Pyrolysis and thermal gasification of sludge – energy production in waste water treatment

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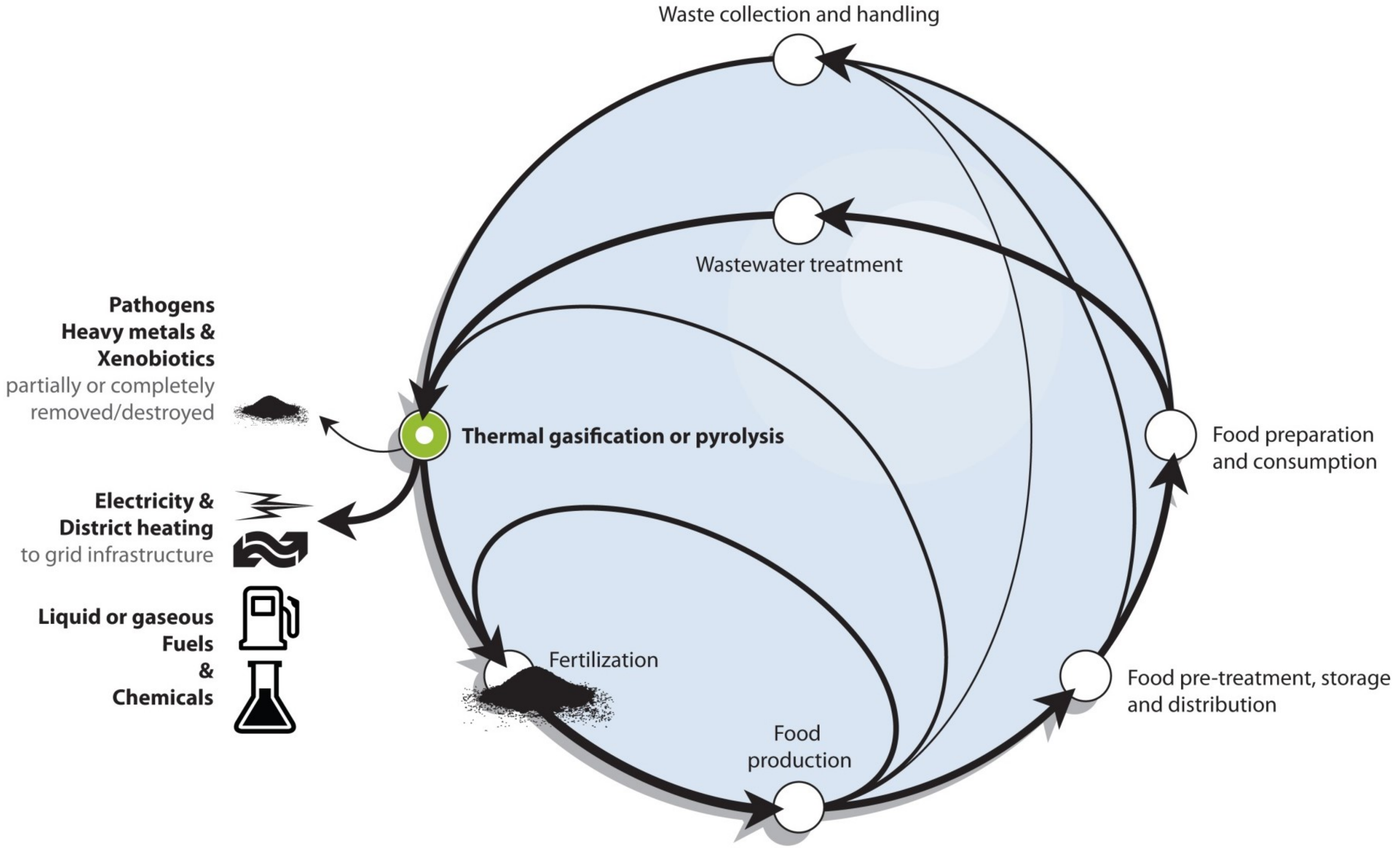
General **motivation behind our work**

1) **Mitigate climate change:** Improve the carbon footprint of the energy sector
2) **Reduce pollution:** Reduce pollution and risks associated with management of secondary resources
3) **Improve recovery and recycling** of critical elements e.g. phosphorus (P).

Motivation: **Secondary resource management**

Sustainable use of biomass & waste



BASIC

THERMAL CONVERSION

Introduction of **thermal gasification**

Heating organic material will initiate

- **Drying**

Surface Water and moisture

Heat

Introduction of **thermal gasification**

Heating organic material will initiate

- Drying
- **Torrefaction**

Heat

Cell-bound water and Simple organic molecules (e.g. Organic acids)

Introduction of **thermal gasification**

Heating organic material will initiate
- Drying
- Torrefaction
- **Pyrolysis**

Heat →

Pyrolysis gas:
Tar
Simple hydro-carbons
CO
CO_2
Water
H_2
CH_4
Etc.

Introduction of **thermal gasification**

If pyrolysis char is exposed to oxygen

➢ **Char combustion/oxidation**

Air/ O_2

HEAT &

Exhaust gas:

CO_2
Water
(N_2)
+
HCl
SO_2
NO_X
CO
etc.

