producing from woods hemicellulose is cheaper and less energy intensive than when producing it from cellulose. (Leppänen 2010; Leppänen K. Spetz P. Kitunen V. Ilvesniemi H. Ojamo H. Nyman O. Pennanen K. 2009)

Metla (Finnish Forest Research Institute) has made studies of ethanol production from hemicellulose, but this method is developed to separate hemicellulose out from other wood particles before pulp cooking. This method is not developed to produce just ethanol, because rest of the wood can be used in cooking process. The basic ethanol production stages are presented at the figure 17. (Leppänen 2010; Leppänen etc. 2009)

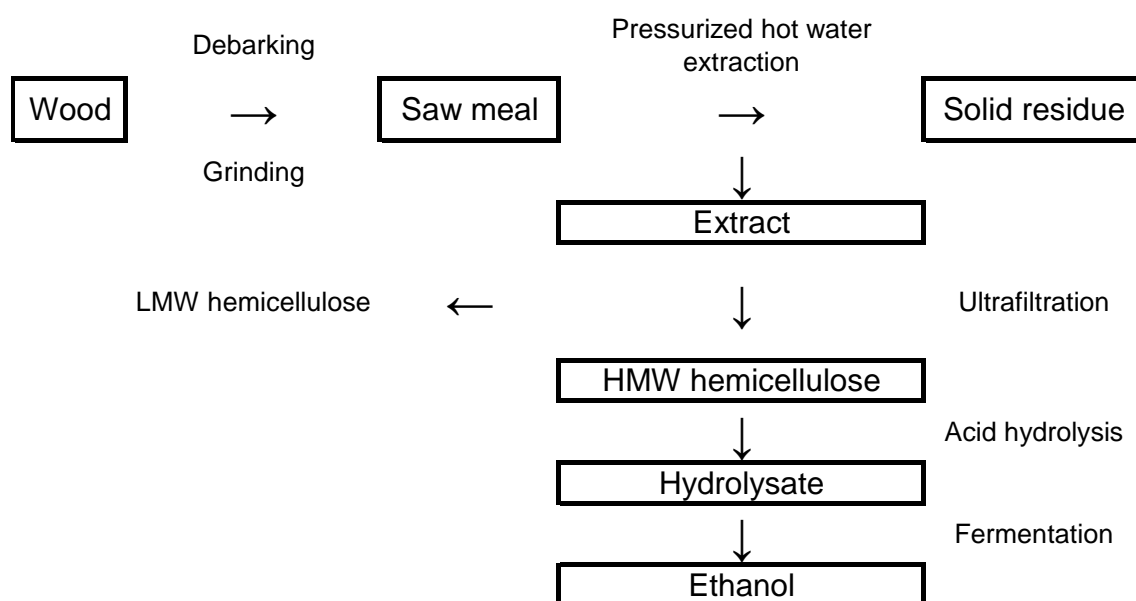


Figure 17. From wood to ethanol. (Leppänen etc. 2009.)

Extraction sets requirements for raw materials, because extraction is first stage on bioethanol producing. Bioethanol production from wood is not done yet in industry scale. Bioethanol is suitable for petrol motors and combustion at least. (Leppänen 2010; Leppänen etc. 2009)

Pre-treatment

Pre-treatment is very important stage in bioethanol production, because bioethanol producing sets strict limits for raw material. Particle size must be like in sander dust and particles must be thin. Otherwise diffusion problems drop yield in extraction stage. Length and width are not crucial in extraction process. (Leppänen 2010; Leppänen etc. 2009)

Raw material does not have to be dry when it is entering the bioethanol production. Moisture just affects in amount of dry raw material. Drying does not affect on process working. In Metla's studies bark was separated, but in industry scale bark may not be a

problem, studies from how bark would affect on process have not yet been done. Requirements for raw material are presented in chapter 6.4. (Leppänen 2010; Leppänen etc. 2009)

Extraction

The purpose of extraction is to separate hemicellulose out from the wood so that other particles can be used in different processes. Incoming raw material has strict limits which are presented in chapters 6.5 and 6.6. In briefly it can be said that thickness is very important. Yield can drop almost 40 % if particle thickness is too thick. Extraction is done by using heat and pressure. This extraction method is called pressurized hot water extraction. Temperature range must be over 160 °C depending on wanted yield and other process parameter. Pressure must be high enough so that water stays in liquid form, at least 10 bar. Residence time vary 1/2-2 h depending on other process variables and wanted yield. Yield in extraction varies a lot, 100 % yield is possible to achieve if temperature is high enough and extraction time is long enough. In Metla's laboratory scale studies yield was 80 % in the temperature of 180 °C. (Leppänen 2010; Leppänen etc. 2009; Vanninen 2009, 27-29.)

