FS treatment – Pyrolysis

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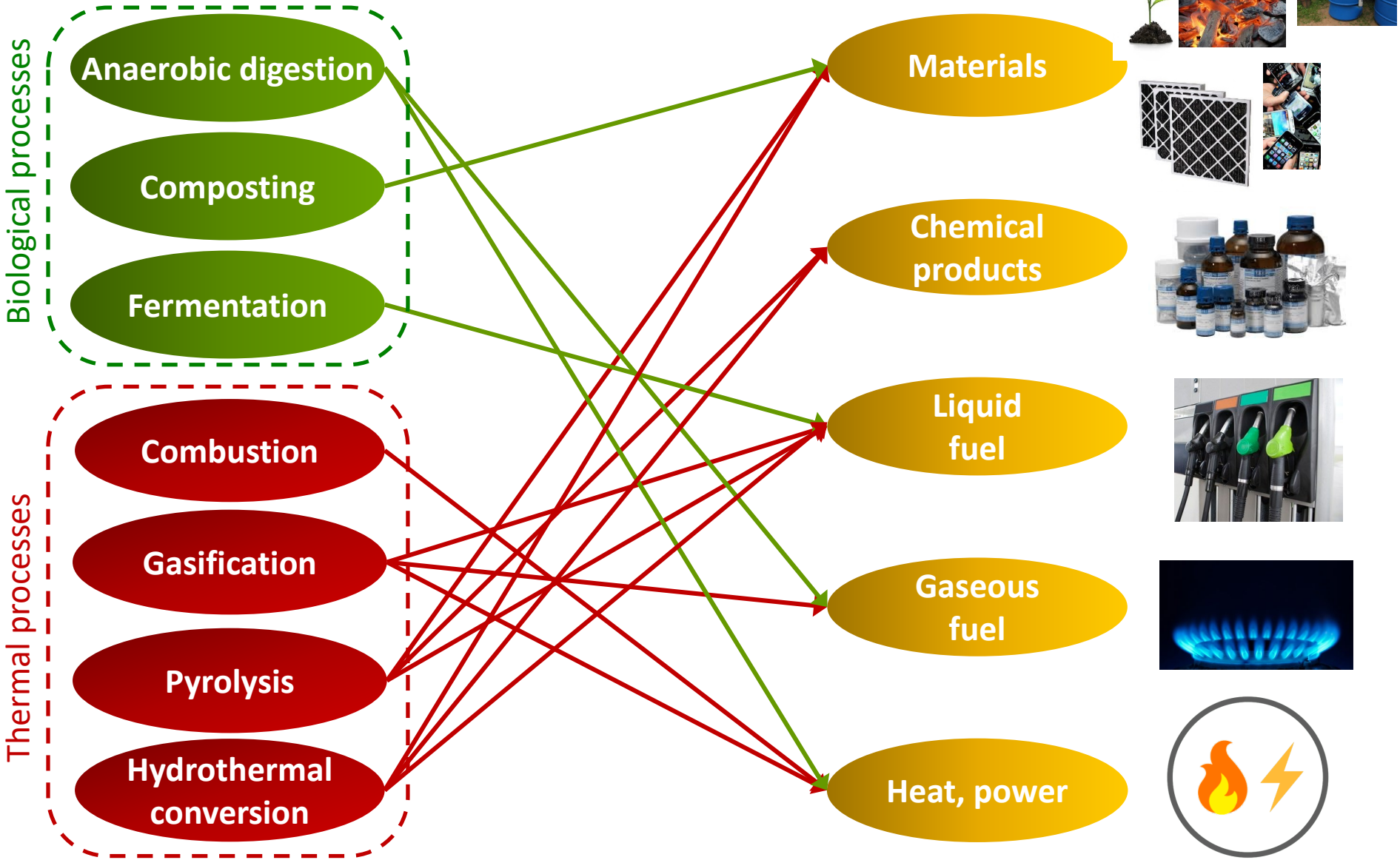
Dry and wet waste?

"Dry" waste — **Moisture < 60 w%**

Wet waste — **Moisture > 60 w%**

How to turn waste into a resource?



How to turn waste into a resource?

✓ No pathogens!

