

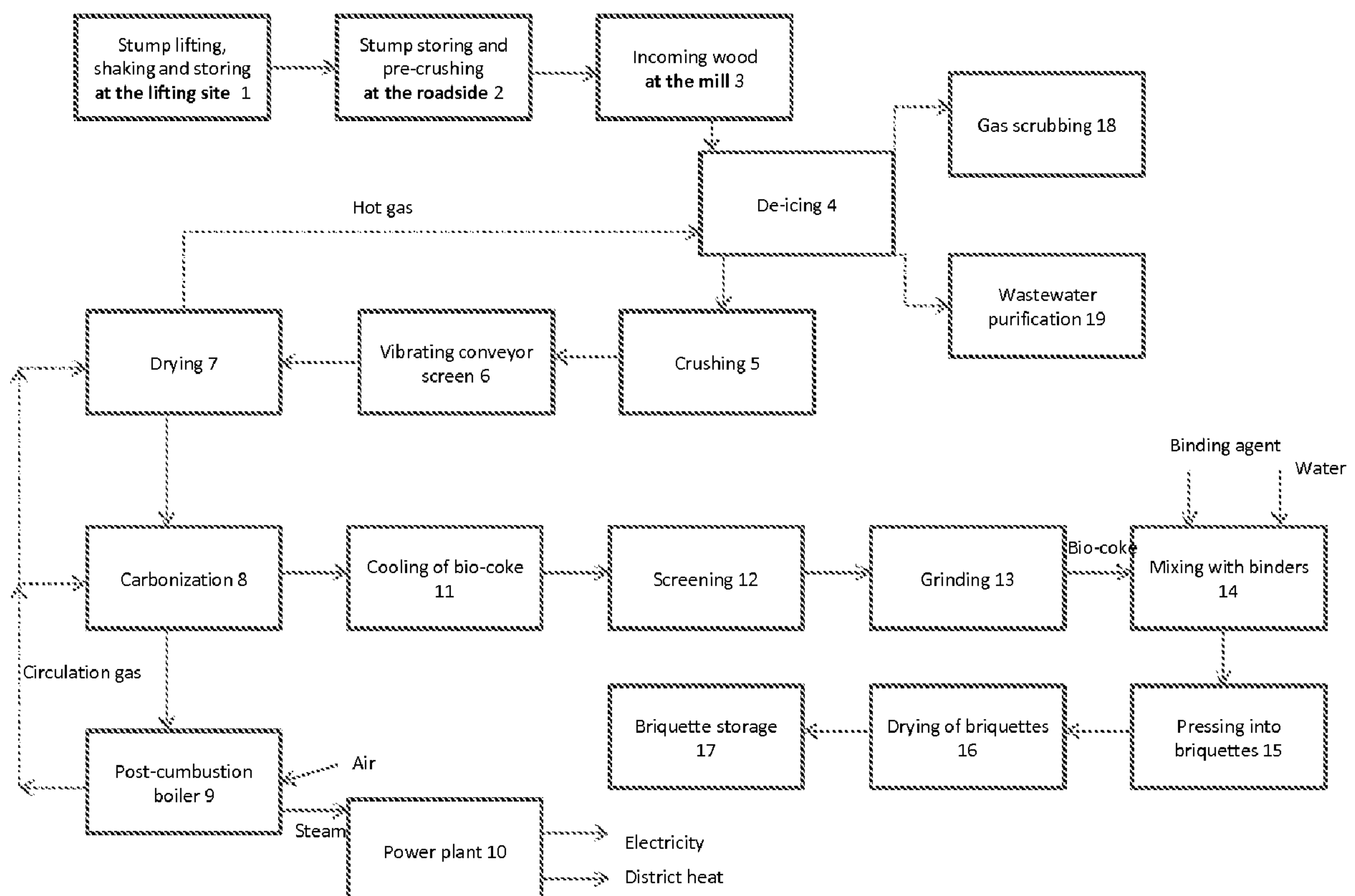


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(54) **Titre : PROCEDE DE PRODUCTION DE BIOCHARBON**

(54) **Title: METHOD FOR PRODUCING BIO-COKE**



(57) **Abrégé/Abstract:**

The invention relates to a method for a continuous fabrication of bio-coke briquettes suitable for use in metallurgical industry by a method where the purpose is to obtain bio-coke having sufficient strength, low ash content as well as low phosphorus and sulphur content and a suitable lump size.

