MADKEM

independent innovations

BIOCHAR KILN TECHNOLOGIES

2010 / early 2011

BIOCHAR KILNS

Foreword by:
Nikolaus Foidl

Systematic of charcoal kilns:

Material flow

Charcoal kiln types can principally be divided into batch or continuous, and into vertical and horizontal systems depending of the type of raw material used for charring.
Vertical systems use gravity to move the incoming material through the drying and charring zones towards the char cooling and outlet zone.

Horizontal systems have normally gravity or blower driven pre-drying and then a rotating or flat bed vibrating or scraper system to move the pre-dried material through the charring/out gassing zone towards the cooling and extraction zone. In rotating systems the kiln can be inclined, or paddles or screws that are located inside the kiln (center or wall attached) ensure the transport of feedstock.

All continuous systems have a seal at the inlet and outlet of the retort to prevent oxygen from entering the charring zone, and a cooling device to prevent the char from igniting at it comes in contact with outside air.

Pre-drying

Pre-drying can either be independent from the charring operation, or heat from flaring the pyrolysis offgases can be utilized. For pre-drying operations, not more then 30 % of the total heat generated is usually needed.

In a batch system, heat can be supplied directly or regulated via a heat exchanger.

If a heat exchanger is used, the maximum temperature of heated air used to dry feedstock should not exceed 130 degrees Celsius to lower the risk of self-ignition, particularly when wood chips, saw dust or grain hulls are used.

In a continuous system, direct or indirect drying can be used. Direct systems use the hot gases with exclusion of oxygen at different temperature levels. Indirect systems use hot air from a heat exchanger or steam that passes either through the feedstock or over a heat transfer area.

A special variation of drying is radiant heat applied by flaming pyrolysis. In this case most of the evolving steam is cracked through high temperature and water gas shift reaction into CO and H2 and burned again in the burner together with the rest of the gases.

Some clients want to recover the high value content of smoke substances (active ingredients are Furans and Butenoloides / Karrikinolides) in the temperature range of 80 to up to 380 degrees Celsius or 80 to 250 degrees Celsius and if used in animal fodder between 80 and 180 degrees Celsius.
Farm environments have a use as well for low and high temperature tars to impregnate fence posts against fungal decay and termite attacks.

Sealed introduction of the pre-dried raw material into the kiln. In order to minimize introduction of air into the charring section of the kiln, different sealed introduction devices are in use. For fine materials like sawdust, rice hulls and chips agricultural screw conveyors are common, for chips and sawdust, rotating cell valves are also used, and for bigger pieces square or round pistons can be used. All devices should minimize the introduction of oxygen and should seal after transfer of the product from the pre-drying to the charring section to avoid combustion inside the drying section.

Charring

If barbeque or cooking charcoal is the desired end product then charring should be done up to a process temperature of 550 degrees for one hour to assure low volatile content inside the charcoal. Volatile content below 12% prevents the char from flaming when burned.

For agricultural use as a growth enhancer, CEC increaser or water retention enhancer, char should be produced at a temperature range between 350 to 450 degrees Celsius, preferably below 400. The higher volatile content (up to 35% depending on raw material and charring temperature) increases the attraction of specialize bacteria and therefore the available minerals in the root vicinity. After the volatiles are consumed by the fungal and bacterial community, the increased pore volume and surface area provides high cation exchange capacity (CEC) to retain water-soluble ions in the root zone so they are not leached away. The increased fine pore volume provides a refuge for bacteria, protecting them from grazers.

Charring can be accomplished by introducing the required heat indirectly through a heat exchange area or directly by blowing the hot inert gases from the burner through the biomass. Flaming pyrolysis, where the incoming fine material is burned in the gas/airstream is one of the more extreme forms of providing the charring heat by radiation. All three forms of heat transfer, convection, conduction and radiation, are involved in charring, and in a specific design, one or two forms will be prevalent. In order to transfer heat, nearly all systems, hot gas velocity will be relatively high in order to maintain a high differential temperature. The smaller the particle size, the higher the heat transfer and out gassing area and the faster charring will proceed. Using direct hot gas injection allows the addition of steam at different temperature levels and sometimes the injection of air. Raw material size, pretreatment, drying and end use of the desired product determines the best combination of intake technology, drying technology, heat transfer technology and charring technology.
Once the char has reached the desired quality, it is cooled, either naturally in batch systems, or by water or steam injection in continuous systems. After extraction, chars may need to be crushed to the desired particle size and again sprayed with water to avoid autoignition from freshly exposed surfaces coming in contact with oxygen. In order to increase the effectiveness of the char in soil, it can be preloaded with desired macro, micro and trace elements as well with amino-acids and sugars.

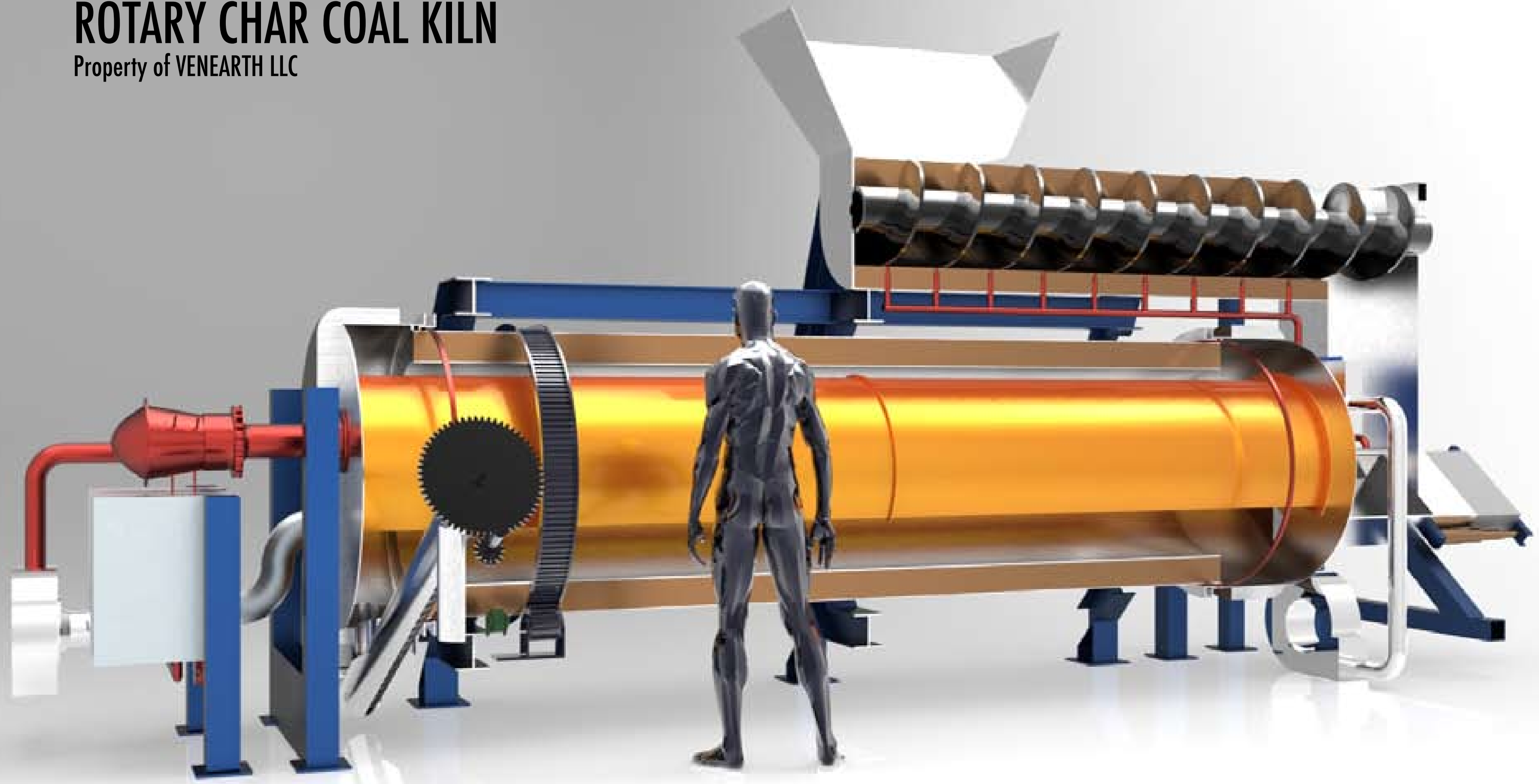
Images: Nikolaus Foidl

ROTARY CHAR COAL KILNS

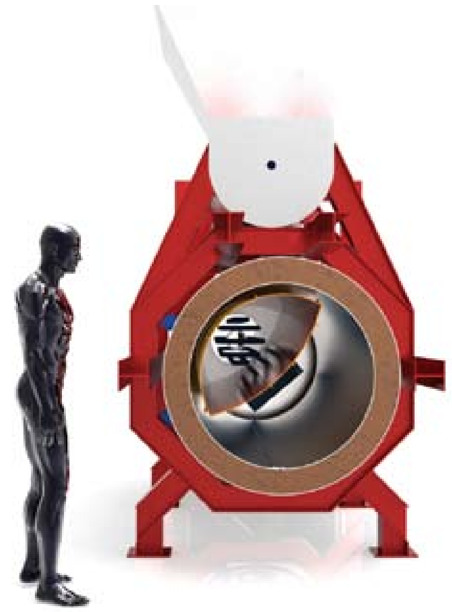
Property of VENEARTH LLC

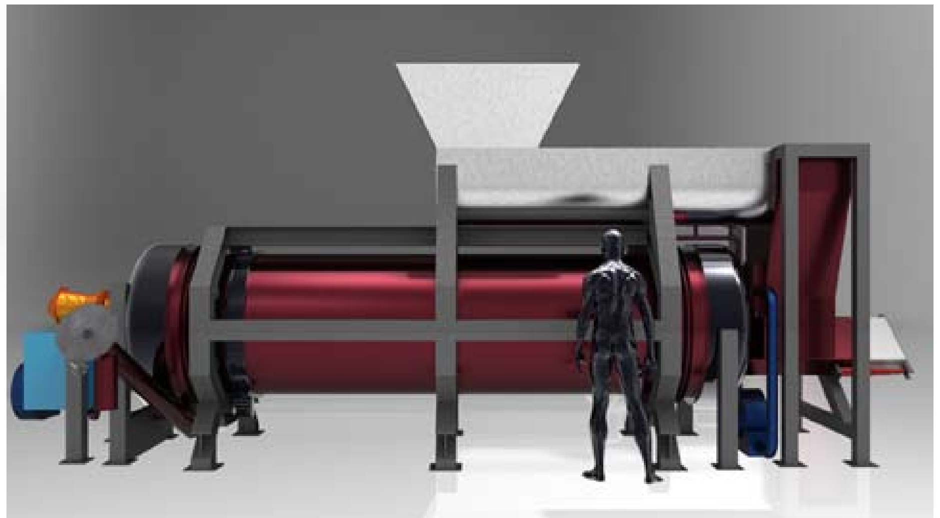
Rotating kiln with radiating heat hube. Feed in with a square hydraulic piston feeder. Condenser could take out condensates before burning the gases. Double Pulse Jet Burner / regulable from 30 to 100%. Pre- Drying with hot gases around 130 Degrees Celsius. This rendering illustrates the 300 kg char per hour unit.