Thermal processes

- Combustion
- Gasification
- Pyrolysis
- Hydrothermal conversion

"Dry" waste

"Dry" waste

"Dry" waste

Wet waste

- Materials
- Chemical products
- Liquid fuel
- Gaseous fuel
- Heat, power






Reaction conditions and major product distribution of various thermochemical processes

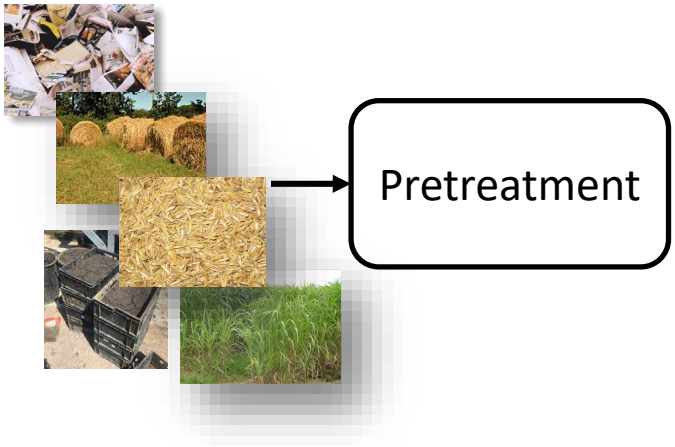
Bio-oil oriented	Syngas oriented	Biochar oriented	Biochar oriented	Approximately equal compositions
Fast pyrolysis	***Gasification***	***Torrefaction***	***hydrothermal carbonization***	***Slow pyrolysis***
Temperature: 500-1000 °C	Temperature: 750-900 °C	Temperature: ~290 °C	Temperature: 180-300 °C	Temperature: 300-700 °C
Residence time: < 2 s	Residence time: 10-20 s	Residence time: 10-60 min	Residence time: 1-16 h	Residence time: hour-days
Biochar yield : 12 %	Biochar yield : 10 %	Biochar yield : 80 %	Biochar yield: 50-80 %	Biochar yield :35 %
Bio-oil yield : 75 %	Bio-oil yield : 5 %	Bio-oil yield : 0	Bio-oil yield : 5-20 %	Bio-oil yield :30 %
Syngas yield : 13 %	Syngas yield : 85 %	Syngas yield : 20 %	Syngas yield: 2-5 %	Syngas yield :35 %

Pyrolysis: main steps

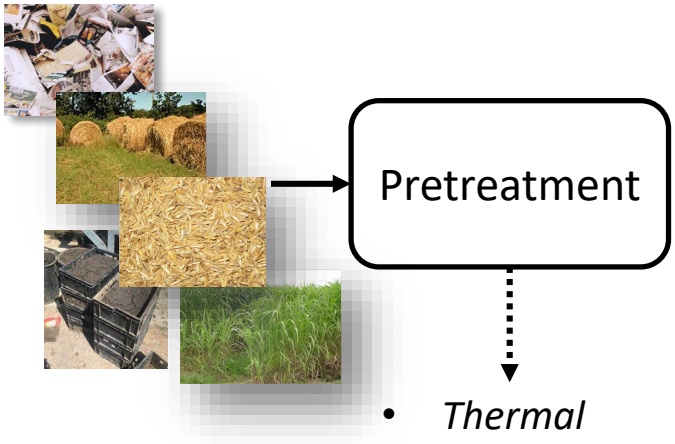
- Pyrolysis: heating of organic material in absence of oxygen;
- The volatiles evaporate partly, and a product (charcoal) remains, consisting for a large part (normally 80%) of carbon;
- Slow pyrolysis: low heating rate and long residence time is also called carbonisation, and emphasises the **solid charcoal as main product**;
- Slow pyrolysis: simple, robust and cost-effective process that is applicable to small scale and farm-based biochar production
- Fast pyrolysis: high heating rate and short residence time: emphasises the liquid product.

- See https://www.youtube.com/watch?v=Zzv6fIDsNwM&t=109s
- See **https://www.youtube.com/watch?v=Ut3I7OIPFR8**

Pyrolysis: main steps



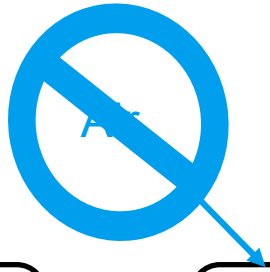
Pyrolysis: main steps



Pretreatment

- *Thermal*
  - Drying
- *Mechanical*
  - Milling

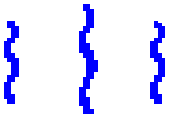
Pyrolysis: main steps



Pretreatment

Pyrolysis

Gas



Liquid

Char

- T=300-700 degrees C
- Atmospheric pressure
- Inert atmosphere
- Heating rate: 1 degree C.min^{-1} to 500 degrees C.s^{-1}
- Reaction time: s to h

