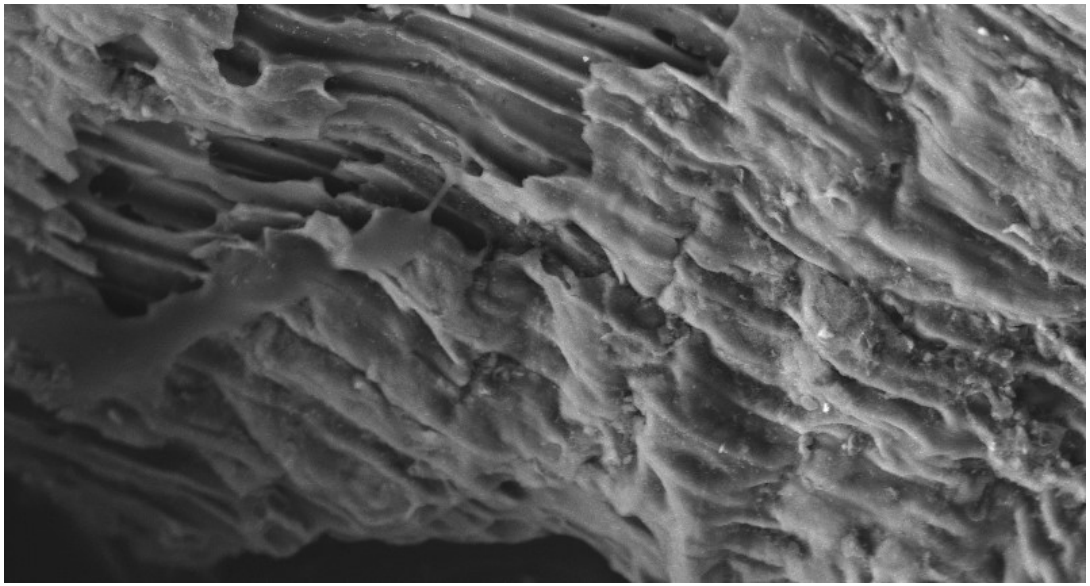
BIOCHAR –
JUST A BLACK MATTER IS NOT ENOUGH!



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Sulzbach-Rosenberg, Germany

What is biochar?
Definition

- Carbonaceous material
- Consists almost of carbon and ash (depends on feedstock
- oxygen an hydrogen were depleted
- Porous surface structure was formed
- Produced by thermochemical conversion with the absence of oxygen
- Derived from biomass
- Intent to be applied in soil
- Further application options are investigated too

