Commercial biochar production and its certification

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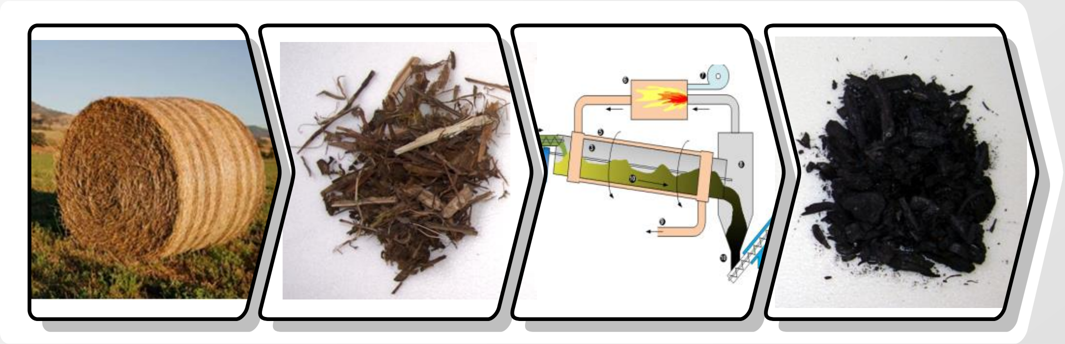

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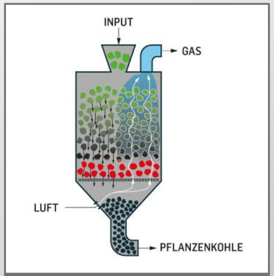
Interreg Conference

10/12/13 - Groningen

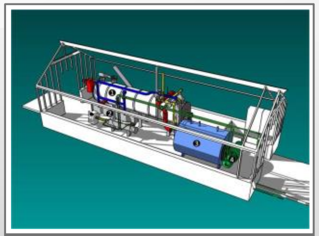
Commercial systems

- Currently, many commercial designs and systems available…

Agritherm

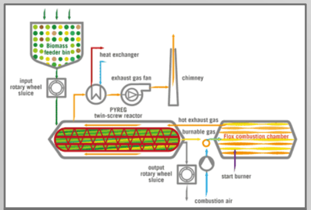


Schottdorf

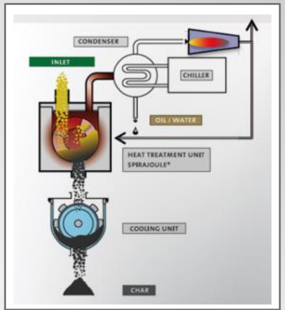


Black Carbon

Biomacon



Pyreg



Biogreen Energy

Carbon Gold

Regenis

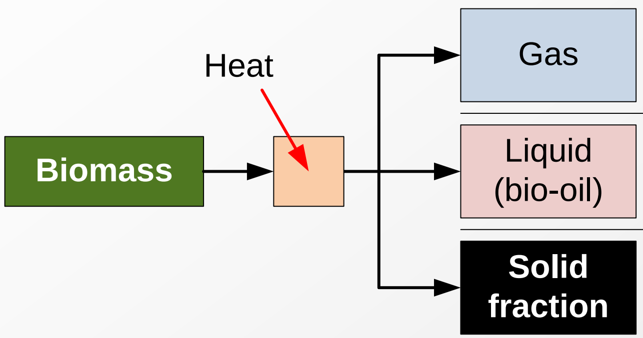
Carbon Compost

… and many more

- How to select/classify according to appropriateness ?
- → Important criteria

Commercial systems

- **1. Thermochemical process type**



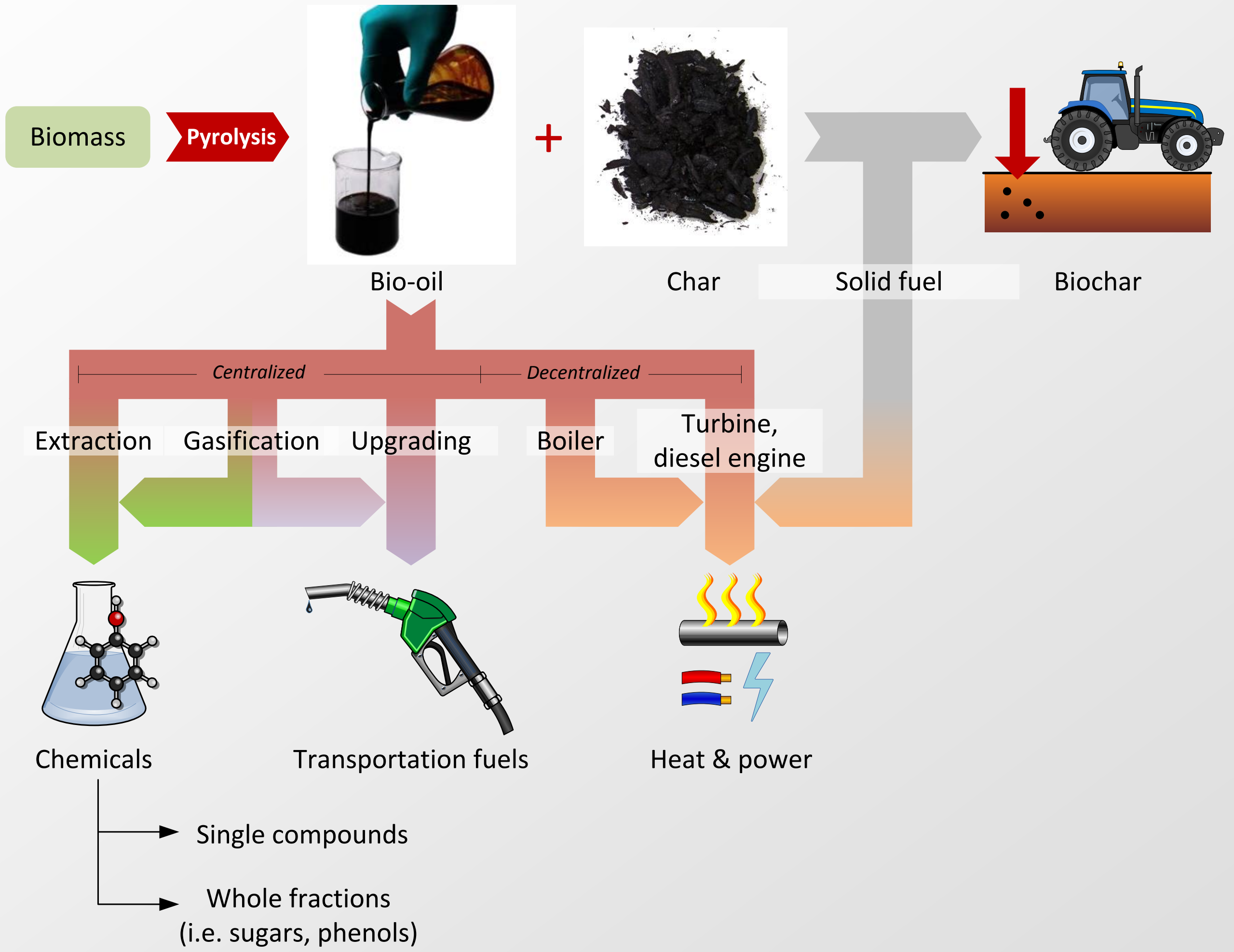
Product distribution (*wt%*)	Torrefaction	Slow pyrolysis carbonisation	Fast pyrolysis	Gasification
Gas	5	35	13	85
Liquid (bio-oil)	20	30	75	5
Solid fraction	75	35	12	10

