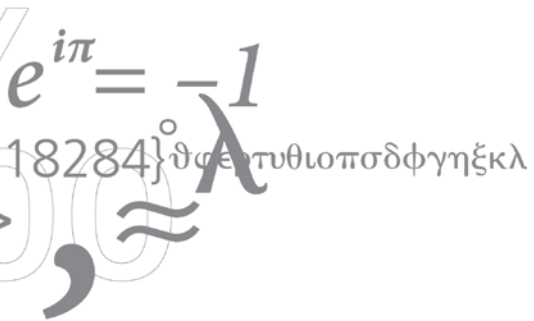


# About DTU KT/CHEC/BGG

## - what, how and why

Biomass Gasification Group, Technical University of Denmark

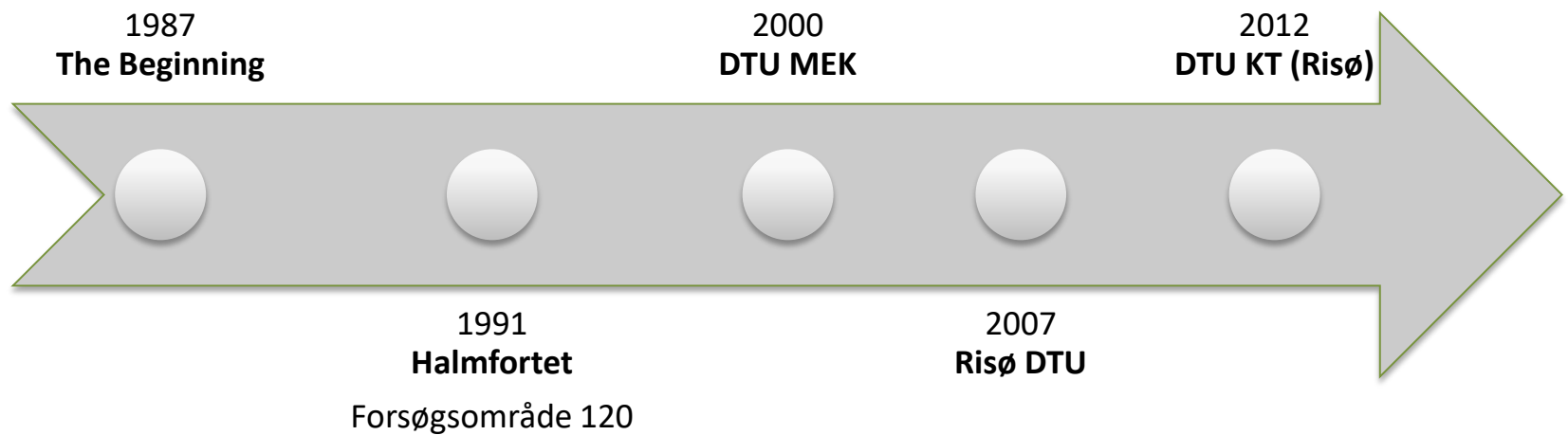


ABOUT BGG

**WHO, WHY AND WHAT?**



# CHEC/BGG - History



# BGG - History

25 years of R&D and demonstration has resulted in two pre-commercial gasification processes and one commercial system for drying and pyrolysis of wet organic resources:

1. **The TwoStage gasifier**, a high temperature process for gasification of wood (developed in cooperation with COWI)
2. **The PYRONEER gasifier** (Low Temperature Circulating Fluid Bed), a low temperature process for gasification of low grade biomass e.g. straw, manure and waste (developed in cooperation with Danish Fluid Bed Technology)
3. **Steam drying and slow pyrolysis** of e.g. sewage sludge or fish manure (developed in cooperation with AquaGreen)



# CHEC/BGG – Staff 2018



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PhD student



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PhD student



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Ulrik Henriksen  
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Flemming Frandsen  
Associate professor

## Emeritus



Hanne Østergaard  
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Helge Egsgaard  
Senior scientist

## Diagnostics



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Senior Scientist



Sønnik Clausen  
Senior Scientist



Peter Christensen  
Technician



# CHEC/BGG – Facilities at Campus Risø



Workshop

Research Facility



# CHEC/BGG – Facilities at Campus Risø, 313



## PHYMLAB

*Physical and mechanical testing*

Grindability  
Pelletization  
Humidification  
Drying  
Sampling  
Etc.