Pyrolysis: main steps

Pretreatment

Pyrolysis

Gas

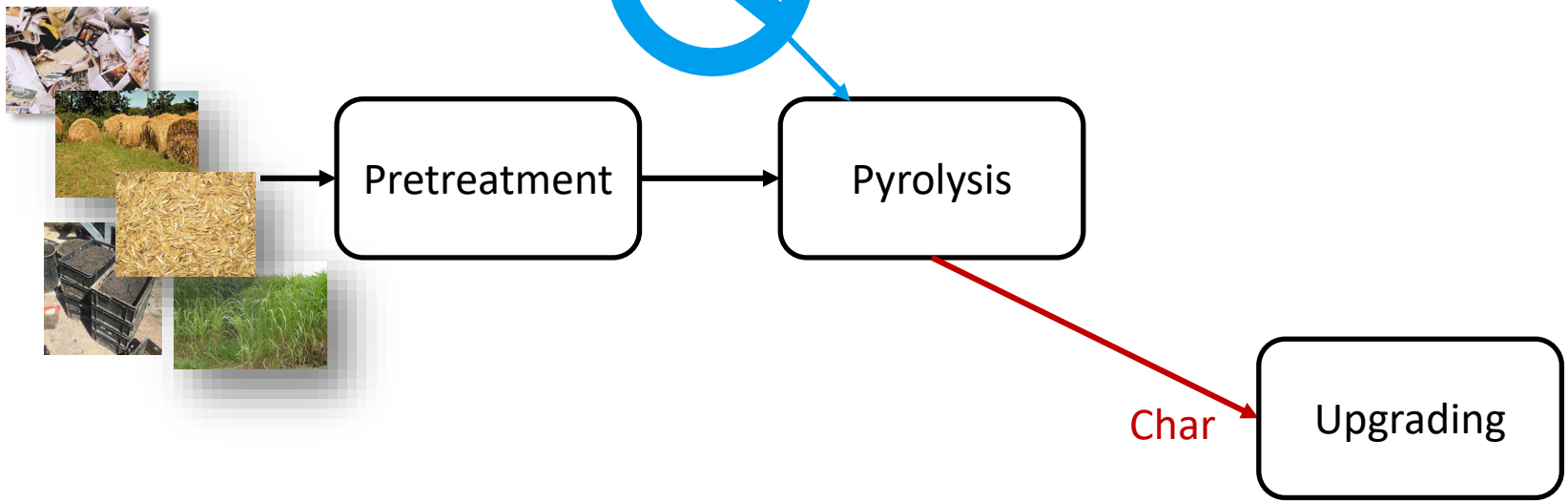
Liquid

Char

Slow pyrolysis (1-10°C.min^{-1})

- ❑ T=300-700 degrees C
- ❑ Atmospheric pressure
- ❑ Inert atmosphere
- ❑ **Heating rate: 1 degree C.min^{-1} to 500 degrees C.s^{-1}**
- ❑ Reaction time: s to h