Filtration

The purpose of filtration is to decrease amount of the water. Filtration was done by the membrane filter. Metla uses cellulose acetate membrane with cut-off of 5000 Da (Dalton) and a surface area of 0,93 m². Filtration has biggest effect on yield. The yield of concentration is around 50 % of extraction yield so its biggest reason for low yield of bioethanol production. (Leppänen 2010; Leppänen etc. 2009; Vanninen 2009, 27-29.)

Hydrolysis

The purpose of hydrolysis is to break polymers into monomers. Hydrolysis can be done with different kind of acids or chemical mixtures. Strong acid- , diluted acid – and enzymatic hydrolysis are used. Metla uses hydrochloric or sulphuric acid in their hydrolysis process. Sulphuric acid might be better, because it is easier to remove in neutralizing process. Ph-level was 1-2 and temperature can be up to 140 °C. Residence time varies, lowest residence time is 2 hours. The yield is very depended on process variables, up to 60 % yield is possible to achieve. Acid content can not be too high otherwise acid start to break sugars into other compounds which is not wanted. Metla does not have experience on enzymatic hydrolysis. In enzymatic hydrolysis acid “cocktail” must be chosen carefully, because success depends on that. After hydrolysis process neutralizing is needed because yeast does not work in too high acid condition. Neutralizing is done with NaOH (Sodium hydroxide) or calcium hydroxide. PH-level after neutralizing is around 5,5, but it might vary depending on yeast. (Leppänen 2010; Leppänen etc. 2009; Vanninen 2009, 27-29.)

Fermentation

Fermentation is done by yeast. Fermentation process is very simple, just add yeast and sugars into same boiler and wait until fermentation ends. This process is relatively long, it can take up to 144 hours (6 days total yield in Metla’s bioethanol production test was 32 kg/1000 kg of dry wood). This 32 kg was 36 % of the theoretical maximum and filtration is the main reason for such a low yield. (Leppänen 2010; Leppänen etc. 2009; Vanninen 2009, 27-29.)

6.2 Biomethanol

“Methanol is produced by methanol synthesis from synthetic gas feedstock” (Russo 2006, 10). Methanol is usually produced from natural gas but this final thesis concentrate how methanol is produced from wood biomass. Advantages of methanol are following:

- can use as a fuel for combustion

- as feed for methanol engines
- limited share of current vehicles even thou it has positive affect on vehicles engines, like increased octane number

- increased overall emissions quality.

Disadvantages of methanol are following: significantly lower energy content than fossil fuels and it is high toxicity. Methanol can be converted into dimethyl ether (DME). Methanol production chain is presented in figure 18. (Ohlström etc. 2001, 15-35; Russo 2006, 10)

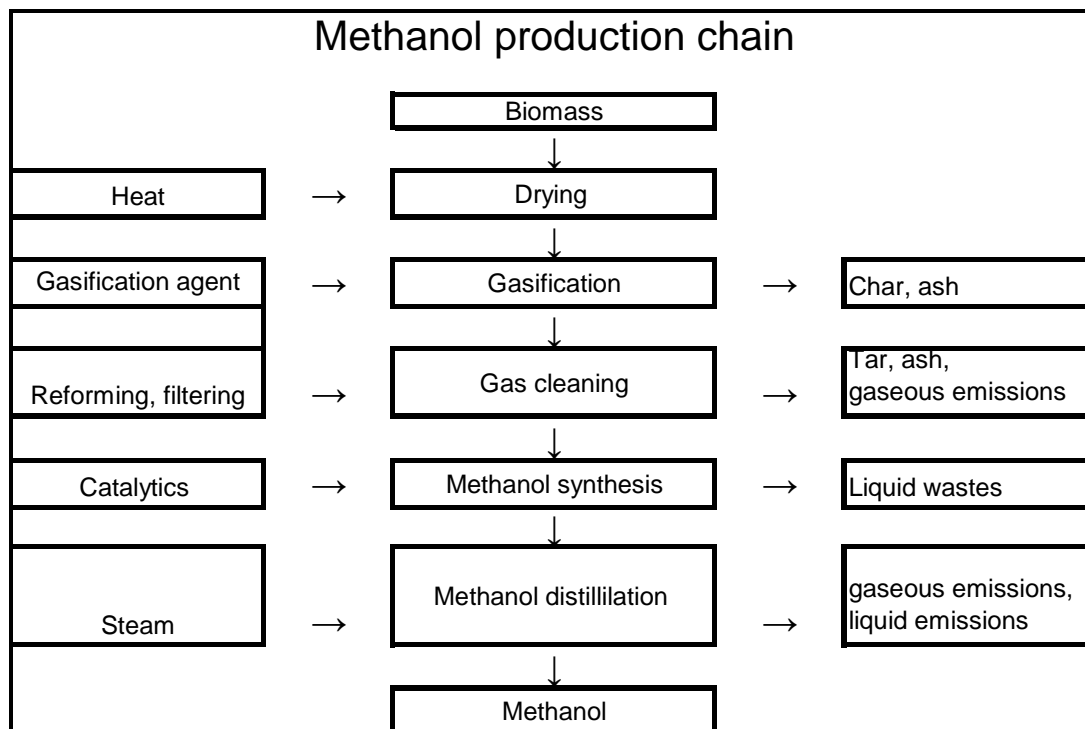
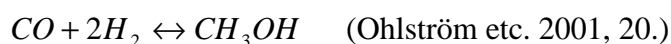