Feedstock
Any kind of biogenic material

Biowaste

Garden- and greenwaste

Digestate

Manure

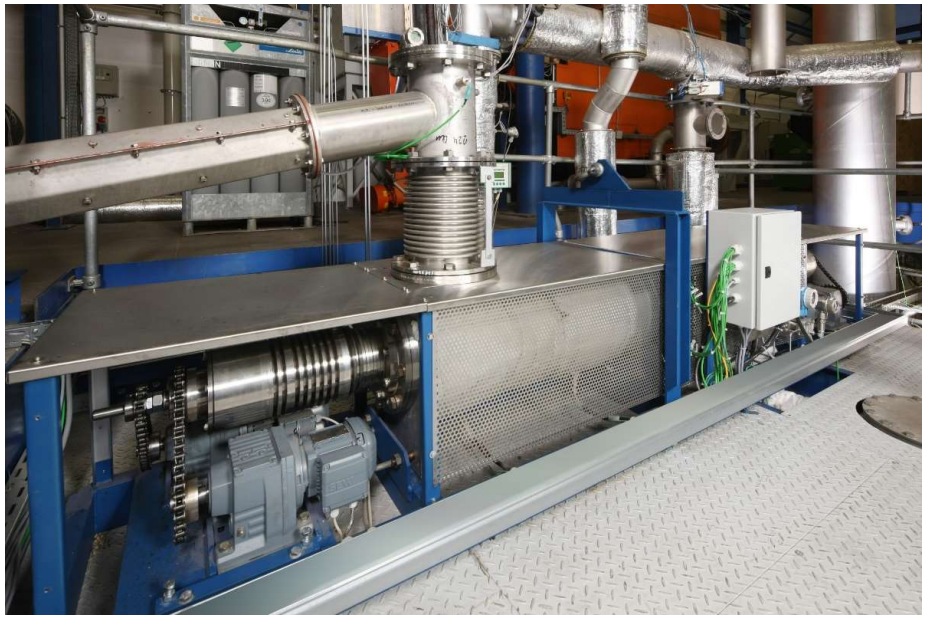
Straw

Hay

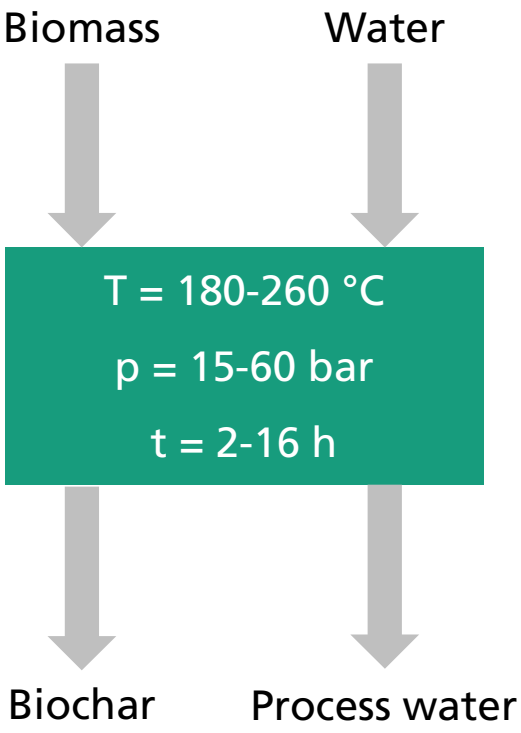
(Residual) wood

Skins of citrus fruits

From charcoal to biochar
From history to modernity



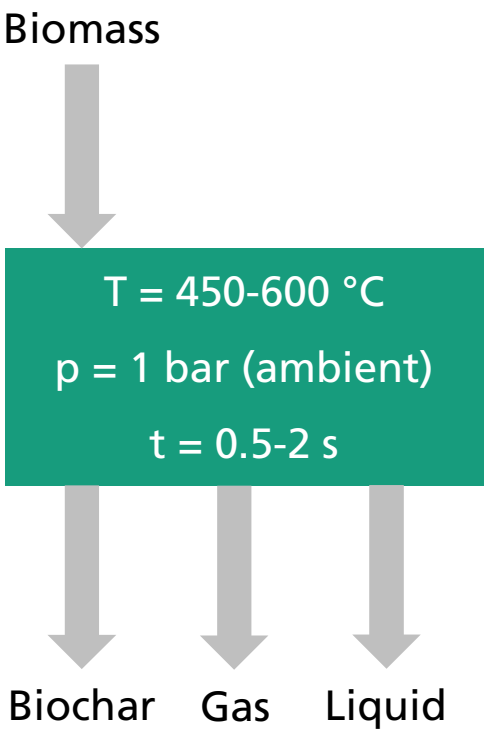
Processes
Hydrothermal Carbonisation (HTC)



- Feedstock biomass with high water content possible (no drying required)
- Biochar with high content of oxygen and hydrogen, but less PAH content
- Biochar has to be dried
- Large quantities of process water containing COD

SUNCOAL TerraNova energy
AVALON Industries ingelia
Avello Bioenergy

Processes
Fast pyrolysis



- Absolute dry and finely grounded feedstock is required
- Biochar with high content of oxygen and hydrogen
- High acidity of the oil as well as high water and oxygen content
- Lowest biochar yield compared to slow and intermediate pyloysis