ROTARY CHAR COAL KILN
Property of VENEARTH LLC



Rotary Char Coal Kiln with Steam Pre-dryer and Top Positioned Feeder screw and piston feed on the bottom. For sludges and very wet material. These renderings display a 150 kg char per hour unit.

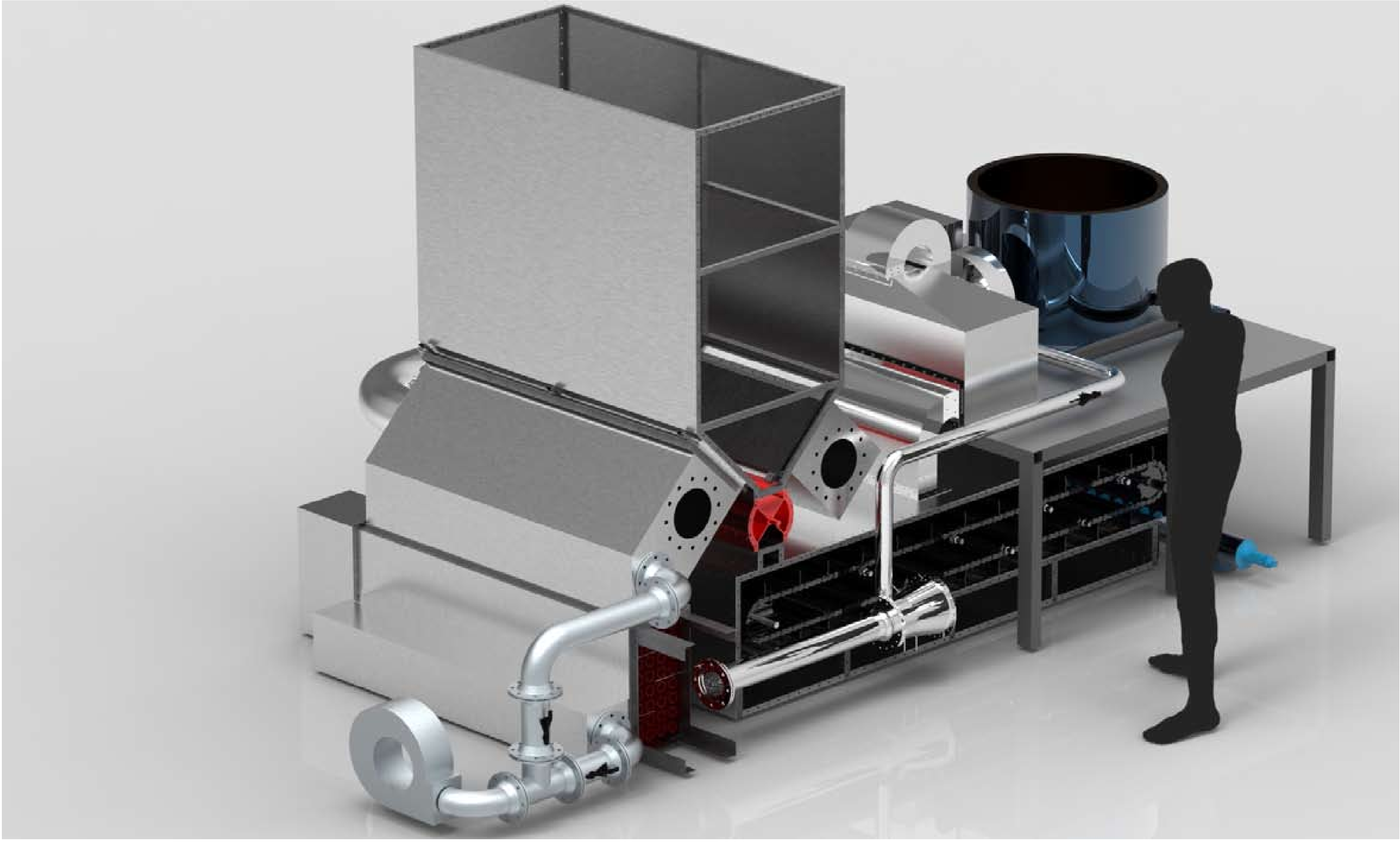




Horizontal Scraper Moved Flat Bed Kiln

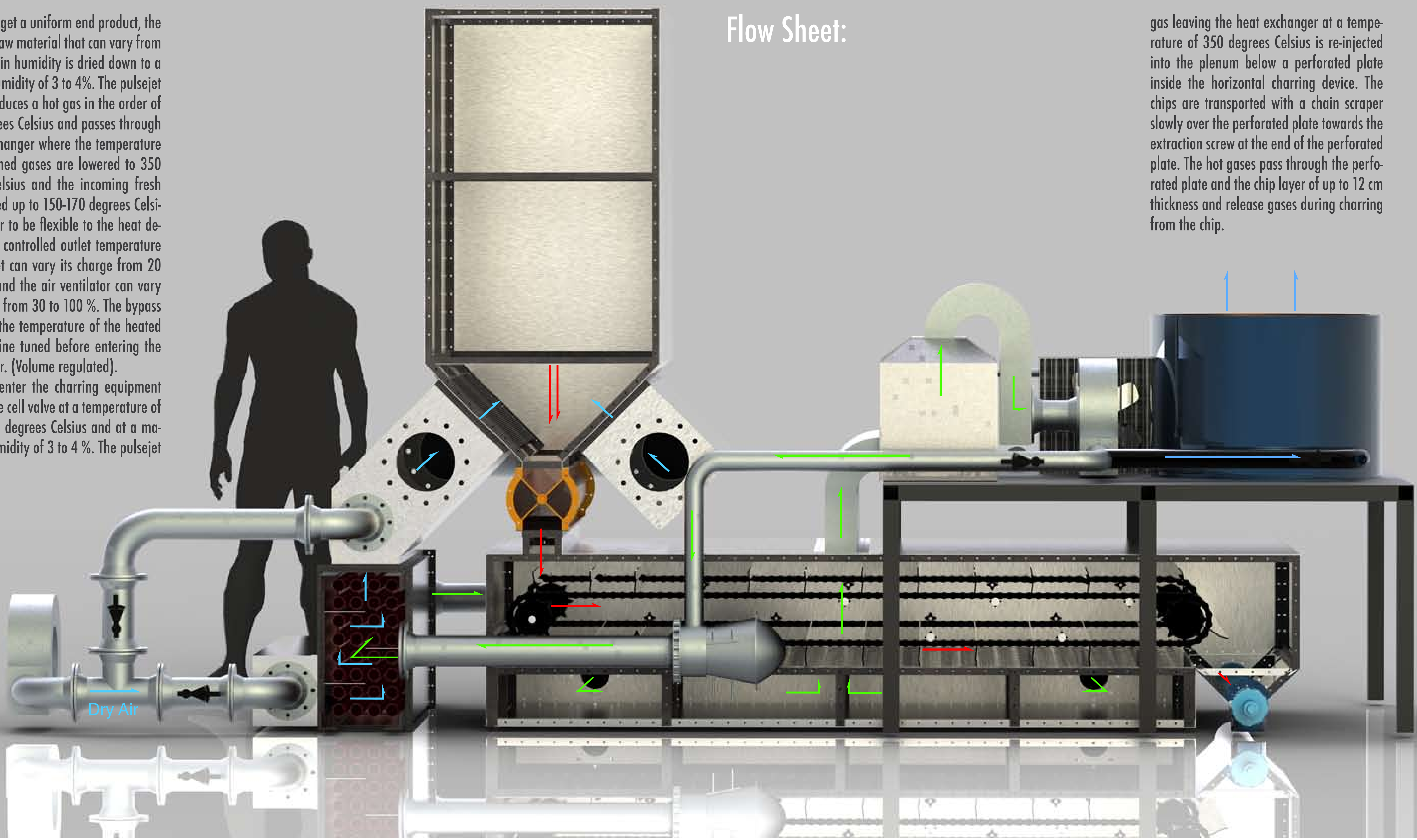
Property of VENEARTH LLC

Charcoal production costs are split into the following categories:
About 70 to 75% are raw material cost including sizing, handling and transport.
20 to 25% are labor costs where as higher the capacity of the unit as lower the labor costs per ton end product.
Hardware costs depending on the complexity and the material quality of the unit, tend to be between 5 to 10 % of the costs of the end product.
As energy production is the main competitor for the bio char, the cost of the future end product depends mainly on the raw material price.
This is calling for highest raw material transfer efficiency or Carbon in raw material recovery to get the costs for bio char or recovered Carbon down.
High temperature processes get higher hardware efficiency with lower char quality and lower raw material to char efficiencies.



Flow Sheet:

In order to get a uniform end product, the incoming raw material that can vary from 15 to 30% in humidity is dried down to a uniform humidity of 3 to 4%. The pulsejet burner produces a hot gas in the order of 1200 degrees Celsius and passes through a heat exchanger where the temperature of the burned gases are lowered to 350 degrees Celsius and the incoming fresh air is heated up to 150-170 degrees Celsius. In order to be flexible to the heat demand at a controlled outlet temperature the pulsejet can vary its charge from 20 to 100 % and the air ventilator can vary his volume from 30 to 100 %. The bypass air allows the temperature of the heated air to be fine tuned before entering the chip hopper. (Volume regulated).
The chips enter the charring equipment through the cell valve at a temperature of 150 to 170 degrees Celsius and at a maximum humidity of 3 to 4 %. The pulsejet gas leaving the heat exchanger at a temperature of 350 degrees Celsius is re-injected into the plenum below a perforated plate inside the horizontal charring device. The chips are transported with a chain scraper slowly over the perforated plate towards the extraction screw at the end of the perforated plate. The hot gases pass through the perforated plate and the chip layer of up to 12 cm thickness and release gases during charring from the chip.