## CHEMLABS

*Chemical and analytical testing*

GC  
HPLC  
Extraction  
TGA  
Heating value  
Etc.



# CHEC/BGG – Facilities at Campus Risø, 321



## THERMOLAB

*High temperature testing*

Macro-TGA  
Pyrolysis  
Torrefaction  
Drying  
Annealing  
Etc.

## WORKSHOP

*Preparation and large scale testing*

Welding  
Cutting  
Construction  
SOFC setup  
LT-CFB setup  
Etc.



# 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).



# CHEC/BGG – Areas of focus

- 1) Thermal conversion of organic resources
  - a) Thermal gasification
  - b) Pyrolysis
  - c) Incineration and combustion
- 2) Characterization of fuels, chars, ashes and systems
- 3) Drying, feeding and handling systems
- 4) Analytical chemistry & theoretical chemistry
- 5) Diagnostics



# GASIFICATION R&D **AT CHEC/BGG**



# Gasification at BGG – tech. milestones

**20 years** of research, development and demonstration has resulted in two pre-commercial gasification processes:

- » The TwoStage gasifier, a high temperature process for gasification of wood (developed in cooperation with COWI)
- » The PYRONEER gasifier (Low Temperature Circulating Fluid Bed), a low temperature process for gasification of low grade biomass e.g. straw, manure and waste (developed in cooperation with Danish Fluid Bed Technology)