Figure 18. Methanol production chain. (Ohlström etc. 2001, 15.)

Raw material for methanol production can vary from coal to biomass. Raw material is first converted into synthetic gas via gasification process. Gasification process can be done with gasifier types which are presented in chapter 4.1.1. In methanol production it is recommended to use oxygen as a gasification agent to avoid nitrogen. Gas quality requirements for methanol production are higher than if synthetic gas is used for burning. Synthetic gas requirements can be achieved with two different cleaning methods which can be divided roughly to: Cold and hot gas cleaning. In typical pressure methanol synthesis reaction is 50-100 bar and temperature is 225-270 °C. The reaction is hard to control because of the high heat release rate. Methanol reaction is shown in following formulas. (Ohlström etc. 2001, 15-35)



Needed raw materials and quality for methanol production is similar than gasification because biomethanol production is based on gasification. Different gasification processes have different raw material quality requirements and wanted raw material quality requirements are presented in chapter. 4.4. (Ohlström etc. 2001, 15-33; Russo 10-11.)

6.3 Raw materials for bioethanol production

Bioethanol production needs relatively pure raw material. Stumps and other wood biomass are not recommended. Round wood is the main raw material source. Finnish and foreign wood species are possible to convert to bioethanol, but the form of sugar might change between wood species. There has not been done research for that subject, but in theory it is possible to produce bioethanol from every wood species. Bark was separated in Metla's laboratory scale research to minimize variance but in industry scale small amount of bark might be acceptable. Bark does not contain so much sugar than actual round wood and amount of extractives is higher, extractives might seal the

filtration fabric. More study is needed how bark affect on bioethanol production. Needles contain less sugar than round wood so needles must be taken away before extraction. (Leppänen 2010; Leppänen etc.2009.)

6.4 Required raw material quality for bioethanol production

Moisture

Moisture does not have effect on process line working, it just affects on the amount of the dry raw material. In Metla's research fresh saw meal was stored at -20 °C. How moisture affects in industry scale bioethanol production has not been studied yet, but Metla thinks that moisture is not critical property and variance is allowed. (Leppänen 2010; Leppänen etc.2009.)

Particle size

Particle size and shape is the most critical properties for raw material. Length and width does have impact on yield, but it is recommended that particle size is smaller than normal chip size (2-8 mm). It is easier to handle and hemicellulose come out from the wood easier, residence time is shorter. The most crucial property for raw material is thickness. Particles must be smaller than average chip, otherwise hemicellulose in the middle of wood particles does not come out during the extraction and yield drops significantly. Thickness must be below 2 mm, if it is a "normal" chip (thickness 2-8 mm), yield is 40% lower compared to sander dust. In wood pre-treatment has to be concentrate to achieve wanted thickness level. Fine material does have affect on extraction process, but it might seal during the ultra filtration of the filtration fabric. Filtration fabric cleaning is done by washing, so fines are not a big problem. (Leppänen 2010; Leppänen etc.2009.)

Impurities

Bioethanol production tolerates impurities relatively well. Rocks and metals in small amount are not a problem. Lignin is the biggest problem and extractives also cause problems. Lignin disturbs whole process and production becomes harder. Extractives do not have effect on extraction, but extractives seal the ultra filtration fabric. So washing is needed more often if raw material contains lot of extractives. Extractives in high concentration disturb fermentation process. In wood pre-treatment it is good to separate all extractive sources (bark, needles etc.) out to guarantee undisturbed bioethanol production process. (Leppänen 2010; Leppänen etc.2009.)