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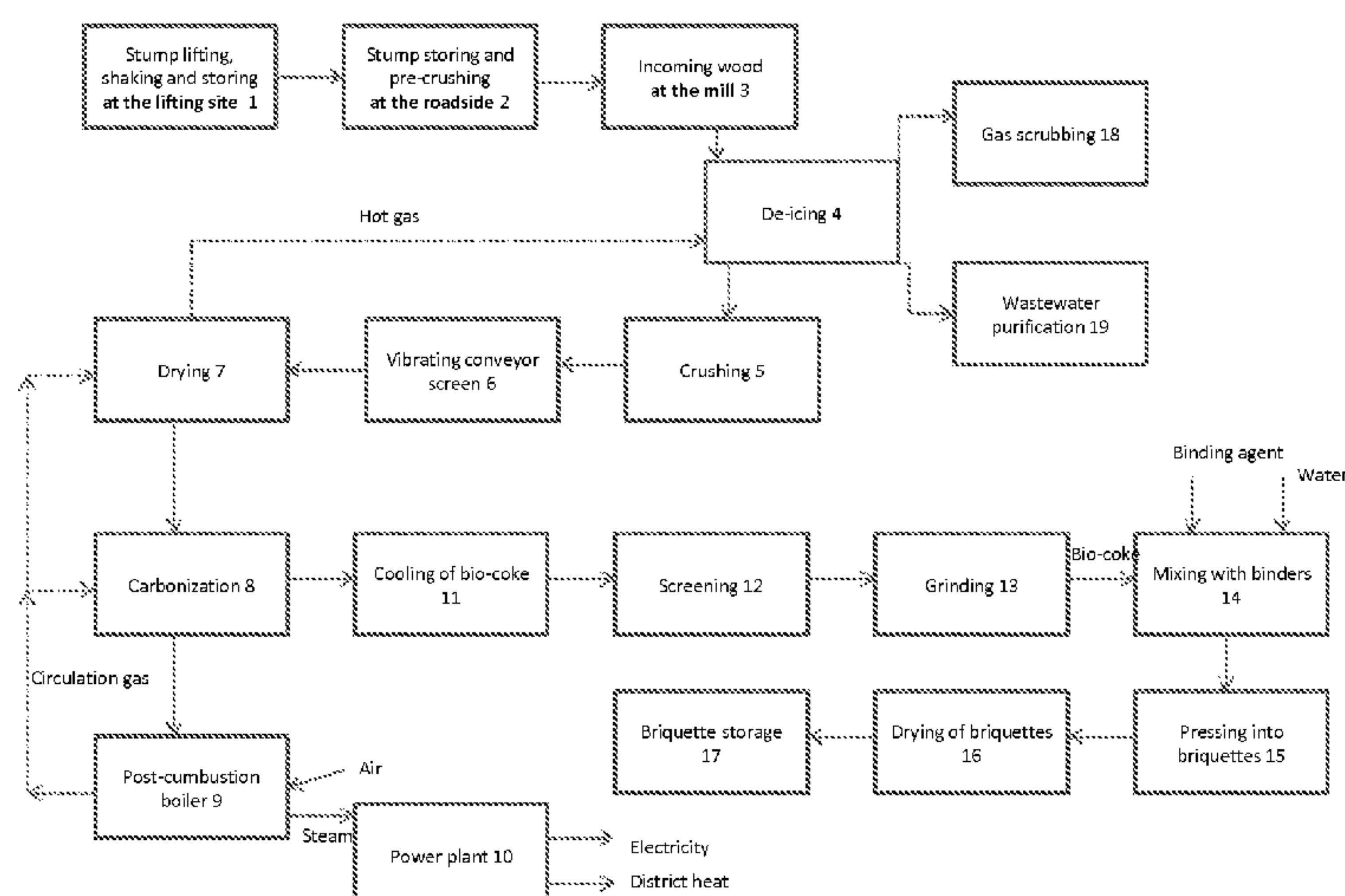


Figure 1

(57) Abstract: The invention relates to a method for a continuous fabrication of bio-coke briquettes suitable for use in metallurgical industry by a method where the purpose is to obtain bio-coke having sufficient strength, low ash content as well as low phosphorus and sulphur content and a suitable lump size.

METHOD FOR PRODUCING BIO-COKE

FIELD OF THE INVENTION

The invention relates to a method for the continuous production of bio-coke suitable for use in metallurgical industry by a method where the purpose is to obtain bio-coke with a desired lump size, sufficient strength uniform in every direction, low ash content, low volatiles content as well as low phosphorus and sulphur content, and low electrical conductivity, by using raw materials that enable economic production of bio-coke.

BACKGROUND OF THE INVENTION

In recent decades the coke used in metallurgical industry has been manufactured mostly from fossil carbon. Nowadays, measures to combat climate change also have to be taken into account more emphatically in metallurgical processes and in the selection of materials used in them. Therefore biomass-based coke will make a viable alternative to fossil carbon in the future and, in addition, it may also allow participation in carbon dioxide emissions trading.

The production of bio-coke from the same raw materials as those used by the sawmill and pulp industries weakens its economy. Cheaper biomass materials are currently used for energy production. These materials include low-grade timber, crown mass, stumps, large decayed/defective wood, waste wood from construction, peat, straw, reed canary grass, surplus grain etc. A common problem with these materials is that their ash and impurity contents are higher than those of pure wood.

For instance, a considerable proportion of the wood in an entire tree is contained in its stump. The stump of a spruce, for example, may contain as much as about 30% of the stemwood volume of the tree. On the other hand, spruce stumps are loosely attached to the ground and there are 600 to 940 spruce stumps per logging area hectare. It is sufficient to maintain the land's growing power if 5 to 10 % of the stumps are left in the forest.