Slow pyrolysis: main steps



Slow pyrolysis: main steps

Pretreatment

Pyrolysis

Char

Upgrading

- *Thermal*
  - Activation
- *Mechanical*
  - Pelletizing
  - Briquetting

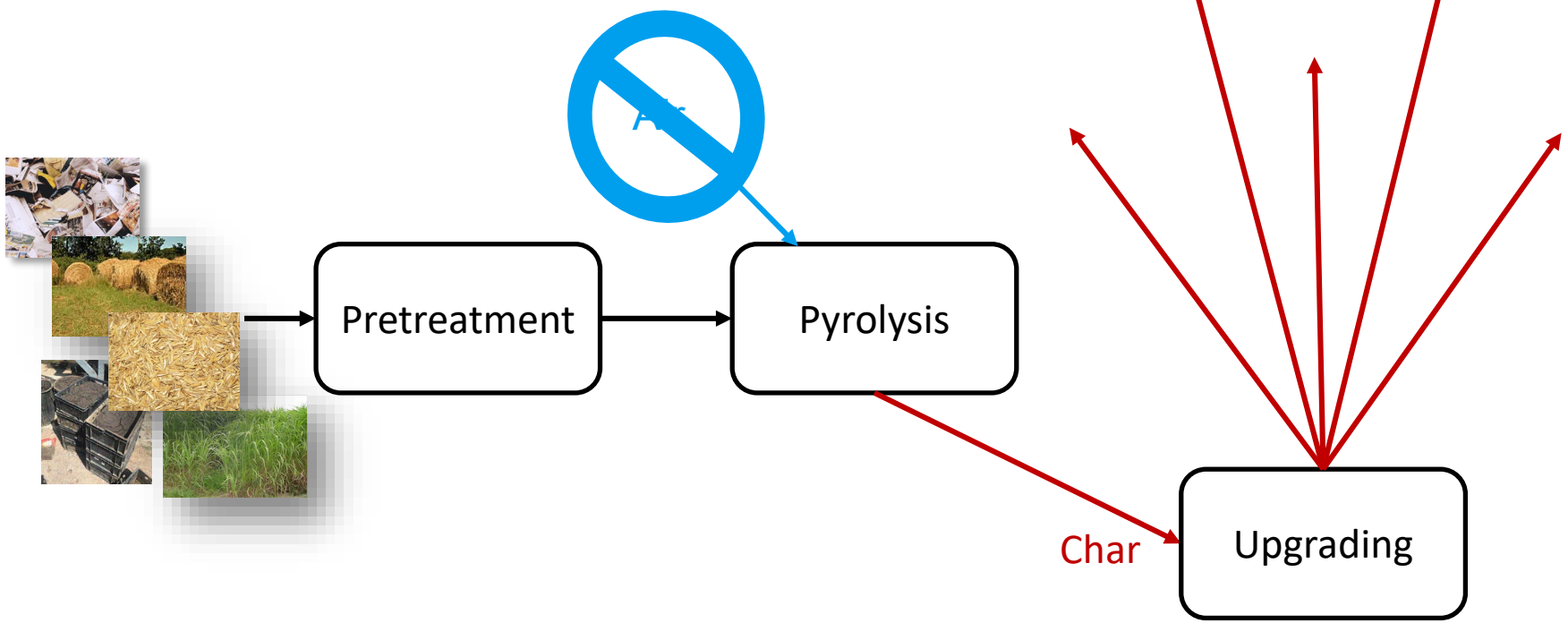
Char mechanical upgrading

Pellets

Briquettes

- ✓ Char densification
- ✓ Mature and robust processes

Slow pyrolysis: benefits



Slow pyrolysis: benefits

Pretreatment

Pyrolysis

Air

Char

Upgrading

Soil improver

Water/gas filtration

Additive in AD

Fuel

Electrochemical storage

Solid fuel

Substitution to wood charcoal

- Solution to deforestation
- Cleaner combustion

- Toxic emissions when unefficient stove is used
- Social acceptance (household)