● Desired product

- Both fast pyrolysis and gasification constrained by process conditions toward optimal yield and quality of bio-oil, syngas respectively.
- Valorisation trajectory for bio-oil and syngas ?
  - On-site: heating
  - On-site: cogeneration, syngas (proven, commercially available) – bio-oil (experimental)
  - Off-site: upgrading and/or isolation of chemicals out of bio-oil (experimental)
- **2. Valorisation of coproducts**
  - See above

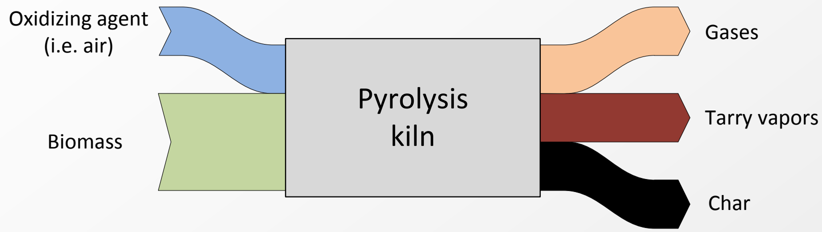
Commercial systems

- **2. Valorisation of co-products**
  - i.e. bio-oil



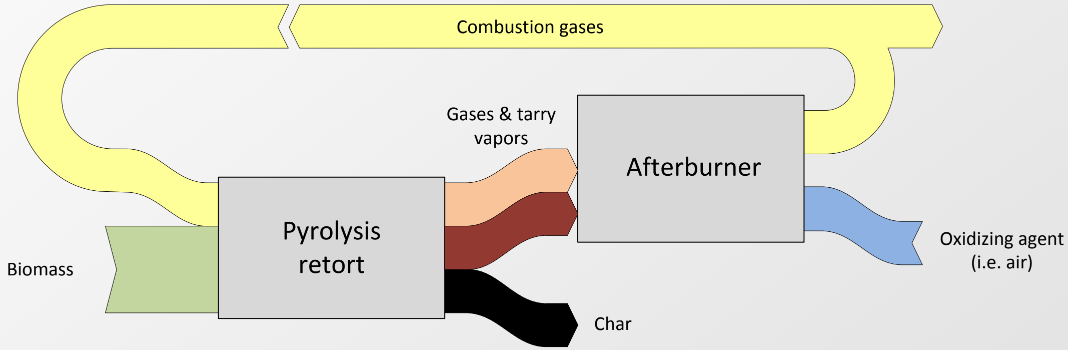
Commercial systems

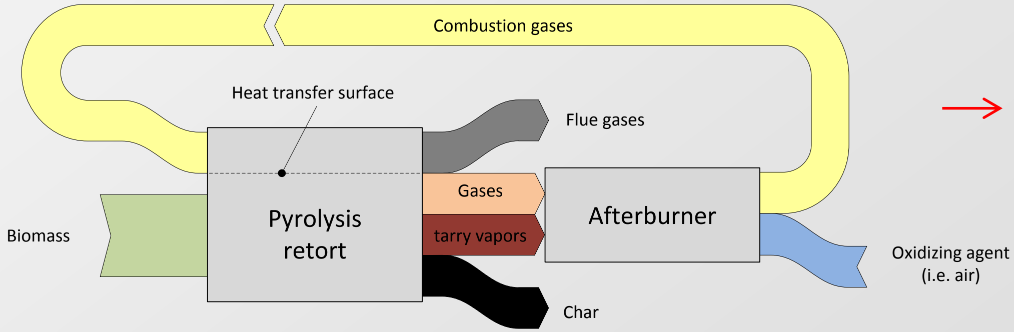
- **3. Heating mode**
  - Autothermal



→ Effect on yield, char homogeneity

  - External heating: either direct or indirect heating using combusted pyrolysis vapors/gases