Charcoal or wood coke, which is a certain kind of bio-coke, has been manufactured in batch fashion for thousands of years. Batch carbonization has been carried out for example in different kinds of pits, retorts or wagon retorts. Continuous carbonization is carried out for instance in a horizontal or vertical retort, drum kiln or fluidized bed reactor.

Continuous carbonization processes taking place in a vertical shaft kiln (a retort) are represented by the Lambiotte and Lurgi processes. The wood material of a fairly large unit size, e.g. 200 to 400 mm, is fed into the kiln from the top and travels through the drying, carbonizing and cooling steps in the kiln. The gases are conveyed upwards from below. The steps may be separated from each other by a gas-lock.

The continuous coking of peat and wood in a drum kiln, where the lump size is a maximum of 50 mm, is described for example in CA application publication 1 054 088 (FI56549). The method is described in more detail as applied to the processing of eucalyptus wood, for example in the Master's thesis: Latva-Somppi, J.: Study of carbonization of eucalyptus, pages 25 - 28, Helsinki University of Technology 1989. First the wood is chipped and after this it is dried by means of the exhaust gases exiting a combustion chamber. The exhaust gases may be conveyed to a feed silo. The dried wood is screened, and fine material may be fed into the same combustion chamber in which the gas exiting coking is burned. When the moisture content of the wood has fallen to a value below 10%, it may be fed into the coking furnace. The coking furnace functions on the countercurrent principle, i.e. hot gases and wood material are fed into the furnace from opposite ends. The carbonization temperature is 500 to 900°C depending on the requirements set for the charcoal. The temperature required for carbonization is achieved by burning a part of the gases formed in carbonization, and additional heat is obtained with an auxiliary burner. The gases, tar and fly ash formed in carbonization are burned in the combustion chamber as is the waste wood generated in wood chipping. After combustion, the hot combustion gases are conveyed to a boiler, and water is fed into the piping thereof to produce pressurized steam and then electricity and district heat. The charcoal that is produced is cooled for example with water, after which the charcoal is classified. Fine carbon material can be briquetted or burned in the combustion chamber.

A continuous carbonization process has been developed for carbonizing sawdust and other wood waste in a fluidized bed furnace. Some of these methods are disclosed for example in US patent publications 3,977,947, 4,510,021 and 6,808,390. An inert bed, such as a bed of sand, is commonly used, but the first one of US publications mentions the use of previously carbonized material as the bed material. In most cases, wood is fed into the bed material, although it can also be fed from the upper section of the furnace. In each method described carbonization is carried out at a maximum temperature of 650 °C.

The cited publications mostly discuss the cheapest possible production of bio-coke from biomass, but they completely fail to take into account the strict quality criteria for bio-coke required in the fabrication of ferroalloys, for instance.

Metallurgical coke is subjected to both quality and cost requirements
5 that may be addressed by selection of raw materials, process units and process conditions. Studies have shown that the compressive strength of wood coke is not a clear-cut matter; instead the compressive resistance along the grain is considerably higher than perpendicularly against the grain. The wood quality and carbonization temperature also affect strength. On the other hand, research has
10 shown that ash and impurity components concentrate in the finer fraction of bio-coke. The volatile substances in bio-coke decrease as the carbonization temperature rises. The electrical conductivity and electrical resistance of the coke can also be adjusted using the carbonization temperature.

OBJECT OF THE INVENTION

15 The object of the present invention is to disclose a method for a continuous production of bio-coke, which meets the quality criteria set by the metallurgical industry, particularly with regard to the fabrication of ferroalloys, and produces coke from low-cost raw materials by the method presented, taking the required characteristics of coal into account.

20 SUMMARY OF THE INVENTION

According to one aspect the invention relates to a method for a continuous production of briquetted bio-coke to be used in the metallurgical industry, whereby the biomass raw material that is to be processed in order to produce bio-coke briquettes with low impurity, sulphur and phosphorus content, sufficient
25 strength and low volatiles content, as well as the desired strength and lump size, has its mechanical impurities removed and is pre-comminuted, for example by crushing, and pre-dried before transportation to the processing site and comminution to processing fineness.

According to another aspect of the invention the method for continuous
30 production of bio-coke to be used in metallurgical industry comprises

- providing biomass raw material,
- removing mechanical impurities from the biomass raw material,
- pre-comminuting the biomass raw material,
- pre-drying the biomass raw material,
- 35 — comminuting the biomass raw material into processing fineness,

- drying the biomass comminuted into processing fineness, and
- carbonizing the biomass raw material to obtain bio-coke.

The pre-drying is typically performed in outdoor air and temperature. Typically the moisture content of the biomass raw material is after the pre-drying
5 approximately 30 to 50%.

According to an embodiment of the invention the method comprises pre-comminuting the biomass raw material. Pre-comminuting means a rough comminuting of the biomass raw material, which is done for example for transportation purposes. The particle size to which the biomass raw material is pre-
10 comminuted depends on the process with which continuous carbonization will take place: retort, drum or fluidized bed. Typically the size of pre-comminuted biomass raw material is in the range of 20 to 100 mm.