Homogenous

Particle size must be same all the time, because it has very critical effect on yield. Process tolerates moisture variance, but process optimization is easier if variance is low. Impurities are good to separate, but as mentioned earlier non wood impurities are not the problem in small amount. Ash content in Metla's research was constant. Higher ash content does not affect on extraction process, but ash might disturb fermentation stage. It is good to separate all ash sources (bark, needles etc.) out. (Leppänen 2010; Leppänen etc.2009.)

7. Wood biomass

The term of biomass refers to non-fossilized and biodegradable organic material originating from plants, animals, and microorganism derived from biological sources. (Demirbas 2008, 46.) Wood biomass involves trees with commercial structure and forest residues not being used in the traditional forest products industries. Wood biomass sources can vary a lot. Wood biomass sources are presented at the table 2. (Demirbas 2008, 45-58.)

Table 2. Sources of available forest and wood manufacturing residues (Demirbas 2009, 57.)

Source of residue	Type of residue
Forest residue	Branches, bark chips, leaves/needles, stumps, roots and sawdust
Lumber production	Bark, sawdust, split wood
Plywood production	Bark, sawdust, veneer clippings and wastes, panel trim, sander dust
Paper and board production	Slab chips, pulping reject, sawdust, screening fines

At table 2 are presented sources of the forest and wood manufacturing residues. Sawdust is mainly converted into pellets because then it is easier to transport and storage. (Demirbas 2009, 57.)

7.1 Wood structure and composition of wood

Wood composition in general is presented at the table 3. Wood is two-third holocellulose (cellulose and hemicellulose) and one-third lignin. The rest is extractives, other organic matter and inorganic matter. Bark and leaves contain less cellulose than wood and also amount of hemicellulose is lower. Their extractives content is higher

than in wood so it can be said that bark and leaves are not as good fuel raw material as wood. Composition might change in different wood species but values are relatively exact. Wood contains around 85% volatile compound so it requires large firing space. (Hakkila, Verkasalo 2009, 133-204; Vanninen 2009, 6-15.)

Table 3. Composition of different wood parts (Vanninen 2009, 6.)

Compound	Wood	Bark	Leaf and needles
Cellulose	40	20-30	20-30
Hemicellulose	25-35	10.-15	10.-25
Lignin	20-30	10.-25	15-35
Extractives	3.-4	5.-20	kesä.45
Other organic material	1	5.-20	not defined
Inorganic material	<0,5	2.-5	2.-5

Cellulose is an organic compound with the formula $(C_6H_{10}O_5)_n$, a polysaccharide consisting of a linear chain of several hundred to over ten thousand β (1 \rightarrow 4) linked D-glucose units. Cellulose chains tend to be arranged parallel and form crystalline structure. Cellulose is a main biomass raw material. Cellulose is insoluble material, most solvents and cellulose do not have melting point but they decompose at over 300 °C. (Hakkila, Verkasalo 2009, 133-204; Vanninen 2009, 6-15.)

Hemicelluloses are amorphous polysaccharides and their molar mass is lower than cellulose's. Hemicelluloses contain different sugars (xylans, galactoglumannans) and sugars create blocks between the hemicellulose units. Hemicelluloses are shorter in length than cellulose and their molecular structure is branched. Also hemicelluloses are more reactive than cellulose. (Hakkila, Verkasalo 2009, 133-204; Vanninen 2009, 6-15.)

Lignin is a chemical compound that is most commonly derived from wood and it works as a binding agent in the wood. It provides plant with added mechanical strength. Lignin has a complex structure and lignin molecular weight is high. Lignin forms

benzene rings with are link together with aliphatic chains. Structure of lignin is amorphous and it is more soluble than cellulose. (Hakkila, Verkasalo 2009, 133-204; Vanninen 2009, 6-15.)

Extractives are organic compounds, mainly terpenes. Terpenes are mainly volatile compounds so they are not a problem in biomass conversation. (Hakkila, Verkasalo 2009, 133-204; Vanninen 2009, 6-15.)

Table 4. Proportion of ash in the wood and bark of stem and branches in southern hardwoods in the United States (Hakkila, Verkasalo 2009, 154.)

Tree component	Wood	Bark
	Ash, % of dry mass	
Stem	0,75	7,87
Branches	0,94	6,76

As at table 4 presents bark contains much more ash than wood, which is the main reason why bark is usually separated out before the process. This becomes more and more crucial when end product is further converted e.g. Fischer-Tropsch synthesis. Ash causes many difficulties in processes. Fly ash causes problems in gasification and in general ash makes process optimization difficult in different processes. Concentration of primary elements in wood and bark is presented at the table 5. (Hakkila, Verkasalo 2009, 133-204)

Table 5. Concentration of some mineral elements in stem wood and stem bark of the five main tree species in Finland and of twenty-two hardwood tree species in the southern United States (Hakkila, Verkasalo 2009, 154.)