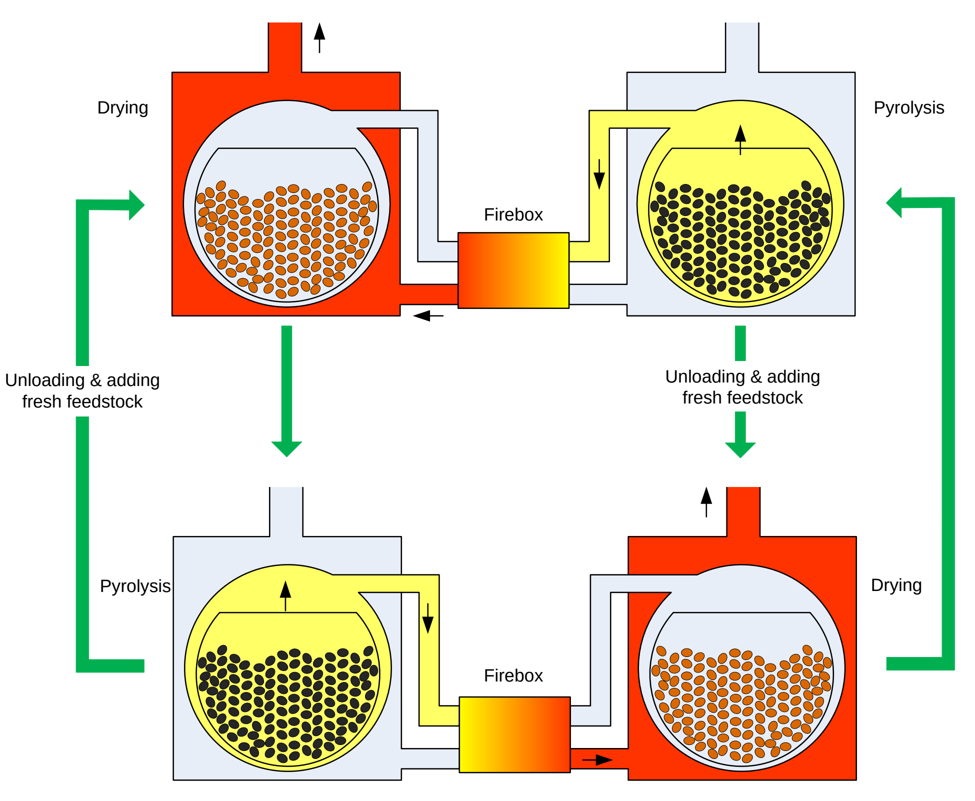




→ System complexity, meintenance

  - Using an external fuel (i.e. gas, or even electricity)

Commercial systems



- **3. Operation mode**
  - Batch
  - Continuous
  - Semi-continuous (i.e. Von Marion Retort) →
  - Drawbacks batch versus continuous,
    - Poor thermal efficiency
    - Poor co-product utilization
    - Smaller units
- **4. Feedstock suitability**
  - Morphology: particle size
  - Biomass composition: water content
    - Most pyrolysis systems tolerate up to 20 - 30 *wt%* water in the feedstock
    - However, more latent heat required to heat the biomass to pyrolysis temperature
    - Pyrolysis gases and vapors diluted with steam → affects external heating processes
  - Ash
    - Ends up in the char
    - May act catalytically in pyrolysis (relevant to fast pyrolysis, i.e. bio-oil quality)

Commercial systems

- **4. Feedstock suitability**
  - Morphology: particle size

Sawdust	Pellets and chips	Cordwood
< 2 ~ 3 mm	~ several cm's	Whole logs, up to 1 m
	 	
Fast pyrolysis systems, small size required to sustain high rates of heat transfer	Slow pyrolysis systems, usually in reactor systems with some form of mechanical agitation (pressure drop relatively high in packed bed reactor systems)	In traditional charcoal and industrial charcoal kilns – ensures proper gas flow in packed bed systems

← Energy requirement for pretreatment (milling, comminution)

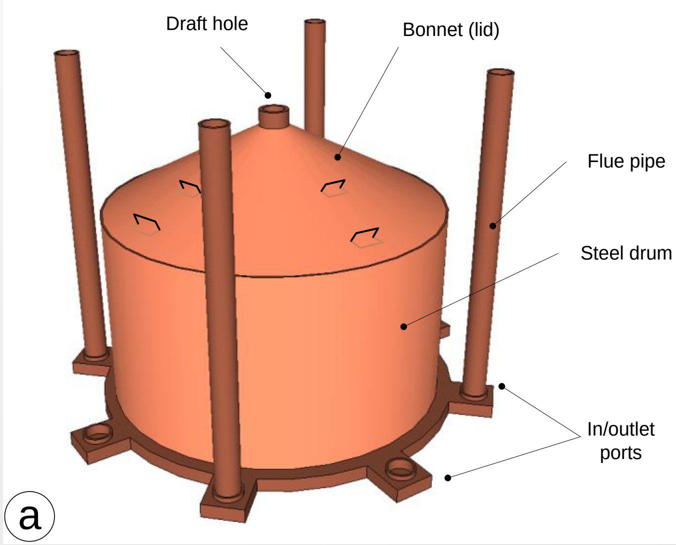
Biomass residence time in the pyrolysis reactor →

  - Feedstock flexibility: seasonal changes !
- **5. Scale of operation (decentralized vs centralized)** and **transportability**