btg biomass technology group

ENSYN

EMERGENT WASTE SOLUTIONS

KIT Karlsruher Institut für Technologie

Avello Bioenergy

bioliq®

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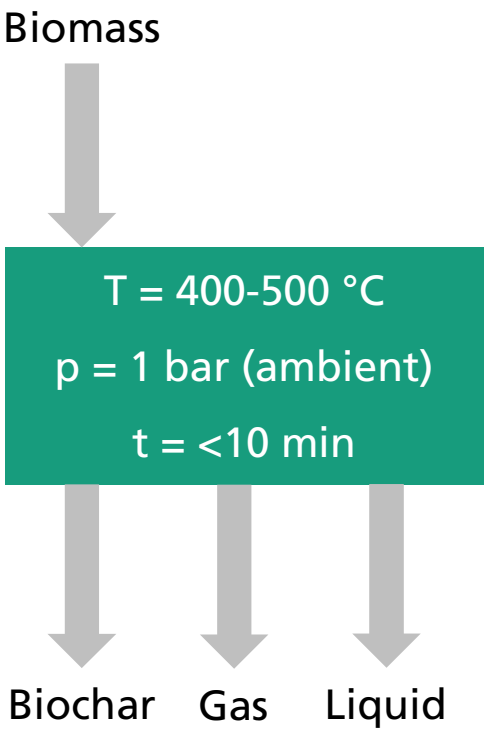
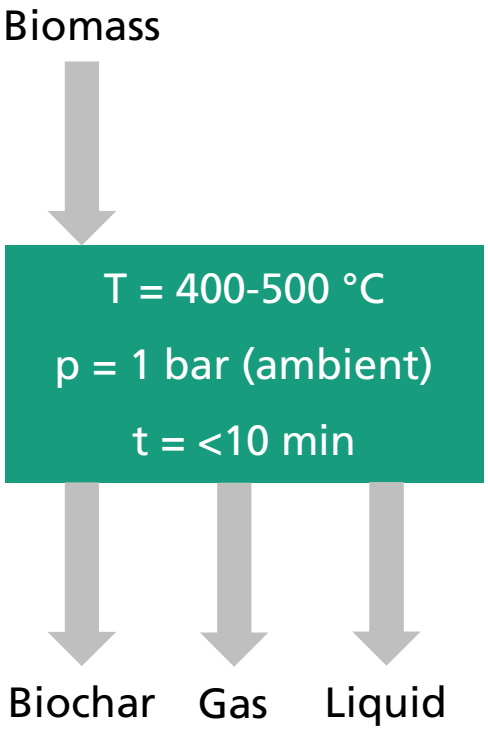
Processes
Intermediate pyrolysis



- Feedstock with a certain percentage of moisture is possible (up to 40%)
- Coarse, shredded, chopped or briquetted material
- Biochar with low content of oxygen and hydrogen
- Biochar yield is between slow and fast pyrolysis

Processes

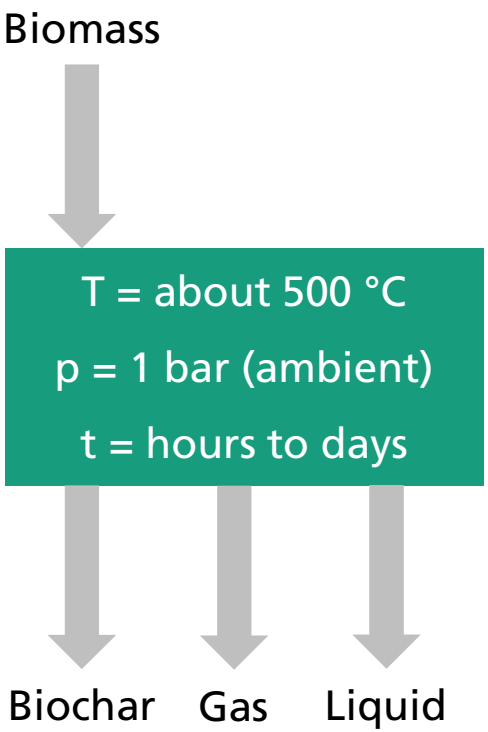
Intermediate pyrolysis combined with post reforming (Thermo-Catalytic Reforming TCR®)



- Feedstock with a certain percentage of moisture is possible (up to 40%)
- Coarse, shredded, chopped or briquetted material
- Biochar with very low content of oxygen and hydrogen
- Almost free of PAHs
- Oil has very low acidity as well as in water and oxygen content
- Biochar yield is between slow and fast pyloysis