# Gasification at BGG

## TwoStage Down Draft gasification

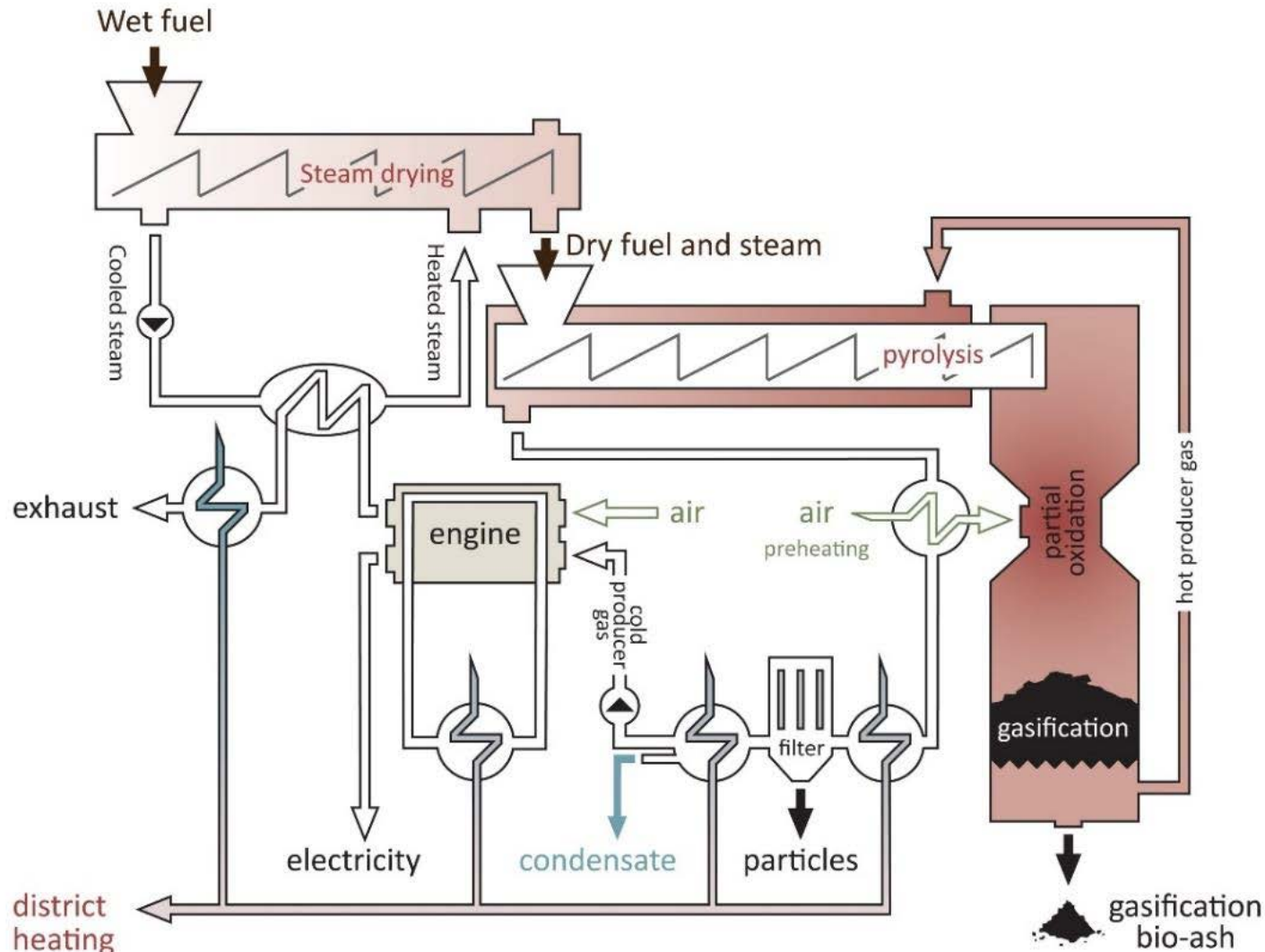
- Small scale application ( $<2 \text{ MW}_{\text{TH}}$ ). Stand alone unit.
- **Eff.:** Cold gas efficiency up to 93%
- **Fuel:** Wood chips, sewage sludge pellets and straw with additives

## Low Temperature Circulating Fluidized Bed gasification (LT-CFB/Pyroner)

- Fully scalable. Stand alone (R&D) or w. boiler (current)
- **Eff.:** Hot gas efficiency up to 95%
- **Fuel:** Straw, sewage sludge, manure fibers, biogas fibers, various organic residues from food industry and fuel mixes



# 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



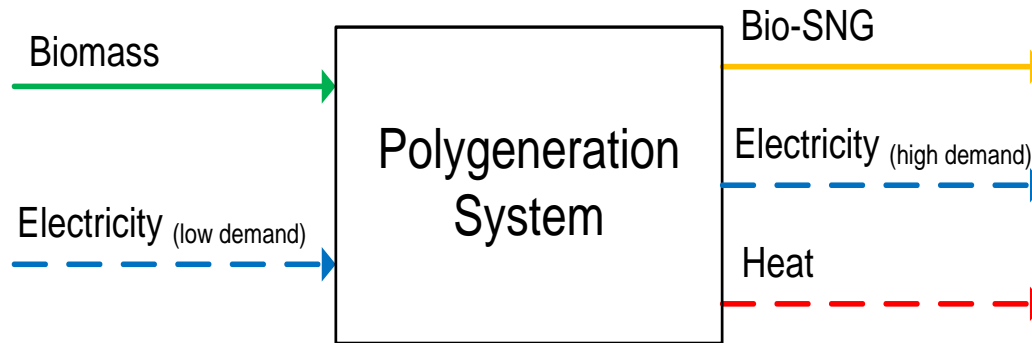
# TwoStage gasification **perspectives**

- 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)