Commercial systems

- **Examples of commercial systems: 1. Steel charcoal kilns**

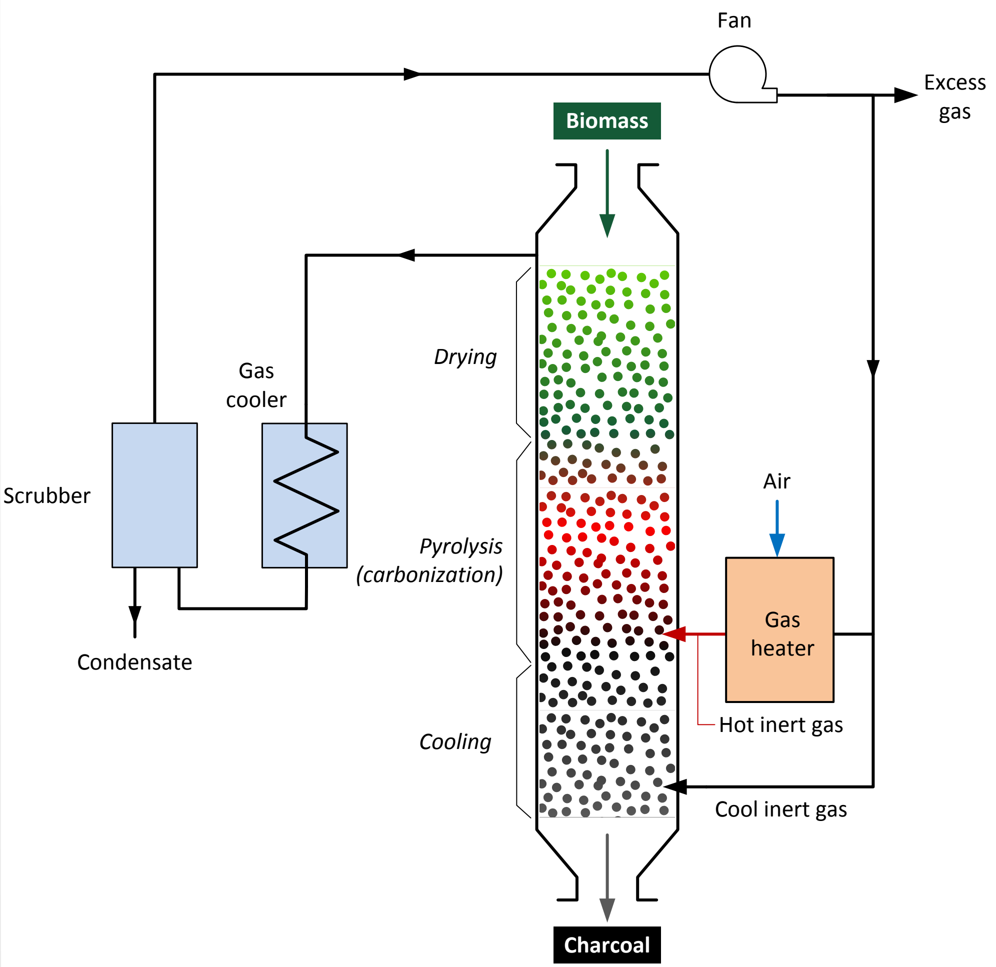
  - E. g. **Four Seasons Fuel New Hamspire Kiln** (a) and **Carbon Gold's SuperChar 100 Mk II** (b)
  - Slow pyrolysis (carbonization)
  - No recovery of byproducts
  - Autothermal – yield = 25 *wt%*
  - Batch process (SuperChar 100: batches of 500 kg biomass yielding 100-125 kg biochar in an 8 hour cycle)
  - Using cordwood (as well as chipped wood) as feedstock, can process harvest residues as well (forced draft by centrifugal fan – Mk II)
  - Small scale and transportable
  - Low cost
  - Low degree of process control (i.e. actual pyrolysis temperature), may be subjected to interbatch variability



Source: Carbon Gold

Commercial systems

- **Examples of commercial systems: 2. Industrial charcoal kilns**
  - E. g. **The Lambiotte Retort**
  - Slow pyrolysis (carbonization)
  - Recovery of vapors: i.e. acetic acid
  - Externally, direct heated using combusted pyrolysis vapors and gases
  - Continuous process
  - Using cordwood as feedstock
  - 30 *wt%* charcoal yield
  - Scale 12500 ton charcoal/(yr.retort) – 2 Retorts (Prémery, France)



Source: M. Gronli

Commercial systems

- **Examples of commercial systems: 2. Industrial charcoal kilns**

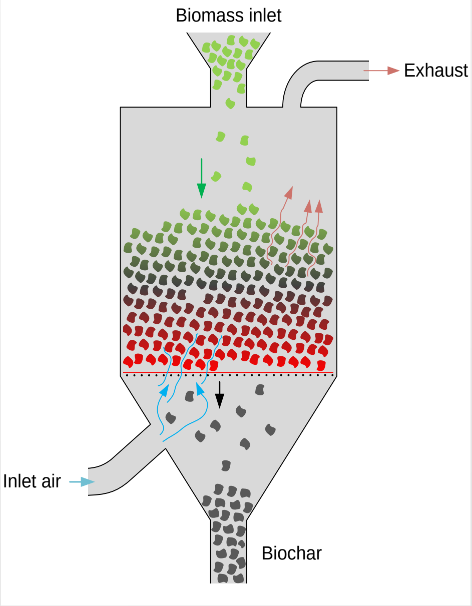
- E. g. **The Lambiotte Retort**
- Closed down in 2002
- Slated for demolition in 2013

- Other (working) similar examples:
- SIMCOA (Kemerton, AU) – 27000 ton/yr charcoal for metallurgical smelting. Charcoal yield = 35 *wt%*
- Chemviron Carbon (D) – 25000 ton/yr in Reichert retort (originally Degussa/Evonik), coproduction of acetic acid. Charcoal yield = 34 *wt%*