susteen
sustainable resources from waste

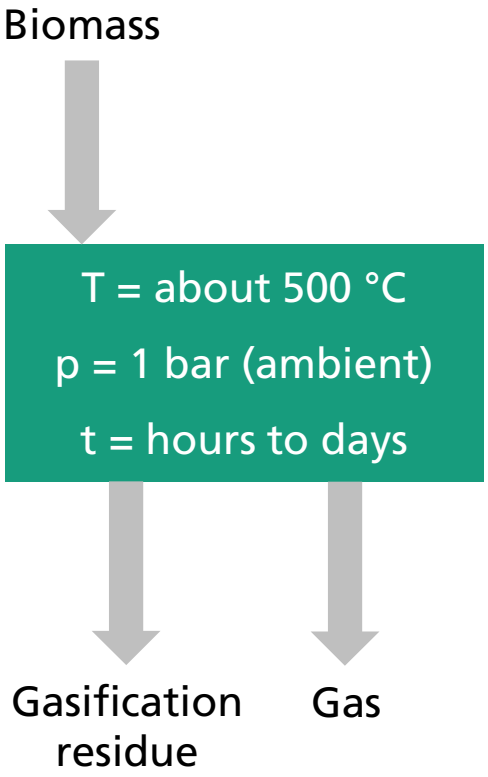
Processes
Slow pyrolysis



- Feedstock is shaped from briquette size to whole logs
- Usual process for charcoal production
- Pyrolysis vapors are almost used to heat the process
- Liquid products are acetic acid and alcohols
- Highest biochar yield compared to slow and intermediate pyloysis

Degussa process

Processes
Gasification



- Main product is the hydrogen and carbon monoxide rich gas
- Depending on gasification agent tar content can increase up to 100 g/m_N^3
- Process is optimized to reduce the carbon content in the solid gasification residue
- Gasification residue contains often higher concentration of PAHs (no biochar)

RENERGI

CHOREN*

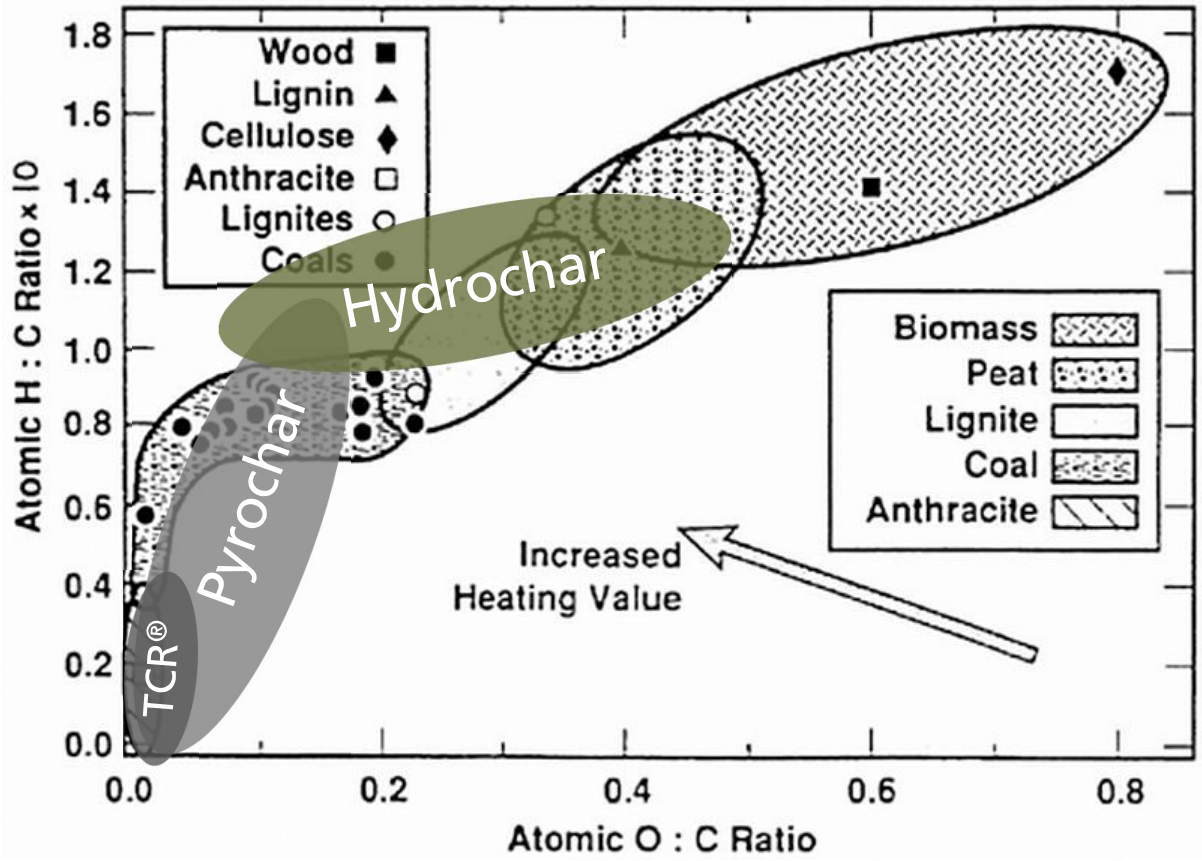
TOTAL BioTFuel

Fulcrum BIOENERGY

*insolvent

Fraunhofer UMSICHT

Properties
Degree of Carbonisation



Properties
Contaminants – polyaromatic hydrocarbons (PAH)