Tree component	Concentration of primary elements, %			
	P	K	Ca	Mg
Two softwoods in Finland				
Stemwood	0,01	0,06	0,12	0,02
Stem bark	0,08	0,29	0,85	0,08
Three hardwoods in Finland				
Stemwood	0,02	0,08	0,08	0,02
Stem bark	0,09	0,37	0,85	0,07
Twenty-two hardwoods in southern United States				
Stemwood	0,02	0,16	0,19	0,04
Stem bark	0,03	0,20	3,05	0,11

Table 5 confirms that bark contains much more metals than wood. These metals affect on ash content and usually metals are unwanted materials for the process. Good debarking becomes more important in process which requires purity and fluent raw material flow. (Hakkila, Verkasalo 2009, 133-204.)

7.2. Moisture and heating values of different wood biomasses

Normally wood moisture content in biomasses is around 60 % depending on wood types, wood age, year seasons and growth place. Also moisture varies in different parts of the wood. In Finland wood has higher moisture content when wood is harvested than subtropical countries woods. Moisture content has a huge impact on heating value. When moisture is increasing then the heating value is decreasing because water must be evaporated before actual burning can happen. Wood material heating values are presented at the table 6. In the wood water appears in free water or bounded water. Water which fills the space between lumen and intercellular is called free water and water inside the wood cells is called bounded water (Hakkila, Verkasalo 2009, 133-204.)

Table 6. Heating values of different tree components of pines in the Southern United States. (Hakkila, Verkasalo 2009, 203.)

Material	Calometric heating value of southern pines, MJ/kg
Liquid residues	34-37,8
Commercial charcoal from wood and bark	26,1-29,6
Resinous wood from mature stump	23,8-25,2
Needles	20,8-21,2
Stem bark at tree butt	20,6-21,3
Stem bark at tree top	19,9-20,5
Stem wood	19,3-21,7
Early wood	19,7-20,4
Late wood	19,5-20,4
Root wood	19,9-20,2
Old cones	18,8-19,0
Dried sulphate black liquor after removal of tall oil	13.5-14,3

Charcoal and liquid residues have higher heating values than any other wood part as table 6 presents. Stumps heating value is higher than any other wood part, so stumps are great energy sources if plant can use them as raw material. Bark and needles heating values are little bit higher than round wood, which is quite interesting point. The reason for that is that bark contains more extractive which has higher heating value than cellulose. Moisture content has crucial impact on heating value and so also the on economy efficiency, as table 7 shows. (Hakkila, Verkasalo 2009, 133-204.)

Table 7. Effective heating value of wood residue from Scots pine and birch pulpwood as a function of moisture content in Finland. (Hakkila, Verkasalo 2009, 204.)

Source of residue	Tree species	Basic density kg/m ³	Moisture content, %		
			0	40	60
MJ/kg dry mass					
Wood	Pine	405	19,3	17,7	15,6
	birch	480	18,6	17,0	14,9
Bark	Pine	265	19,5	17,9	15,8
	birch	480	22,6	21,0	18,9
branches	Pine	415	20,2	18,6	16,5
	birch	500	18,7	18,1	16,0

Moisture content affects on heating value very much, so wood biomass is dried as dry as possible before transportation into plant. Pine has higher heating value than birch even if its density is lower. Bark of the birch has better heating value than pine bark, but difference between densities is quite big so difference can be explained with that. Pine bark's heating value decreases more than birch bark's when moisture starts to decrease. Branches also have better heating values than round wood. Normally wood biomass moisture content is between 20-50 % when it comes to the plant. Bark has in that moisture content the best heating value but bark is on other quite difficult raw material because it contains lot of extractives as table 7 presents. Bark and branches are good raw materials for power plant if ash content and extractives are not a problem, because these have higher heating values than round wood. Also homogeneity might become a problem when bark and branches are used as raw material. (Hakkila, Verkasalo 2009, 133-204.)

7.3. Wood biomass transportation and handling

Wood biomass transportation and handling sets specific challenges, because its collecting and transportation differs from logs and pulpwood transportation and handling. In the following chapters wood biomass transportation chains and its handlings are presented.

7.3.1 Small round wood (Thinning)

Thinning woods are collected during the thinning. An average diameter for energy wood from thinning is around 7 cm. These energy woods can be transported into plant via many different transportation chains. Spruce is not delivered in trunk because too many nutrients leave the forest in form of needles. Most common transportation chain is presented at the figure 19. Over 90 % of thinning woods is cutted with roadside chippers (Integrated- or non-integrated chipper). Other used transportation chains are:

Terminal chipping and chipping in the end use location. (Asikainen 2010; Kärhä 3/2008; Kärhä 4/2008.)