Ash

Introduction of **thermal gasification**

If pyrolysis char is exposed to heat + CO_2 and/or heat + steam

- ➢ **Char gasification**

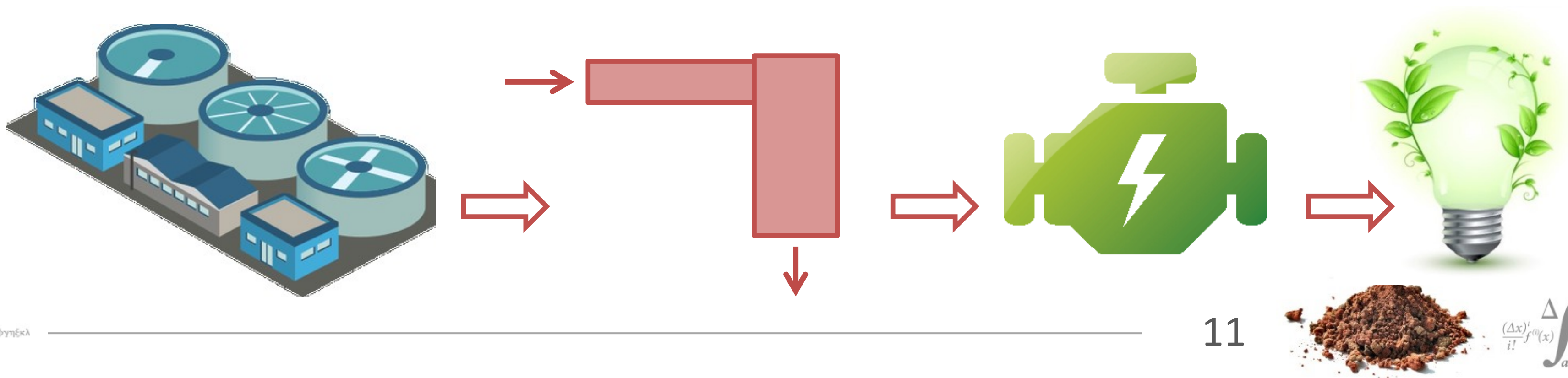
CO_2/
Steam
+
HEAT

Gasification product gas:
H_2
CH_4
CO
CO_2

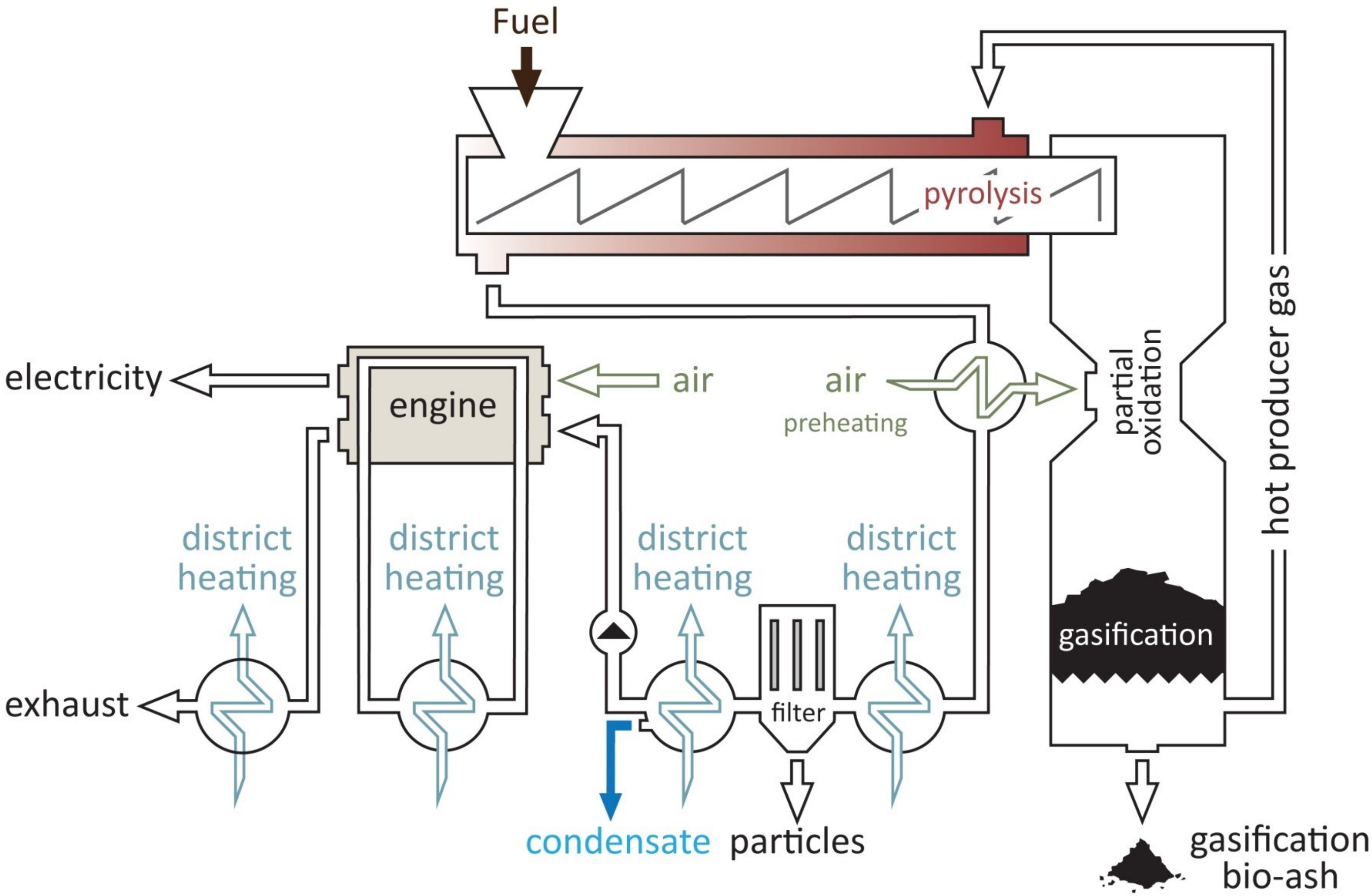
Ash

Activity | Thermal Treatment of Sludge

- **Ongoing projects related to thermal treatment of sludge from wastewater treatment and recirculating aquaculture systems**
- **The focus is on, energy, environmental advances and recirculation of plant availability of nutrients**
- **Different thermal solutions are tested**



Introduction of **the TwoStage gasifier**



Introduction of **the TwoStage gasifier**

Camilla
Thermal capacity: 25-50 kW
Location: DTU Risø Campus
Owner: DTU

Viking
Thermal capacity: 75-100 kW
Location: DTU Risø Campus
Owner: DTU

TwoStage gasification **perspectives**

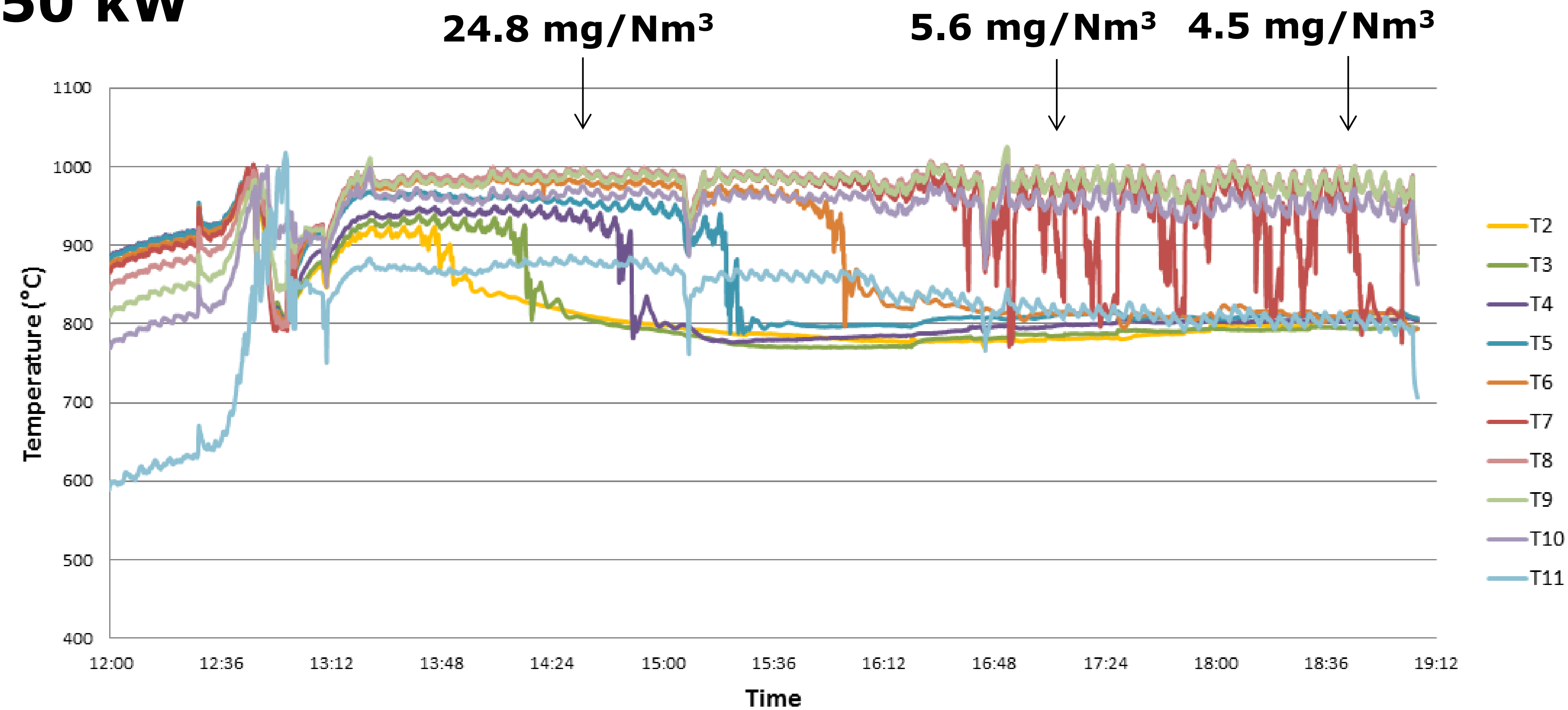
- High gasification efficiency > 95%
- High electrical efficiency >40% with gas engines
- Potential electrical efficiency >50% with SOFC
- Ideal for de-centralised combined heat and power production (CHP)
- High total efficiency (CHP mode) >100% (LHV)

