ABOUT AVA-CO2

AVA-CO2 offers world-wide solutions to convert biomass into a sustainable source of energy. As a pioneer in hydrothermal carbonisation (HTC), AVA-CO2 plans, implements and operates HTC plants on behalf of its customers. These facilities turn plant residues efficiently and profitably into high grade CO_2-neutral biocoal or CO_2-negative biochar.

The Swiss Company with its headquarters in Zug, Switzerland and subsidiaries in Germany and Switzerland has in 2010 put the world's first industrial-size HTC demonstration plant into service. 2012 followed the implementation of the world's first industrial production plant.

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AVA-CO2
THE MINUS IS THE PLUS

ENERGY OF THE FUTURE

ABOUT US

AVA-CO2 is a pioneer of hydrothermal carbonisation (HTC). By putting into operation the world's first demonstration plant on an industrial scale in 2010, the company has made the HTC technology ready for industrial use.

AVA-CO2 has established another milestone in 2012 by commissioning the world's first commercial industrial HTC plant for the production of CO_2-neutral AVA cleancoal.

Used on an industrial scale, hydrothermal carbonisation opens up completely new perspectives for reducing greenhouse gases and generating renewable energy from biogenic residues.

TAILORED TO YOUR NEEDS

AVA-CO2 is the leading supplier of HTC plants on an industrial scale. Closely adapting to the individual requirements of our customers we provide customised solutions - world-wide.

A PIONEER

Since October 2010 AVA-CO2 operates the world's first industrial-size HTC demonstration plant with an annual production capacity of 1,000 tonnes of CO_2-neutral AVA cleancoal.

2012 the world's first HTC industrial plant was put into operation in the "Technologiezentrum Ost-Vorpommern" (TZO) in East Germany. After overall completion the plant will have a yearly production capacity of 8,000 tons AVA cleancoal.

AVA-CO2 offers customised solutions. Every customer has specific requirements when implementing HTC projects. The modular design of the AVA-CO2 plants allows us customers to meet all these individual needs.

The different modules cover every production step, starting from biomass preparation, moving to carbonisation and finally to separation and process water treatment. They are flexibly adapted to the specific customer requirements and seamlessly integrated into a continuous production process.

PROFITABLE

The proprietary Multi-Batch process developed by AVA-CO2 allows efficient, profitable and sustainable operation of HTC plants on an industrial scale.

HTC–TECHNOLOGY WITH A FUTURE

Hydrothermal carbonisation (HTC) converts biomass into CO_2-neutral coal, by a thermo-chemical, anaerobic process. The highly efficient, exothermic process takes place in an aqueous solution under pressure at a temperature of 220° C.

During that process hydroxide anions (HO^-) and hydrogen cations (H^+) are split off from the organic molecules and combine as water (H_2O). The dehydrated organic molecules merge to form many different hydrocarbon compounds. This process is very similar to carbonisation in nature.

A wide range of different dry and damp biomass is suitable for processing by HTC. The AVA-CO2 plants show a carbon efficiency of more than 90% and a net energy balance exceeding 70%.

OUR RANGE OF SERVICES

AVA-CO2 helps customers to successfully implement HTC Projects around the globe. AVA-CO2 experts support customers, starting with the planning, moving on to implementation and finally to operate and monitor the plants. The Multi-Batch process developed by AVA-CO2 is robust, reliable and highly efficient and permits seamless integration into the customers' continuous production process.

OUR PRODUCTS

AVA cleancoal is a high-value, CO_2-neutral source of energy with a high heating value, qualifying for CO_2 certificates. The product can be easily stored and transported. The high ash melting point, the high carbon content, the outstanding alkali index and its flexibility of use as powder, or coal pellets are additional advantages.

AVA biochar is an important component in soil improvement and is suitable for sustainable treatment of dry and nutrient-poor soils. The product binds CO_2 in the long-term, and in this way helps to reduce greenhouse gas emissions.

CO_2-NEUTRAL

The AVA-CO2 HTC process transforms biomass into CO_2-neutral AVA cleancoal, in a thermo-chemical, anaerobic process.

ABOUT AVA-CO2

AVA-CO2 offers world-wide solutions to convert biomass into a sustainable source of energy. As a pioneer in hydrothermal carbonisation (HTC), AVA-CO2 plans, implements and operates HTC plants on behalf of its customers. These facilities turn plant residues efficiently and profitably into high grade CO_2-neutral biocoal or CO_2-negative biochar.

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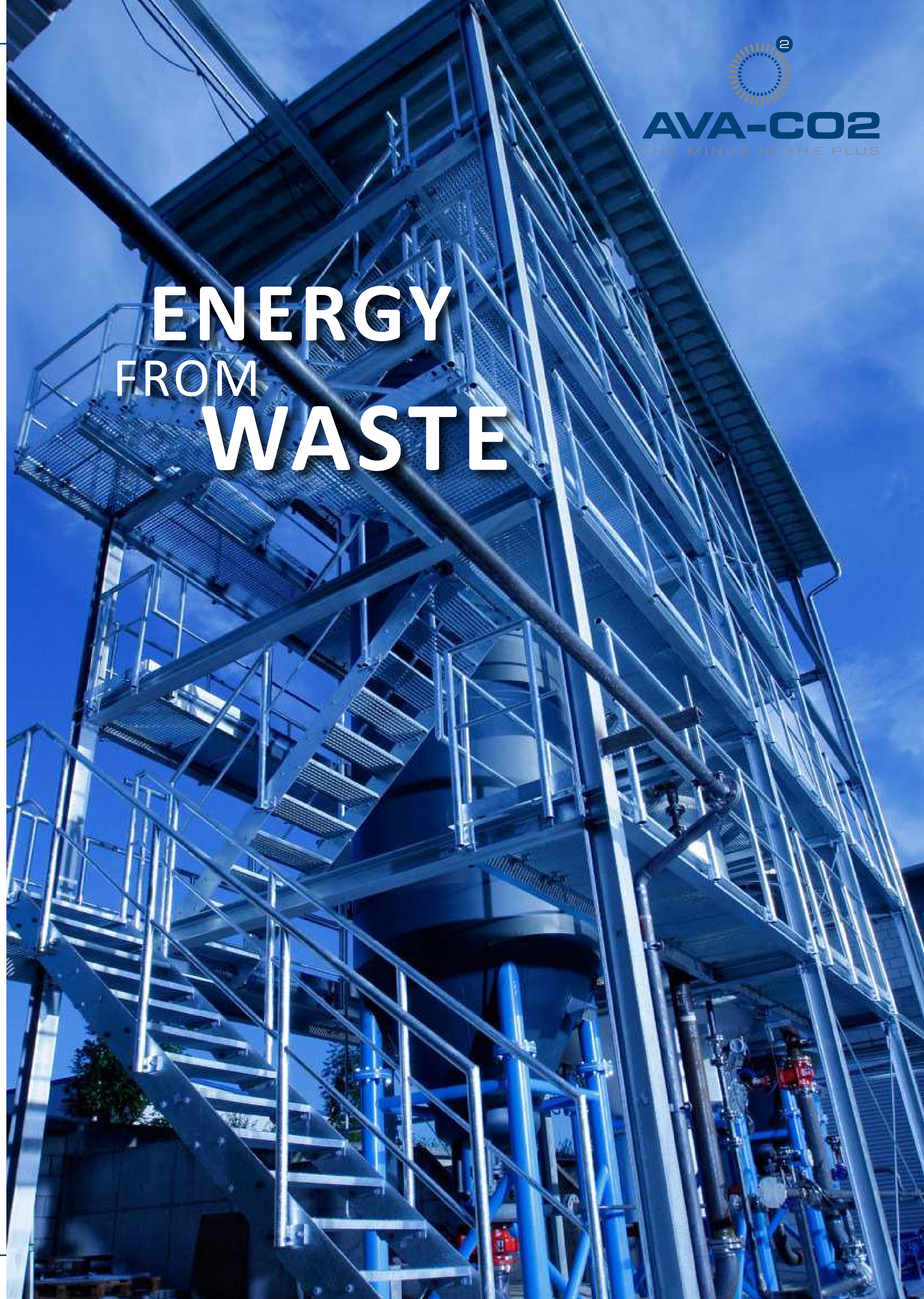

ABOUT US

AVA-CO2 is a pioneer of hydrothermal carbonisation (HTC).