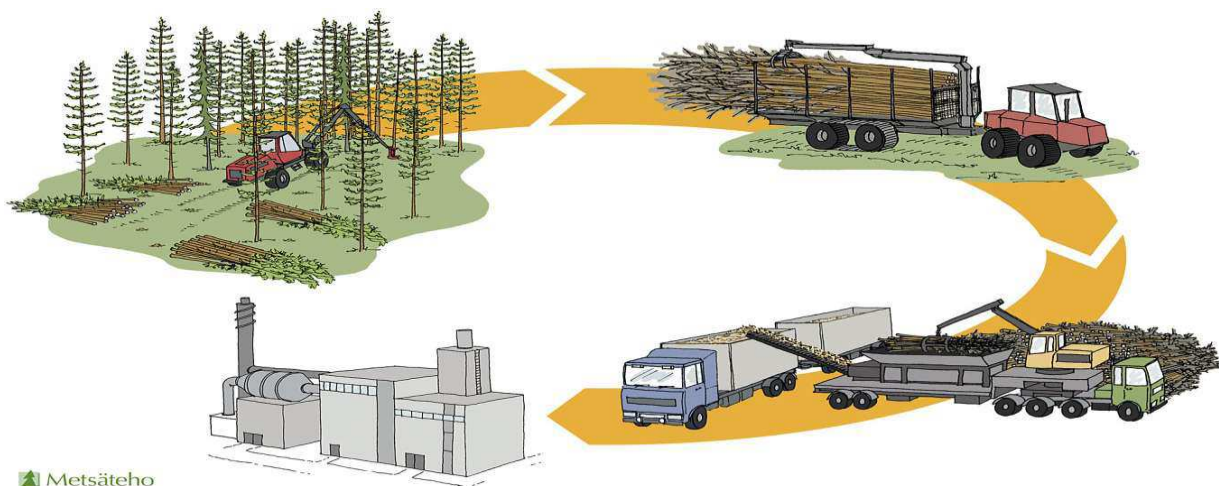


Figure 19. Non-integrated roadside chipping chain. (Kärhä 3/2008, 5.)

In this chain, chipping is done with roadside chippers. Roadside chipping can be done in two different ways, by integrated chipper and chipping truck or second way: by an independent chipper and chip truck. Both methods have advantages and disadvantages. Independent chipper with truck suites almost in every situation, but utilization rate is relatively low, because truck or chipper might have to wait on each others. Knowledge for this method is widely available. Integrated chipper and chipping truck is not dependent on other machine's presence and long distance transportation can be done with one machine. Transportation capacity is quite small. Common for these two methods is that both require large roadside storage and they are very messy. After the chipping process chips are transported to the end user via terminal or straight. Average chip size is around 80 mm x 80 mm. Fines are separated. Fines drop down to the ground and stay in forest. Oversized chips are recycled back into the chipper. There might be variance in chip size between the equipment suppliers. (Asikainen 2010; Kärhä 3/2008; Kärhä 4/2008.)

7.3.2 Logging residues

Logging residues are collected during the logging. Logging residues contain e.g. branches and needles. Most common logging residues transportation chain is roadside chipping, it covers around 70 % of all transported logging residues. Used chippers are similar than used for thinning woods. Other methods are following: Terminal chipping, end user chipping and plot chipping. Terminal chipping transportation form is presented at the figure 20. Logging residues can be transported into terminal in bales or in bulk. (Asikainen 2010; Kärhä 3/2008; Kärhä 4/2008.)