# TwoStage gasification **perspectives**

## Biomass Gasification Polygeneration:



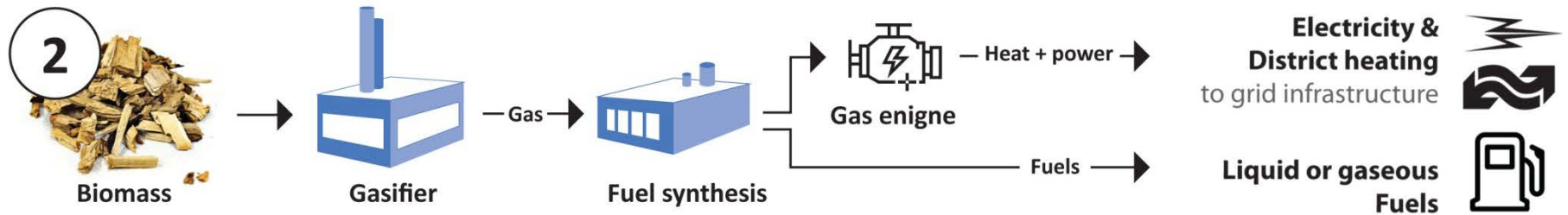
- Pilot scale oxygen blown TwoStage gasification of wood
- System analysis modeling of polygeneration plants
- Development of large-scale TwoStage Gasifier concepts



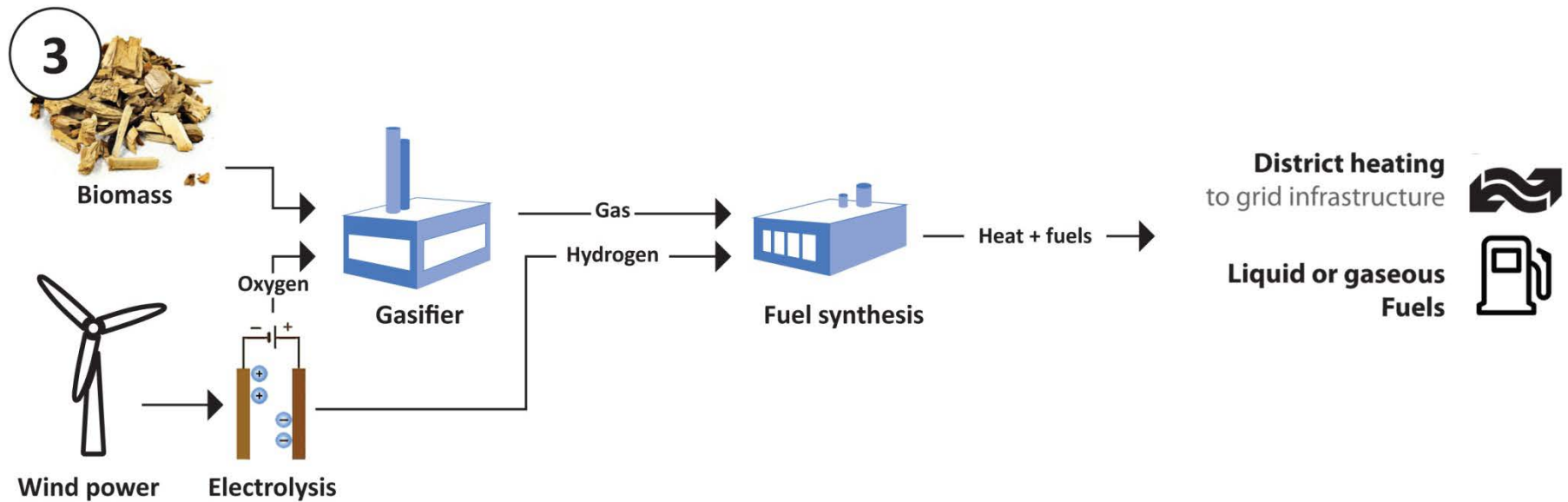
# Basic **thermal gasification systems**