By putting into operation the world's first demonstration plant on an industrial scale in 2010, the company has made the HTC technology ready for industrial use.

Besides the utilisation of biogenic residues AVA-CO2 has also specialised in the efficient and profitable utilisation of waste flows such as sewage sludge, the organic fraction from bio-waste containers and plant residues to produce CO_2-neutral HTC-coal.

PIONEER

Since October 2010 AVA-CO2 operates the world's first industrial-scale HTC demonstration plant. In 2012 AVA-CO2 has established another milestone by putting into operation the world's first commercial industrial HTC-plant.

SEWAGE SLUDGE

Hydrothermal carbonisation of sewage sludge has a much better energy and CO_2-balance compared to conventional thermal drying. An additional advantage is the complete sanitation of the sewage sludge during the HTC process.

Each year millions of tons of sewage sludge accumulate throughout the world.

Due to hygienic and soil ecological reasons an ever increasing part of it must be thermally processed.

To be processed thermally sewage sludge must be dried beforehand. A recent research study conducted by the Zurich University of Applied Sciences (ZHAW) as well as our own research, have shown that hydrothermal carbonisation has a significantly better CO_2 and energy-balance compared to conventional thermal drying processes.

In addition, during the HTC-process the sewage sludge is completely sanitised, vastly simplifying storage and transport of HTC-coal.

BIO-WASTE CONTAINER

Organic residues from households and the restaurant and catering industry represent a great energetic potential which is today still largely unused.

In Germany alone several million tons of organic residues from households accumulate every year.

This material is still unused as a source of energy. Biogenic waste from the restaurant and catering industry is not adequately used either, despite offering great energetic potential.

AVA-CO2 hydrothermal carbonisation plants use these valuable residues efficiently and turn them within a few hours into a high quality source of energy in the form of biocoal.

Hydrothermal carbonisation is an ideal, hygienic and CO_2-efficient solution to turn the organic fraction of bio-waste containers into CO_2-neutral energy.

PLANT RESIDUES

Green waste from roadside vegetation, fallen leaves, clippings and similar biomass accumulate throughout the year due to general landscaping. The methods of utilisation of this waste common today are mostly expensive and energetically inefficient.

Hydrothermal carbonisation now offers the possibility to utilise such biomass in an efficient energetic manner.

Independent studies show that due to its superior utilisation of organic matter HTC has a better carbon footprint compared to other utilisations available today.

HTC is able to transform rather problematic biomass into high quality biocoal and thus making a valuable contribution to the CO_2-neutral energy production.

AVA Biomass

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GENERALITIES

As a simplification, Hydro-Thermal Carbonisation (HTC) is a chemical reaction by which hydroxyde anions (HO^-) and hydrogen cations (H^+) are extracted from organic molecules to recombine as water. The dehydrated organic molecules recombine in a host of different polymers, enriched in carbon, in a process much like the natural coalification process. As water is a most stable molecule, the removal of each water molecule from the biomass organic molecules frees some energy, making the HTC-reaction an exothermic process.

The HTC-reaction will therefore work best with feedstock rich in hydroxide anions such as sugars, starches, cellulose or hemicellulose, and less well with feedstock poorer in the same hydroxide anions, such as proteins or lignin.

In addition to its chemical composition, the physical structure of a particular biomass material may affect its suitability for HTC. In particular, lignin gives wood its structural strength, but its fibre structure slows down the HTC-reaction.

SUITABLE BIOMASS

As a simplification, biomass rich in cellulose and hemicellulose and poor in lignin is the ideal feedstock.

Biomass rich in protein (such as grains) is also most suitable and generally yields very high quality biocoal.

The following biomass types can therefore be considered very well suited to the HTC-process (illustrative and non-exhaustive list):

- Grassy materials (straw, corn stalks, bagasse, etc.)
- Spent grains (from distilleries or breweries), malting waste
- Waste coffee grounds or spent tea leaves
- Palm fronds and other residue from oil palm plantations, waste from other oil-producing plants (rapeseed, soya bean, sunflower seeds, olives, etc)
- Sugar beet, etc.
- Fruit industry waste (in particular citrus citrus peel and pulp)
- Cereal husks (rice, wheat, etc)
- Disposal of waste-water sewage sludge or digestor sludge (n.b. resulting biocoal is of a lesser quality)

LESS SUITABLE BIOMASS

Meat by-products are generally unsuitable as a feedstock for the HTC-process, although it seems to be acceptable to include up to 20% meat waste in an otherwise vegetal feedstock.

Animal waste may present problems such as high potash, nitrate or ammonium content (chicken manure for instance). Others such as horse manure are, however, well suited.

Wood chips, bark, saw dust and other woody waste make difficult feedstock because of their high lignin content.

Greencut (twigs, bark, etc) reacts much slower and yields an unhomogeneous end-product. It can also be contaminated with sands and stones, necessitating pre-treatment steps.

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AVA cleancoal®

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OVERVIEW

AVA cleancoal is a high grade, CO_2-neutral energy source produced from biomass by means of hydrothermal carbonization (HTC). Carbon is extracted from the biomass in a highly efficient, exothermic process. The reaction takes place under pressure at 220°C in an aqueous suspension. The transformation from biomass to end product takes place in just a few hours.

AVA cleancoal can be produced from many different types of wet, humid or dry biogenic waste.

TECHNICAL DATA

Calorific value:	25 MJ/kg Hu (DIN)
Carbon content:	65 %
Fixed CO_2:	2.4 kg*
Particle size:	99 % < 300 µm
Ash melting point:	1,400° C
Sulphur value:	0.1 % - 0.5 %
Toxic substances:	Within the limits applying to foodstuffs

The results of the inorganic analysis of AVA cleancoal depend on the biomass used to produce it. The above mentioned reference values were determined using brewers spent grains. All data are per kilogram of AVA cleancoal.

ADVANTAGES

- CO_2-neutral energy source.
- Higher energy value than lignite.
- Stable, hydrophobic product with outstanding storage and transport characteristics.
- Low transport costs per MJ due to high energy density.
- Excellent combustion characteristics.
- Very low toxic substance and heavy metal values. These values are within the limits stipulated for foodstuffs and are therefore harmless.
- High ash melting point.
- Low nitrous oxide (NOx) values at combustion due to the excellent combustion behaviour of AVA cleancoal.
- Provides entitlement to CO_2-certificates.
- No expensive special burners required. A significant advantage compared to direct combustion of biomass.