Sludge feedstocks and Ash Fertilizer

PoC - Gasification of Sewage Sludge

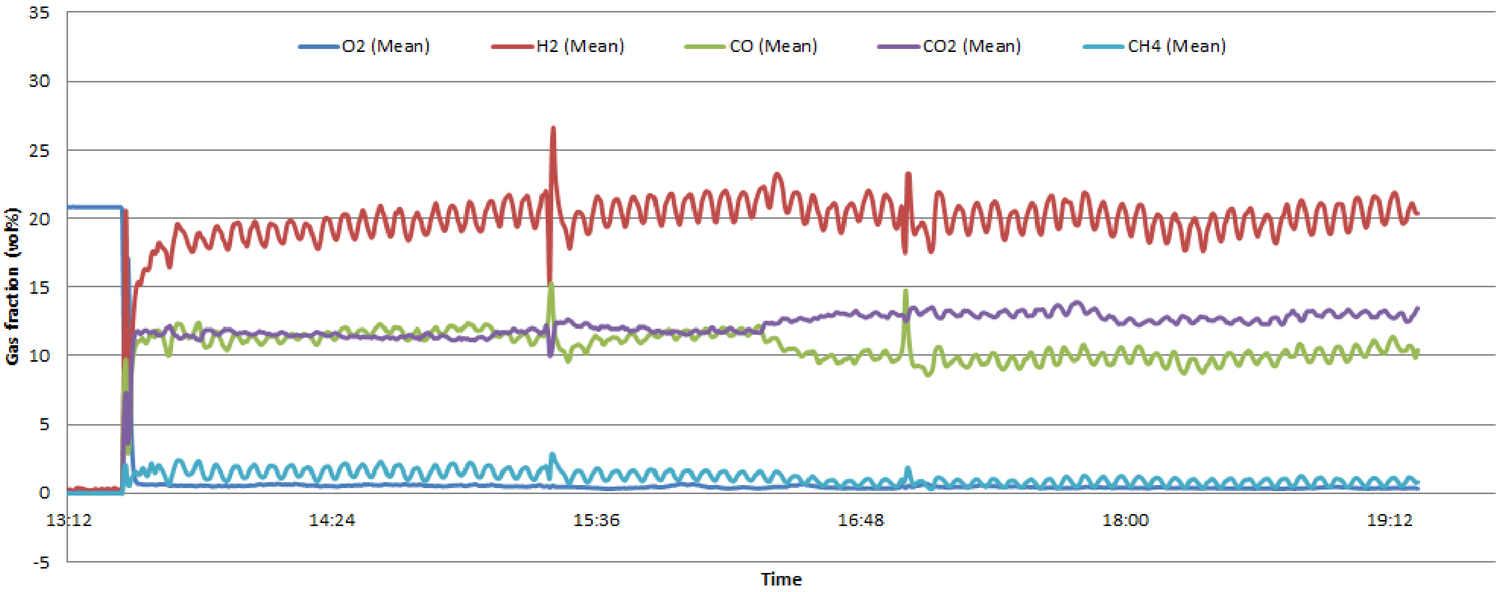
Tar concentration

50 kW

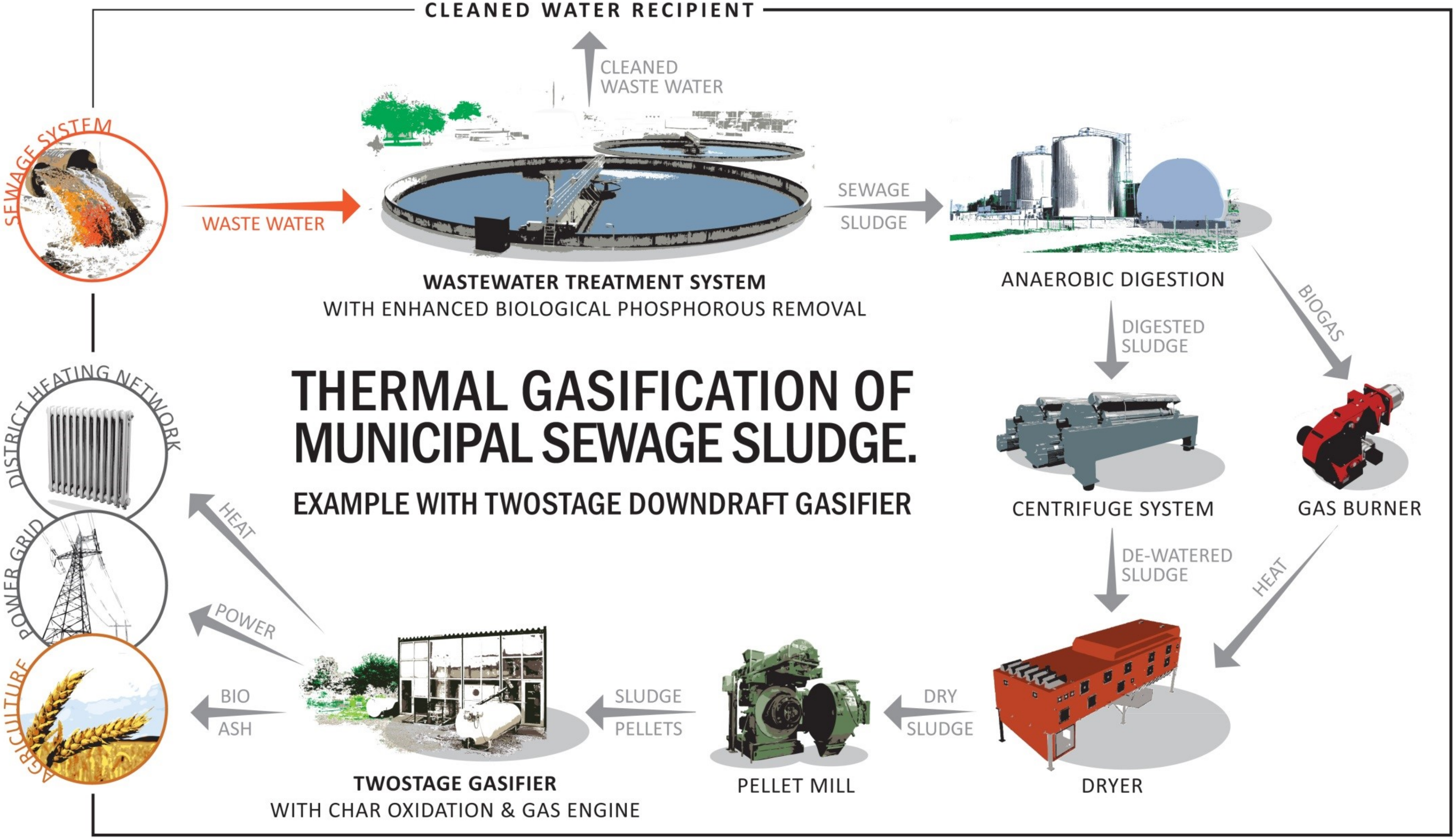


Allowable tar level for gas engine: ~50 mg/Nm^3

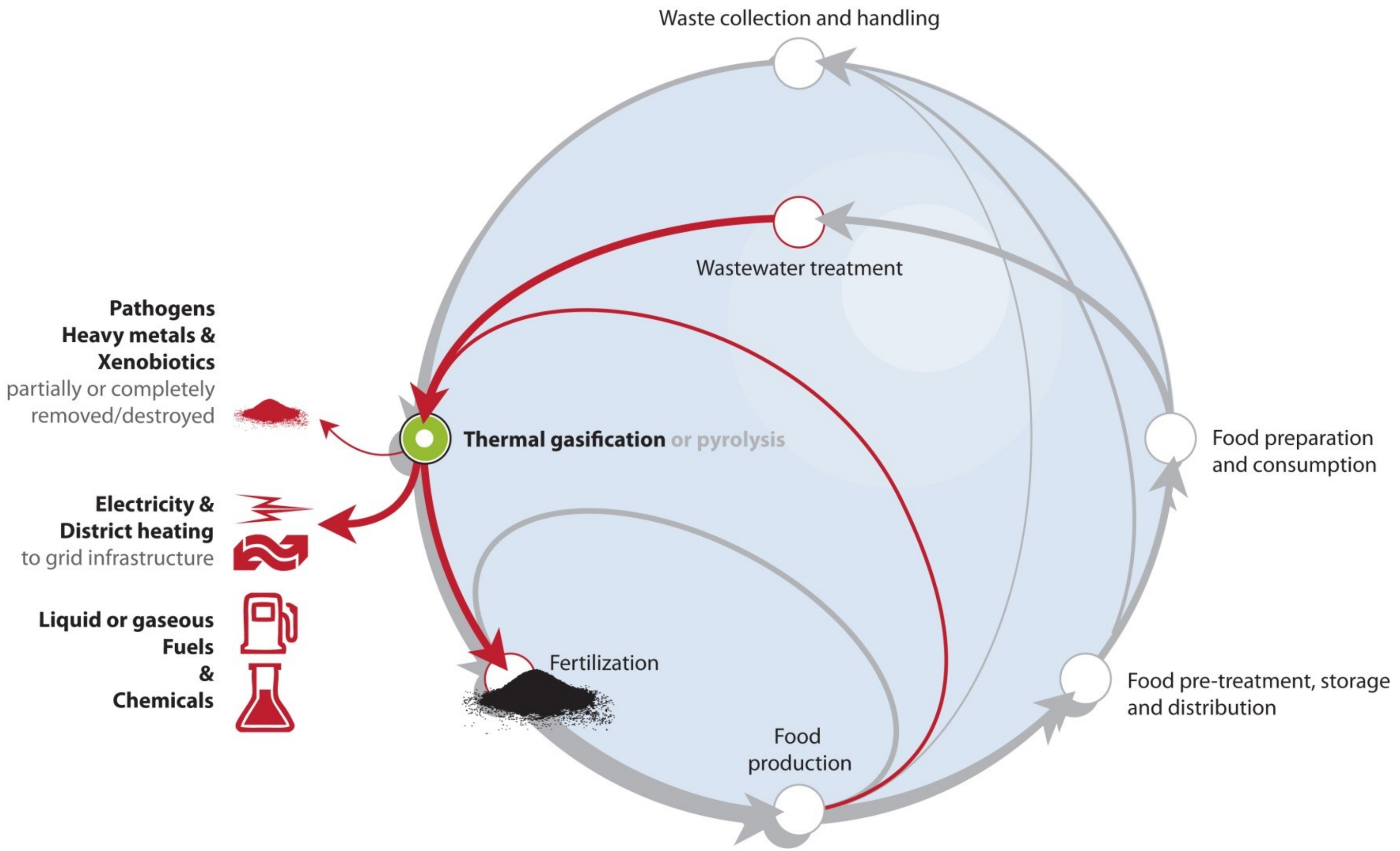
Gas composition during experiment



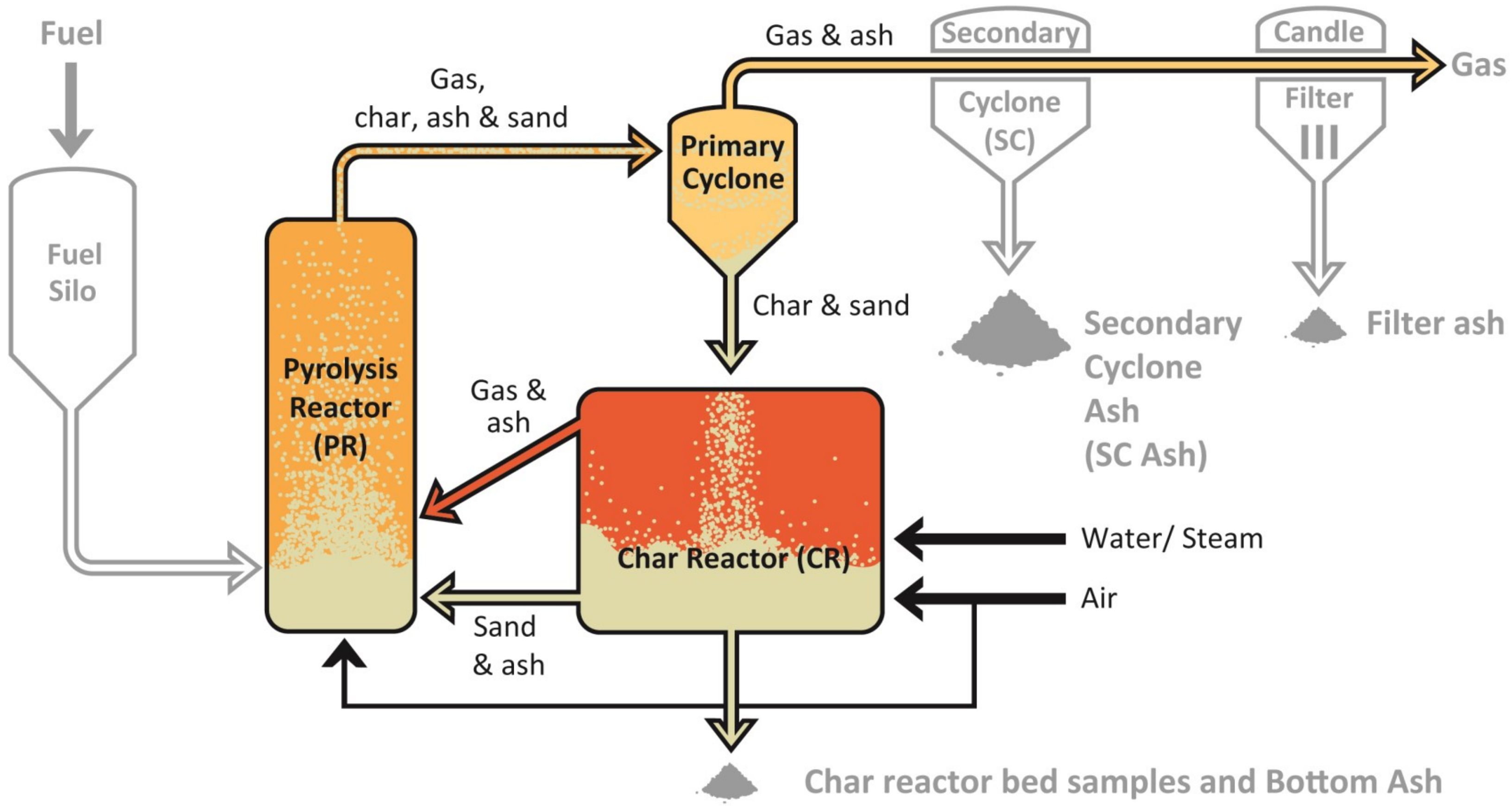
Average gas composition		
CH_4	1,1	v%
CO	10,7	v%
CO_2	12,4	v%
H_2	20,2	v%
N_2	55.7	v%