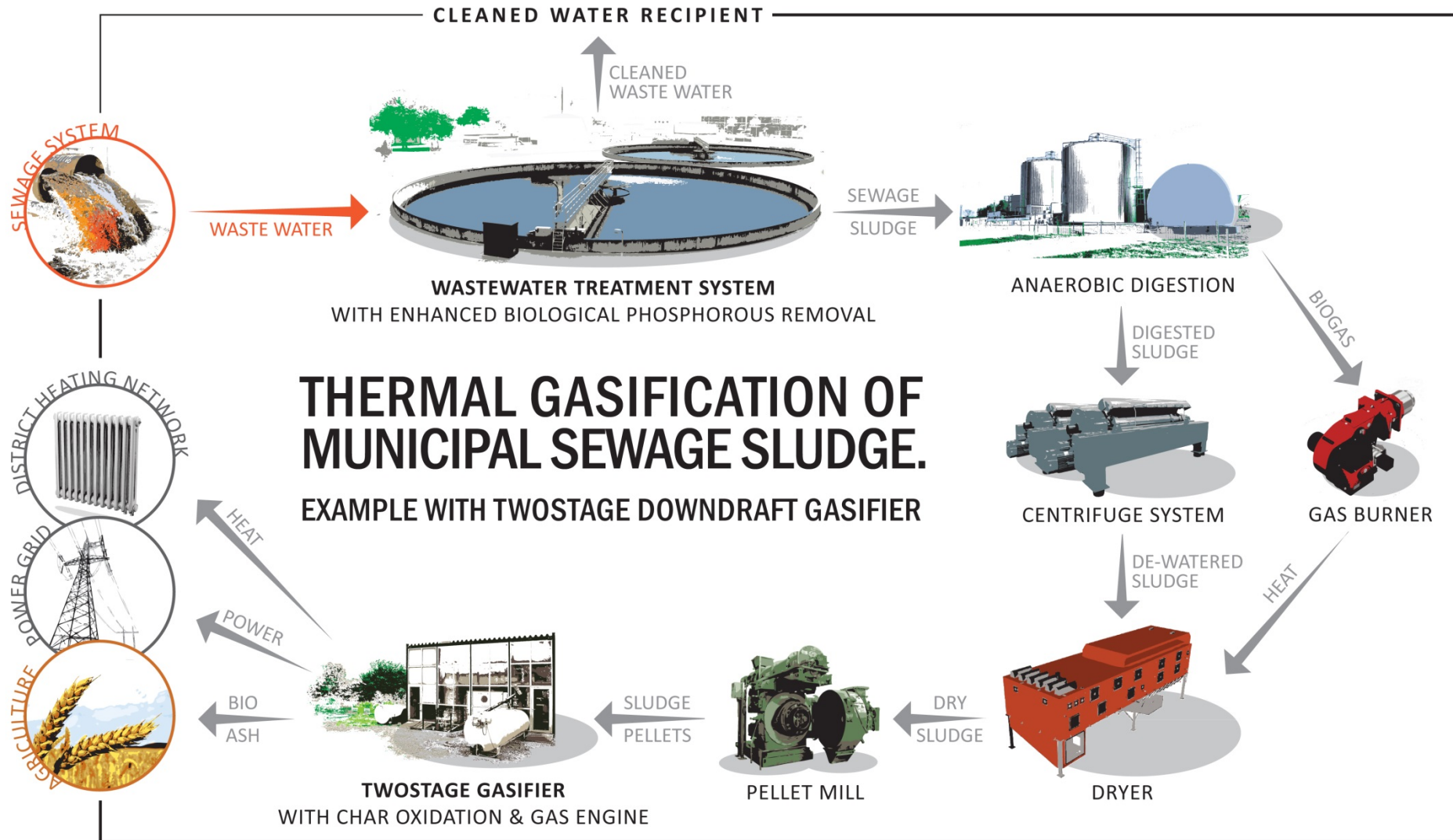


# Advanced **thermal gasification