According to an embodiment of the invention, the biomass raw material is crushed before being conveyed to impurities removal.

15 According to an embodiment of the invention, the mechanical impurities are removed from the biomass raw material with a vibrating screen.

According to one embodiment of the invention, the mechanical impurities are removed from the biomass raw material by gravity separation.

According to the invention, the crushed biomass raw material that is
20 free of impurities is dried before being conveyed to carbonization.

The drying is typically performed at a temperature of 100–200°C and typically the moisture content of the comminuted biomass raw material is approximately 10 to 20 %.

According to an embodiment of the invention the biomass raw material
25 is comminuted to processing fineness before it is carbonized. Typically the size of the biomass raw material particles is 0.1 to 50 mm, more typically 5 to 20 mm.

According to an embodiment of the invention, the biomass is carbonized at a temperature of 650 to 1000°C, typically at 750 to 1000°C.

According to an embodiment of the invention, the drying and carboni-
30 zation of the biomass raw material are performed in separate reactors.

According to an embodiment of the invention, the drying of the biomass raw material is carried out in a fluidized bed reactor, in which the biomass raw material to be treated forms the bed of the drying reactor.

According to an embodiment of the invention, the carbonization of the
35 biomass raw material is carried out in a fluidized bed reactor, in which bio-coke forms the bed of the carbonization reactor.

According to another embodiment of the invention the drying and/or carbonization of the biomass is performed in drum kilns.

According to yet another embodiment of the invention, the drying and carbonization of the biomass raw material is carried out in a shaft furnace.

5 According to an embodiment of the invention, a first part of the gases and dust generated in the carbonization of the biomass raw material is burned in a carbonization reactor with an air deficit. A second part of the gases generated in the carbonization of the biomass raw material is conveyed to a post-combustion boiler, where they are burned.

10 According to another embodiment of the invention, a first part of the gases and dust generated in the carbonization of the biomass raw material is burned in a carbonization reactor with an air deficit. Tar is recovered from a second part of the gases generated in the carbonization of the biomass raw material, and is used as a binding agent in briquetting.

15 According to an embodiment of the invention, the thermal energy generated in the post-combustion boiler is utilized in a power plant to produce electricity and district heat.

According to an embodiment of the invention, the cooled exhaust gases of the post-combustion boiler are conveyed to the drying and carbonization of
20 the crushed biomass.

According to an embodiment of the invention, the particle-like bio-coke formed in carbonization is conveyed to indirect air cooling, from which the hot air is conveyed to a carbonization reactor.

25 According to another embodiment of the invention, the particle-like bio-coke formed in carbonization is conveyed to indirect water cooling.

According to a further embodiment of the invention, the particle-like bio-coke formed in carbonization is conveyed to direct cooling with inert gas.

30 According to an embodiment of the invention, the cooled bio-coke is screened and the finest fraction, rich in ash and impurities, is separated to optimize the ash content of the coke product.

According to an embodiment of the invention, the cooled and purified bio-coke is ground, mixed with a binder and water, pressed into briquettes and dried.

35 According to an embodiment of the invention, the size of the briquettes is 10 to 40 mm.

According to an embodiment of the invention, any biomass raw material that is frozen is de-iced before removal of impurities using the hot gases generated in drying. In this application de-icing means that any possible ice on the frozen biomass raw material is removed and the frozen biomass is de-frosted.

5 The gases generated in the de-icing are conveyed to gas scrubbing, and the waters generated in the de-icing and gas scrubbing are conveyed to the wastewater purification step before being discharged from the cycle.

According to an embodiment of the invention, the biomass used as raw material for carbonization is tree stumps.

10 According to another embodiment of the invention, the biomass used as raw material for carbonization is peat.

According to a further embodiment of the invention, the biomass used as raw material for carbonization is logging waste.

15 According to a further embodiment of the invention, the biomass used as raw material for carbonization is reed canary grass.

According to a further embodiment of the invention, the biomass used as raw material for carbonization is straw.

According to a further embodiment of the invention the biomass used as raw material may be a mixture of any combination of the above raw materials.

20 According to an embodiment of the invention the bio-coke thus produced may be formed into briquettes, typically the bio-coke is pressed into briquettes.

According to an embodiment of the invention the briquettes are dried.