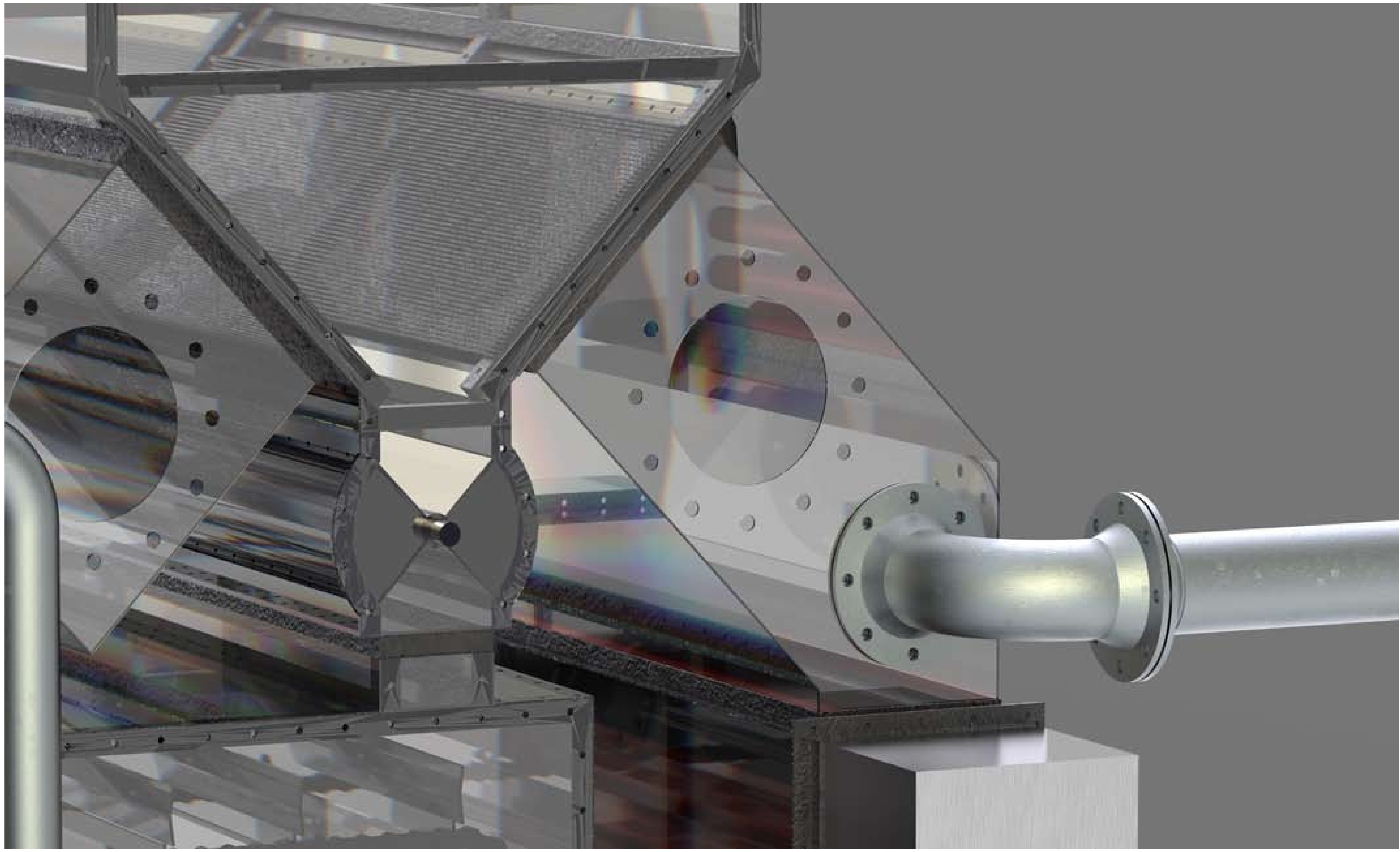
These gases are recovered on top through a channel that guides the gases into a condenser where all condensable parts are separated and collected in a closed bin. The non-condensable gases are pressed with a blower into a gas line that feeds the pulse jet burner and / or burns the remaining gases in a swirl burner.
In a future commercial unit the gases will be burned completely in the pulsejet burner and the excess energy will be vented off with the air ventilator so we can avoid the swirl burner.

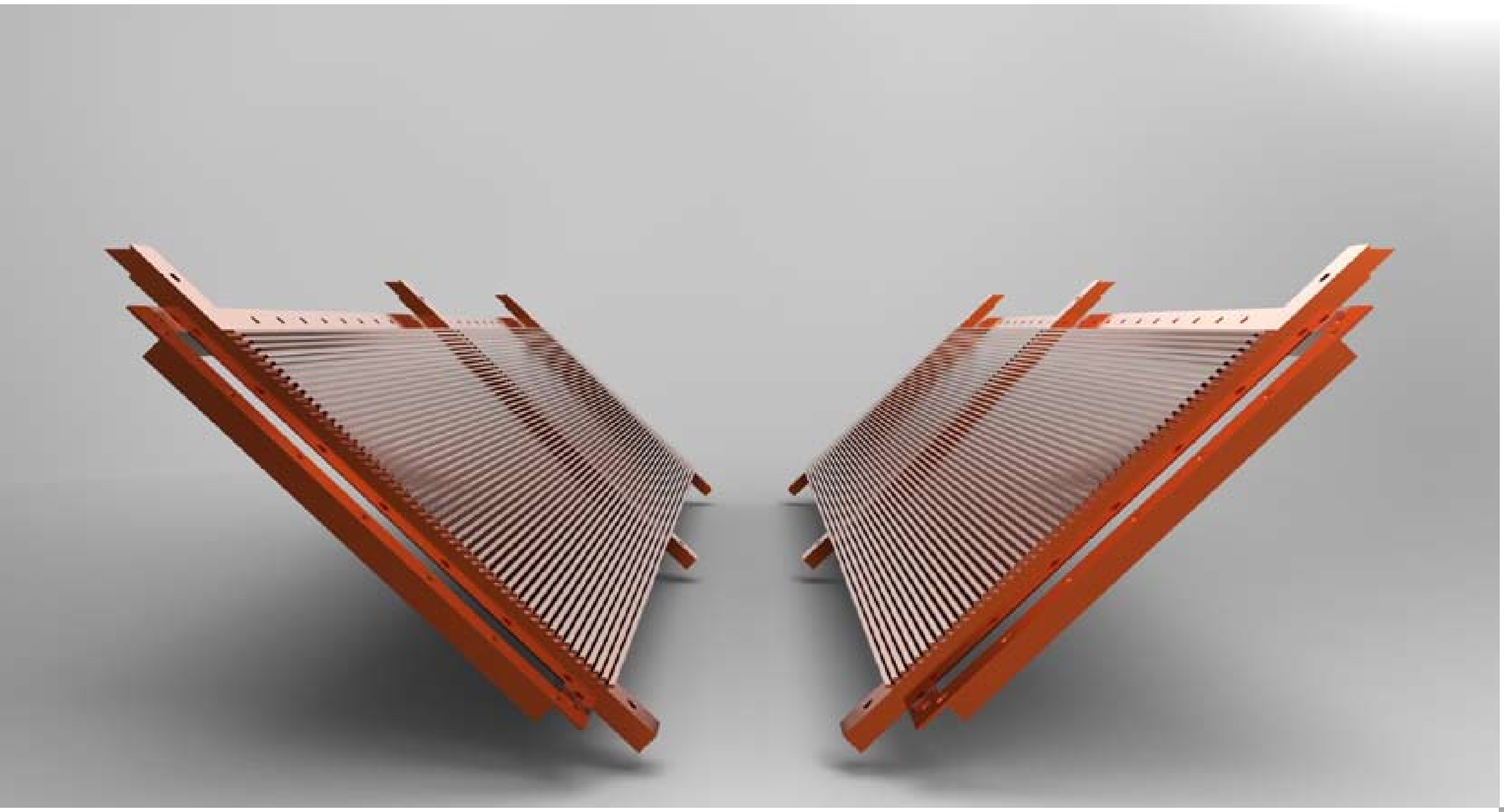
Charring efficiency is between 33 to 35% based on dry raw material; an other 36 % of the dry raw material weight is recovered as condensate, and around 30 % is burnable gas to sustain the process.
The percentage of burnable gas can be regulated with the condenser temperature; max recovery is at 75 degrees Celsius condenser temperature.
The overall dimensions of the unit without a feeder are 4,5 meter long, 2,4 meter wide and 2,4 meter high which is within the maximum transport-dimensions on public roads.
To increase char quality and raw material to char transfer efficiencies we have to first dry the incoming raw material and then char it at controlled temperatures over longer residence time. High temperature process has 20 to 26 % transfer efficiency based on dry raw material, low temperature, longer residence time charring, leads to 33 to 36% transfer efficiency and as this low temperature avoids formation of phytotoxic tars as well allows the recovery of some 25 to 36% of the dry raw material as growth stimulating, condensed liquids. The remaining 30 to 42 % of burnable gases are sufficient to satisfy the heat requirement of the charring process.

The unit is sturdy and easy to regulate without sophisticated electronics, every blacksmith on countryside should be able, regarding equipment, tools and know-how, to maintain or repair the unit.

One ton of dry biomass contains about 50% or 500 kg of carbon. Torrefaction retains about 94 % of this carbon or 470 kg, remaining mass is 900 kg of torrefied material. Torrefaction takes place between 180 to 280 degrees Celsius. Half-life time in soil is around 40 to 60 years. Pyrolisis at 450 degrees Celsius retains about 46.2 % or 231 kg of the total carbon. From the original dry biomass 33 % or 330 kg are retained as solid char. Half-life time is around 150 to 250 years.
Pyrolisis at 700 to 900 degrees Celsius retains about 34 to 37.6 % or 170 to 188 kg of carbon. From the original biomass only about 20 to 26% or 200 to 260 kg are retained as solid char. Half-life time in soil is over 300 years.

Combined pyrolisis at 390 degrees Celsius and condensable recovery from the evolving gases retains about 33 to 38% or 330 to 380 kg of char or 45 to 51.6 % or 225 to 258 kg Carbon. Half-life time in soil is around 180 to 200 years. As well in condensable liquid there will be retained between 30 to 36 % of the dry biomass or 300 to 360 kg or 195 to 234 kg Carbon or 39 to 46.8 % of the original Carbon. In total the combined solid / liquid recovery will retain between 84 to 87.6 % of the original Carbon with an expected half-life time of 2 to 3 month.