Source: Google Earth, Panoramio.com

Commercial systems

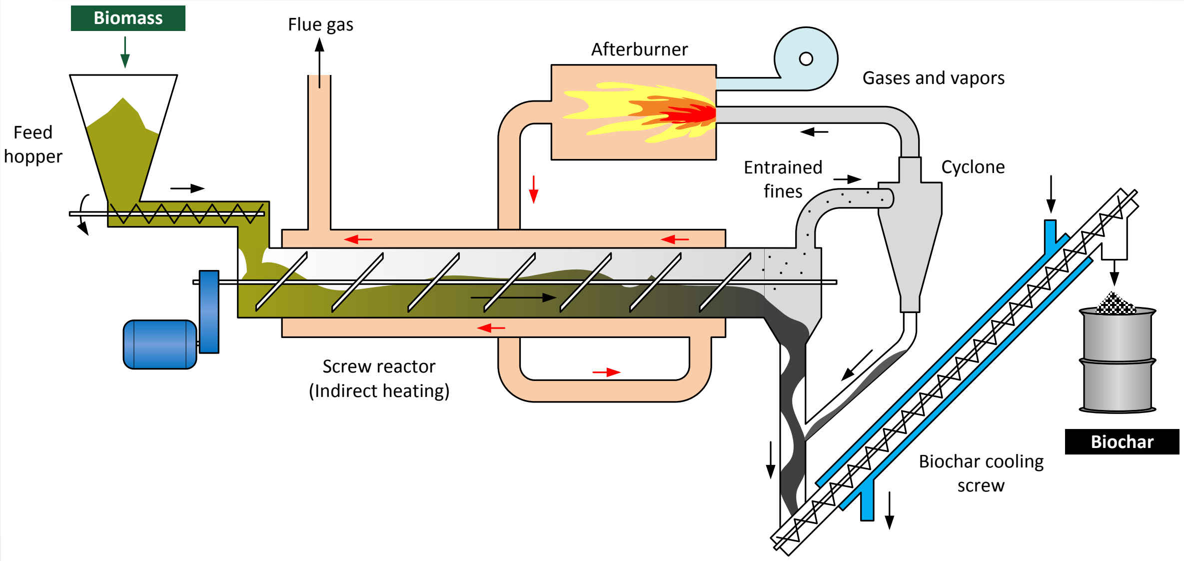
- **Examples of commercial systems: 2. Industrial charcoal kilns**
  - E. g. **The Schottdorf Kiln**
  - Slow pyrolysis (carbonization) at 700°C
  - Pyrolysis gas/vapors suitable for thermal recovery (300 kW)
  - Autothermal process
  - Continuous process
  - Wood chips as feedstock, but agricultural residues apply as well
  - 33 *wt%* biochar yield
  - Scale: 6 ton/day of biomass, 2 ton/day charcoal
  - Biochar sold by Carbon Terra



Source: Schottdorf

Commercial systems

- **Examples of commercial systems: 3. Auger and rotating drum reactors**



- E. g. **The Pyreg 500 unit**
- Slow pyrolysis (carbonization)
- High degree of process control
- Residual heat recovery for biomass drying and/or domestic heating
- Externally heated using combusted pyrolysis gases/vapors
- Continuous process

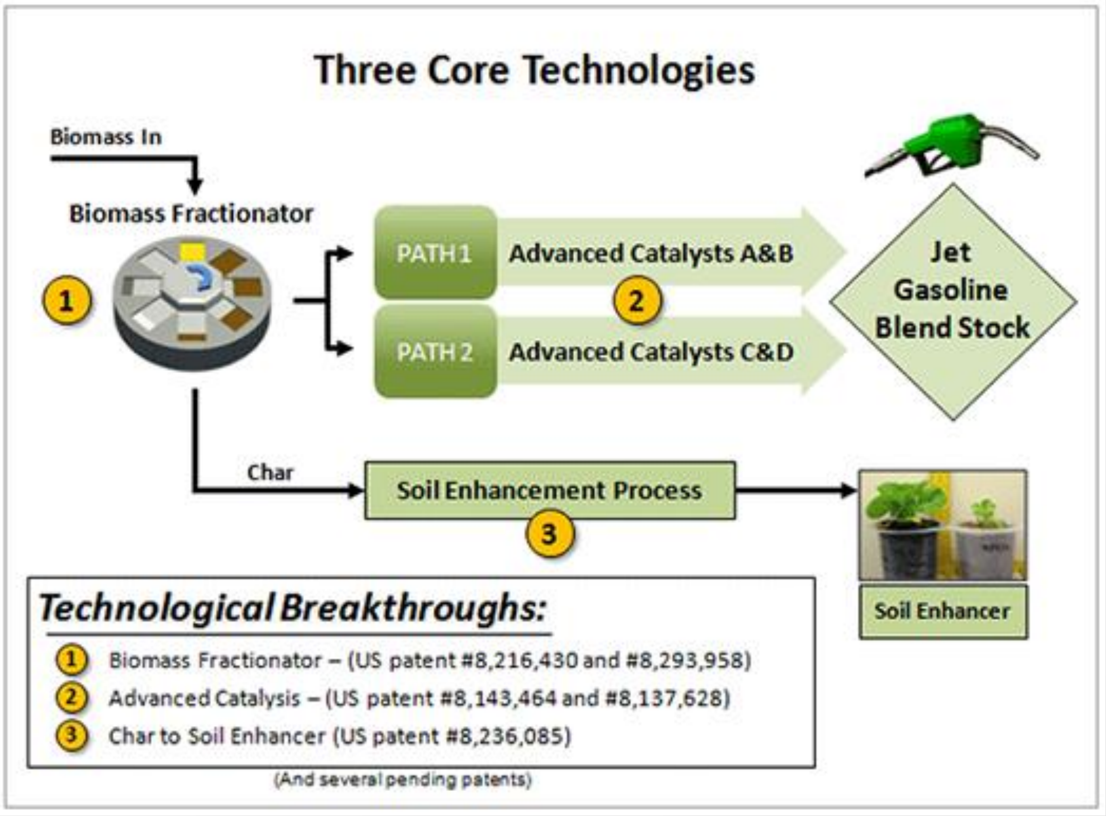
- Chips, pellets as feedstock. Very high feedstock flexibility due to mechanical auger.
- 27 *wt*% biochar yield (average)
- Scale: 1 ton/day biochar
- Multiple commercial implementations today (Sonnenerde, AU; Swiss Biochar, CH; Verora, CH)

Source: Pyreg

Commercial systems

- **Examples of commercial systems: 4. Fast pyrolysis**

  - E. g. **Cool Planet Energy Systems (US)**
  - Fast pyrolysis
  - Catalytic upgrading of the bio-oil into 'green' gasoline
  - External heating
  - Continuous process
  - Feedstock: pine and spruce (milled to sawdust)
  - Scale: 10^7 gallons/yr green gasoline – could amount up to 10000 ton char/yr – highly centralized
  - Refinery to be completed end of 2014 (Alexandria, LA)



Certification

- To conclude: many pyrolysis systems available, as well as wide range of feedstocks

  → Do they all produce a char that could be labeled as 'biochar' ??