* The carbon content in one kilogram of AVA cleancoal is approx. 65 %, i.e. 650 grams. In the combustion process, each carbon (C) atom combines with two oxygen (O) atoms to form CO_2. Carbon atoms have a specific weight of 12, while the specific weight of oxygen is 16. Consequently, a CO_2 molecule will have a specific weight of 44 (2 x 16+12). The weight of the CO_2 generated in the combustion process is therefore 3.666 (44/12) times higher than that of the burnt carbon. Accordingly, the weight of the CO_2 fixed in one kilogram of AVA cleancoal is approx. 2.4 kg (650 grams x 3.666).

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Hydrothermal Carbonisation

Energy from Biomass

Thomas M. Kläusli
CMO
AVA-CO2

February 2013

WHAT IS HTC?

- ✓ HTC basically copies the natural process of coalification – just much faster (2-4 hours)
- ✓ HTC is a thermal-chemical process NOT a biological process
- ✓ HTC is a wet process and most suitable for wet biomass with a TS of 25 -50% DMC
- ✓ HTC works at temperatures of approx. 220 degrees C and pressure levels of approx. 220 bar
- ✓ HTC can treat biomass of cellulose, hemi-cellulose and protein nature –not lignin
- ✓ HTC is very flexible in terms of feedstock
- ✓ HTC is the most efficient process to turn wet biomass into a solid form of energy (CO_2-neutral biocoal)
- ✓ HTC is commercially available

WHAT IS HTC?

Natural process HTC is a kind of «aqueous carbonisation» that uses pressure and heat to release carbon from biomass under pressure and heat. HTC is very similar to the natural process of coal formation.

Bergius Friederich Bergius first described HTC in 1913, for which he won the Nobel Prize in 1931.

Biocoal Hydrothermal Carbonisation can convert different types of wet biogenic waste materials into high-quality CO_2-neutral biocoal within a short time.

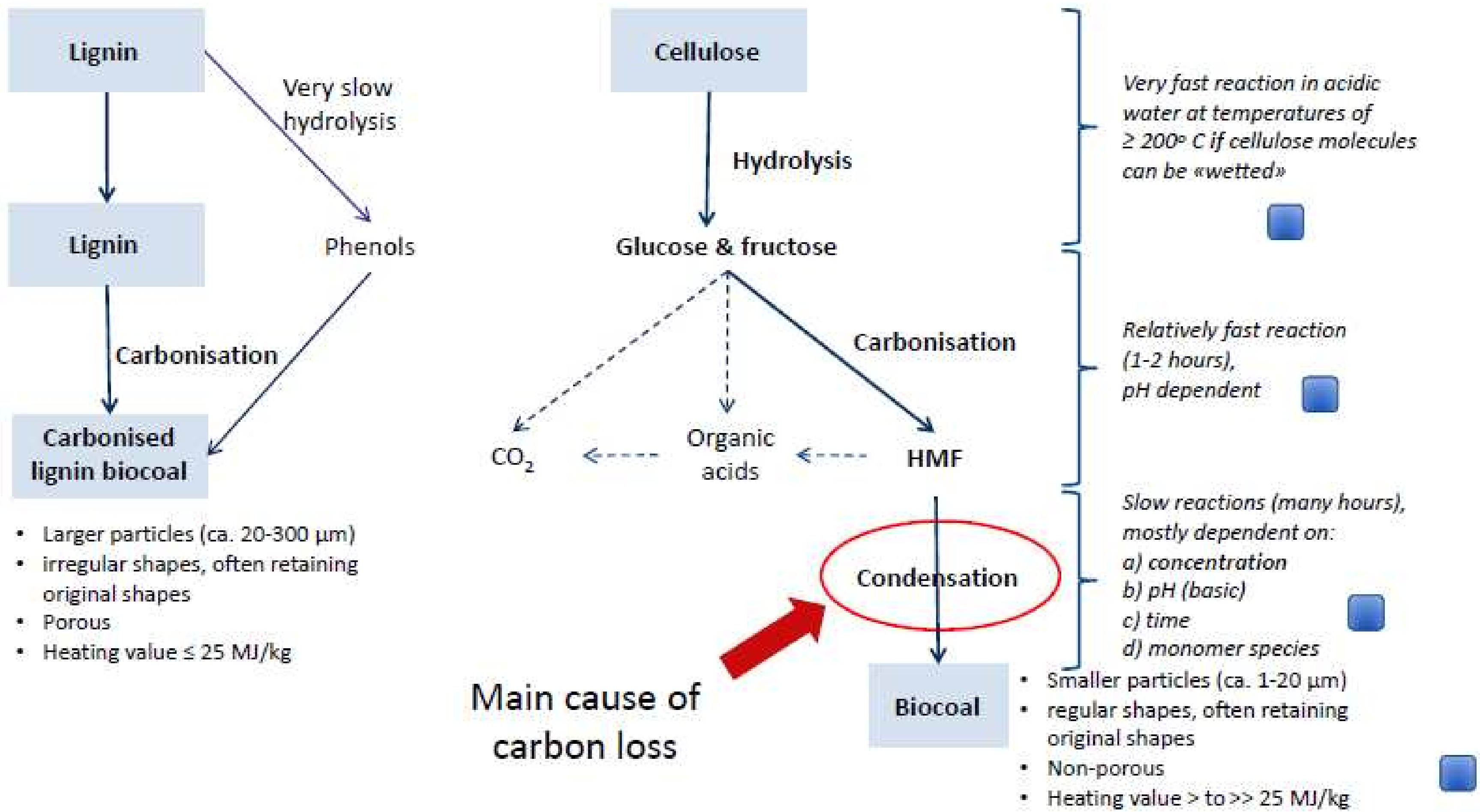
Biochar Alternatively, biochar can also be generated through the HTC-process. A product similar to humus which can be used for soil enhancement and to capture and store CO_2.

Waste Disposal Biomass waste is effectively disposed of producing typically biocoal with lower heating values, but freed from bacteria and other undesirable chemicals such as hormones.

A SHORT HISTROY OF HTC

1913	Friederich Bergius discovers the HTC-principle.
1931	Friederich Bergius wins the Nobel Prize.
1991	Dr. Andrea Kruse from the Karlsruhe Institute of Technology starts researching HTC.
2006	Prof. Markus Antonietti publishes a study on HTC.
2009	AVA-CO2 is founded. AVA-CO2 puts into operation pilot plant K3-335.
2010	With HTC-0, AVA-CO2 puts into operation the first plant worldwide to run on an industrial scale.
2011	Industrial scale test batches conducted on HTC-0 with various types of biomass
2012	With HTC-1 AVA-CO2 constructs the worlds first commercial HTC industrial plant.
2013	Further HTC-plants implemented by AVA-CO2.

WHAT IS HTC?