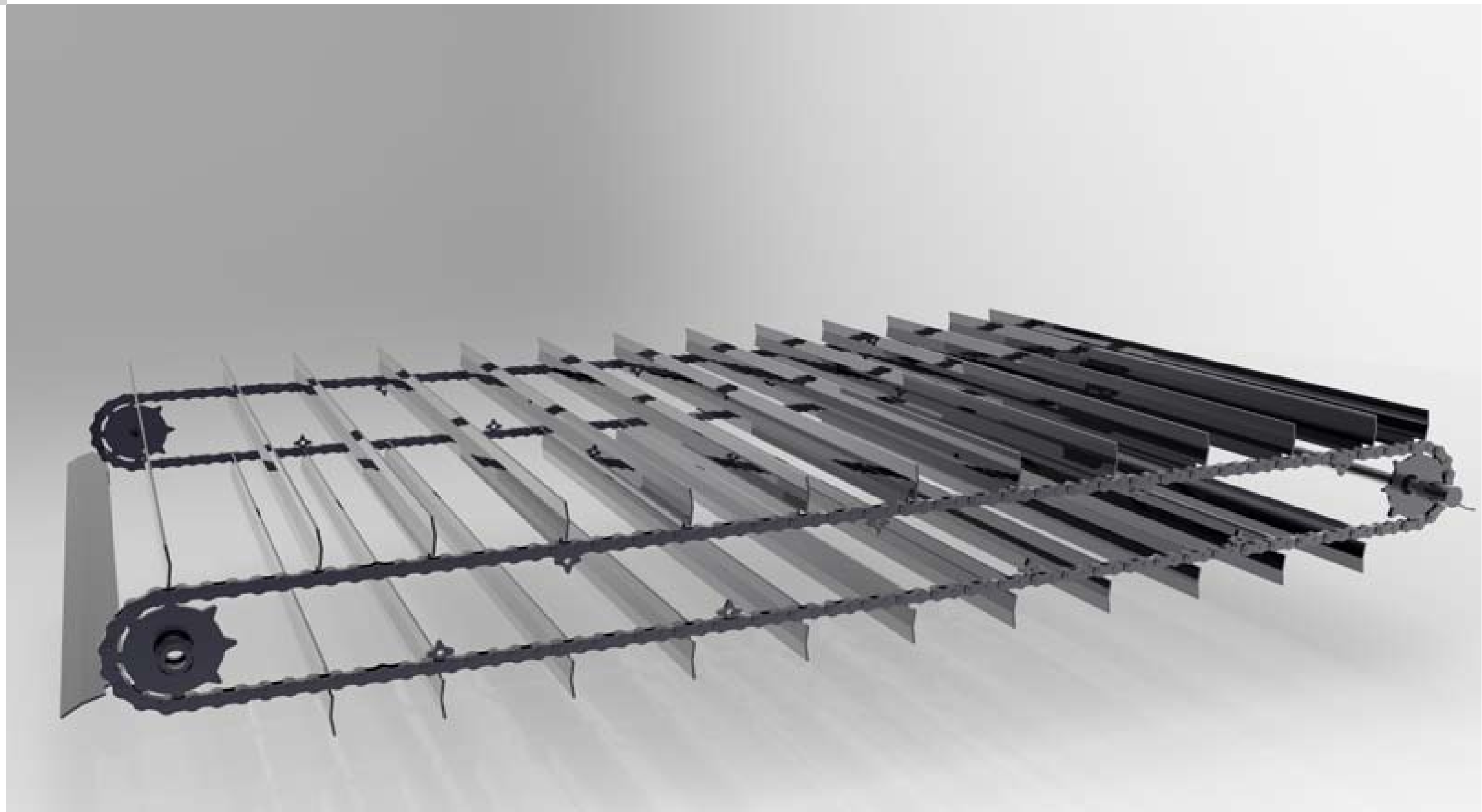


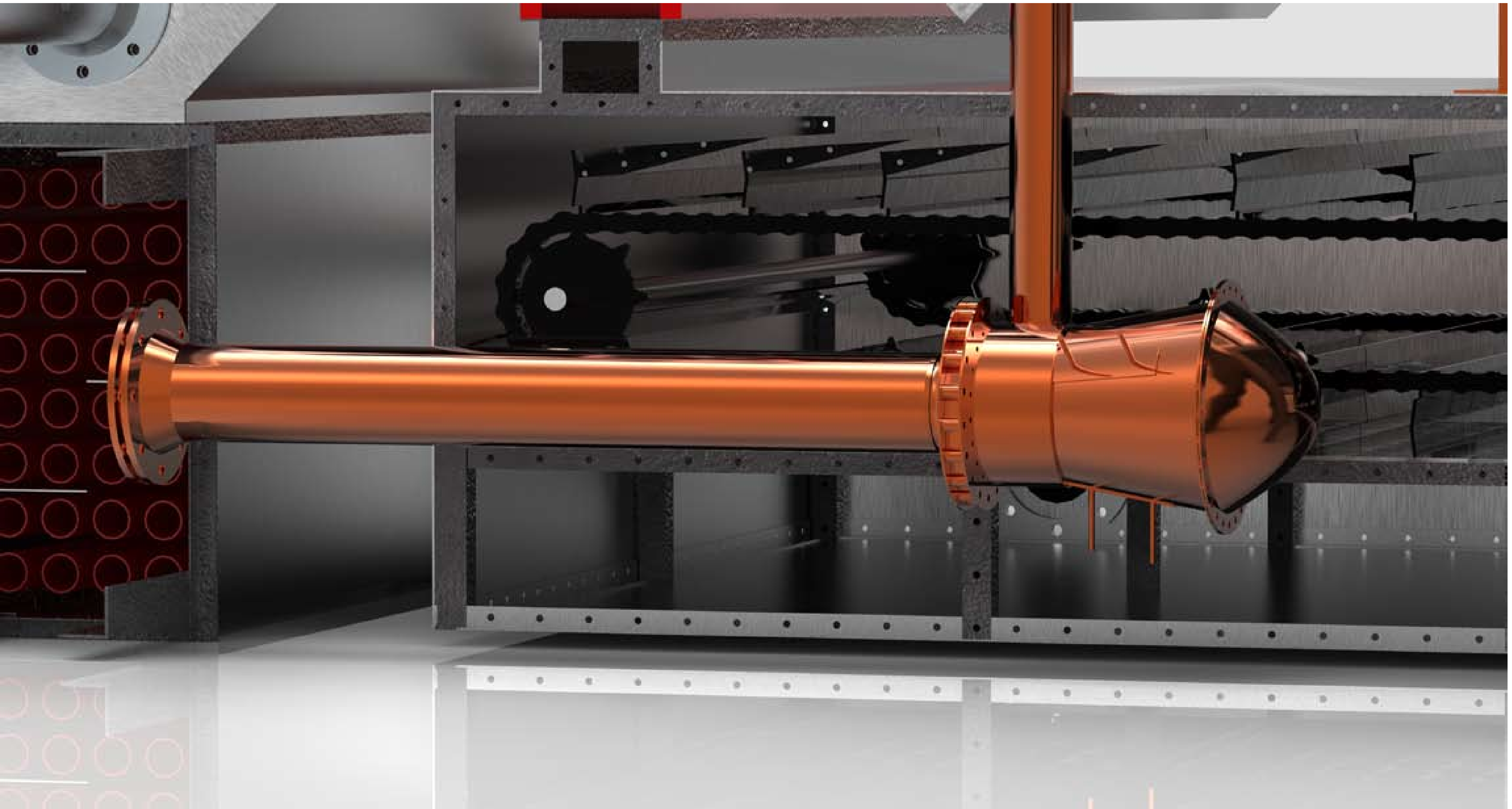
Cost-Benefit

Assumptions:
300 days a year in operation / 8 hours a day
Raw material costs around 90 US$ / ton of dry material
High temperature reactor investment costs around 120.000 US$
Low temperature reactor investment costs around 85.000 US$/65.000 US$
Average labor cost per ton Char 167 US$ / ton

	Prod. Hardware	labor /ton	raw material	hardware cost/ton	
High temp reactor	200 kg/h	125 US$/t	950.400 US$	50	US$/t
450 ° pyrolisis	150 kg/h	167 US$/t	486.000 US$	36	US$/t
390 ° pyrolisis	310 kg/h	80.65 US$/t	489.000 US$	23	US$/t

The high temp. reactor produces 2400 tons in 5 years at a labor cost of 125 US$/ton and a raw material equivalence cost of 396 US$/ton char and a equivalent hardware cost of 50 US$/ton of char totaling 571 US$/ton.
The 450° pyroliser produces 1800 tons of char in 5 years at a labor cost of 167 US$/ton and a raw material equivalence cost of 270 US$/ ton char and an equivalent hardware cost of 36 US$/ton of char totaling 437 US$/ton.
The combined char and condensates pyroliser produces 3720 kg product at a labor cost of 80.65 US$/ton and a raw material equivalence cost of 131.45 US$/ton and a hardware equivalence cost of 23 US$/ton of product totaling 235 US$/ ton.
Assuming a price of 500 US$/ton we would loose money on the high temperature char and earn only 113400 US$/ 5 years on the 450 ° pyrolizer.

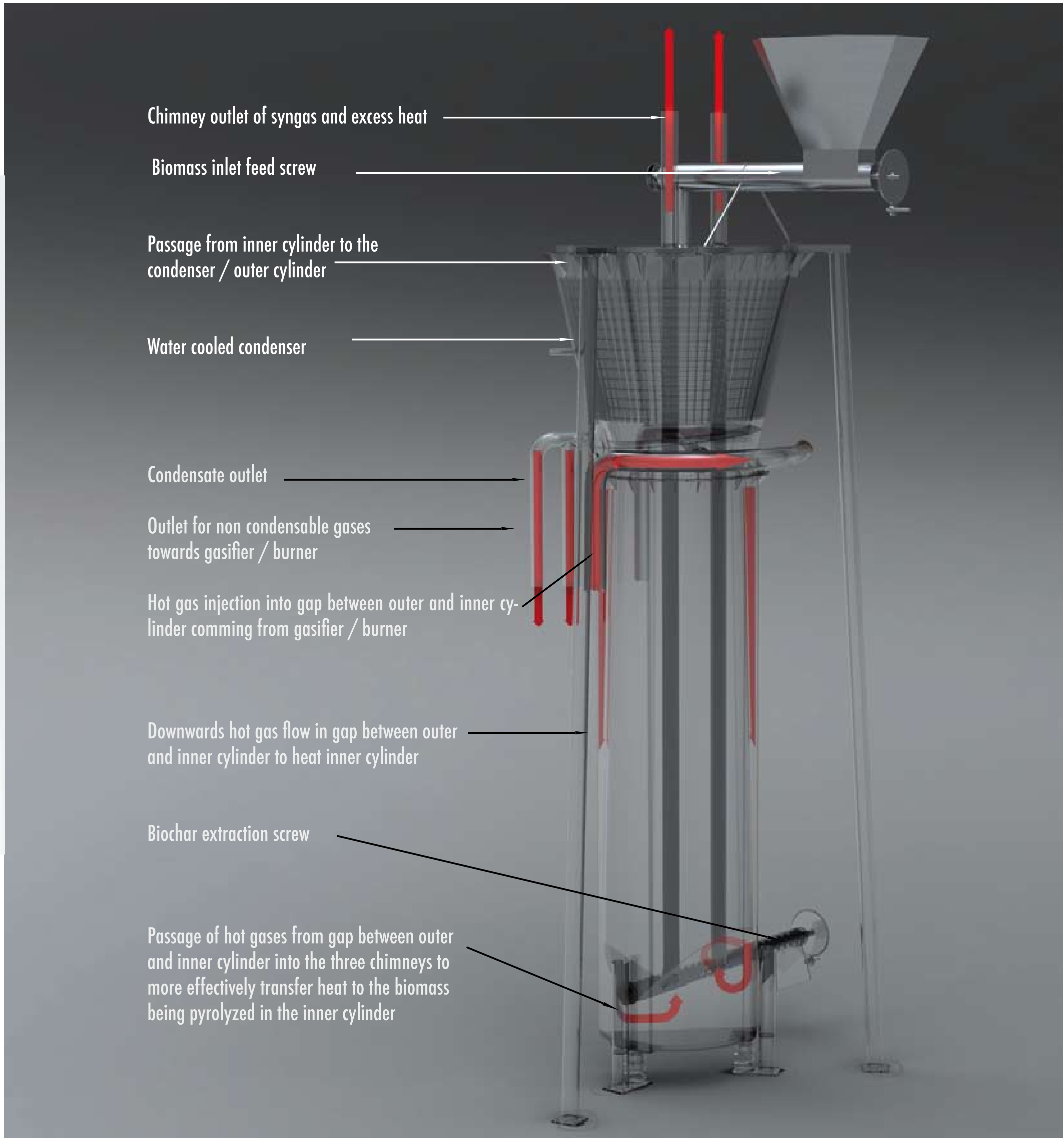




For the pulse jet burner and the high temperature tubes inside the heat exchanger Ma 253 is used. The rest of heat-exposed materials are SS 316 and non- heat exposed structural components are made of galvanized material. In case of the combined char plus liquid the total product is 1860 tons char and 1860 tons concentrated liquid. If we calculate after deducting the costs for added minerals per liter of 4 US$ and then sell it for 10 US$/ liter we would only in the liquid make some 11.160.000 US$ revenue. This would allow us to lower the price for the char down to 50 US$/ton which would bring us a revenue of 93.000 US$ for the char portion alone but make us very competitive in the char market.

Vertical Char Coal Kiln

Property of Tulum S.A.



The kiln outlined in this set of rendered and manufacturing drawings has an internal retort volume of approximately 5 cubic meters. It is installed on a concrete slab or pods to provide stability, under a roof to protect it from the weather. It stands approximately 7.5 meters tall and the outer cylinder is about 2 meters in diameter at the top.