CLEANED WATER RECIPIENT
CLEANED WASTE WATER
SEWAGE SYSTEM
WASTE WATER
SEWAGE SLUDGE
WASTEWATER TREATMENT SYSTEM
WITH ENHANCED BIOLOGICAL PHOSPHOROUS REMOVAL
ANAEROBIC DIGESTION
BIOGAS
DIGESTED SLUDGE
THERMAL GASIFICATION OF MUNICIPAL SEWAGE SLUDGE.
EXAMPLE WITH TWOSTAGE DOWNDRAFT GASIFIER
DISTRICT HEATING NETWORK
CENTRIFUGE SYSTEM
GAS BURNER
HEAT
DE-WATERED SLUDGE
HEAT
POWER GRID
POWER
AGRICULTURE
BIO ASH
SLUDGE PELLETS
DRY SLUDGE
TWOSTAGE GASIFIER
WITH CHAR OXIDATION & GAS ENGINE
PELLET MILL
DRYER

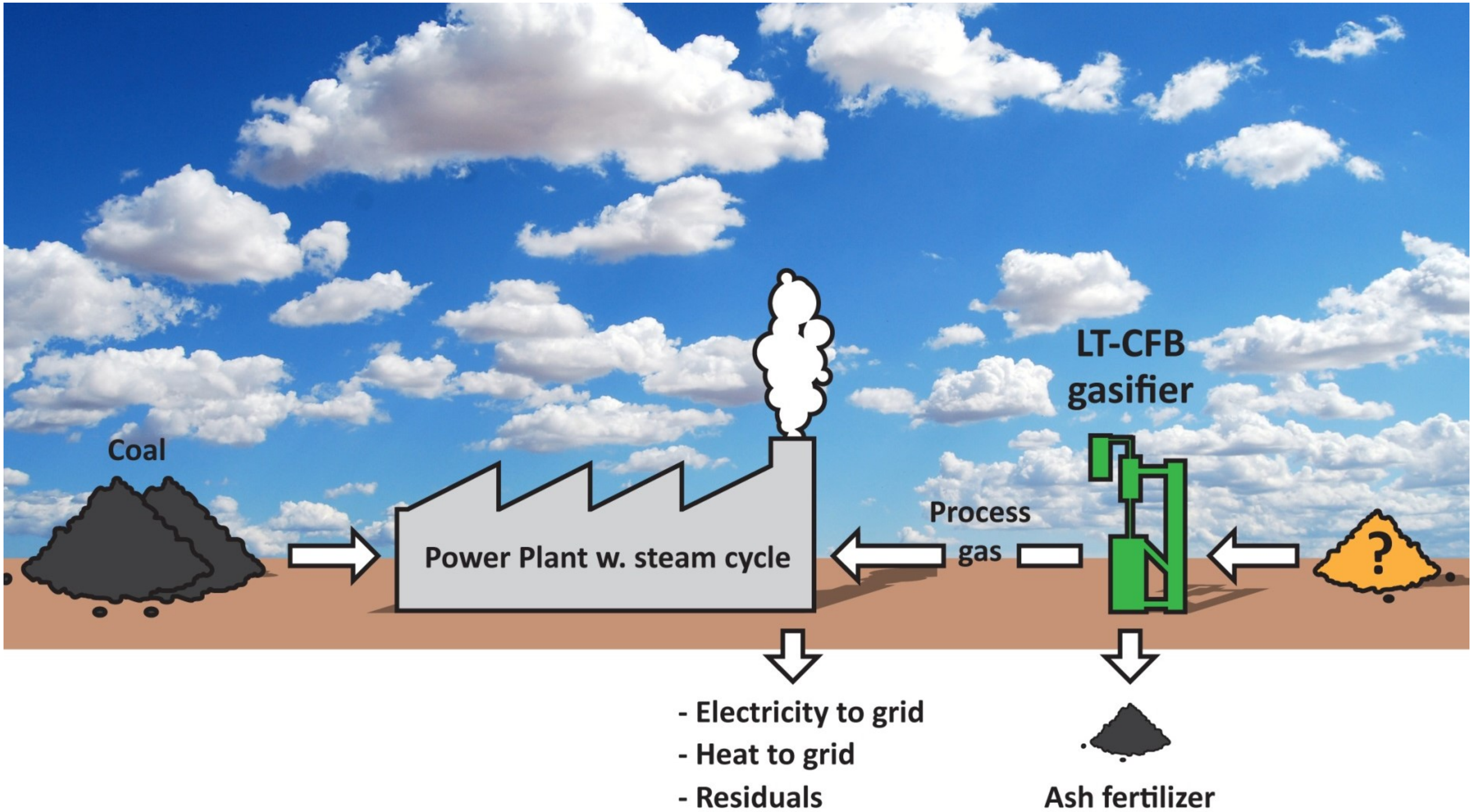
Sustainable use of sewage sludge (& straw)



Introduction of **the LT-CFB gasifier**



Introduction of **the LT-CFB gasifier**



Thermal capacity: 100 kW
Location: DTU Risø Campus
Owner: DTU

Thermal capacity: 6000 kW
Location: Asnæs power plant
Owner: DONG Energy

LT-CFB gasification **perspectives**

- Highly efficient utilization of problematic low grade biomass and waste for large scale power plants
- Conversion of gas/oil fired power plants to 100% biomass
- More biomass based energy production – Now!
- Increased flexibility of fuel and products

Bench Scale Dryer

AquaGreen

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Test of Pyrolysis Gas Burner

AquaGreen

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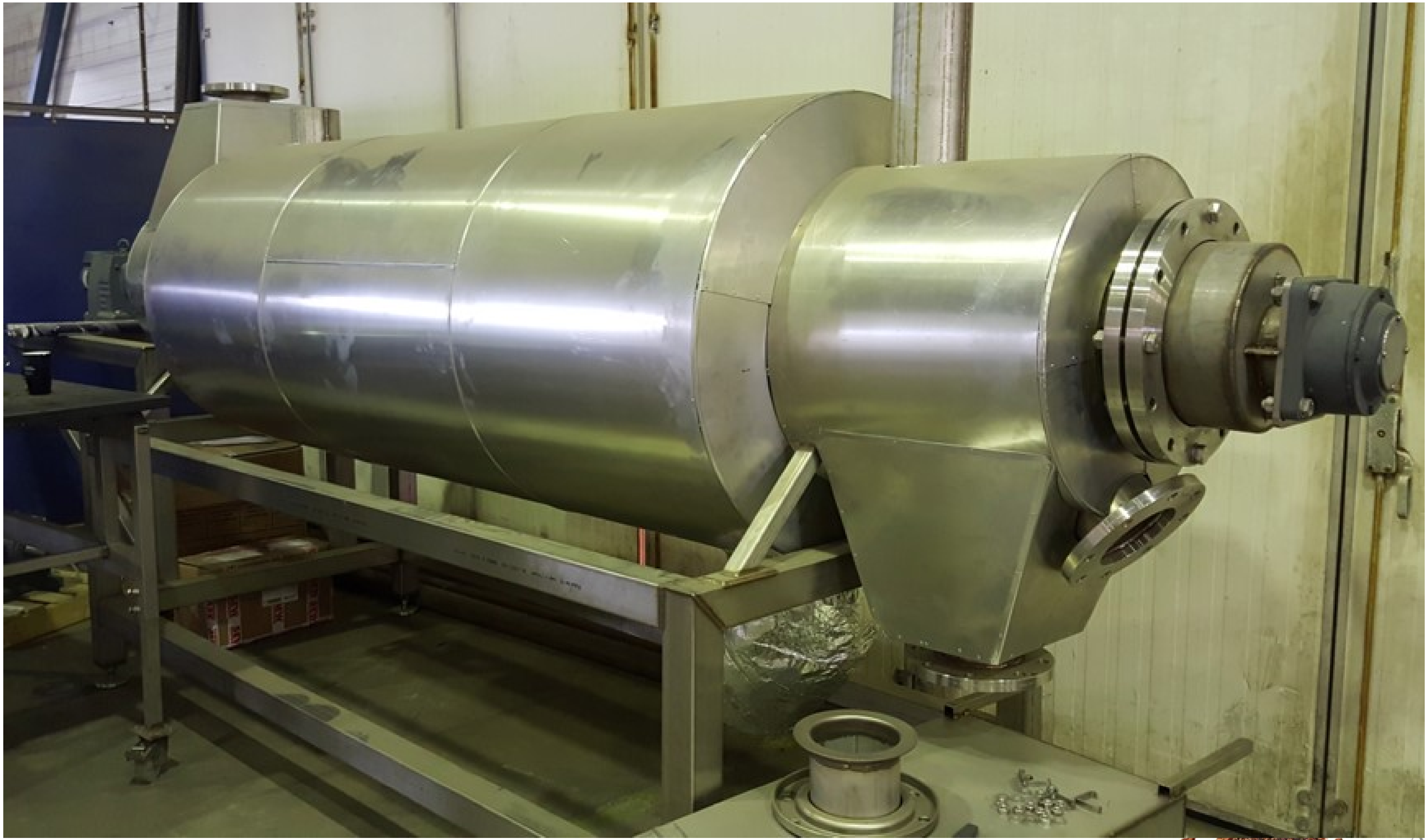
First Full Scale Dryer Installed, 100 kW input

First Full Scale Pyrolysis Unit, 100 kW input



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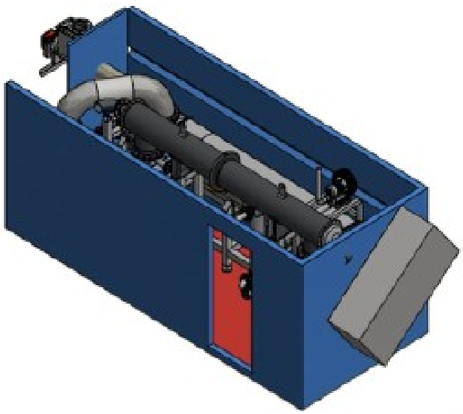
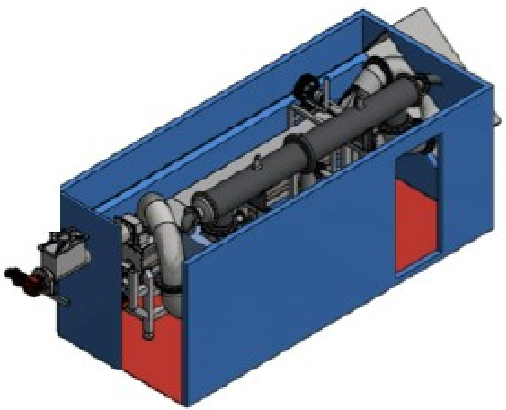
WW Treatment Plant for Vandcenter Syd





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ASH FERTILIZER QUALITY AT BGG

WHY AND HOW?