25 According to an embodiment the invention also relates to a method for producing particle-like bio-coke for use in reduction occurring during an environment-friendly production of a ferroalloys, whereby coke of sufficient strength, low ash, sulphur and phosphorus content and low volatiles content is produced continuously from biomass raw material, the method comprising the following steps:

- 30 a) lifting of tree stumps, dividing them into pieces, typically into 2 to 4 pieces, and shaking off impurities
- b) storing and pre-drying them at the lifting site
- c) storing, pre-drying, pre-cleaning and pre-comminuting them at the roadside
- d) de-icing the crushed stumps, comminuting them to particle-like form
- 35 e) transporting the ground crushed stumps by vibrating conveyor screens to a storage silo

- f) drying the crushed stumps
- g) carbonizing the dried crushed stumps in a carbonization reactor, where a first part of the gases and dust formed in the carbonization of the biomass raw material is burned in the carbonization reactor with an air deficit
- h) feeding a second part of the gases formed in the carbonization of the biomass raw material to a post-combustion boiler, where they are burned and the thermal energy that is generated is utilized to produce electricity and district heat and the cooled circulation gas is conveyed to the drying and carbonization of the particle-like biomass raw material
- i) conveying the particle-like bio-coke formed in carbonization to cooling and conveying the cooling medium used either to the carbonization reactor or to the post-combustion boiler
- j) screening the cooled particle-like bio-coke formed in the carbonization and conveying to briquetting, the first step of which is grinding
- k) mixing the fine particle-like bio-coke with water and a binding agent, thus controlling the strength of the bio-coke
- l) pressing the bio-coke mixture into briquettes
- m) drying the briquettes .

The size of the particle-like pieces varies in this application and depends on the raw material and processes used. Typically in the beginning of the processing the size of the particle-like pieces may be between 0.2 to 1.5 m and later on in the process it can be from 0.1 to 50 mm.

The screening in j) removes the fine ash-rich fraction from the fraction conveyed to briquetting. This improves the quality of the final coke.

LIST OF FIGURES

Figure 1 presents a flow chart of a bio-coke production method according to an example embodiment of the invention.

DETAILED DESCRIPTION

The use of stump material for the production of bio-coke is not completely taken away from energy production, as part of the carbon contained in the stump material produces added value in carbonizing and in this case too energy comes from some of it.

Carbonization or pyrolysis or coking means the physical and chemical decomposition of an organic solid substance in an oxygen-free space under the effect of heat. It is the step preceding actual combustion or gasification, in which the volatile substances contained in the fuel are removed as a result of thermal decomposition forming water vapour, gas and tar components. A porous carbonized residue or coke is left behind. Carbon generated from wood is called charcoal.

Wood coke is one type of bio-coke. The material used for producing bio-coke is typically biomass or vegetal materials. These include various nutshells, waste generated in wood processing such as sawing waste, sawdust or bark. In addition, the trunks of the eucalyptus tree for example are used for production after the branches and leaves have been removed for the fabrication of eucalyptus oil.

The wood carbonization process can be divided into various steps. The first step is drying or the evaporation of water, which occurs at temperatures of 100 to 200°C. The decomposition of the wood is still minor at this stage. The decomposition of wood material starts in the second step, when mainly the oxygen-containing gases in the wood are released. This occurs at a higher temperature, i.e. around 200 to 280°C, when carbon dioxide and carbon monoxide, water and water-soluble substances such as acetic acid are released from the wood. The third step, which occurs at temperatures of 280 to 500°C, could be called a hydrocarbon step, and at this point the exothermic decomposition of the wood, i.e. the reaction, proceeds by itself and produces heat. As a result of the decomposition reactions, more acetic acid, methanol and tar are removed from the wood. The amount of gas generated is large compared to the earlier steps. The actual carbonization of the wood can be regarded as occurring at temperatures of around and above 500°C.

In practice the continuous carbonization process may be implemented at least in a retort, drum kiln and fluidized bed furnace.

When bio-coke is to be produced continuously for use in the metallurgical industry, such as in the reduction stage of ferroalloy production, the bio-coke must fulfil certain criteria. The C_{fix} content of the coke must be as high as possible, over 75%, the amount of volatiles below 1%, the amount of alkali below 0.2%, the sulphur content below 0.07% and the phosphorus content below 0.03%. C_{fix} means fixed carbon, which is not removed along with the volatiles into the tar substances or gases, but becomes a carbonization residue, from which the ash

portion has been removed. All the percentages mentioned in the text indicate percentages by weight. The coke should also be sufficiently strong when hot, so that it does not break up into dust when fed into a furnace. The electrical conductivity of the coke should be sufficiently low. The lump size of metallurgical coke should be in the region of 10 to 25 mm. Coarser coke cannot be used for example in the reduction of ferrochrome, because its electroconductivity is too high. For its part, finer coke causes the compression of the bed and as a result uneven gas distribution. The fabrication of coke with a high C_{fix} content and a low amount of volatiles requires a high carbonization temperature, i.e. it should be at least 700°C.

With low-cost biomass raw materials, there is a risk that the amount of ash and impurities may rise too high unless attention is paid to them in every process step. If the amount of impurities in bio-coke is to be minimized, this should be taken into account already at the growth and original treatment site of the renewable biomaterial. A precondition for the formation of high-quality bio-coke is that no foreign matter should be present in carbonization. For instance the bed of sand in the prior art fluidized bed furnace mentioned above causes an increase in the amount of harmful substances in the finished bio-coke product.

The batch production of coke requires the cooling and discharging of the kiln between every batch. Therefore continuous coke production eliminates expensive work stages, the energy economy is improved and the carbonization process is optimized.