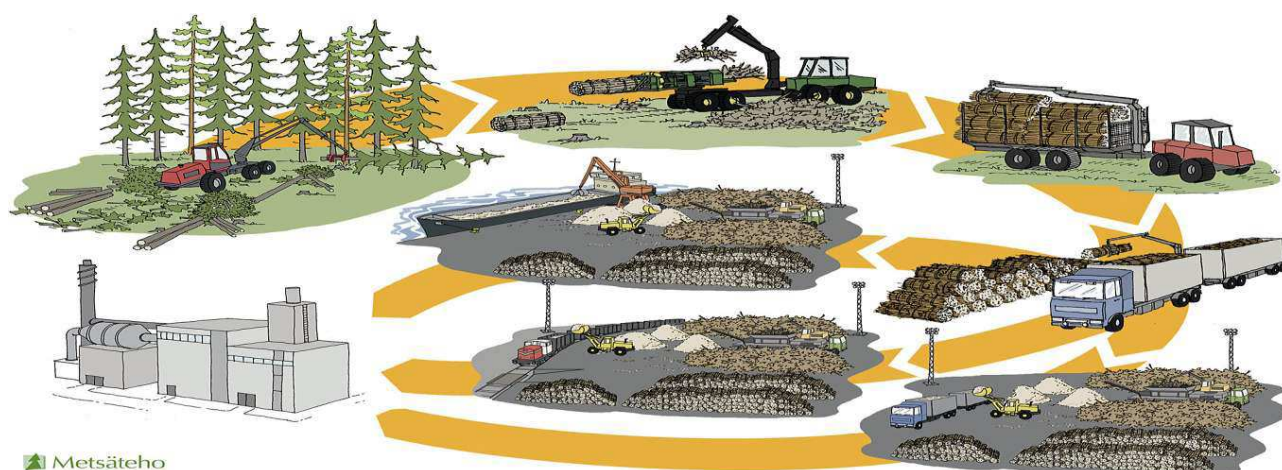


Figure 20. Logging residues terminal transportation chain. (Kärhä 3/2008, 8.)

Bale terminal chipping and bulk terminal chipping have both advantages and disadvantages. In both ways good chipping result is easier to achieve and chipping is more efficient than in roadside chipping. Raw material can be collected in smaller plots than in roadside chipping because all raw materials are collected in same place before chipping. Also winter is not a problem like it might be in roadside chipping. Baling the raw material saves transportation cost, because material is packed more tightly than in bulk, but baling on the other hand increases harvesting costs and baling wires must be separated before chipping. In terminal chipping transportation to terminal might be

quite long and extra handling increases costs. Terminal chipping has relatively high production costs, which sets limits for this method. An average chip size is around 80 mm x 80 mm after terminal chipping. There might be some variance between equipment suppliers. (Asikainen 2010; Kärhä 3/2008; Kärhä 4/2008.)

7.3.3 Stumps

Stumps are lifted up and splitted in two or four parts during or after the logging. Stumps are left into the forest to dry. Drying time is over a year. During the drying soil and sand drops to the ground. The most common transportation chain for stumps is end use location chipping, which is presented at the figure 21. 80 % of stumps using is transported this method and rest of goes through terminal chipping transportation chain. All raw materials come in bulk into plant, because stumps baling is quite difficult. (Asikainen 2010; Kärhä 3/2008; Kärhä 4/2008.)

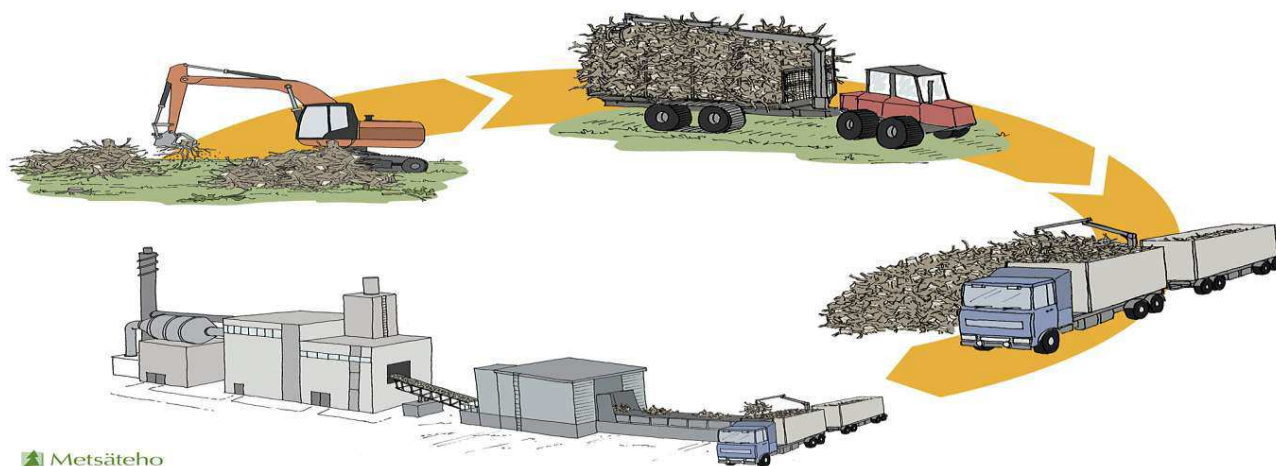


Figure 21. End use location chipping transportation chain. (Kärhä 3/2008, 13.)