General **motivation – why ash?**

1) Improve the life cycle impact of thermal gasification:

- **Reduce pollution e.g. toxicity and eutrophication**
- **Recover and reuse critical elements**
- **Enhance soil quality and sequester carbon**

2) Improve feasibility of thermal gasification in a circular economy:

- **Develop new markets**
- **Valorise ash products**

BGG Focus: Increase P security

- P is a **pre-requisite for all life as we know it** and irreplaceable in DNA, ATP, phospholipids etc.
- P consumption is increasing rapidly while the commercially available P-stocks are depleting and likely to **reach a peak within the next 50-100 years** (Cordell et al., 2009).
- Phosphorus on **EU's list of critical resources** since 2014

Cordell, D.; Drangert, et al, 2008: The story of phosphorus: global food security and food for thought. Global Environmental Change 19, 292-305.

Ash investigations: Effect on plant yield

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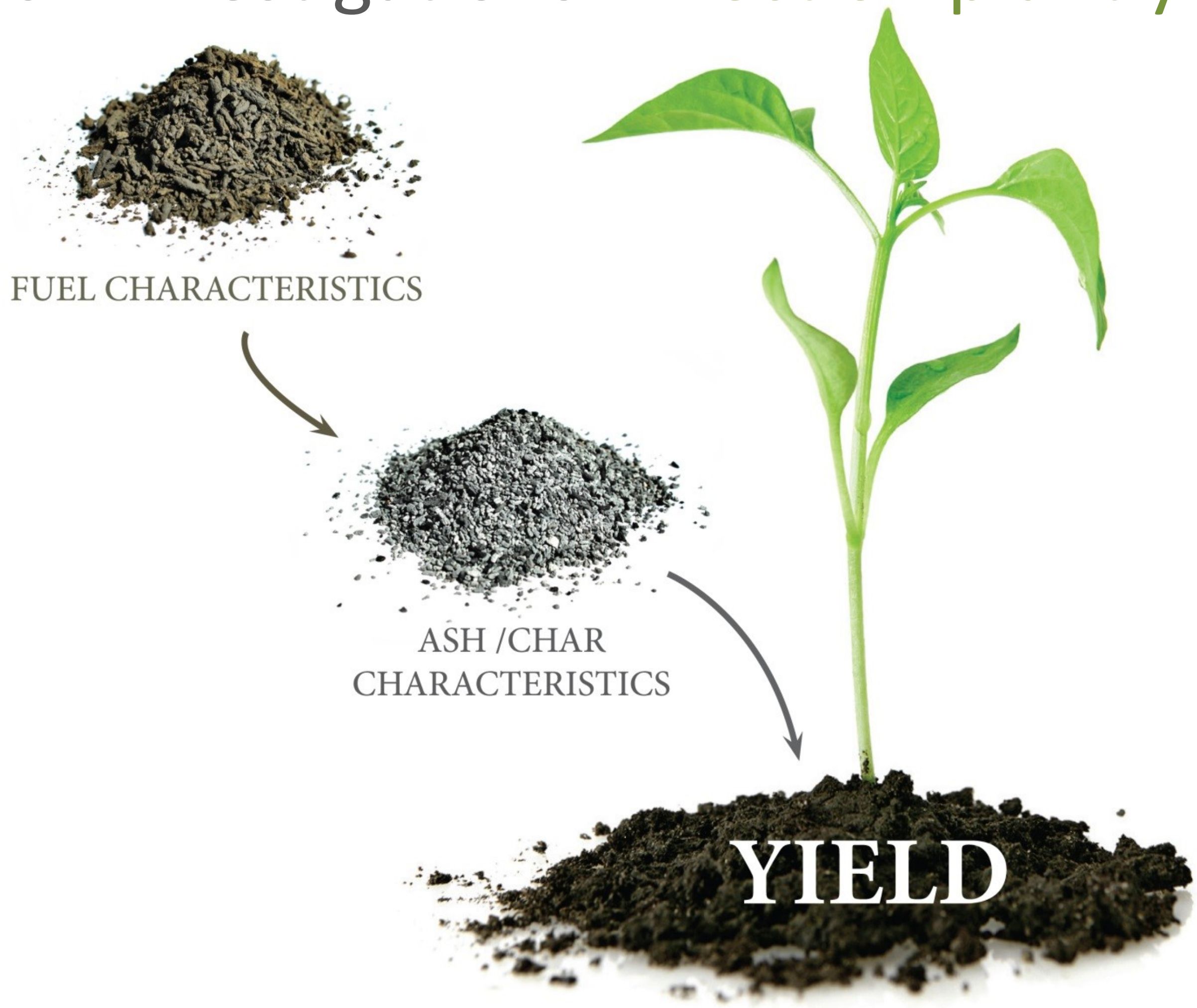
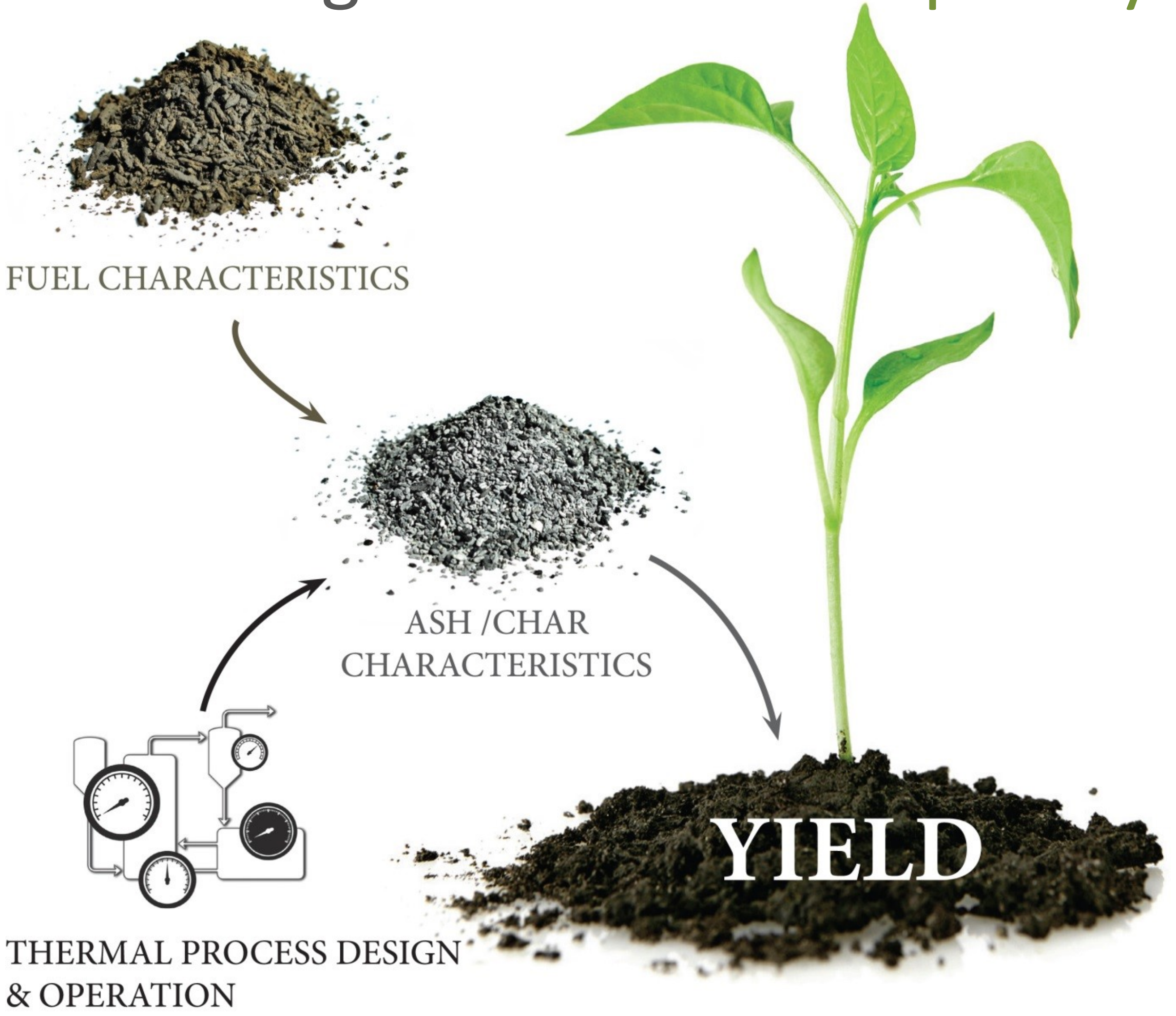
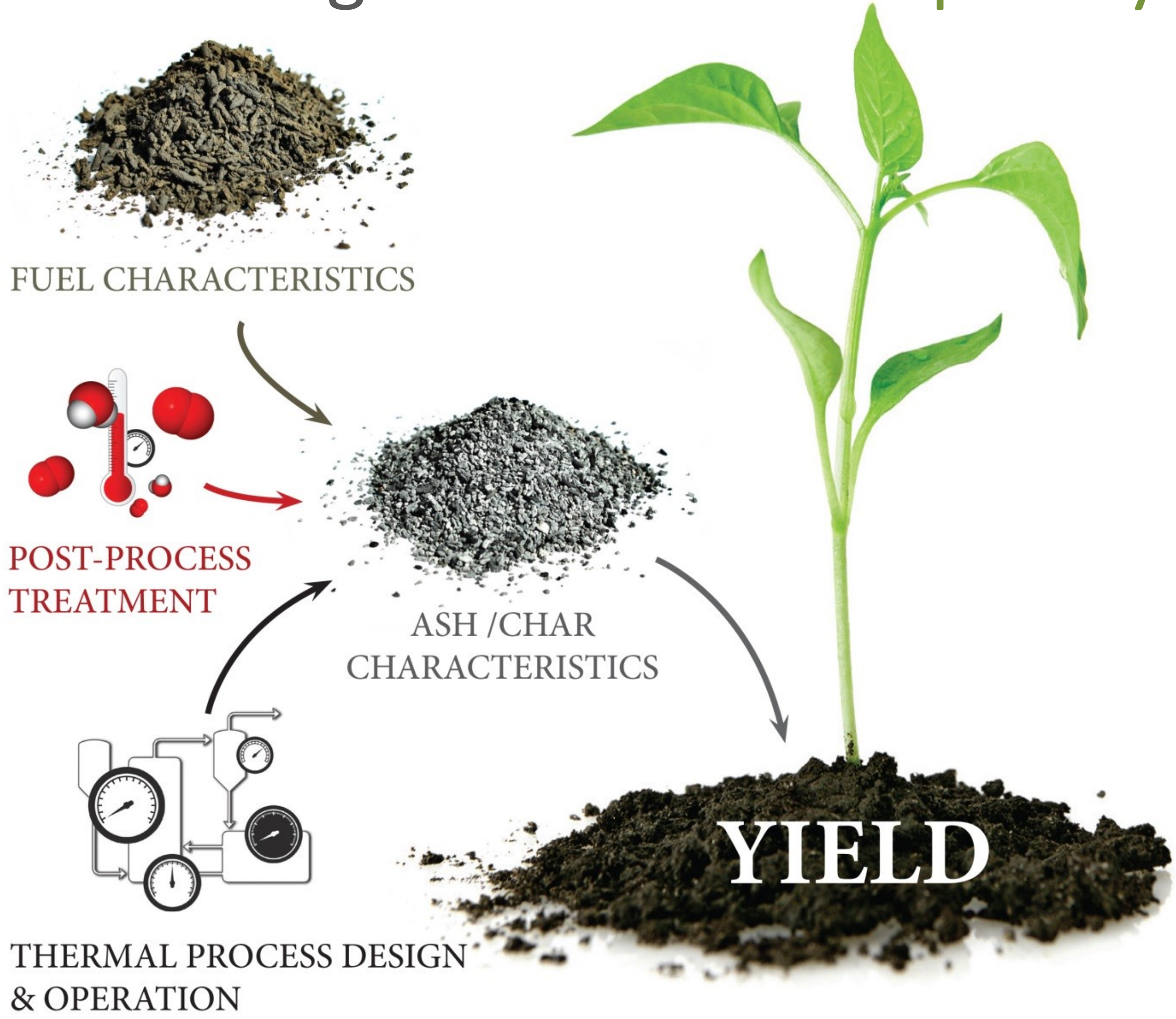