The fabrication of bio-coke used in the reduction of ferroalloys from low-cost raw materials requires more work stages than conventional bio-coke production, which is why all secondary material generated during bio-coke production should be utilized to the fullest to allow overall process costs to be kept competitive. The advantage of bio-coke is that it is produced from renewable natural material, it maximizes quality and minimizes the use of energy, various emissions to air and water as well as the amount of waste generated.

An embodiment of the method according to the invention is illustrated by a flow chart in the attached Figure 1. For example, when tree stumps are used as raw material, the minimization of impurities can be taken into account already at the forest: the stumps are lifted from the ground at the logging area when it is unfrozen, during lifting the stumps are chopped into pieces, typically into two to four pieces and the soil is shaken off (1) so that the majority of the humus remains in the hole left by the stump. After this, the stumps may be stored in piles for a few weeks and in roadside storage for about a year, so that stones and sand

come off the stumps more easily. The stumps are pre-comminuted, typically at the roadside, i.e. they are chipped/crushed using a crusher equipped with a screen (2). The particle size to which the stumps are comminuted depends on the process with which continuous carbonization will take place: retort, drum or fluid-
5 ized bed. As a consequence, larger transportation loads are obtained than in the transport of whole stumps. The water content of the stump pieces decreases during storage and impurities are removed when they are handled dry.

The crushed pre-comminuted tree stumps to be processed are conveyed to the receiving area (3). In some cases the crushed stump material may
10 be frozen and is first conveyed first to a de-icing treatment (4), which is carried out using hot gas obtained from a later drying step (7). If a de-icing treatment is not required, the crushed stump material is conveyed directly to comminution (5), where it is given a homogenous particle-like form. The particle size to which the stumps are comminuted depends on the process to be used for continuous car-
15 bonization: retort, drum or fluidized bed. When a fluidized bed is used, comminution is made to a smaller particle size of 5 to 20 mm. A smaller particle size, as fluidized bed processing in general, reduces carbonization time due to effective transfer of material and heat.

Since there may still be mechanical impurities adhering to the crushed
20 stump material, such as sand, the material is transported, if necessary, on a vibrating conveyor screen (6) via a gravity separator to a buffer silo. The preferred screen size through which the particle-like material is passed is 5 to 20 mm. The particle-like crushed stump material, which has a moisture content of around 30 to 50%, is conveyed from the buffer silo to the drying step (7). Drying takes place at
25 a temperature of 100 to 200°C and after drying the moisture content of the biomass raw material is around 10 to 20%. The drying step may be carried out in a separate reactor, such as a fluidized bed reactor, containing a bed formed of the biomass raw material to be processed. Likewise, in drum kiln carbonization, drying maybe performed in a separate drum kiln, from which the dried biomass raw
30 material is fed into the carbonization drum kiln. Of course drying may be performed in a different type of reactor than carbonization. In accordance with another alternative, the drying step is performed for instance as a pre-treatment step in connection with a shaft furnace. The energy required for drying is obtained from the circulation gases of the post-combustion boiler (9). Drying of the biomass raw
35 material is a precondition for effective and complete carbonization.

In addition to stumps, other logging waste, peat, straw, reed canary grass, waste wood from construction or surplus grain may be used as raw material for bio-coke. In such cases, for example the crown mass is baled and stored at the roadside, the amount of impurities being reduced as the mass dries out. Likewise, after mowing, reed canary grass is raked, crushed and baled.

The dried biomass raw material with a suitable particle size is conveyed to carbonization (8), which typically takes place at a temperature of 650 to 1000°C, more typically at a temperature of 750 to 1000°C. The carbonization step may be carried out in a reactor that operates continuously as described above, such as a fluidized bed furnace, drum kiln or shaft furnace. When carbonization is carried out in a fluidized bed reactor, it is useful to use previously formed bio-coke as the bed material to prevent impurities from contaminating the bio-coke that is being generated. Additional heating equipment to be used for heating and, if necessary, for controlling the temperature is also arranged into the reactor (not shown in detail in the figure). Preheated combustion air is fed in the carbonization step and combustion takes place with an air deficit, i.e. the amount of air supplied is below the stoichiometric amount required for combustion. Therefore only a first part of the gases formed in carbonization is burned in the carbonization reactor. The majority of the energy required for carbonization is obtained when the gases and dusts formed in carbonization burn in the carbonization reactor. Additional energy is obtained by means of the additional heating equipment and by recirculating the circulation gas of the post-combustion boiler (9) to the carbonization reactor in order to maintain a sufficient temperature. The temperature of the circulation gas conveyed to carbonization is 200 to 300°C. The properties of the bio-coke formed in carbonization are affected significantly by the final carbonization temperature and the carbonization rate. When the carbonization temperature is high, as in the method according to the invention, the product strength is improved and the volatiles content is decreased. When the temperature is around 800 to 1000°C, a product is obtained in which the amount of volatiles is only about 2%. The use of a high carbonization temperature is made possible when the ash content and amount of impurities is minimized in the pre-treatment of the biomass.