End use location chipping is the most cost-effective method in short distance. This method is suitable for large-scale production very well. It has some crucial

disadvantages. First it is expensive when transportation distance is long, because stumps are hard to pack in good density. This method requires large storage space in both end of the transportation route, roadside and plant side. Stumps particle size depends on the end user chippers. In terminal chipping stumps are chipped into same size as logging residues (80 mm x 80 mm). (Asikainen 2010; Kärhä 3/2008; Kärhä 4/2008.)

8. Summary

8.1. Pelletizing

Pelletizing has economy potential in the future. The world's largest pelletizing plant is built in Russia and pellets are used to replace fossil fuels in energy production. Pellets can replace fossil fuels in energy and heat production in the future. Pellets production is subsidized with state funds. The another big customer for pellet plant are private households, they use pellets in household heating to replace fossil fuels. How to make pellet production economy viable is the biggest problem. The costs must be on lower level and price of pellet is too low currently. The technical knowledge is available, but how to make it profitable is a good question.

The wood handling in pelletizing plant does not differ much from pulp wood handling. Raw material must be crushed to smaller particles and more drying is needed. Andritz has knowledge and equipment to supply a wood handling line in pelletizing plant. Some changes on equipment might be needed, but it is now hard to say what kind of changes they are. Future will show that, luckily Andritz is one partner for Russia pelletizing plant. The experience for there is important in the future.

8.2 Combustion

Wood combustion for energy and heat production will grow in the future. The nation's governments and EU subsidize that more and more. The wood based fuels are a good option to replace fossil fuels, maybe not totally but partially. This has many good advantages, CO₂- emissions decrease and global warming decelerate for example. Finnish forest resources have potential to cover crucial part of Finnish energy and heat production.

The technology of combustion is well known inside of Andritz. Andritz built BFB-boilers, which are the best option for large scale energy and heat production. The grate boilers technology might be more economically viable in smaller scale heat production, but economy potential for supplier is low there. Level of wood handling for combustion is not as high as in other processes, e.g. external drying before combustion is not needed usually. This area is highly competent, but Andritz is in a good position, because it can offer whole production line. The further research has to focus on boiler technology. The wood handling is quite simple, because combustion technology does not set specific requirements which are hard to achieve.

8.3 Thermo mechanical conversion

The thermo mechanical conversion is interesting thinking about the future. It might be an option to replace transportation fuels or energy production. Today there are no large scale thermo mechanical conversion plants. The cost level is quite high still, but lot of research has been conducted in this area. It is hard to say which method will become the most interesting in the future. Is it gasification or pyrolysis? These processes have a great potential, because their end product can compete with fossil transportation fuels and the EU and the nation governments are supporting these. Also gasification and pyrolysis can be options to energy and electricity production.

In gasification Andritz has better position than in pyrolysis, because their subsidiary company Carbona Oy produces gasification boilers and makes research all the time for this area. Wood handling for gasification is not so crucial what it is for pyrolysis. Still gasification process sets strict terms for wood handling. Wood processing technology is available with some specific restrict limitations. Research must be done in this area.

Pyrolysis requires more wood handling than gasification. Raw material must be smaller and drier. Interesting point is that which will dominate in the future, is it gasification or pyrolysis? Pyrolysis needs more research, but if technology can get to economically

viable level then pyrolysis opens a whole new business opportunity for Andritz because amount of wood pre treatment is big and it has a significant effect on pyrolysis process.

8.4 Biofuels

The future of the biofuels is depends very much on the political situation. Today the technology is too expensive, but subsidizes will change the situation. Mainly the new biofuels concepts are based on gasification or pyrolysis. To fuels which can replace fossil fuels needs more research. Now it looks that the F-T- synthesis is the most interesting option to produce biofuels.

8.5 Bioalcohols

Biomethanol can be one option for end use of the gasification gas. Bioethanol is an interesting option for separating hemicellulose before pulp cooking. How this will affect pulp quality should to be known, before it can be a commercial use. The bioethanol production from wood is more complicated than bioethanol production from “food-based” raw material, but technology is well known. The research must focus in increasing the yield, which is the main reason why bioethanol production is not economically viable yet. The Andritz wood processing division has potential if bioethanol production becomes commercial. The requirements of bioethanol production can be solved. Some modifications are needed. The research will show what kinds of modifications are needed.

8.6 Wood biomass

Wood biomass can be transported into plant via many different options. There is not only one way to transport biomass, because different variables affect a lot in costs. The research for better and more efficient harvesting method is done all time. Also availability of wood biomass is interesting, because forest resources are big enough to cover industry use but how this biomass can get out from the forests? How much the industry is ready to pay for biomass and how this biomass is measured in the future? For Andritz view interesting question is that how raw material comes into plant and in what form? Wood can be round wood, chips, by bulk or bales. This has effect on wood handling equipments.

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