Ash investigations: Effect on plant yield



Ash investigations: Effect on plant yield



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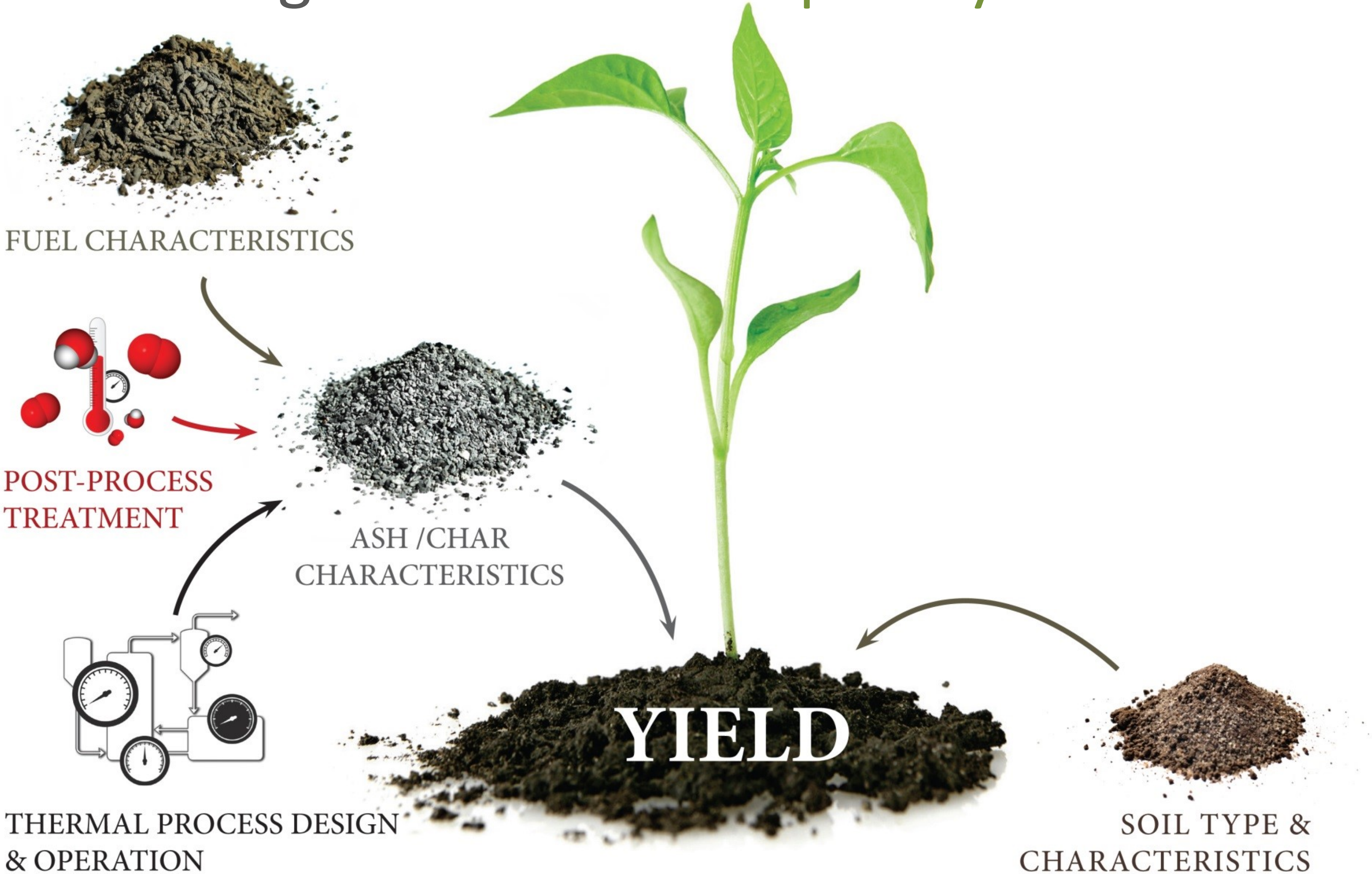
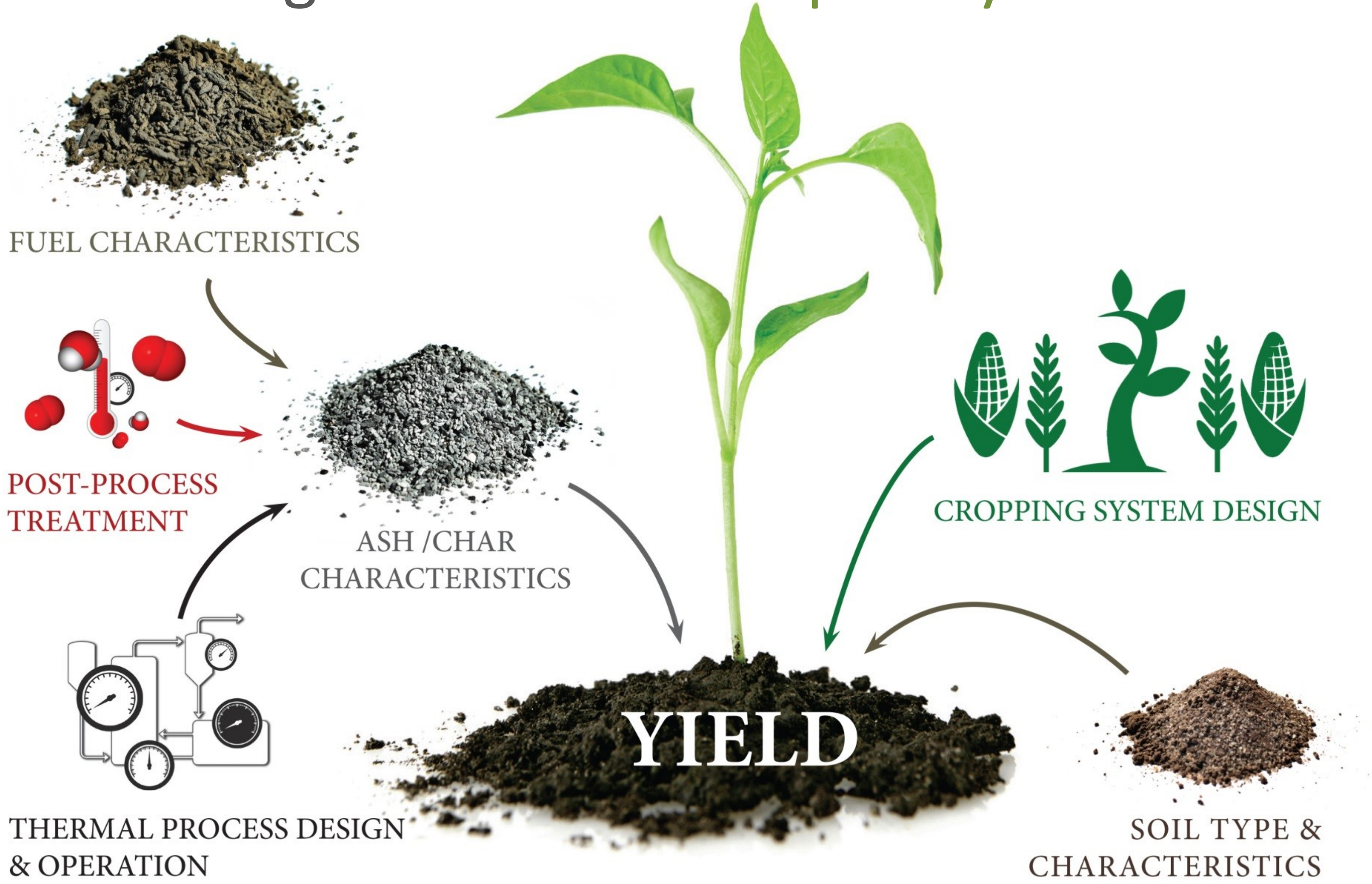
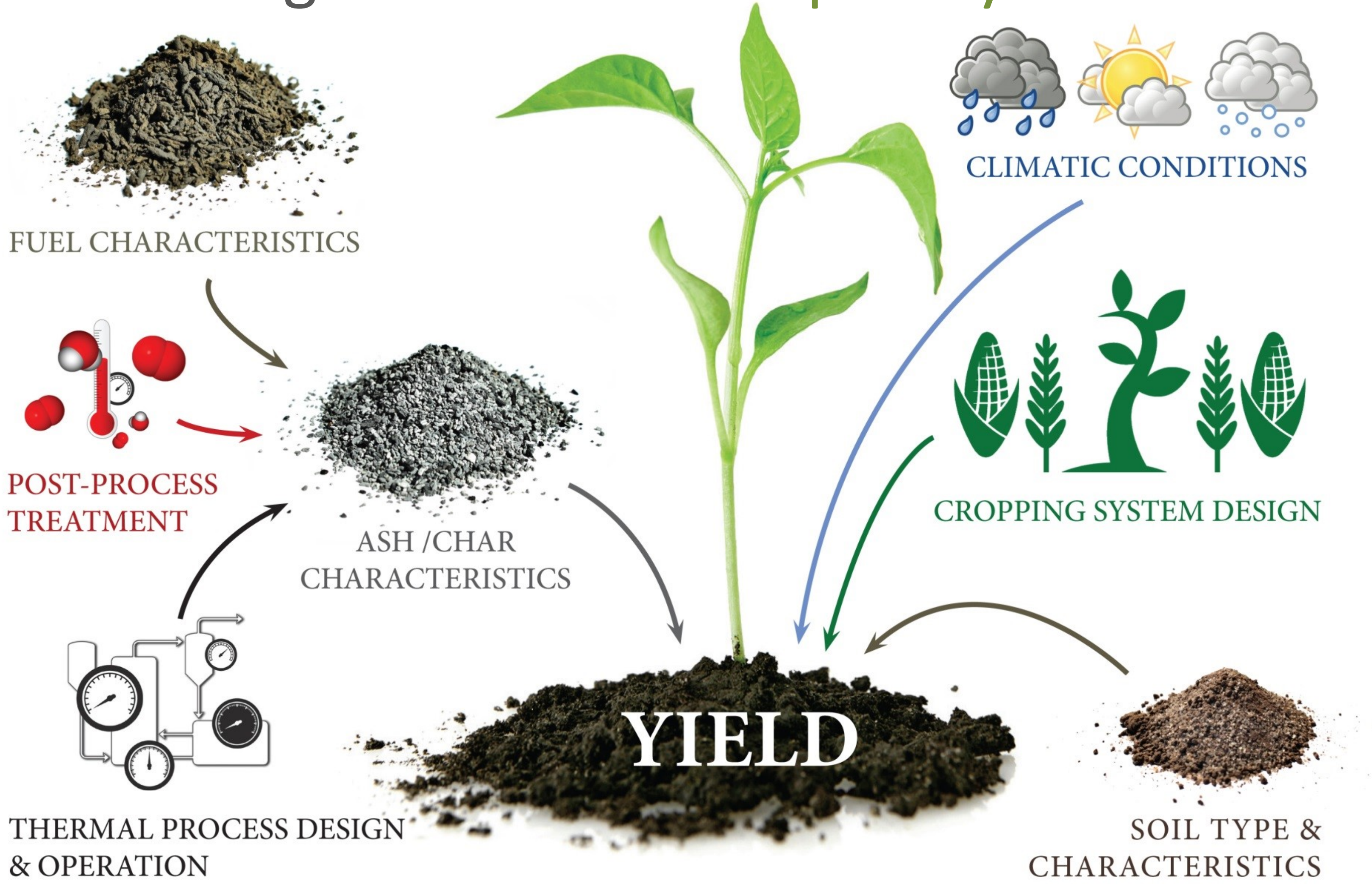