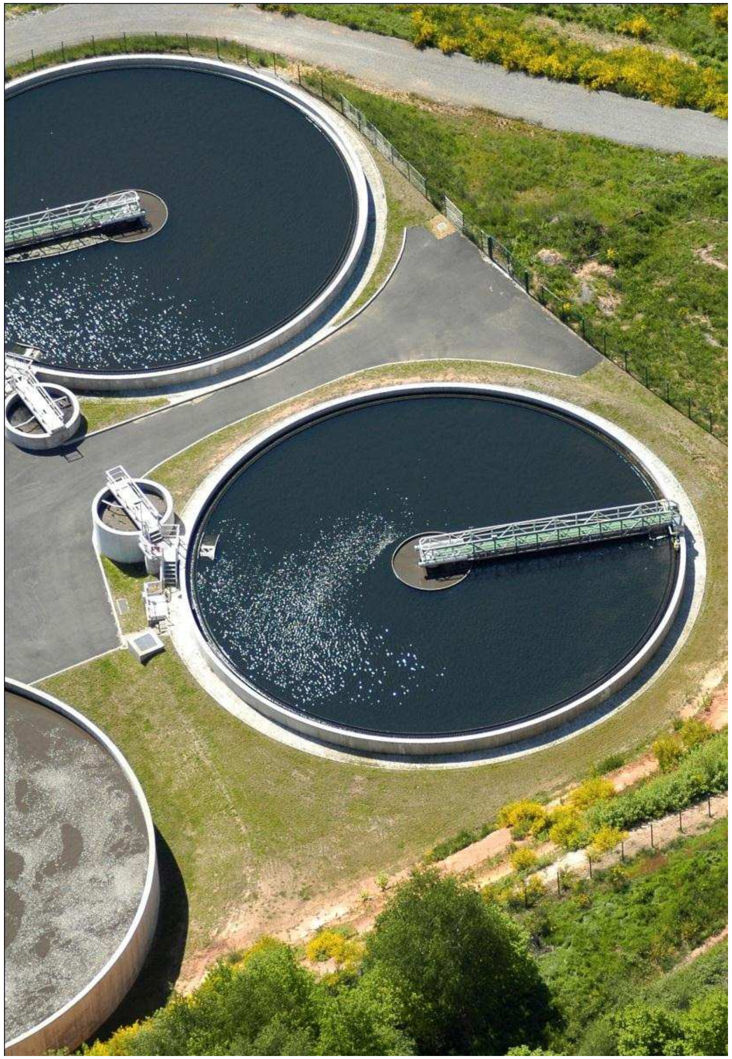
Lignin
Very slow hydrolysis
Lignin
Phenols
Carbonisation
Carbonised lignin biocoal
Larger particles (ca. 20-300 µm)
irregular shapes, often retaining original shapes
Porous
Heating value ≤ 25 MJ/kg
Cellulose
Hydrolysis
Glucose & fructose
Carbonisation
CO_2
Organic acids
HMF
Condensation
Main cause of carbon loss
Biocoal
Smaller particles (ca. 1-20 µm)
regular shapes, often retaining original shapes
Non-porous
Heating value > to >> 25 MJ/kg
Very fast reaction in acidic water at temperatures of ≥ 200° C if cellulose molecules can be «wetted»
Relatively fast reaction (1-2 hours), pH dependent
Slow reactions (many hours), mostly dependent on:
a) concentration
b) pH (basic)
c) time
d) monomer species

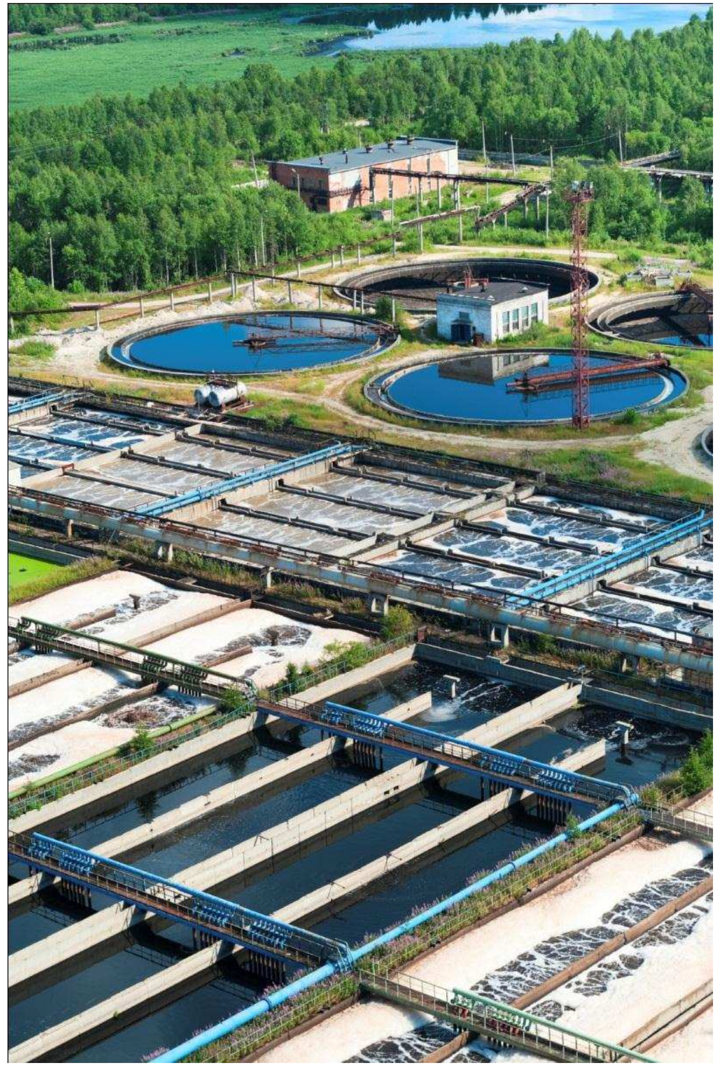
WHAT BIOMASS CAN HTC TREAT?

As a simplification, biomass rich in **cellulose** and **hemicellulose** and poor in lignin is the ideal feedstock. Biomass rich in **protein** (such as grains or sewage sludge) are also most suitable and generally yield very high quality biocoal.

Hydro-Thermal Carbonisation (HTC) is a chemical reaction by which hydroxyde anions (HO-) and hydrogen cations (H+) are extracted from organic molecules to recombine as water. The dehydrated organic molecules recombine in a host of different polymers, enriched in carbon, in a process much like the natural coalification process. As water is a most stable molecule, the removal of each water molecule from the biomass organic molecules frees some energy, making the HTC-reaction an exothermic process. The HTC-reaction will therefore work best with feedstock rich in hydroxide anions such as sugars, starches, cellulose or hemicellulose, and less well with feedstock poorer in the same hydroxide anions, such as lignin.