- Let's go back to the roots: Definition of 'biochar'

> "A solid material obtained from thermochemical conversion of biomass in an oxygen limited environment" (IBI, 2012)

> "A solid material obtained from thermochemical conversion of biomass in an oxygen-limited environment that is used for the safe and long-term storage of carbon in the environment and for soil improvement" (BQM, 2013)

> "A charcoal-like substance that is pyrolysed from sustainable obtained biomass under controlled conditions and which is used for any purpose which does not involve its rapid mineralisation to CO_2" (EBC, 2012)

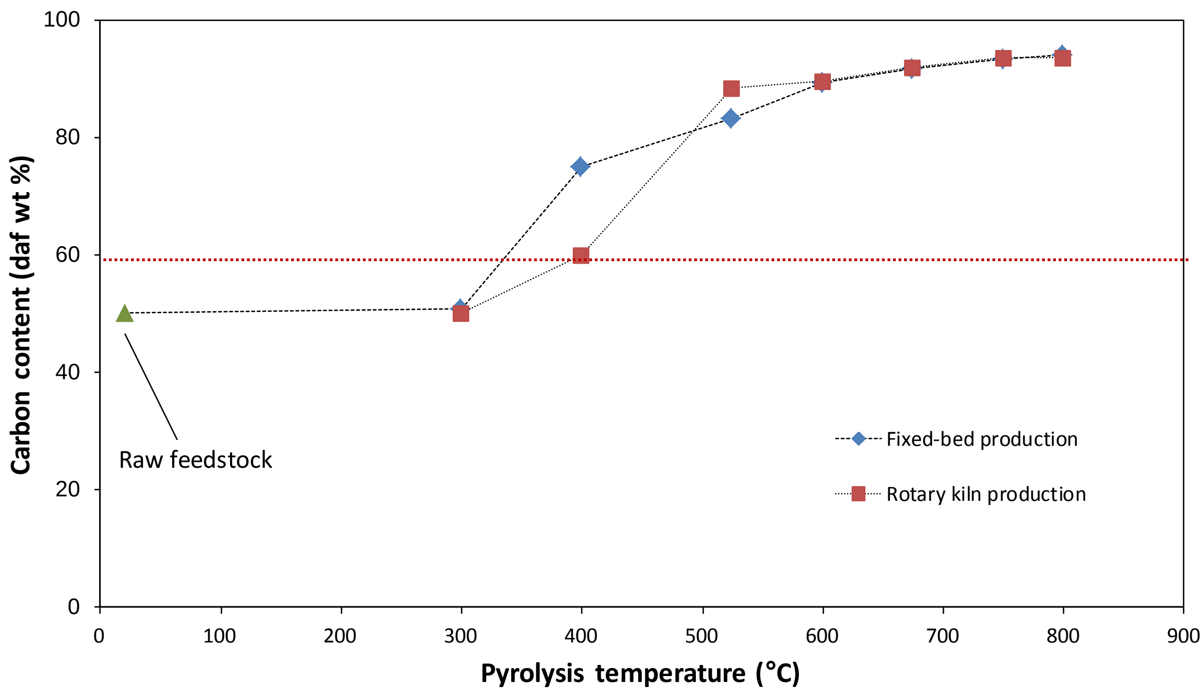
Core concepts	Safe product	Stable	Carbon-rich	Sustainable biomass feedstock & environmentally safe production

- Certification schemes

Certification

- 1. Carbon content
  - **IBI**: Class 1 biochar ≥60 *wt%* org.-C (dry basis); Class 2 biochar ≥30 *wt%* and <60 *wt%* org.-C; Class 3 biochar ≥10 *wt%* and <30 *wt%* org.-C
  - **EBC:** Minimum 50 *wt%* C (dry basis) irrespective whether organic or inorganic (i.e. carbonates) C – however fixed carbon (black carbon) ≥10 *wt%* of org.-C. Materials with < 50 *wt%* C classified as *Bio-carbon minerals*
  - **BQM:** Minimum 10 wt% org.-C (dry basis)

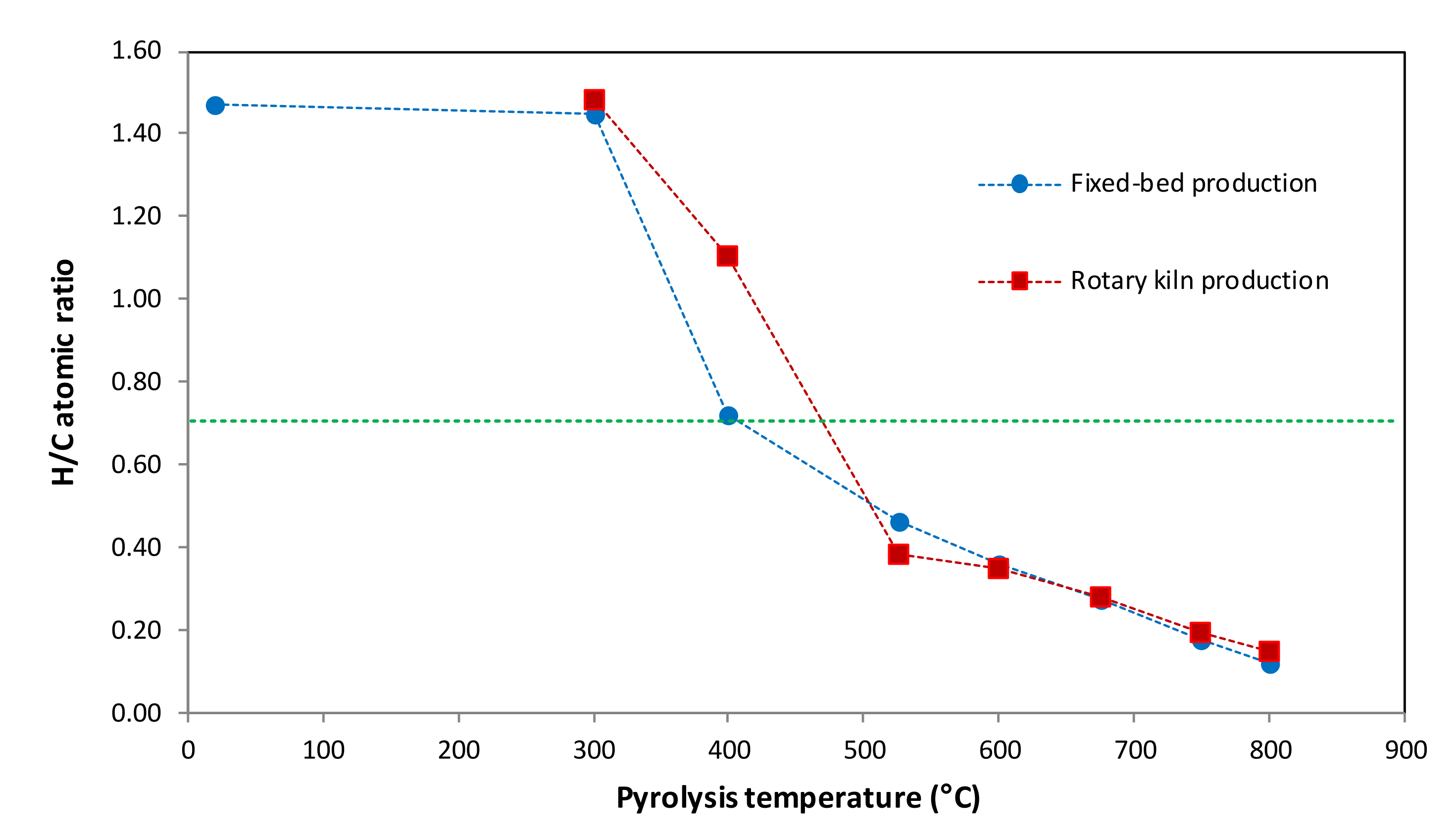
- A simple criterion
- However, feedstocks rich in ash content likely to result in low grade (IBI) or non-biochar (EBC) designation
- Pyrolysis temperature is the largest contributing factor – but significant differences may be seen across different technologies