- PAH formation during pyrolysis by two fundamental mechanisms
  1. Pyrosynthesis:
     gaseous hydrocarbon radicals generated >500 °C undergo reactions to form polyaromatic ring structures
  2. Low temperature formation:
     through condensation, carbonization and aromatization at <600 °C

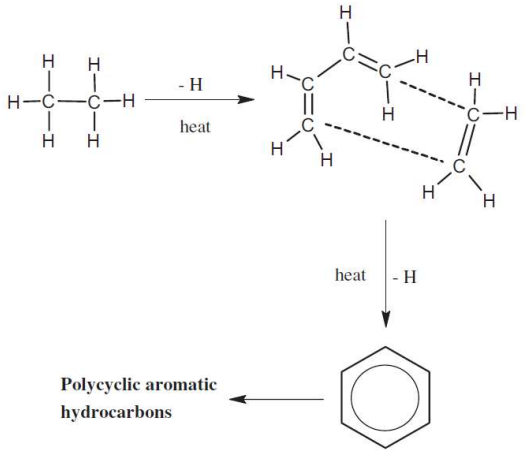


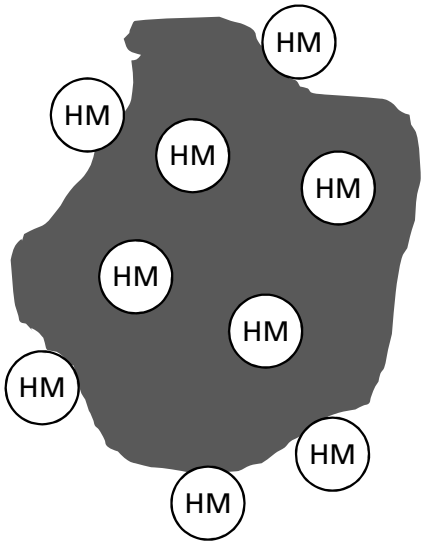
Fig. 2. Pyrosynthesis of PAHs starting with ethane.

- separation of gases from solids at high temperatures
- Controlled processes are needed

Source: IBI Biochar Course 2014

Properties
Contaminants – heavy metals

- More than 20 different kinds of heavy metals found in nature
- A few of them are toxic to human health (e.g. lead, cadmium, arsenic and mercury)
- Heavy metals are a part of the feedstock
- depending on the material different quantities are possible
  - Low quantities in biochar derived from wood
  - High quantities in biochar derived from sewage sludge
- Most of the heavy metals are concentrated during the conversion process
- Depending of process temperature some heavy metals are transferred into the gasphase, e.g. mercury
- Heavy metals are also found on the surface of biochar by adsorption effects



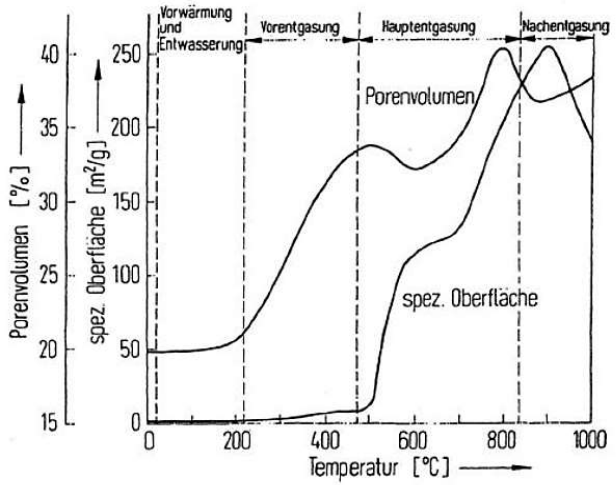
Properties
Surface structure

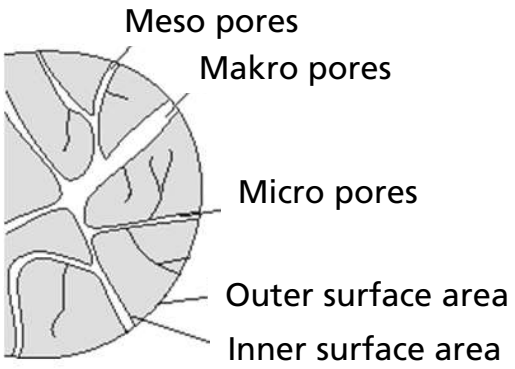
Influencing parameters for the quality of active carbon:

- Ash content (as low as possible)
- Volatile components (favorable between 8-15 %)
- Pyrolysis conditions (temperature)

Pore classification according to International Union of Pure and Applied Chemistry (IUPAC):

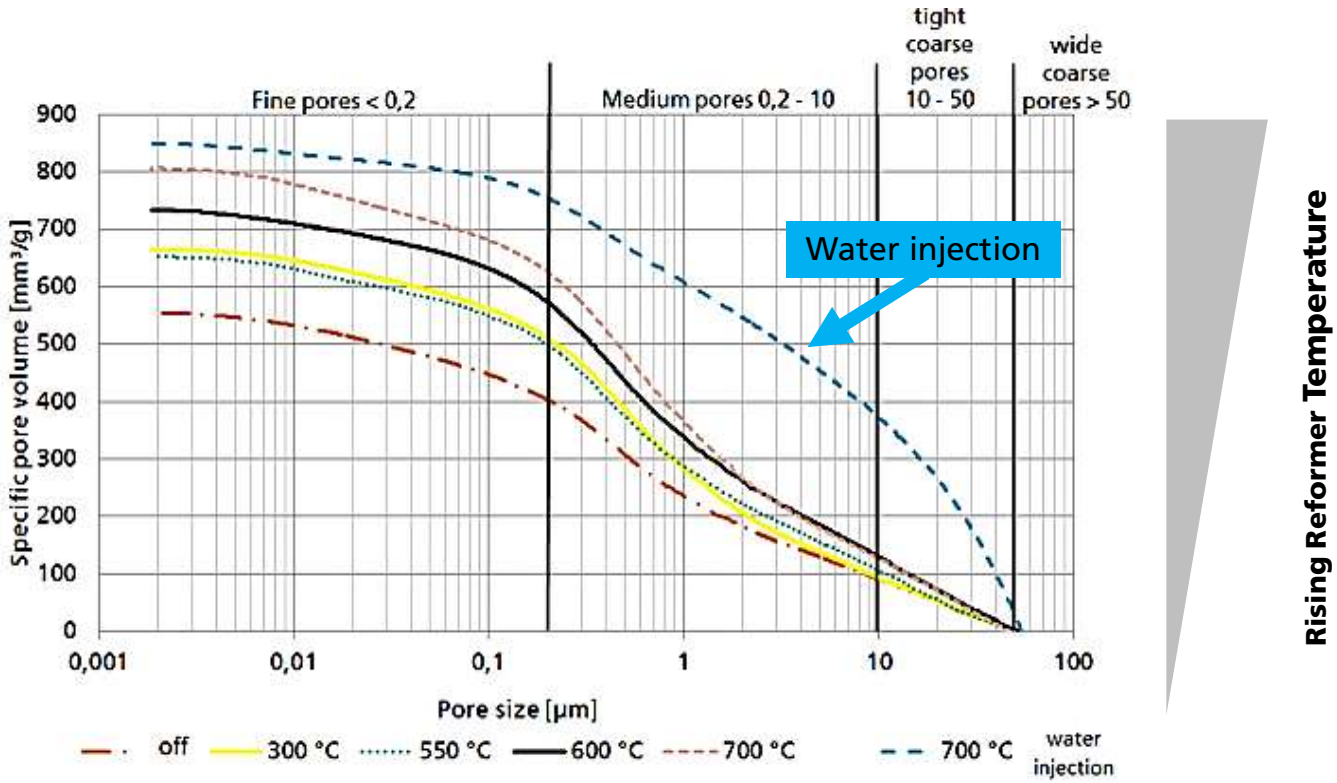
- Macro pores (dP > 50 nm)
- Meso pores (dP = 2-50 nm)
- Micro pores (dP < 2 nm)





Sources: **Benthaus, F.** - ***Rohstoff Kohle. Eigenschaft, Gewinnung, Veredelung 1978,*** Elke Heitling et.al. – Adsorbentien/Poren, www.chemgapedia.de (modified)