HTC FOR SEWAGE SLUDGE? - YES

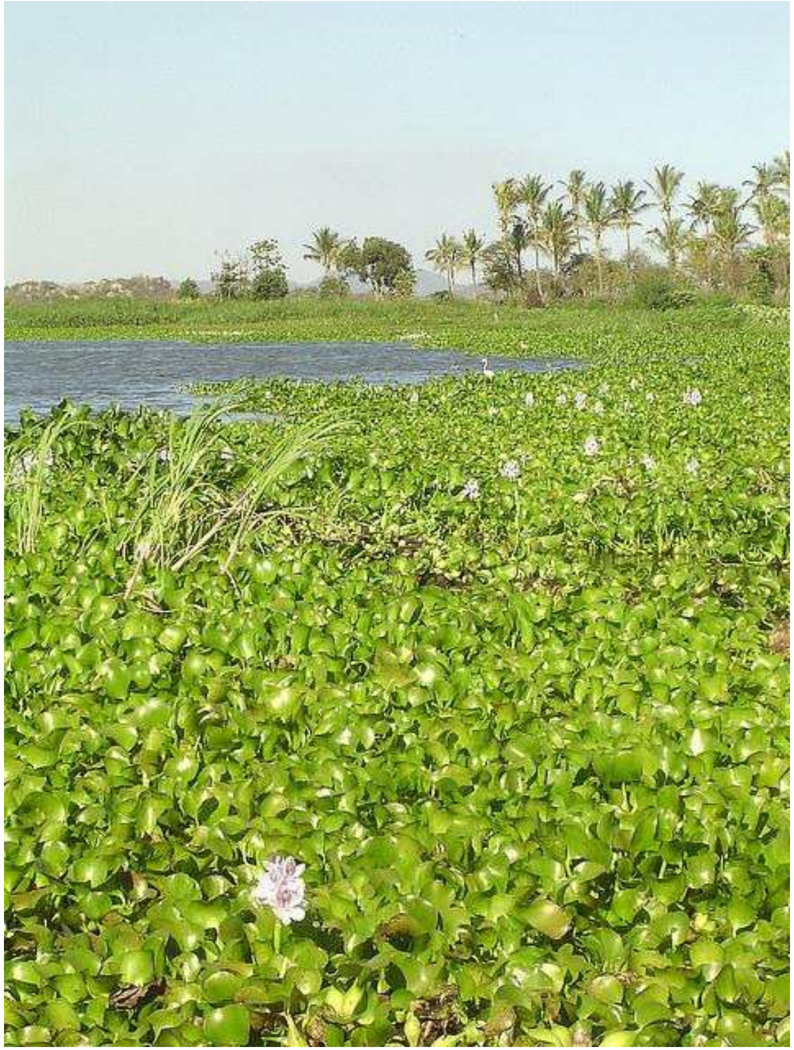




HTC FOR ORGANIC WASTE? - YES

HTC FOR GREEN CUT? - YES

HTC FOR WATER HYACINTH? - YES



HTC FOR MISCANTHUS? - YES

HTC FOR REEDS? - YES

HTC vs. BIOMASS COMBUSTION

HTC is much better than direct biomass combustion. Why? Below find some reasons:

- **AVA cleancoal has a much better combustion behaviour**
- **Ash melting point (Alkali-Index) of AVA cleancoal is much higher**
- **Energy balance of HTC vs. thermal drying is much better**
- **Chloride levels in AVA cleancoal are much lower than in the biomass**
- **Storage and transport for AVA cleancoal is more efficient due to high energy density**

INTEREST IN HTC ACROSS INDUSTRIES

Heineken

AIR LIQUIDE

HOLINGER

ALSTOM

Nestlé

SÜDZUCKER

SAB MILLER

NEXUM ENERGY CORP.

PITTINI PITTINI-STAHI

CEMEX

VEOLIA UMWELTSERVICE

erzo

REMONDIS®

LADURNER UMWELTTECHNIK - ECOLOGIA

ZIEMANN
ZIEMANN GROUP

DSM
BRIGHT SCIENCE. BRIGHTER LIVING.

AWN

BSR

GETEC AG

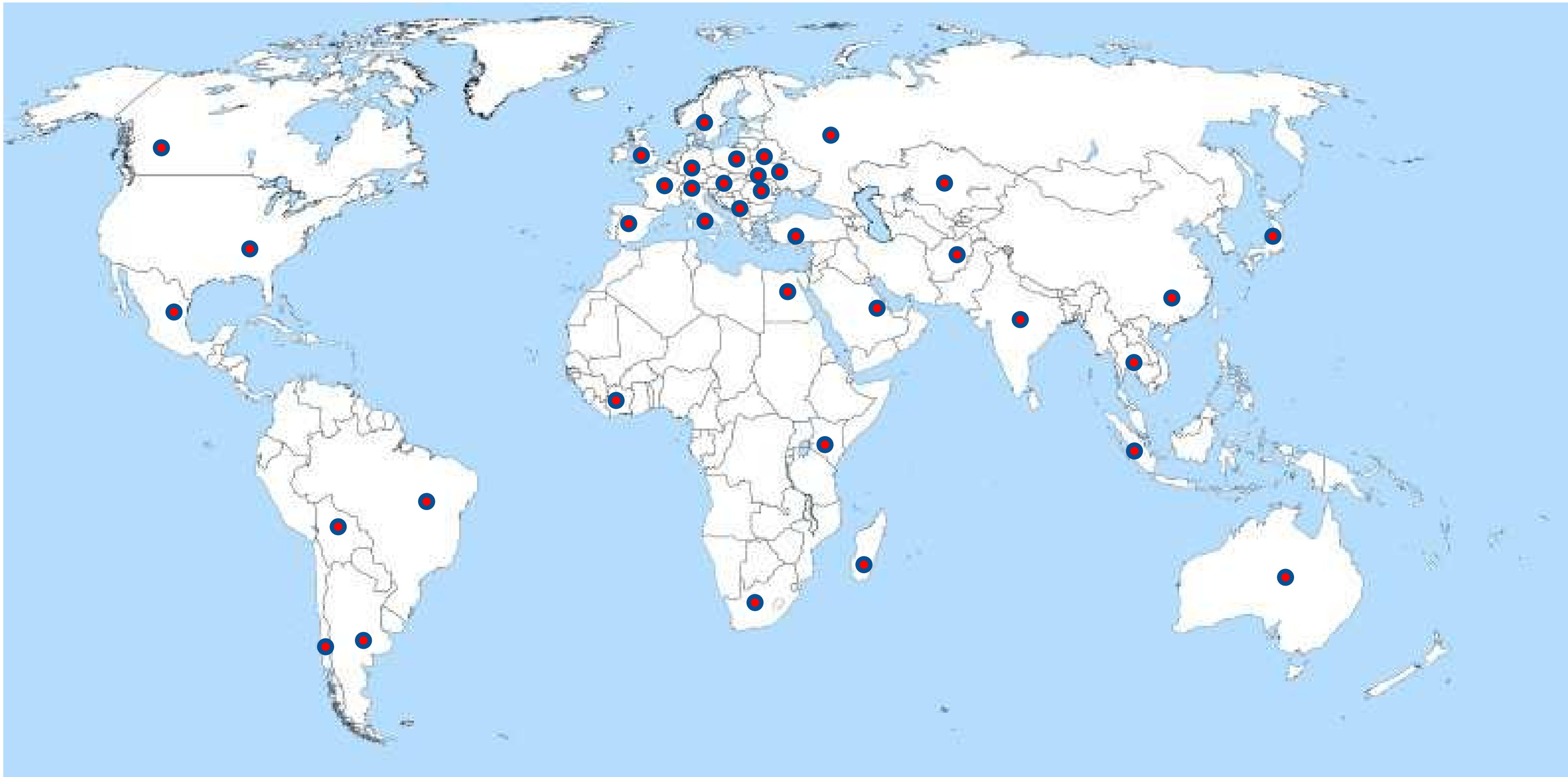
TATA
TATA CHEMICALS EUROPE

SALZGITTERAG
Stahl und Technologie

Rytec

HEIDELBERGCEMENT

GLOBAL INTEREST IN HTC



WHY HTC?

Profitable	AVA-CO2 HTC-plants achieve excellent returns.
Flexible and scalable	High flexibility in different biomasses and scalable plant sizes.
Unique	HTC-plants are able to make use of a wide range of biomass. HTC has the best energy balance of all existing technologies. HTC can handle wet biomass without pre-drying.
Simple	The end products AVA cleancoal and AVA biochar are easy to store and transport. They do not require additional drying. HTC Coal is hydrophobic.
Compatible	AVA cleancoal can be used in existing coal burning plants.
Sterile	HTC end products are due to the processing temperature of 220^0 C and pressure levels of 22 bar sterile.
Robust	HTC-plants can be implemented with existing technologies.
Ethical	AVA-CO2 HTC facilities use biomass waste. Therefore there is no competition with food production.