Certification

- 2. Carbon stability

  - **IBI**, **EBC** and **BQM**: H/C-ratio ≤ 0.7 and **EBC:** O/C-ratio ≤ 0.4

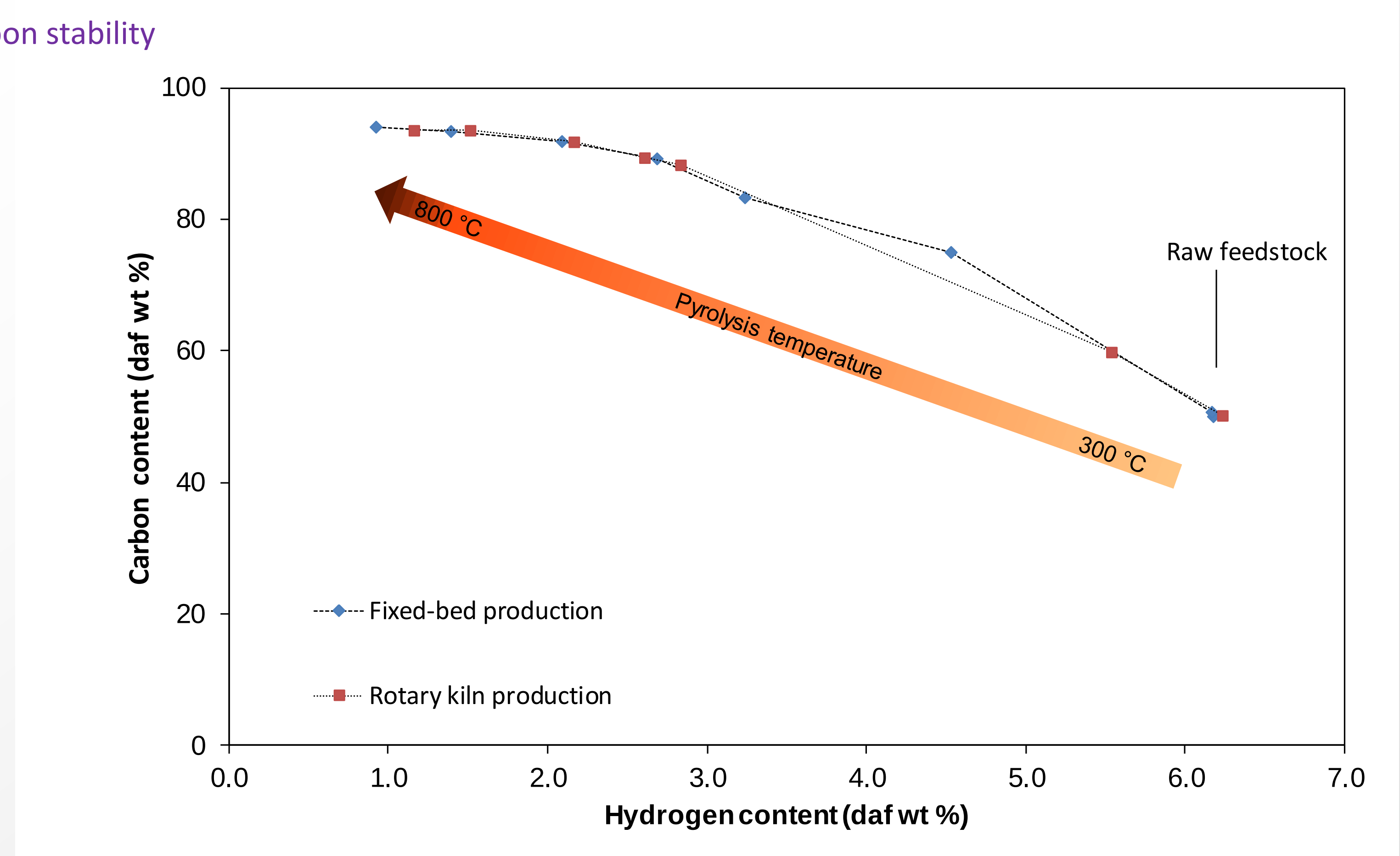


- Pyrolysis temperature is the largest contributing factor – but significant differences may be seen across different technologies