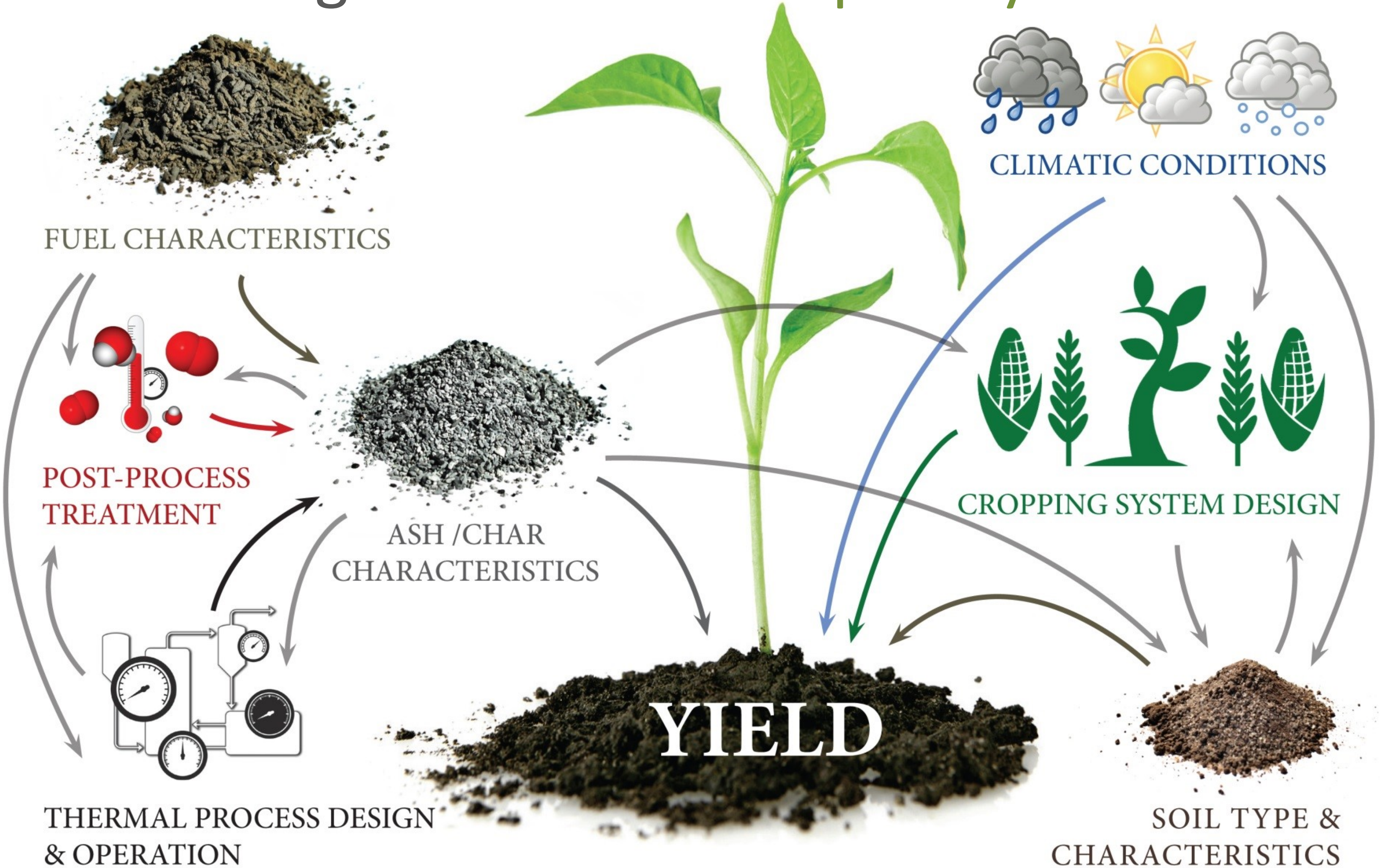
Ash investigations: Effect on plant yield