INDUSTRIAL PARK IN KARLSRUHE

Pilot plant K3-335

Industrial scale plant HTC-0

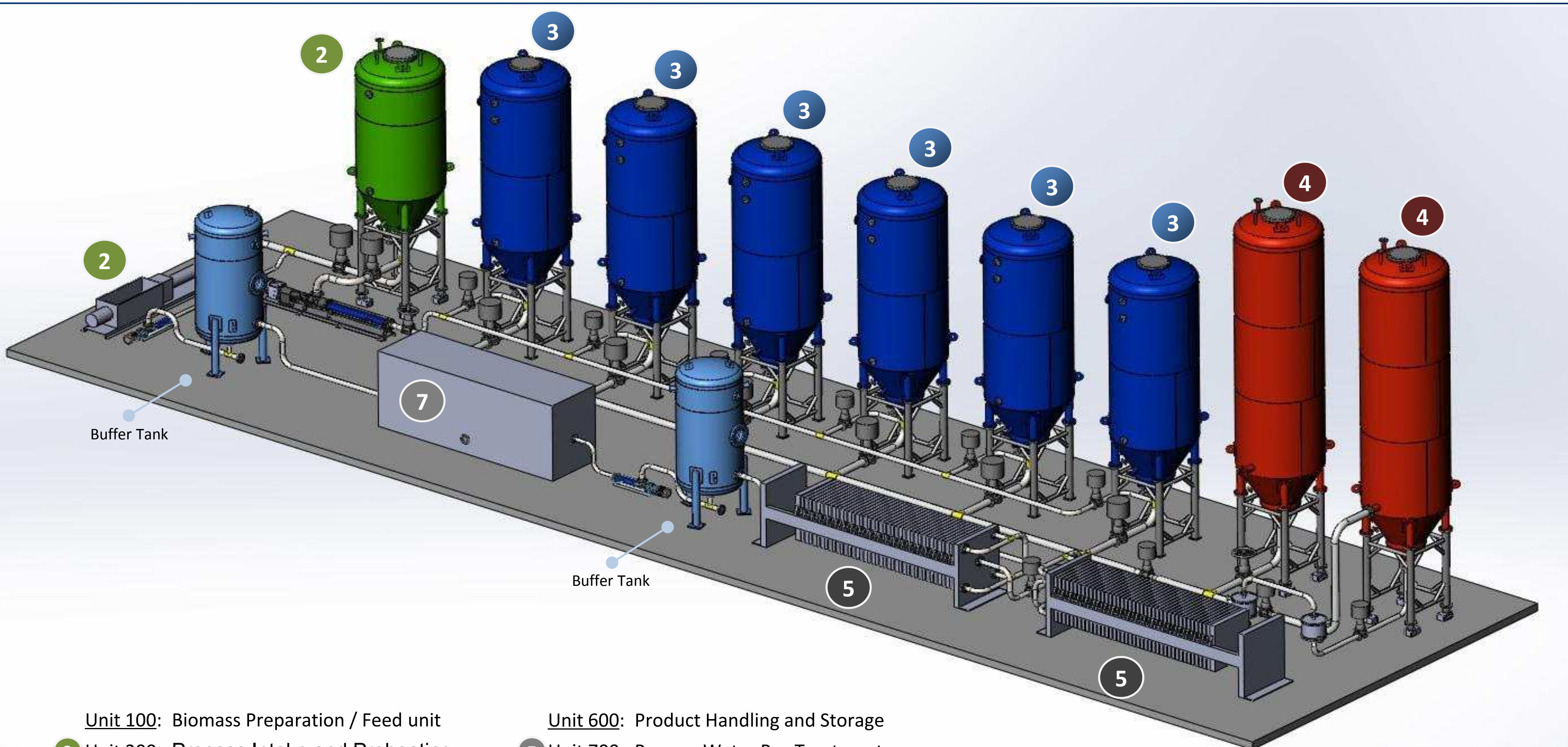
WORLDWIDE FIRST COMMERCIAL HTC-PLANT – RELZOW, GERMANY

Customer:	Eurosolid
Plant Size:	2 HTC-Reactors (Phase I) 6 HTC-Reactors (Phase II)
Biomass Feedstock:	Reed plants from agricultural wetlands 8'000 t/y (4’000 DM t/y) (Phase I)
Biocoal Production:	2’664 t/y (Phase I)
Brief Description:	In March 2011, a center for renewable energies was established in Relzow, Murchin (Mecklenburg-Vorpommern) on the grounds of the former GDR military depots (total 67 ha). Besides HTC the operator focuses also on wind and solar energy.