The flue gases generated in the carbonization reactor contain, in addition to reducing components, carbon dioxide and water vapour, which may react with carbon at high temperatures, decreasing the yield of bio-coke. However, the proportion of loss reactions remains low because the biomass raw material engenders a lot of gas in carbonization, which prevents the wood material or biomass raw material from coming into contact with the flue gases. The temperature of a carbonization reactor equipped with direct heating can be adjusted by means of additional air or additional heating equipment.

The hot bio-coke that is formed is cooled in a cooling reactor (11) by means of a cooling agent. In indirect cooling the cooling agent may be water or air and in direct cooling an inert gas.

The impurities and ash components of the biomass raw material, including calcium, silicon, magnesium, potassium, sodium, iron, phosphorus and sulphur, are concentrated in the finer bio-coke fraction. The ash-rich finest fraction is removed from the cooled bio-coke as required by screening (12). This allows the ash content of the final product to be controlled. The bio-coke product may continue to briquetting. The first step of briquetting is grinding (13). In the next step, the ground bio-coke is mixed (14) with water and a binding agent. The strength required for the briquette application is adjusted by the quality and quantity of the binder. The binder used may be for example starch, bentonite, molasses or tar. Tar can be recovered from the gases exiting carbonization and then used as binder in briquetting. After this the mixture of bio-coke, binder and water is pressed (15) into briquettes of a desired size, which are dried (16). The compressive strength of the briquettes is the same in every direction, and not dependent on the direction of the grain as with pieces of wood coke. Strength may be acted on by the quantity and quality of the binder as well as the briquette drying temperature. The briquette size depends on the application; for instance the coke briquette size required in ferrochrome smelting is 10 to 25 mm. The bio-coke briquettes that are produced are stored.

In indirect cooling, the heated air may be used as the preheated air for the carbonization step. If water cooling is performed, the steam that is generated is conveyed to the piping of the post-combustion boiler (9).

The flue gases that contain the second part of the gaseous, liquid and solid components formed in the carbonization reactor (8) are conveyed to the post-combustion boiler (9) and burned there. The combustion temperature in the boiler is adjusted to be such that the ash components do not melt. It is advanta-

geous to burn also poor-quality ash-rich bio-coke in the post-combustion boiler , if it is not to be made into briquettes with lower quality requirements. Likewise, it is advantageous to burn the dust generated in the drying step (7) in the post-combustion boiler. Water is fed into the circulation gas piping in the walls of the boiler and the energy produced by combustion is recovered from the piping as steam. The steam that is generated is conveyed to the power plant (10), where it is used to produce electricity and district heat. The cooled circulation gas to be removed from the boiler, which has a temperature of around 200 to 300°C, is conveyed to carbonization and drying.

To minimize all the emissions generated in bio-coke production, the wastewater generated in any de-icing (4) of the biomass raw material is also conveyed to the wastewater purification step (19). The exhaust gases formed in the de-icing step are conveyed to condenser gas scrubbing (18), where they are scrubbed with a suitable scrubbing solution. After gas scrubbing the gases may be removed from the cycle and the wastewater that is generated is conveyed to the purification step (19), after which the water cleaned of impurities may also be removed from the cycle.

EXAMPLES

Example 1

36.5 t/h of pre-cleaned, crushed tree stumps are conveyed to the drying area. The moisture content of the material is 40%. After the drying step the moisture content of the material is 12% and its composition is:

	C	50%
	H	6.5%
25	O	41.5%
	N	1.4%
	S	0.05%
	ash	0.55%

The amount of dried stump material conveyed to carbonization is 25 t/h. The carbonization produces 4.5 t/h of bio-coke . The temperature of the gas exiting the carbonization step is around 900°C and its quantity is 35000 Nm³/h. The gas contains about 32 vol.% of hydrogen and about 27 vol.% of carbon monoxide. The gas from the carbonization step is conveyed to a post-combustion boiler, where it is burned and the resulting thermal energy is transferred to the water and steam circulating in the boiler pipes, which are conveyed onward for

the production of electricity and district heat. The gas burned in the boiler produces 71 MWh/h of energy. The temperature of the gas removed from the boiler for circulation is around 300°C.

Example 2

- 5 The table below presents an example comparison of the effect of temperature on bio-coke quality.

Carbonization temp. °C	C _{fix} %	Volatiles %
978	93	2
715	85	11

CLAIMS

1. A method for continuous production of bio-coke particles to be used in metallurgical industry, which method comprises

- providing biomass raw material,
- 5 – removing mechanical impurities from the biomass raw material,
- pre-comminuting the biomass raw material,
- pre-drying the biomass raw material,
- comminuting the biomass raw material into raw particles,
- drying the raw particles into dry particles, and
- 10 – carbonizing the dry particles to obtain bio-coke particles, wherein the carbonization is carried out at a temperature in the range of 650°C to 1000°C.

2. The method according to claim 1, wherein the biomass raw
15 material is comminuted (5) into raw particles before removing mechanical impurities.

3. The method according to any one of claims 1 to 2, wherein the mechanical impurities are removed from the biomass raw material with a
20 vibrating screen (6).