Modification examples
Pore size distribution



Pore size distribution of digestate TCR®-biochar by various reforming temperatures

Application
Soil conditioner – legal regulation

- Regulations on European and country level
  - Biochar is not listed as a fertilizer product in the European fertilizer ordinance (amended in 2019)
  - Recycling products like biochar, ashes and struvite will be added by the end of 2019
- Restrictions in feedstock, e.g.
  - Germany: only untreated clean wood
  - Italy: agricultural residues (plant material)
- Requirements to nutrients content
- Limits for organic and inorganic pollutants

Application
Soil conditioner – International Biochar Initiative (IBI)

- IBI was formed in 2006, Philadelphia, PA.
- The vision: One billion tons of biochar produced within 50 years.
- Standardized Product Definition and Product testing Guidelines for Biochar that is used in Soil are developed in 2015
- Requirements to biochar are defined to ensure the quality for use in soil
  - Test category A – basic utility properties
  - Test category B – toxicant assessment
  - Test category C – advanced analysis and soil enhancement properties
- Product classification:
  Class 1: >60%, Class 2: <60% and 30%, Class 3: <30 % (C_{org})
- After certification process is successfully passed, the IBI Certiefied™ biochar seal is valid for one year
- Implemented in United States and Canada only

Application
Soil conditioner – European Biochar Certificate (EBC)

- Certification is optional in Europe and mandatory in Switzerland
- Guidelines for the European Biochar Certificate from 2019
- Requirements to biochar are defined to ensure the quality for use in soil
  - Test category A – basic utility properties
  - Test category B – toxicant assessment
  - Test category C – advanced analysis and soil enhancement properties
- Guidelines also for production of biochar as feed additive
- Product classification: Basic, Premium and Fodder (different thresholds for pollutants)
- Only biomass from Europe can be used

Application
Soil conditioner – Australien New Zealand Biochar Initiative (ANZBI)

- ANZBI was formed in 2017, Murwillumbah, N.S.W.
- Australian Biochar for Soils Standard was developed in 2019 (draft version)
- Testing criteria quite similar to IBI standards
- Standard based on:
  - Australian Compost Standard AS4454-2012
  - European Biochar Certificate Guidelines 2019
  - IBI Standardized Product Definition and Product Testing Guidelines for Biochar that is used in Soil
- Product classification:
  - High Carbon Biochar (HCB) >70 % C_{org}
  - Medium Carbon Biochar (MCB) 50-70 % C_{org}
  - Low Carbon Biochar (LCB) 30-55 % C_{org}
  - Partially Combusted Organic Material (not biochar) <30 % C_{org}
- Developed for Australia and Newzealand

AUSTRALIA NEW ZEALAND BIOCHAR INITIATIVE Inc. ANZBI

Application
Feed additive – Good Manufacturing Practice (GMP+)

- GMP+ is a Feed Safety Assurance (FSA) certification process
- The whole production chain needs to be GMP+ certified:
  feedstock → conversion → storage → transport
- There is an optional “Feed Responsibility Assurance” (GMP+ FRA) as additional sustainability certification
- Standards from existing initiatives are applied, e.g. Association Food without Genetic Engineering (VLOG e.V.)
- No feedstock restrictions by certification body
- all commercial chars certified by GMP+ and used as feed additive derived from untreated wood

Application
Activated carbon

- Requirements are listed in European standards, e.g.
  - EN 12903 – Powdered Activated Carbon
  - EN 12915 – Granular Activated Carbon
- Any carbon containing feedstock is possible, including coconut shells, wood, peat and coal
- Thresholds for water and ash content are applied
- For the application in water treatment, the content of water extractible substances (heavy metals and PAHs) is limited too



Application
Market survey

- Price for biochar as soil amendment ranges from 200-2,000 €/t depending on quality and market situation
- European market size in 2018 was 0.31 billion US$, forecast for 2023 is 0.59 billion US$
- Global market size in 2018 was 1.48 billion US$, forecast for 2025 is 3.82 billion US$

- Typical price for biochar as feed additive: 1,000 €/t, depending on quality and market situation the price ranges from 500-1,300 €/t

- Activated carbon is available on the market in a rang from 700-1,800 €/t
- The total market value worldwide for activated carbon was estimated on 2.35 billion US$ in 2017

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Thank You!

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