- H/C-ratios appear to be lying on within a continuum

Certification

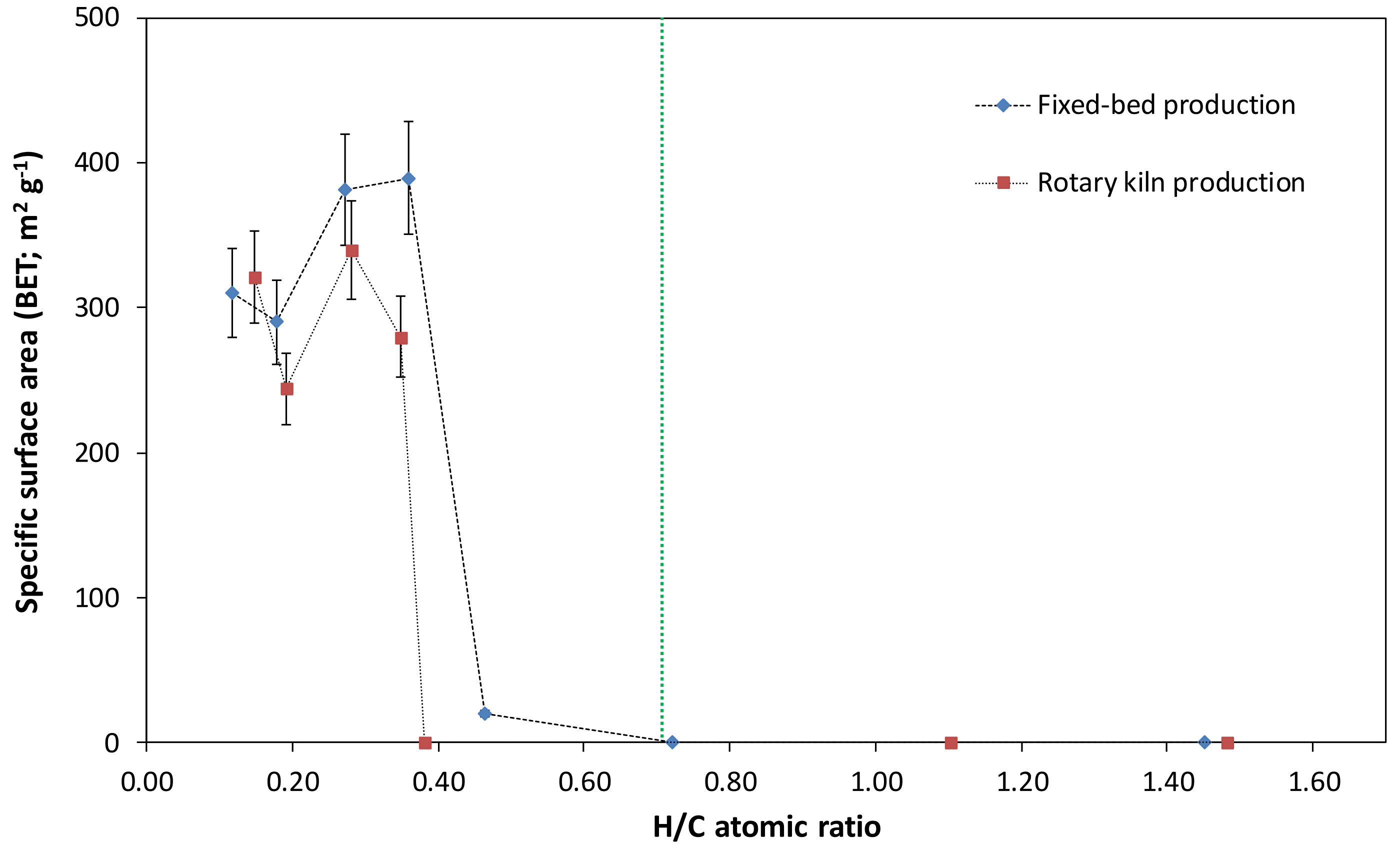
- 2. Carbon stability



- H/C-ratios appear to be lying on within a continuum
- Biochar properties (both chemical and physical) are interrelated. One measurement can act as proxy for others (H/C-ratio).
- Relationships between biochar properties are invariant between pyrolysis methods.

Certification

- 2. Carbon stability



- Biochar properties (both chemical and physical) are interrelated. One measurement can act as proxy for others (H/C-ratio).

- Relationships between biochar properties are invariant between pyrolysis methods. (Specifically within a single feedstock – when comparing multiple feedstocks, corrections for ash content do apply)

Certification

- 3. Product safety
  - **Toxicants:** either already present in the feedstock (heavy metals, PCB) or formed through the pyrolysis process (PAH's, BTX, Dioxins)
  - **Maximum tresholds** for toxicants usually based on local legislation/regulations for soil/fertilizer/compost/…

	IBI	EBC	BQM
PAH	Max. 6 – 20 mg/kg	< 4 mg/kg (premium) < 12 mg/kg (basic) using toluene extraction	< 20 mg/kg (toluene extraction)
Dioxins/furans (PCDDs, PCDFs)	Max. 9 ng/kg I-TEQ	Max. 20 ng/kg I-TEQ	Max. 20 ng/kg I-TEQ
PCBs	Max. 0.2 – 0.5 mg/kg DM	< 0.2 mg/kg DM	< 0.5 mg/kg DM
notes	Depending on the jurisdiction in the area of production/ application	Based on existing Swiss/German regulations	Dioxin and PCB testing only required if feedstock contains elevated levels of chlorine

Conclusions

- **Industrial biochar production** systems
  - Are on the market now
  - With varying degrees of success, some systems not fully proven in a commercial setting
  - Must be evaluated against a large set of criteria

- **Certification**
  - Ensures proper definition of biochar
  - Ensure sufficient controls to guarantee reasonable chemical stability
  - Ensure safety of the biochar product according to known risks
  - However, does not provide a guarantee biochar will 'work'
  - Most industrial systems are (probably) able to meet these criteria, however proper attention is needed to ensure environmentally safe production, using a sustainable feedstock.

Thank you

- Questions ?

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