The infeed hopper shown is supplied with
chipped or chopped biomass which is relatively dry, and an augur feeds it into the kiln. The biomass is then heated indirectly by hot gases which surround the retort and flow up through the 3 chimneys shown protruding from the top.

As the biomass within the kiln becomes charred, it is augured out the bottom of the unit and fresh biomass is augured in the top to replace it. Once started, the kiln can be operated continuously and self-sufficiently, using the energy produced in the pyrolysis process to maintain operation.

The design, with some modification, can be easily scaled up for retort volumes of 10 or 15 cubic meters to more economically process larger waste streams.

Cut through Inner and Outer Cylinder with mounted Condenser and hot gas injection Tube

The kiln is constructed primarily of 2 cylinders of stainless steel sheet metal with a narrow gap between them. The cylinders are both "flared" into a funnel shape near the top. A water-cooled "condenser" surrounds the outer cylinder within the funnel area.

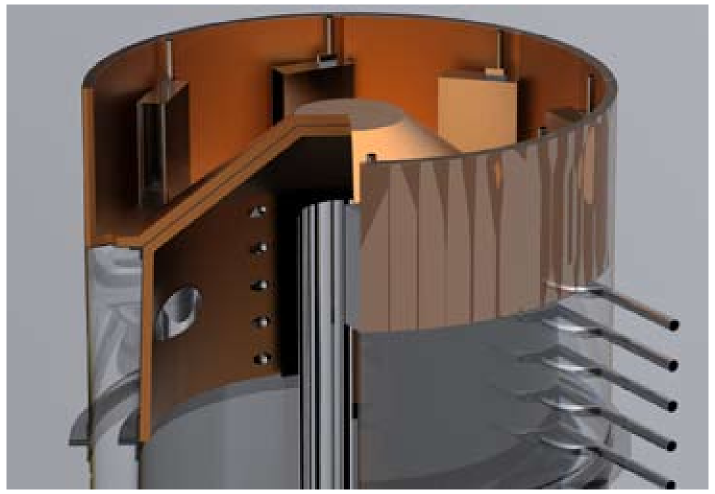
Water circulates within the condenser, cooling the inner surface of the outer cylinder, condensing tar, wood vinegar and water vapor from the gases released during pyrolysis. The condensate is collected and flows out the side of the reactor in a tube to a collection vessel.

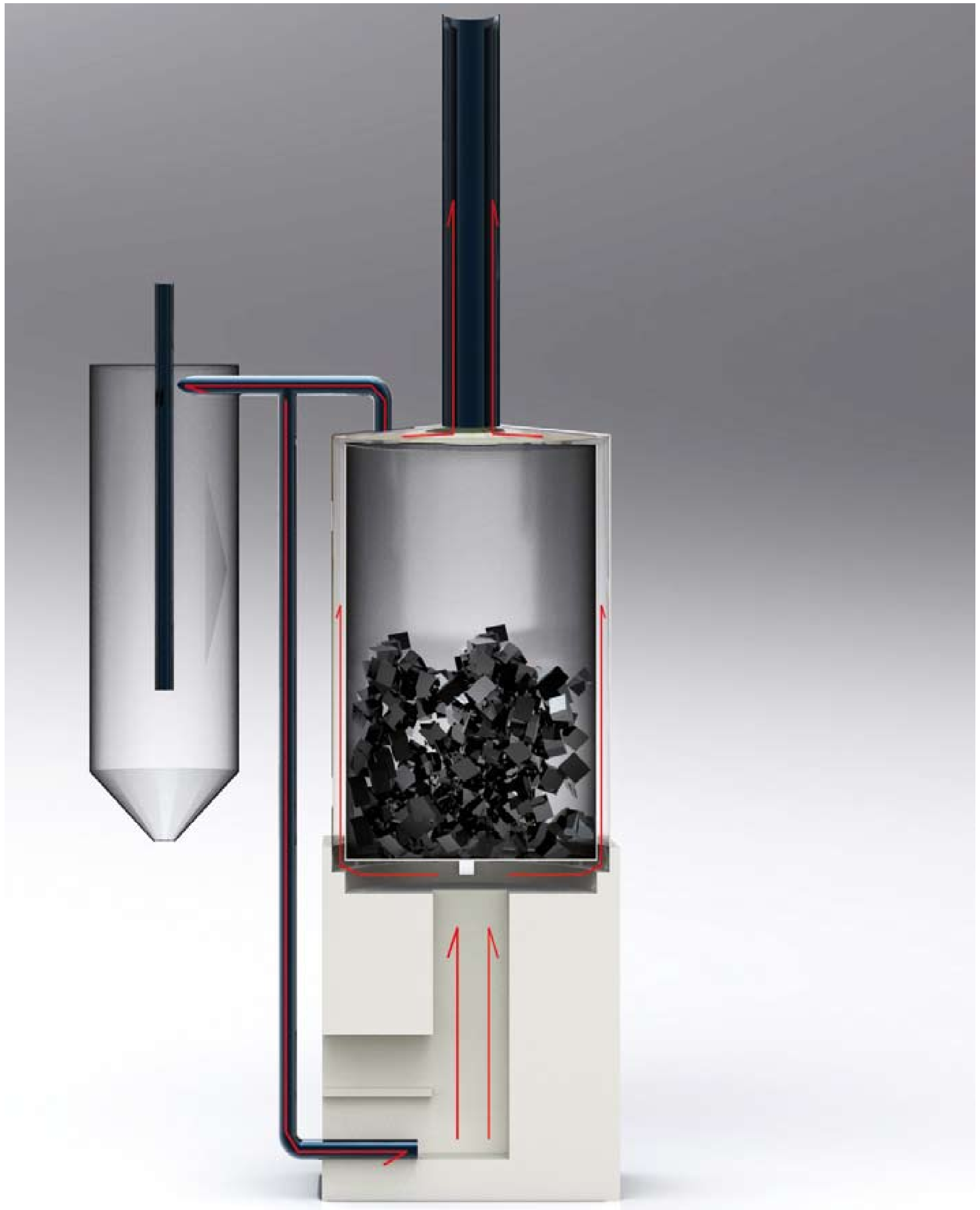
The condensation process serves a dual purpose. First, it cleans the pyrolysis gases of impurities and water vapor, making them both cleaner and easier to burn. And second, the tars and wood vinegar collected are a valuable byproduct that can be used as a chemical feedstock to create a variety of useful substances.

Flaming Pyrolisis Char Coal Kiln

Property of VENEARTH LLC/ TULUM S.A.

Blower injected Chips enter the top burner chamber. Three air injection ports provide the needed air for rotating flame front where the incomming fines and part of the evolving gases are burned. The 900 degree Celsius gases move down through the center tube, and in between the gap of outer and inner cylinder upwards to the flare burner on top of the reactor where the remaining unburned gases are flared. This particular kiln provides relatively large heat exchange areas. The flare burner particularly can be equipped with circular heat exchanger tubes to take off steam for drying or electricity production. The char extraction screw at the bottom is provided with a steam injection nozzle to quench the hot char and to avoid air entering the kiln.



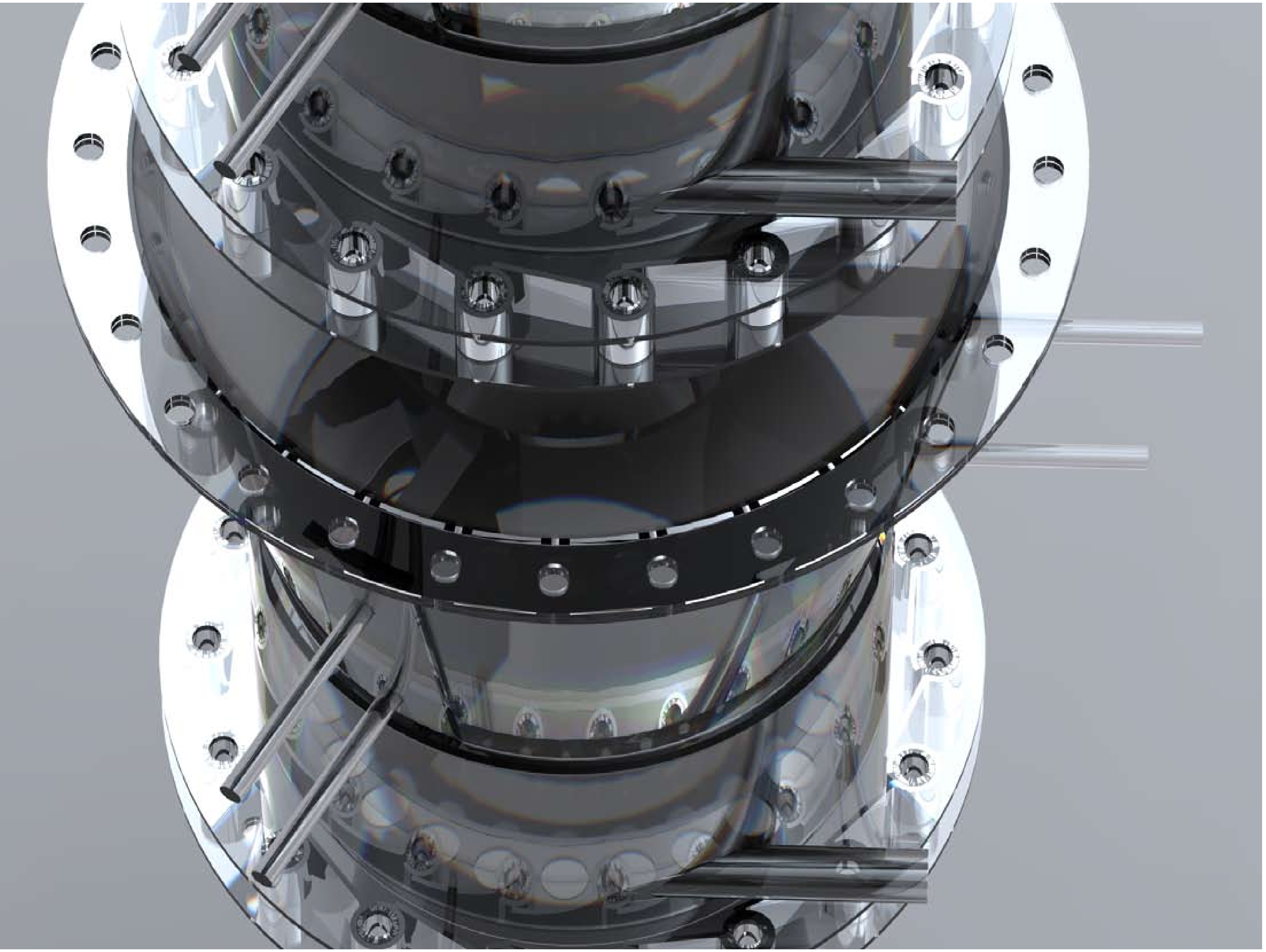


Hornito

Property of PODERCO S.A
Design: Robert Lerner

Subsistence farmers, home gardeners, and other small stakeholders represent a huge potential resource for distributed biochar production worldwide. Reaching this audience with affordable, reliable biochar technology could have a huge impact on carbon sequestration, crop yields, and sustainability of agricultural practices for hundreds of millions of users. The proposed development platform offers the potential for low-cost, controlled, low-emissions biochar production, adaptable to multiple feedstocks and circumstances. A potentially valuable tool for biochar investigators, Hornito can produce small controlled batches from specific feedstocks for pot trials and characterization studies.