Ash investigations: Effect on plant yield



Ash investigations: Effect on plant yield

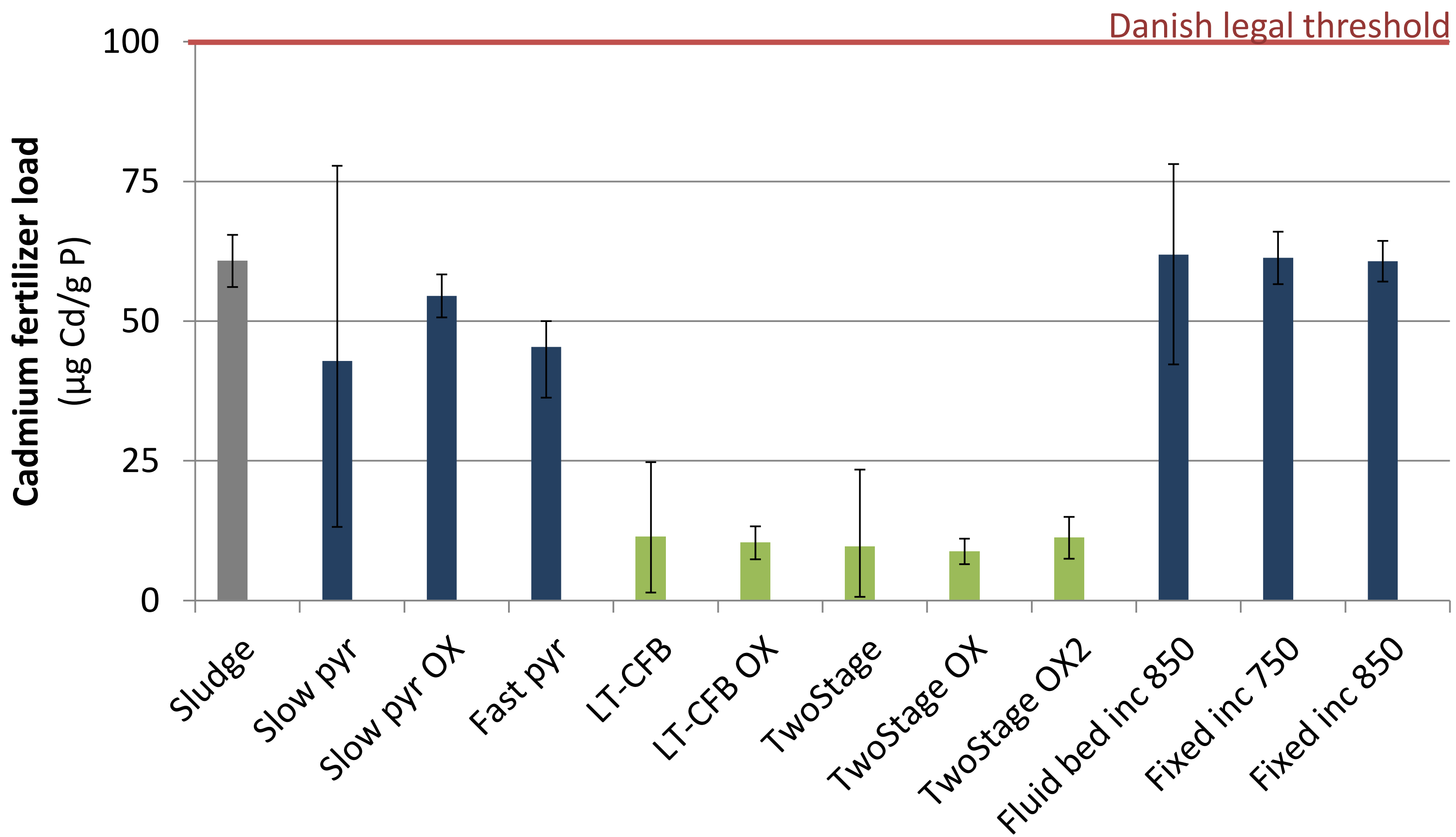


Ash investigations: How?

ASH FERTILIZER QUALITY AT BGG

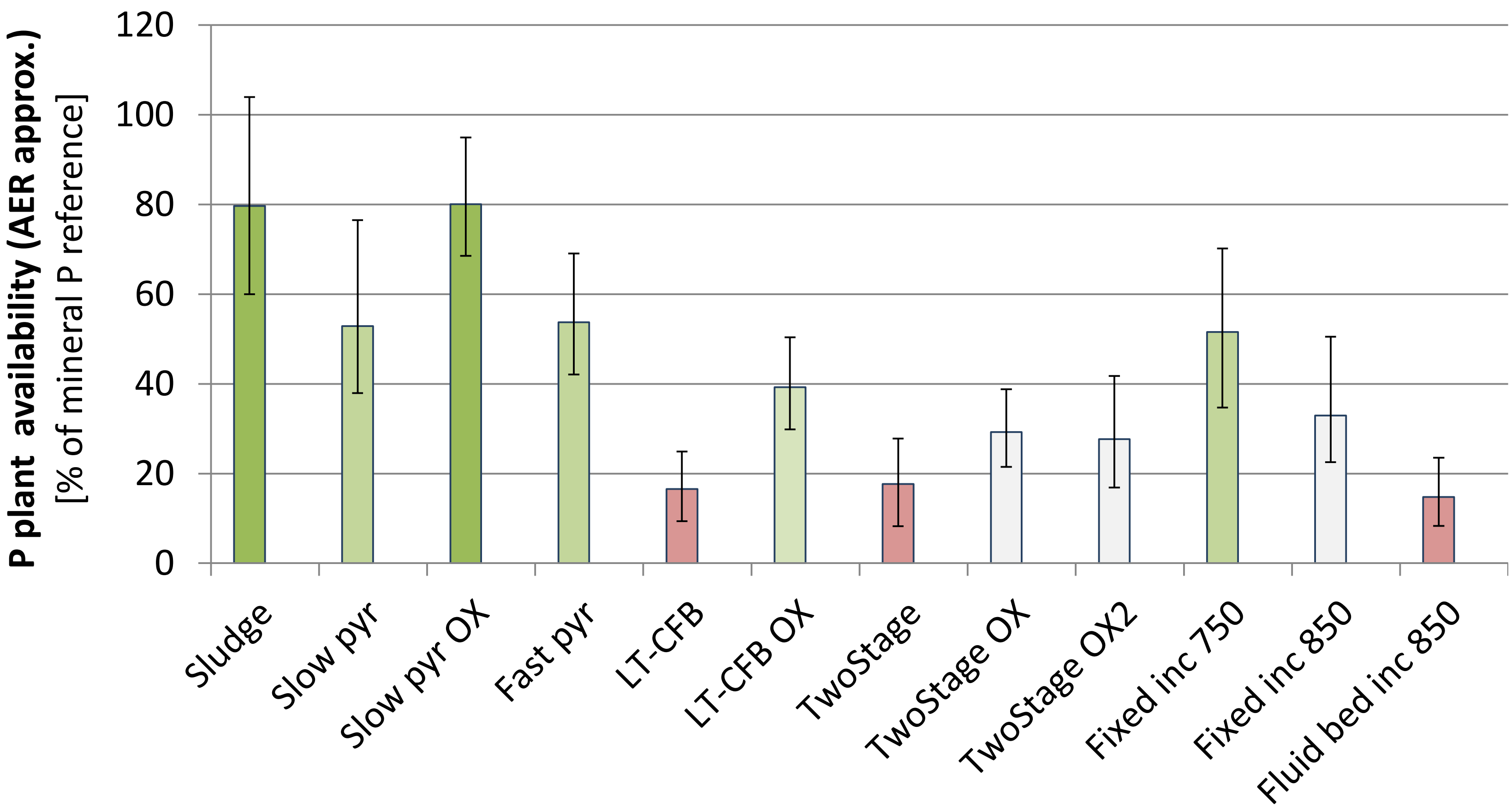
RESULT EXAMPLES

Result example Tech. influence on ash Cd load



Tobias Pape Thomsen, Zsuzsa Sárossy, Jesper Ahrenfeldt, Ulrik Henriksen, Flemming Frandsen and Dorette Sophie Müller-Stöver: *Changes imposed by pyrolysis, thermal gasification or incineration on elemental composition and phosphorus fertilizer quality of municipal sewage sludge*. Journal of Environmental Management 198 (2017) 308-318

Result example Tech. influence on ash P quality



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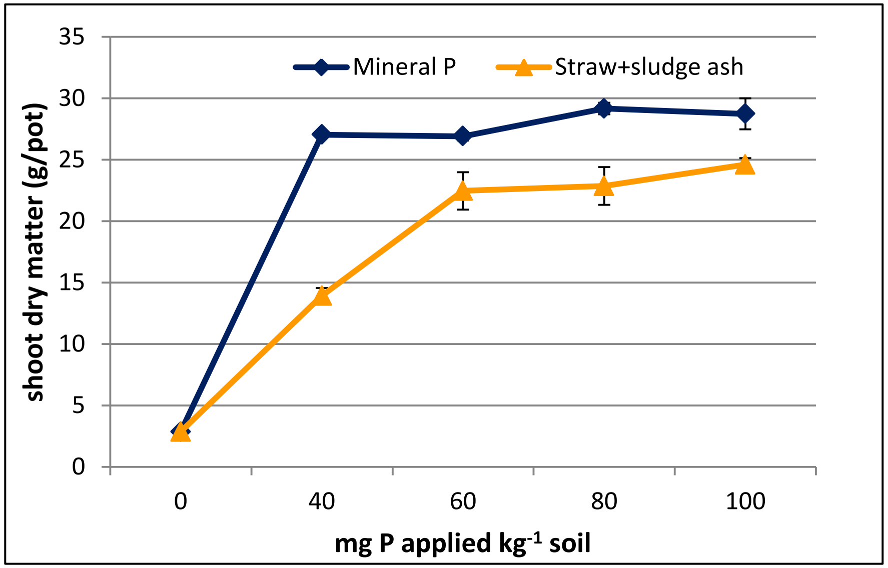
BioAsh| P-fertilization effect of sludge/straw ash



Barley plant response to increasing amounts of sludge/straw gasification ash (40, 60, 80, and 100 mg P kg^{-1} soil)

Bioash/char improves root growth and yields of spring barley cultivated on coarse sandy soils

Control Bioash

Bioash improves the waster retention of the soil

Thank you for your attention

Biomass Gasification Group