Soil improving material

Used in fields

The most mature and popular application

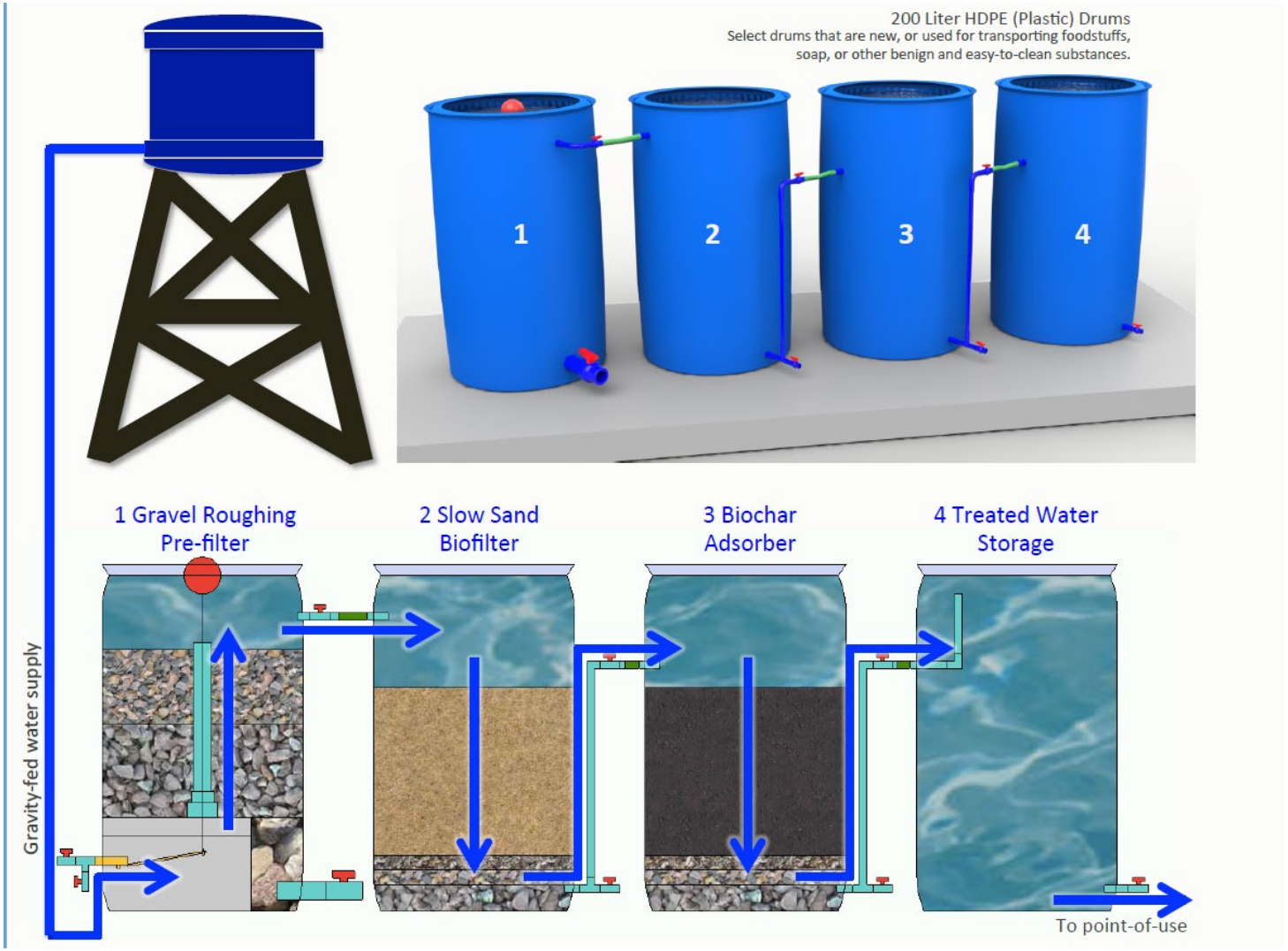
- Increase of crop yield
- Increase of water retention
- Increase of soil stability
- Carbon sequestration

http://biogrow.co.nz/biochar/biochar-fertilisers

No biochar **40 %v/v biochar**

- Unclear link feedstock/process conditions/performance
- High biochar amount required per hectare?
- Heavy metals released in soil?

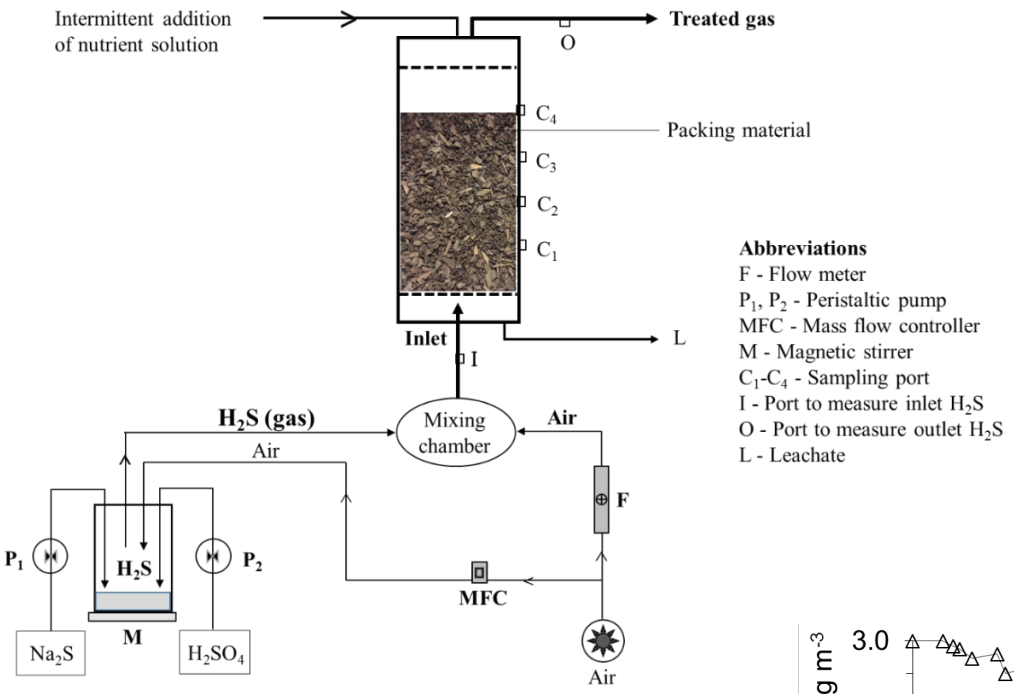
Water-treatment system for developing countries