The basic kiln consists of a drum with removable lid (retort); enclosed by modified drums (fire chamber and insulator); on a Rocket Stove base (biomass stove with long combustion path for high efficiency); with pipe connection from retort drum to fuel feed of stove. Condenser for wood vinegar collection also depicted.



Low Noise Pulse Jet Burner

Property of MADKEM O.G

A low noise pulse jet burner is a pressurized burner option, where high differential pressure of the hot gases, without the use of costly high temperature fans or blowers, is required.

In most kilns where the hot gases have to be regulated in both quantity and pressure, a fan or blower for hot gases is required. In order to avoid the high costs for those technically challenging blowers or fans, a pulse jet burner would be a preferable choice.

Pulsejets can run on a wide range of gas qualities, from very lean to rich, from dirty to humid, and are self-sucking air and gas for their function. The only disadvantage is the noise of the explosion-like burning of the air-gas mix.

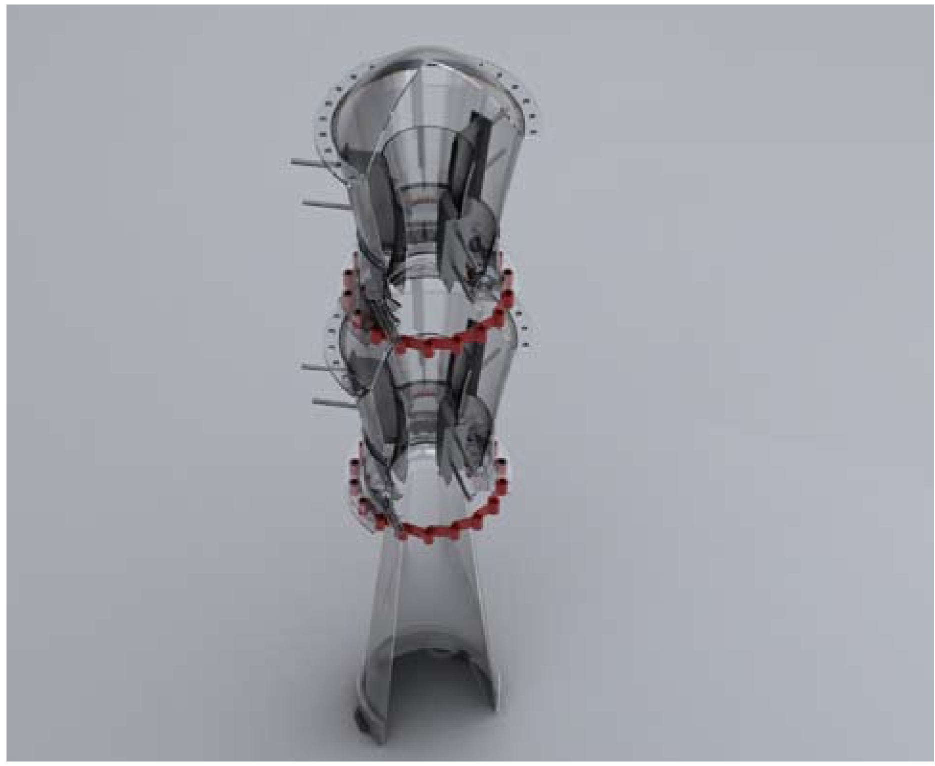
In order to avoid higher noise levels associated with pulse jets, we propose a two-chamber system, where the two standing wave fronts are oriented 90 degrees of phase to each other so they cancel each other out.

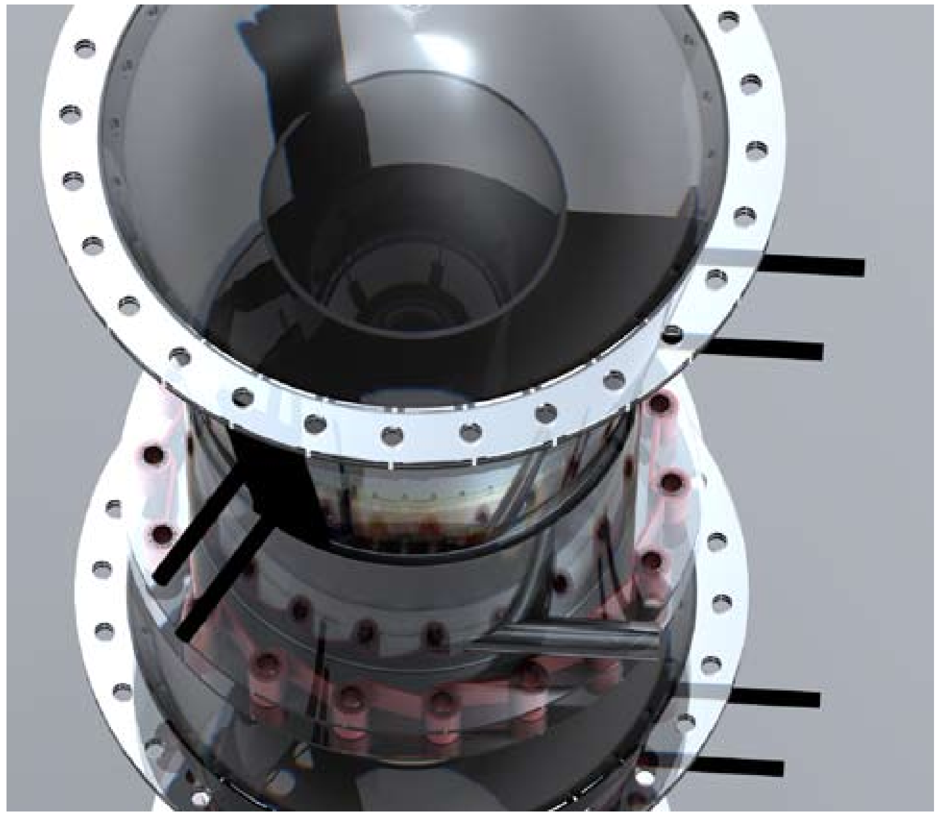
A pulsejet can either produce a pulsing hot gas stream with high velocity but low pressure or a hot gas stream of lower velocity but higher pressure, adapting automatically to the pressure loss of the attached system. Differential pressures of several bars can be sustained.

Power output can be regulated from 30 to 100% of a pulsejet's nominal power by throttling the gas and air feed line.

In an pyrolysis system and in combination with a heat exchanger, the gas temperature for charring and the air temperature of the dryer can be regulated using the same source of pressurized hot gas without additional fans or blowers.

Additional cooling air or used cold gas can be sucked in to regulate gas temperature, using the high velocity stream of hot gases in a venturi valve assembly.