HTC-1 IN RELZOW

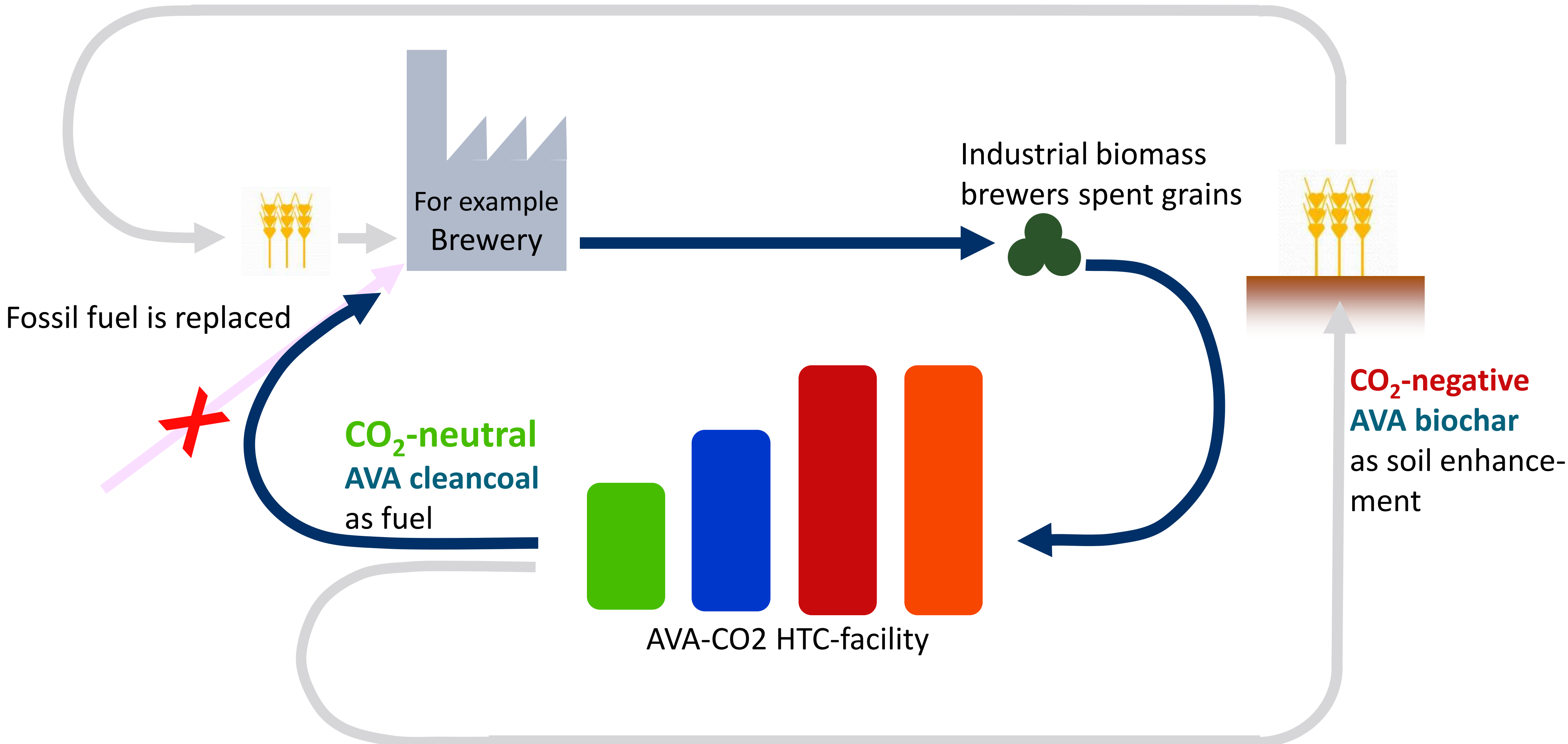
HTC-1 IN RELZOW

AVA-CO2 HTC-PLANT: THE PROCESS UNITS



Unit 100: Biomass Preparation / Feed unit
2 Unit 200: Process Intake and Preheating
3 Unit 300: HTC Process Reactors
4 Unit 400: Process Outlet and Cooling
5 Unit 500: Product and Water Separation
Unit 600: Product Handling and Storage
7 Unit 700: Process Water Pre-Treatment
Unit 800: Waste Water Treatment
Unit 900: Utilities

WHAT EFFECTS DOES HTC HAVE ON THE CO_2 CYCLE?

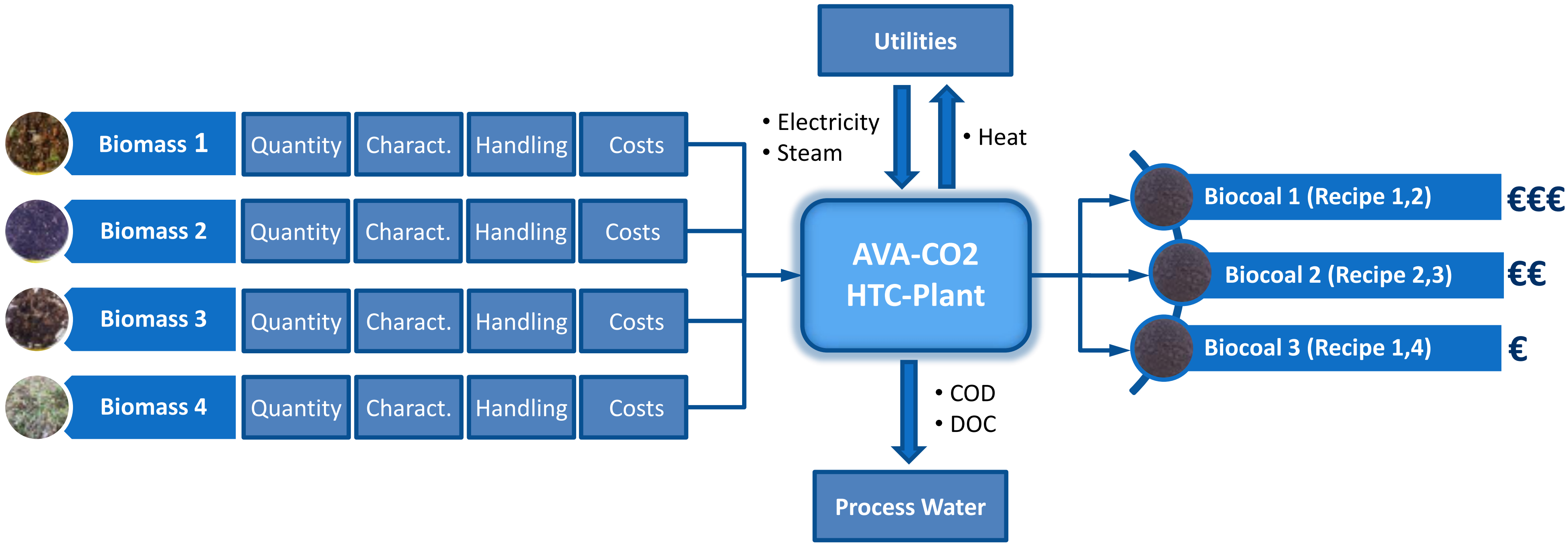


WHO IS AVA-CO2?

1	First commercial plant currently under construction.
2	Research cooperations with two universities: ZHAW and KIT.
25	25 employees from 6 countries in Zug and Karlsruhe.
87	Visitors from 87 different countries to our website.
2009	AVA-CO2 Schweiz AG founded.
2010	HTC-0 - October 2010: the first industrial-scale HTC demonstration plant put into operation.
2012	HTC-1 - October 2012: commissioning of the world's first commercial HTC-Plant
100%	100% privately owned.

AVA-CO2 HTC-APPLICATION DIAGRAM

The following graphic shows the AVA-CO2 HTC-Applications from the biomass into the system until the end product AVA cleancoal®