4. The method according to any one of claims 1 to 3, wherein the mechanical impurities are removed from the biomass raw material by using gravity separation.
25

5. The method according to any one of claims 1 to 4, wherein into the raw particles are dried (7) before carbonization.

6. The method according to any one of claims 1 to 5, wherein the
30 drying and carbonization are carried out in a drying reactor and a carbonization reactor.

7. The method according to any one of claims 1 to 6, wherein the drying is carried out in a fluidized bed reactor, wherein the raw particles form a
35 fluidized bed.

8. The method according to any one of claims 1 to 7, wherein the carbonization is carried out in a fluidized bed reactor, wherein the bio-coke particles form a fluidized bed.

5 9. The method according to any one of claims 1 to 8, wherein one of: the drying of the raw particles; and the carbonization of the dry particles is carried out in one of: a drum kiln; and a shaft furnace.

10 10. The method according to claim 6, wherein a first part of gases formed in the carbonization and dust is burned in the carbonization reactor with an air deficit, a second part of the gases formed in carbonization is conveyed to a post-combustion boiler to be burned.

15 11. The method according to claim 6, wherein a first part of gases formed in the carbonization and dust is burned in the carbonization reactor with an air deficit, tar being recovered from a second part of the gases formed in carbonization and used as a binder in briquetting.

20 12. The method according to claim 10, wherein thermal energy generated in the post-combustion boiler is utilized in a power plant to produce electricity and district heat.

25 13. The method according to claim 10 or 12, wherein cooled post-combustion boiler exhaust gases are conveyed to the drying reactor and carbonization reactor.

30 14. The method according to any one of claims 6 to 13, wherein the bio-coke particles are conveyed to indirect cooling with air, from where hot air resulting from indirect cooling is conveyed to the carbonization reactor.

 15. The method according to any one of claims 1 to 14, wherein the bio-coke particles are conveyed to indirect cooling with water.

35 16. The method according to any one of claims 1 to 15, wherein the bio-coke particles are conveyed to indirect cooling with inert gas.

17. The method according to any one of claims 14 to 16, wherein the cooled bio-coke particles are screened and a finest ash- and impurity-rich fraction is separated to reduce the ash content of the bio-coke product.

5 18. The method according to any one of claims 14 to 17, wherein the cooled, purified bio-coke product is ground, mixed with a binder and water, pressed into briquettes and dried.

10 19. The method according to claim 18, wherein the size of a briquette is 10 to 40 mm.

20. The method according to any one claims 1 to 19, wherein the biomass raw material is frozen and de-iced before removal of mechanical impurities by means of the hot gases generated in drying, gases generated in
15 the de-icing being conveyed to gas scrubbing, and the waters generated in the de-icing and gas scrubbing being conveyed to a wastewater purification step before removal from the cycle.

20 21. The method according to any one of claims 1 to 20, wherein the biomass raw material is selected from the group consisting of: tree stumps; peat; logging waste; reed canary grass; and straw.

22. A method for continuously producing bio-coke particles for use in production of ferroalloys, the method comprising
25 – providing biomass raw material;
– dividing the biomass raw material into pieces, if not already in pieces;
– pre-drying the biomass raw material, if not already dry;
– pre-cleaning the biomass raw material, if not already clean;
30 – pre-comminuting the biomass raw material;
– comminuting the biomass raw material into raw particles;
– drying the raw particles into dry particles; and
– carbonizing the dry particles to obtain bio-coke particles, wherein the carbonization is carried out at a temperature in the range of 650°C to
35 1000°C.

23. A method for the production of bio-coke briquettes for use production of ferroalloys, the method comprising the following steps:

- a) lifting of tree stumps , dividing them into pieces and shaking off impurities ;
- 5 b) storing and pre-drying tree stumps at the lifting site;
- c) storing, pre-drying, pre-cleaning and pre-comminuting tree stumps ;
- d) de-icing the tree stumps and, comminuting the tree stumps into raw particles;
- 10 e) transporting the raw particles by a vibrating conveyor screen to a storage silo;
- f) drying the raw particles into dry particles ;
- g) carbonizing the dry particles in a carbonization reactor to form bio-coke particles, wherein the carbonization is carried out at a temperature in the range of 650°C to 1000°C, where a first part of gases and dust formed in carbonization is burned in the carbonization reactor with an air deficit;
- 15 h) feeding a second part of the gases formed in the carbonization reactor to a post-combustion boiler, in which the second part of the gases are burned and thermal energy that is generated is utilized to produce electricity and district heat and in which the cooled circulation gas is conveyed to the drying step and carbonization reactor ;
- 20 i) conveying the bio-coke particles to cooling and conveying the cooling medium used to one of: the carbonization reactor; and the post-combustion boiler;
- 25 j) screening the cooled bio-coke particles and conveying the bio-coke particles to briquetting, a first step of which is grinding the bio-coke particles to a fine bio-coke powder;
- k) mixing the fine bio-coke powder with water and a binding agent to regulate the strength of a plurality of bio-coke briquettes;
- 30 l) pressing the bio-coke powder and binding agent mixture into bio-coke briquettes;
- m) drying the bio-coke briquettes .