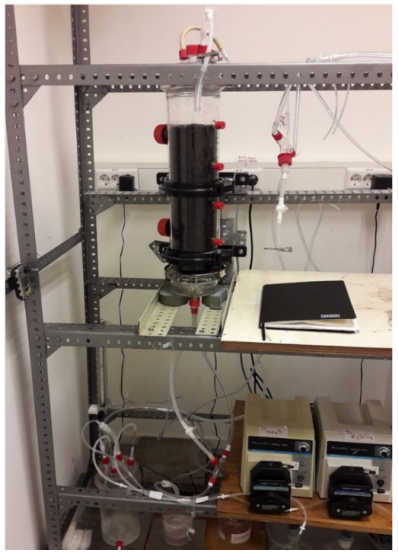
http://www.aqsolutions.org/

http://www.aqsolutions.org/images/2016/02/blue-barrel-system-manual-English.pdf

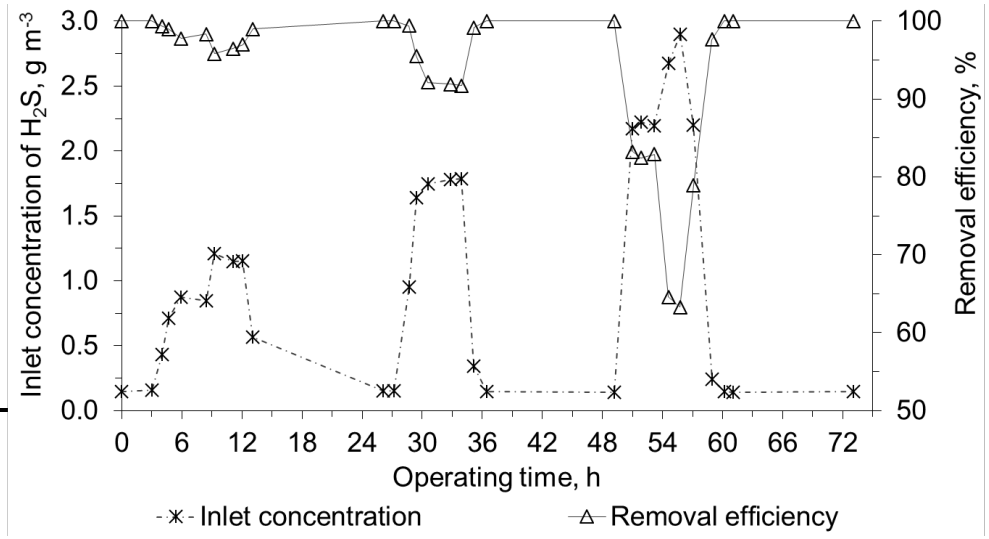
Biochar used with compost as biofilter for H_2S removal



Abbreviations
F - Flow meter
P_1, P_2 - Peristaltic pump
MFC - Mass flow controller
M - Magnetic stirrer
C_1-C_4 - Sampling port
I - Port to measure inlet H_2S
O - Port to measure outlet H_2S
L - Leachate

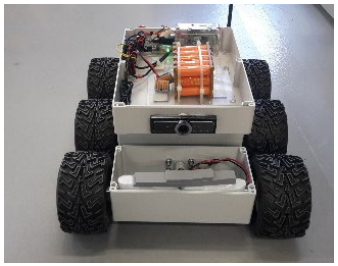


Das, J., Rene, E.R., et al. 2019 Performance of a compost and biochar packed biofilter for gas-phase hydrogen sulfide removal, Bioresource Technology, 273: 581-591



Energy storage

Electrode in supercapacitor or Li or Na-ion battery



- Very high added-value applications
- Feasibility proven (supercapacitor, battery)

- Economics?