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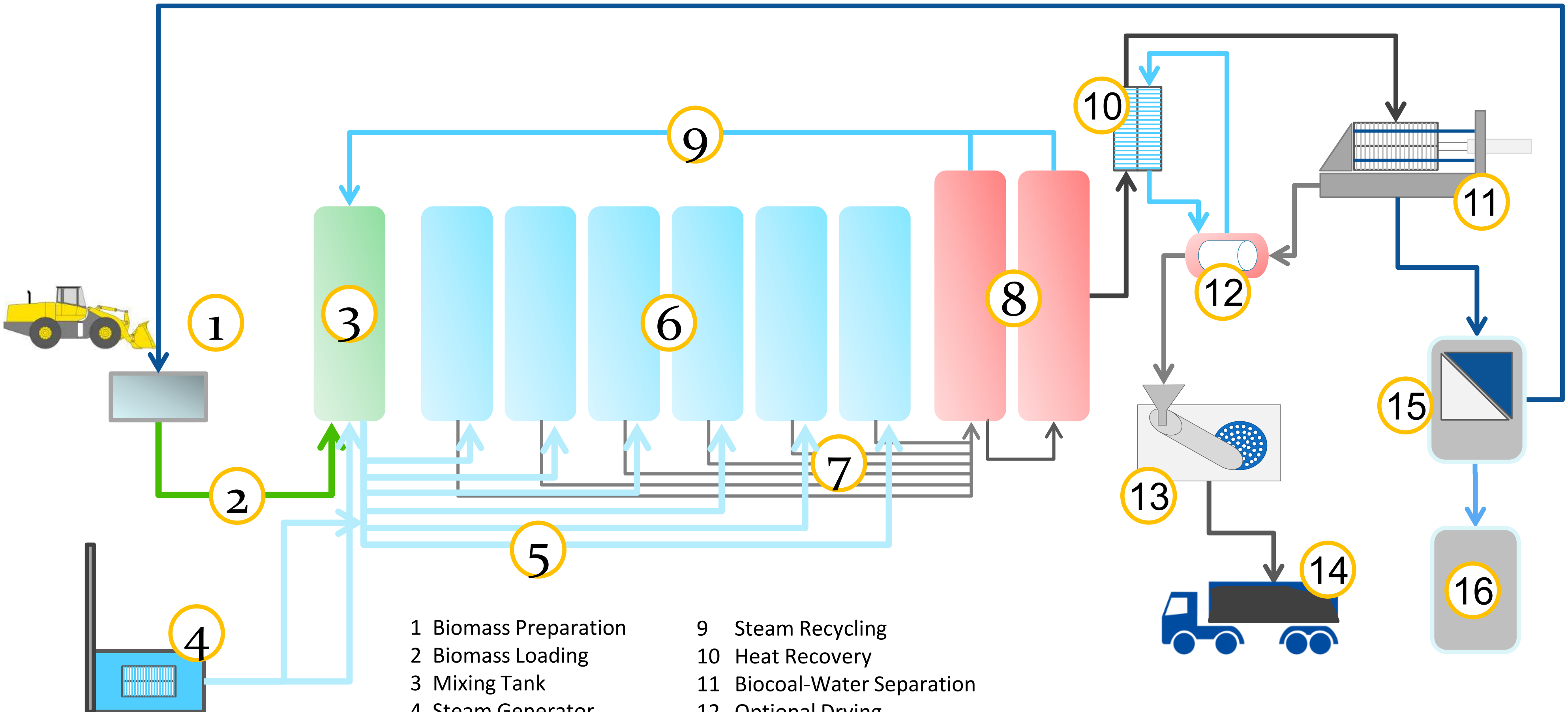
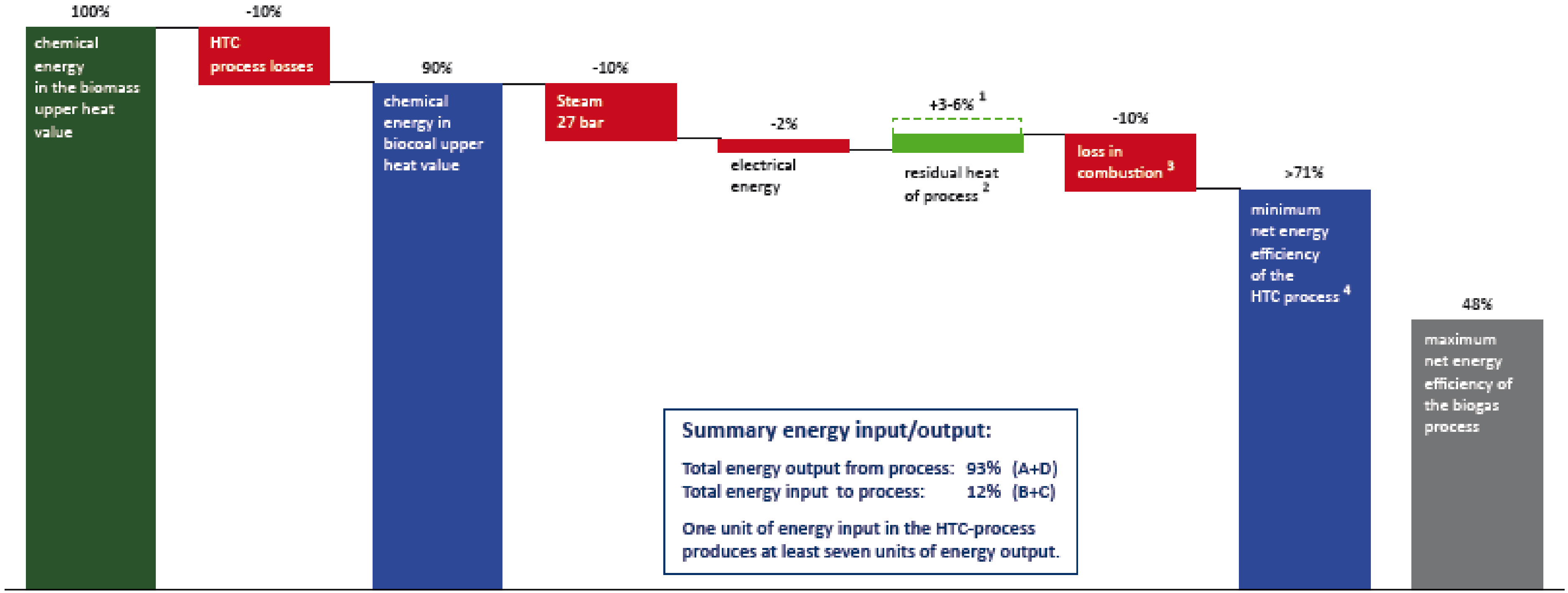
ADDITIONAL INFORMATION

AVA-CO2 HTC PROCESS DESIGN



1 Biomass Preparation
2 Biomass Loading
3 Mixing Tank
4 Steam Generator
5 Direct Steam Injection
6 HTC Reactors
7 Biocoal Transfer
8 Steam Recovery
9 Steam Recycling
10 Heat Recovery
11 Biocoal-Water Separation
12 Optional Drying
13 AVA cleancoal confectioning
14 AVA cleancoal logistics
15 Process water treatment
16 Use of remaining process water

SIMPLE ENERGIEBILANZ



Summary energy input/output:

Total energy output from process: 93% (A+D)
Total energy input to process: 12% (B+C)

One unit of energy input in the HTC-process produces at least seven units of energy output.

Assumptions

The energy efficiency diagram is illustrative and includes the combustion of biocoal in a boiler. The values may change depending on the biomass used in the HTC-process. The figures are based on brewers spent grains as a biomass with a dry matter content of 33%. This overview does not include the loss of grey energy. However, this is typically very small and amounts to 1-2%. We assume that biocoal with 30% of residual moisture is burnt directly. If a higher dry matter content is required, this can be achieved through additional thermal drying, although this would have a direct effect on the energy efficiency of the HTC-process.

Notes

1) Depends on local situations. Potential is 6%.
We go on the basis that only 50% of the residual heat can be used.
2) Approx. 90° Celsius water - provided that the dry matter content of the biomass is 33%.
3) The assumption is a 30% residual moisture content of the biocoal, 4% ash content and boiler not equipped with a condensing economizer. Potentially, this loss can be reduced to 2-3% with a condensing economizer.
4) 71% is the minimum net energy efficiency. Potentially, this value can be increased to 79%.
As a comparison, the maximum energy efficiency of a biogas plant is 48%.

KEY FIGURES*

- Investment: € 6-10 Mio. (turn key)

- Operating time: 300 days per year (7’200 operating hours = 82% capacity utilisation)
- Batches per year: 7.200 (4 Batches per Reactor and day x 300 days x 6 Reactors)

- Biomass: 12’000 t/y TS (1.7 t TS per Batch x 7’200 Batches)
- Biocoal production: 8’200 ton per year (dry matter)
- Heating Value (HHV): 25-30 GJ/t
- Energy Production: 225 TJ

- Energy demand (steam): 5,7 GW/h (1,1 – 1,5 t steam per batch = 0.8 MWh x 7’200 batches)
- Energy demand (electr.): 0,54 GW/h (0,075 MW/h per batch x 7’200)

- Process water: 32’000 m3 (3-6 m3 x 7’200)
- Space requirement: 2’000 m2
- Carbon Efficiency: > 90%
- Net Energy Efficiency: > 70%

* Assumption: Biomass with 25-30% DMC and a Plant with 6 HTC-Reactors (1 HTC-Line)