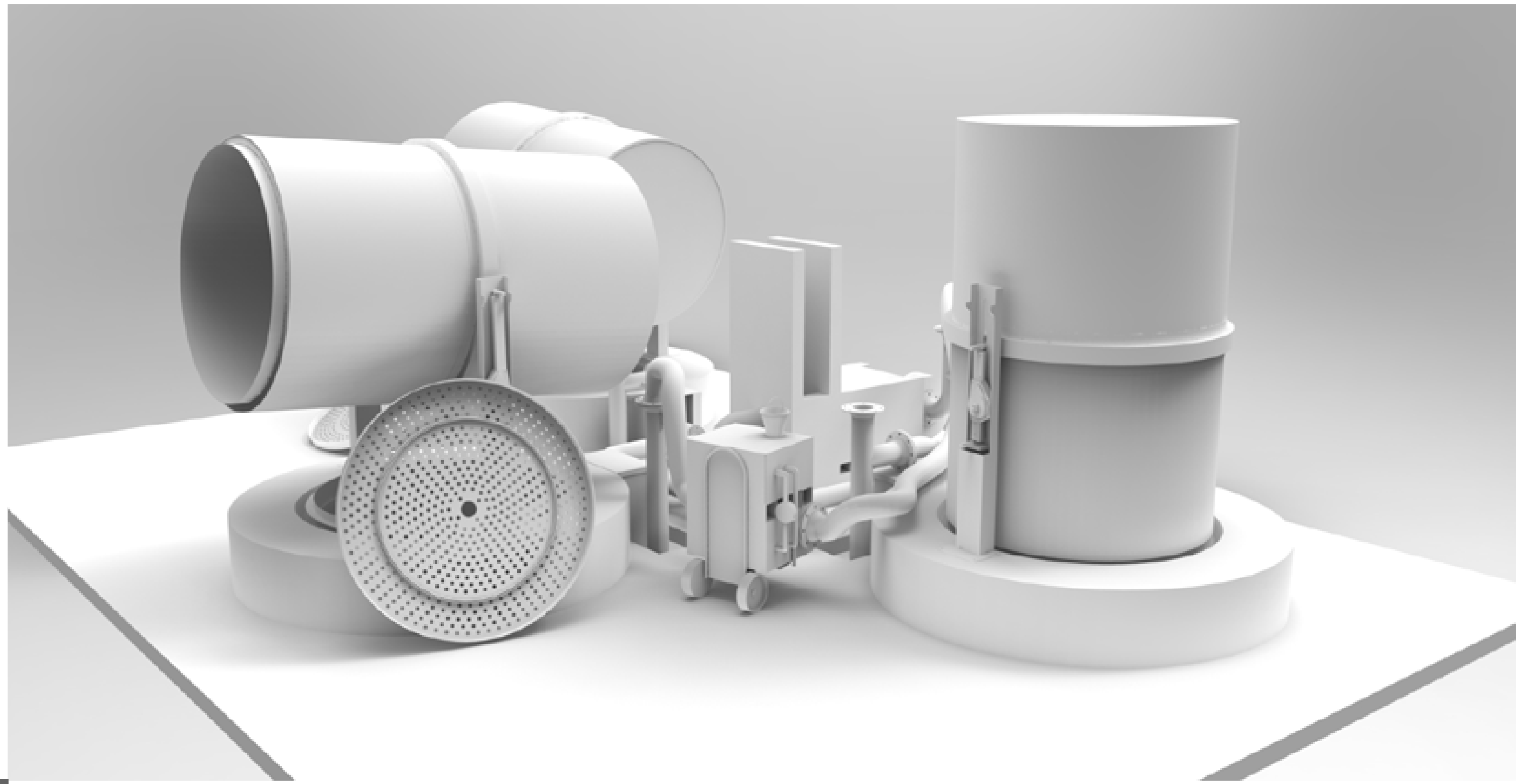


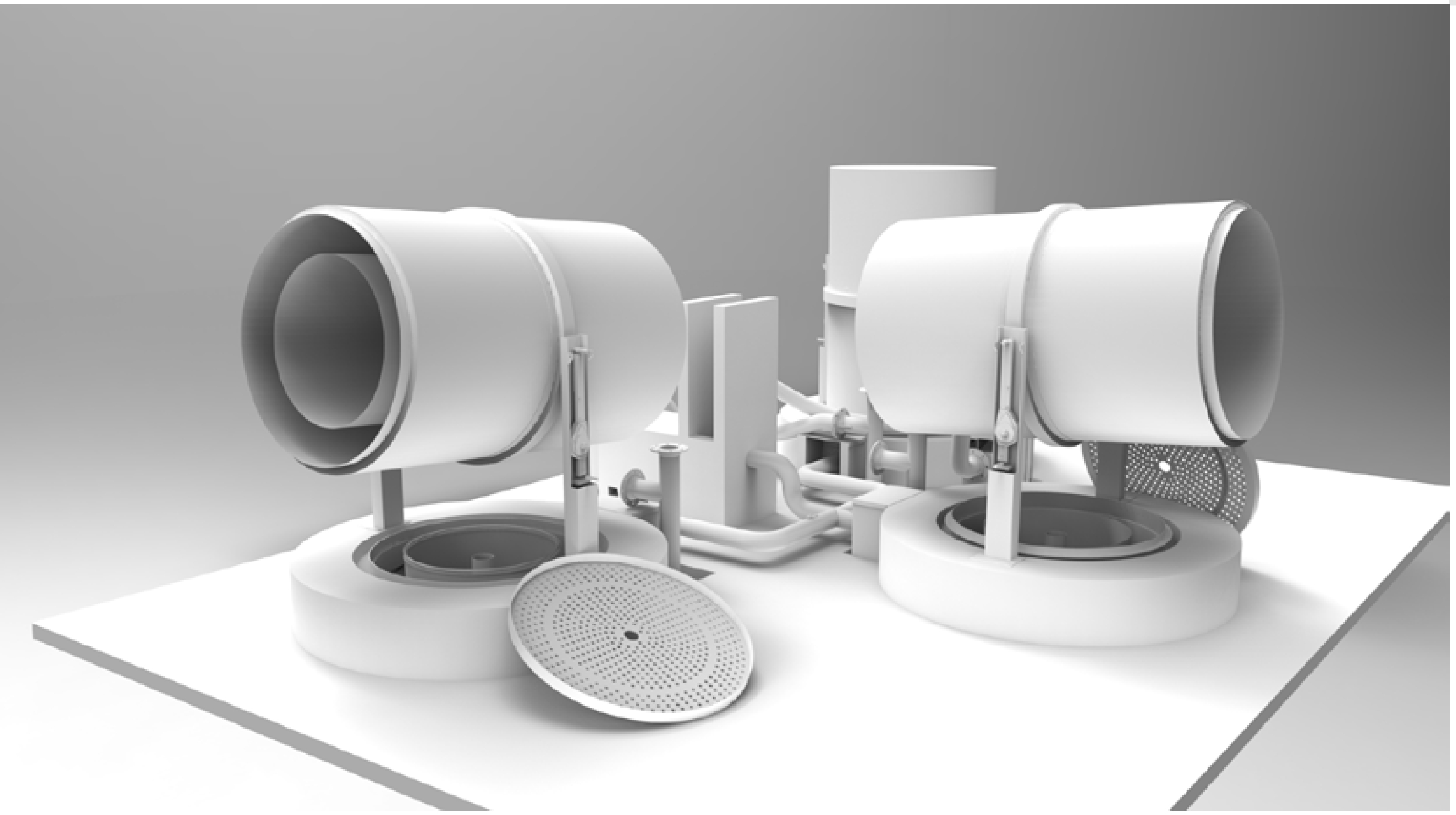
Low Tech High Volume Batch System

Property of VENEARTH / Carbon Gold

For third world or rural situations, low tech- high volume charring systems could be the technology of choice.
This technology approach needs a pre-drying step with the recovery of condensable substances produced in a temperature range between 80 to 280 degrees Celsius.
The process starts in the first kiln with hot gases generated inside the central burner and after a 2 to 4 hours pre-drying phase the logs are heated to over 300 degrees Celsius. At this point, the auto-thermal charring process will transform the logs in after an additional 4 to 6 hours into char. Maximum char temperature during the whole process will not exceed 450 to 500 degrees Celsius.

Charring efficiencies are usually between 33 to 35 %.





In case of wood chips, seed hulls or other small sized materials an additional inner cylinder is inserted to avoid thermal gas flow short circuits and guarantee even charring through out the kiln volume.

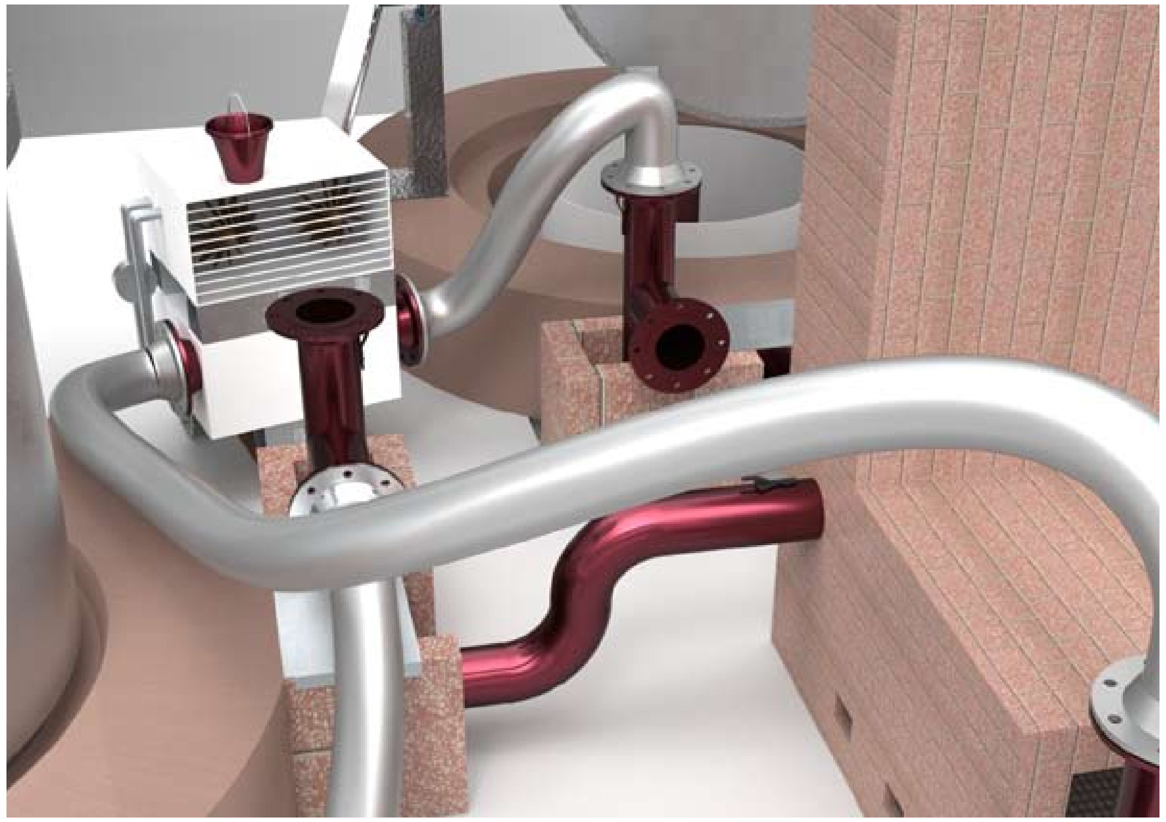
After 4 hours the second kiln can be started and the heat generated with the burnable gases from the first kiln are used to pre-dry the second kiln. In 24 hours all three kilns can be started and brought to the cooling phase of the process.

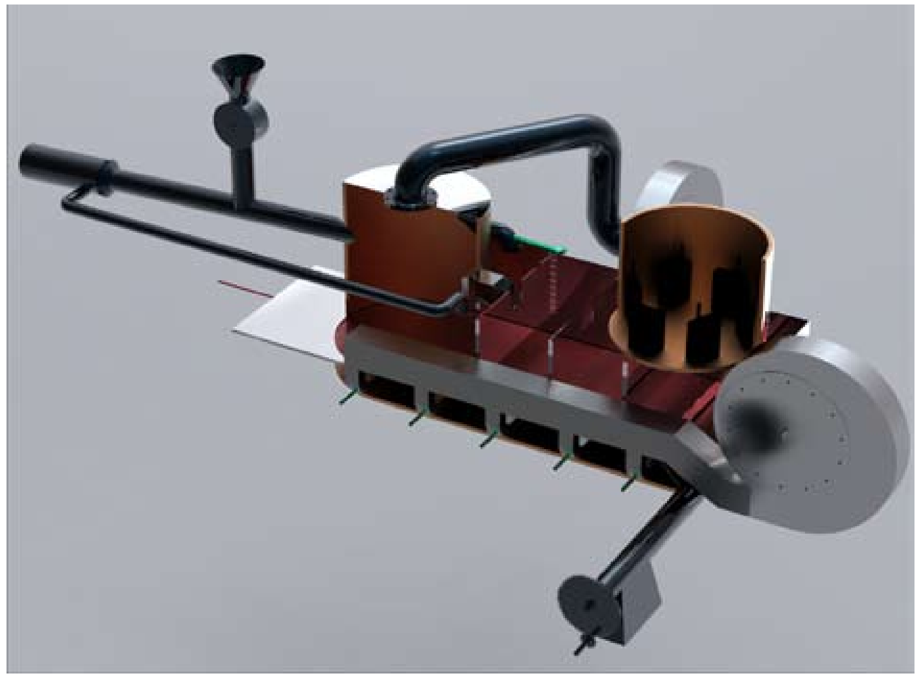
As soon as the first kiln reaches a product temperature below 150 degrees Celsius the kiln can be tilted and emptied, then reloaded with fresh biomass for the next cycle of charring.

In 24 hours this arrangement of 3 kilns with a total volume of 30 m3 can produce about 4 tons of low temperature char from logs with a diameter of up to 15 cm.

MADKEM

As we can employ a mobile condenser for the recovery of condensates produced in the temperature range of 80 to 280 degrees Celsius a total amount of liquid smoke substances including the wood vinegar of around 2 to 2.5 tons per 24 hours can additionally be produced. The vinegar / smoke substances mix, after dissolution of chelating micro and trace elements, can be used as a foliar or edafic micronutrient spray with emergence and growth enhancing properties.