Slow pyrolysis: status and challenges

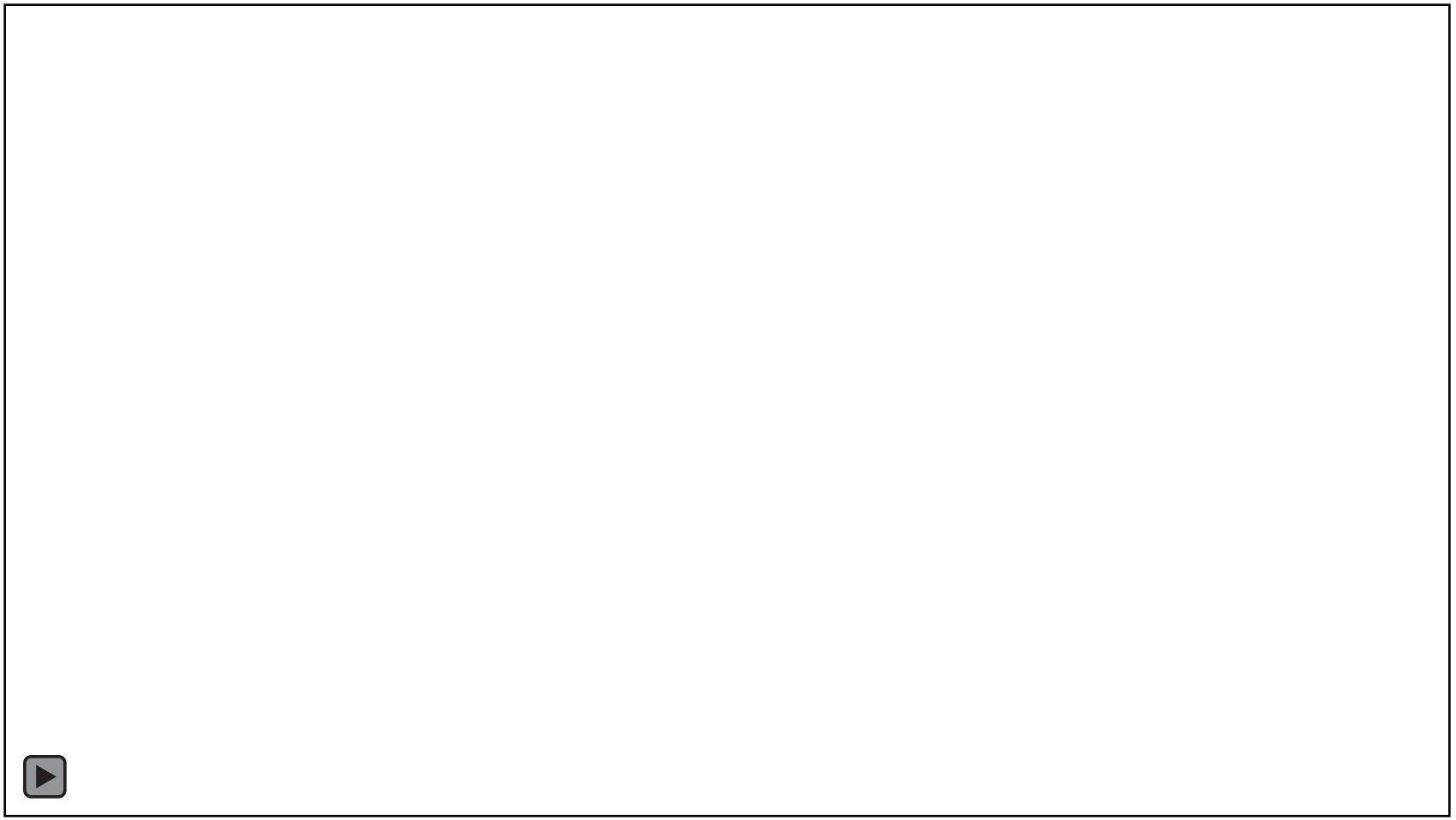
- A few industrial units
- Various scales and levels of complexity
- Strong recent interest all over the world

https://youtu.be/uwGqjo18m_k

- Robust and relatively cheap technology
- Suitable with various scales
- Various end-uses

- Drying cost
- Tailored biochar versus biomass feedstock?
- Cost vs existing products

Accra, Ghana



Thank You!
Any Queries!

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