Flaming Pyrolisis Kiln

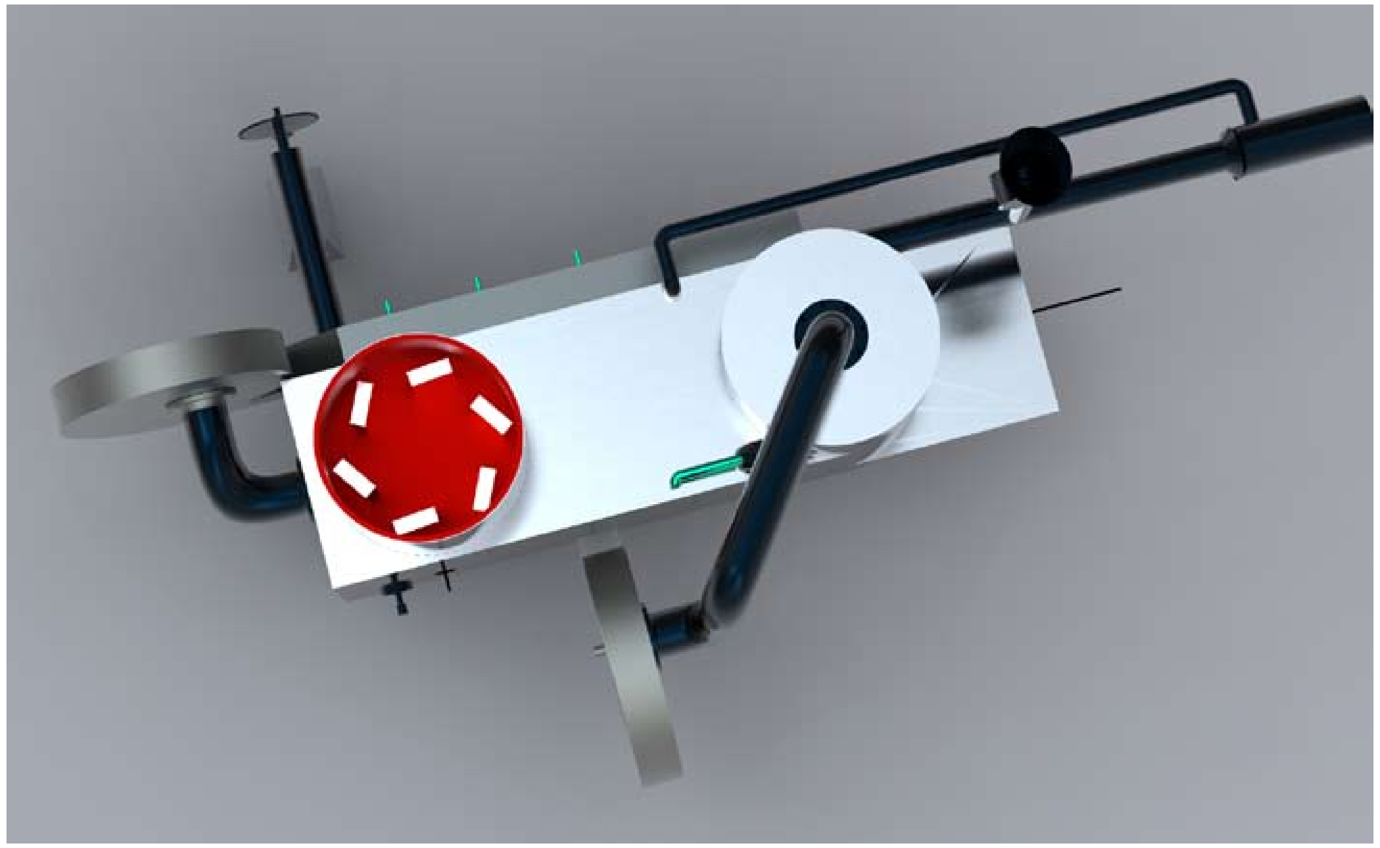
Property of VENEARTH LLC

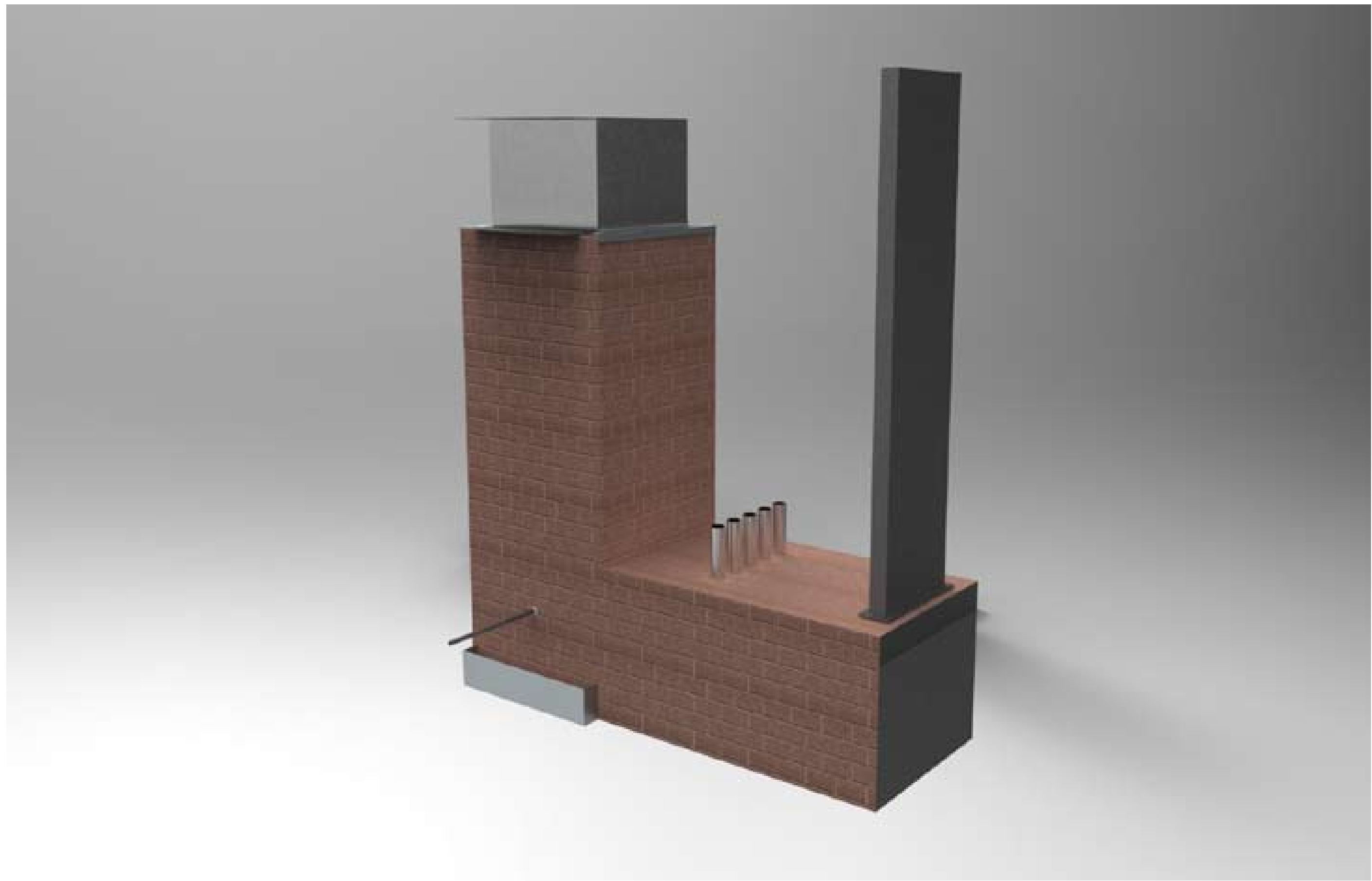
Pulsejet injected chips together with incomming air are partially burned (the very fine particles burn and provide the heat). Radiating flame is used for pre-drying, and the hot remaining gases are blown below the horizontal flat bed, passing through the dried chip. The flat bed sheet has a cyclic movement, pushing the chips through the kiln. Remaining unburned gases are burned in the swirl flare burner on top the unit. Char extraction is done with an injected steam curtain.

Cross Flow Gasifier

Property of PODERCO S.A.

Junks of wood are partially gasified. On top of the gasifier is a 2 valve feeder. Ashes and fine char are collected in a water bin.

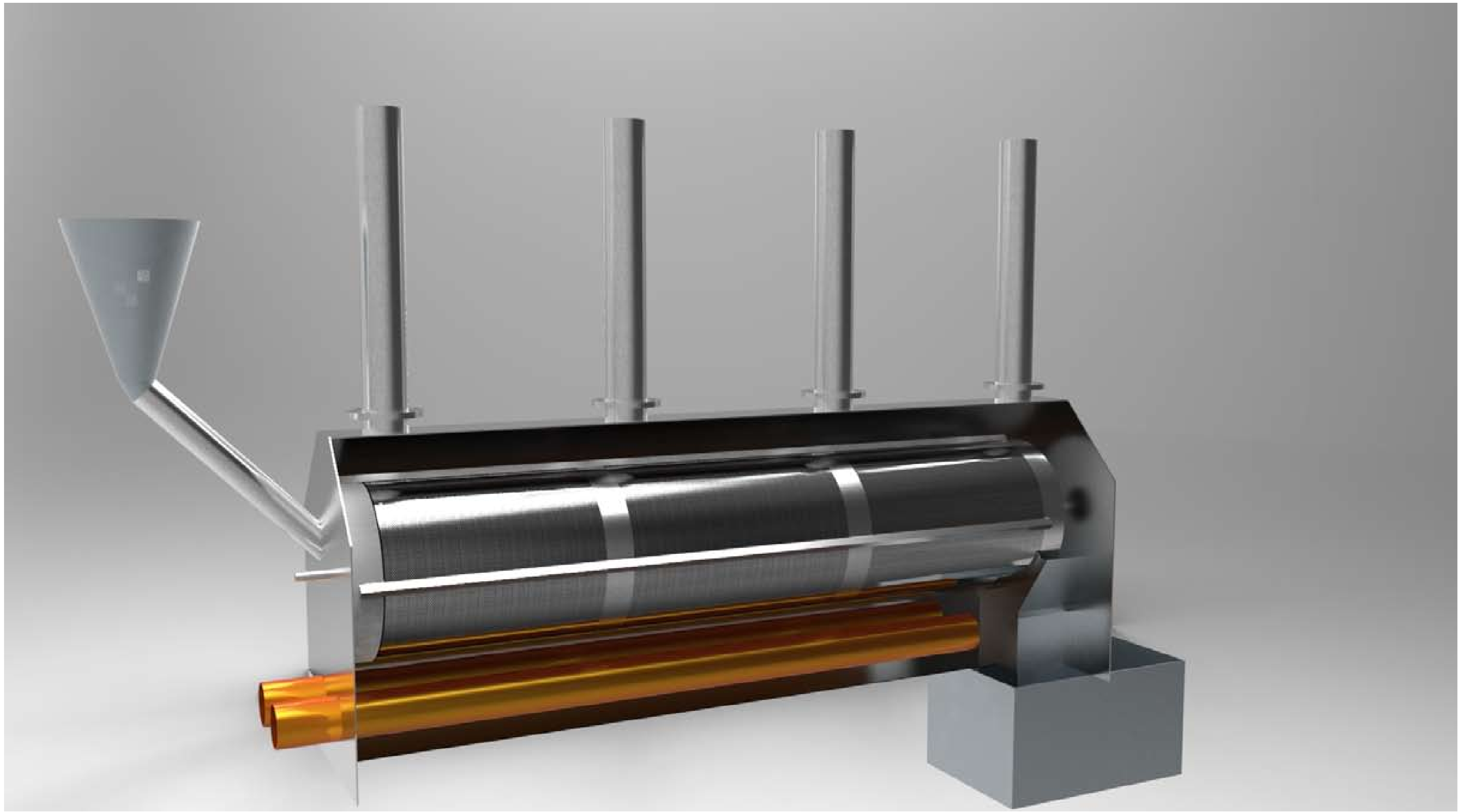




Biochar Mineral Complex Reactor

Property of PODERCO S.A.

Finely milled biochar togehter with chicken manure, clay and calcium magnesium rich minerals plus other essential micro nutrients and sawdust are mixed and fed into the rotating sieve. Two burner tubes on the bottom heat the mixture up during the rotation to a temperature of 180 to 200 degrees Celsius. The extracted product is ready for use as an agricultural amendement. To increase growth, cation exchange capacity and water retention.



MADKEM O.G
Teslastrasse 4.a 8071 Grambach / Austria
UID: ATU66104057
FN Nr. 354832 m
www.madkem.com