systems**

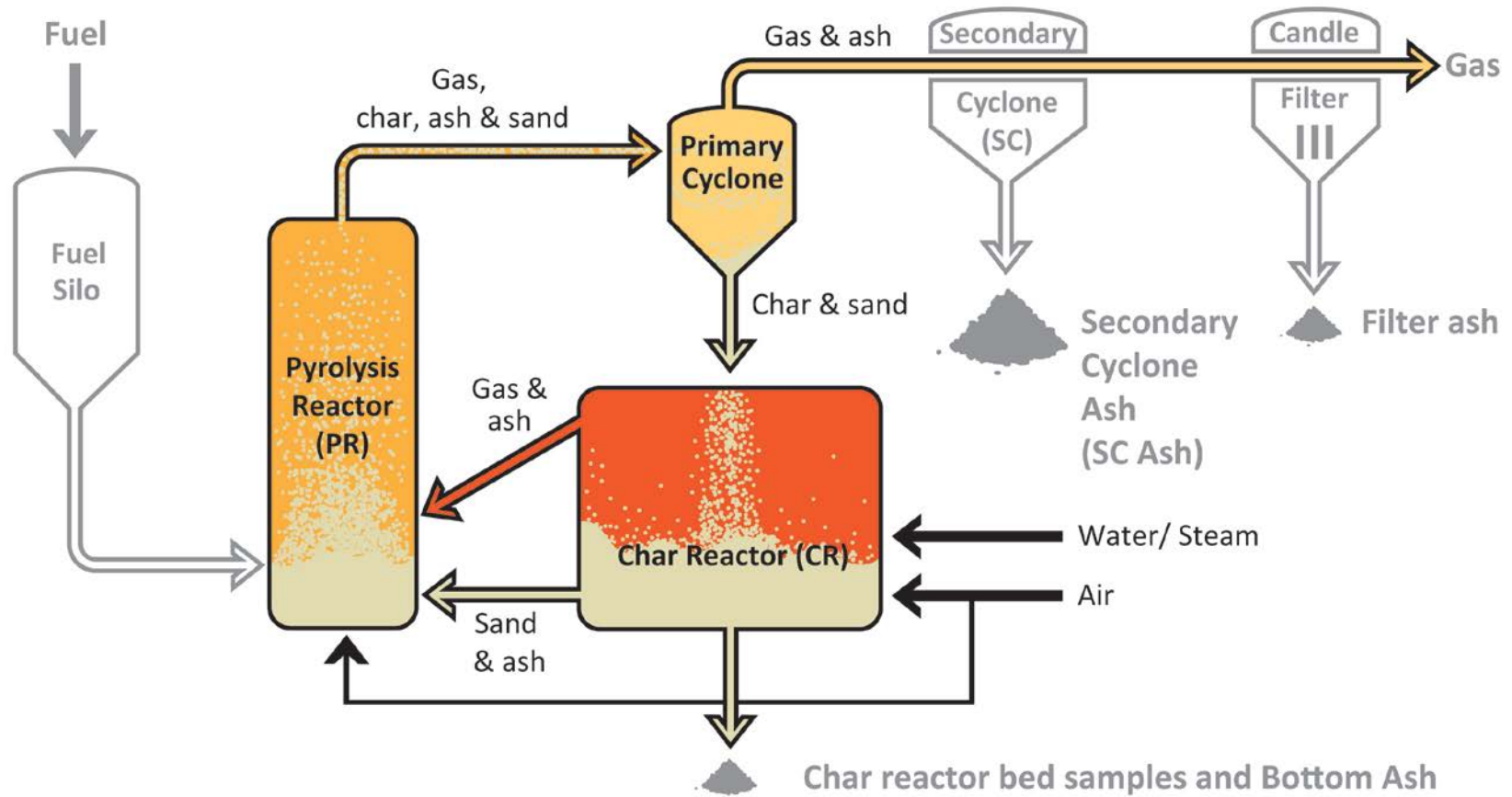


# Next generation **thermal gasification systems**

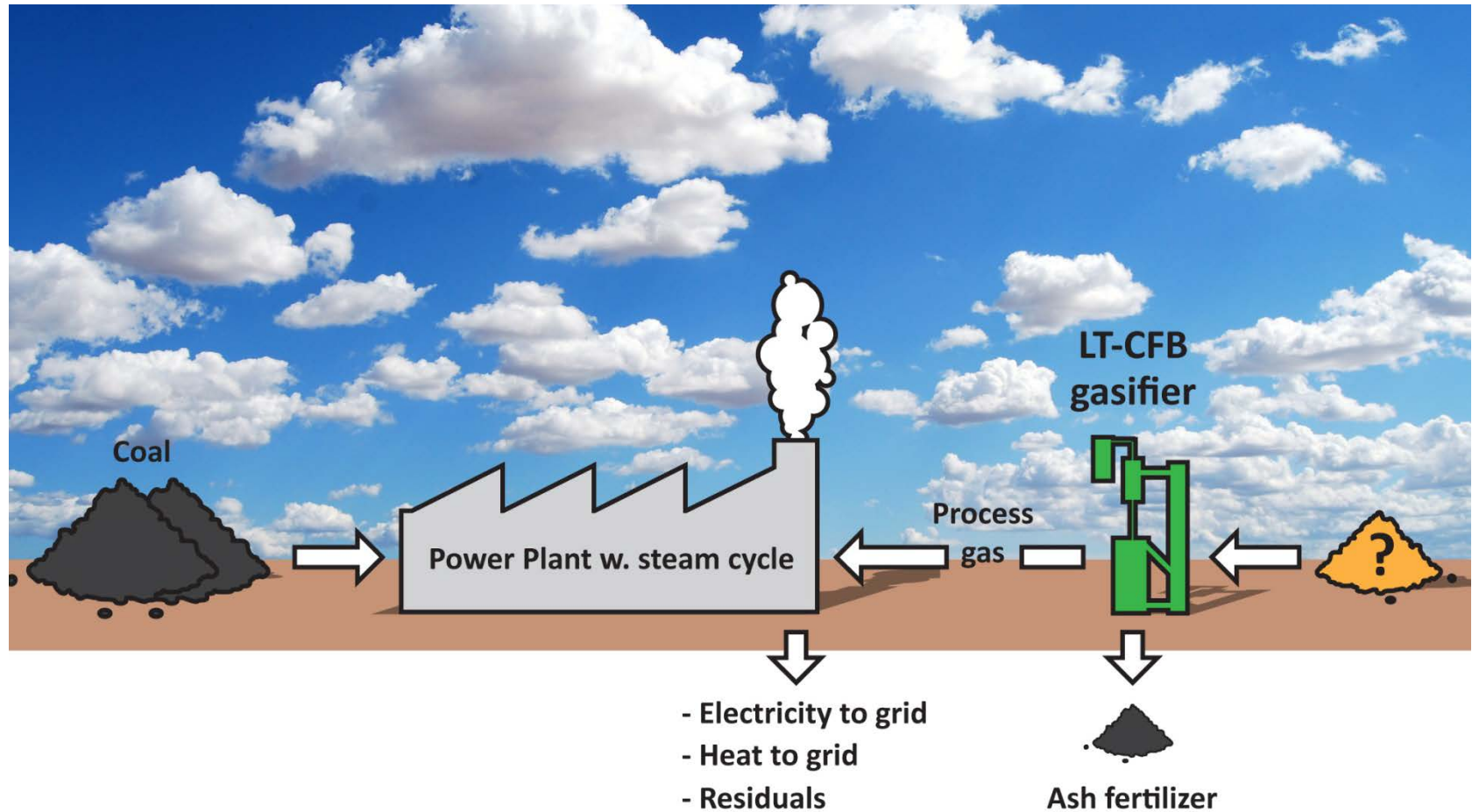




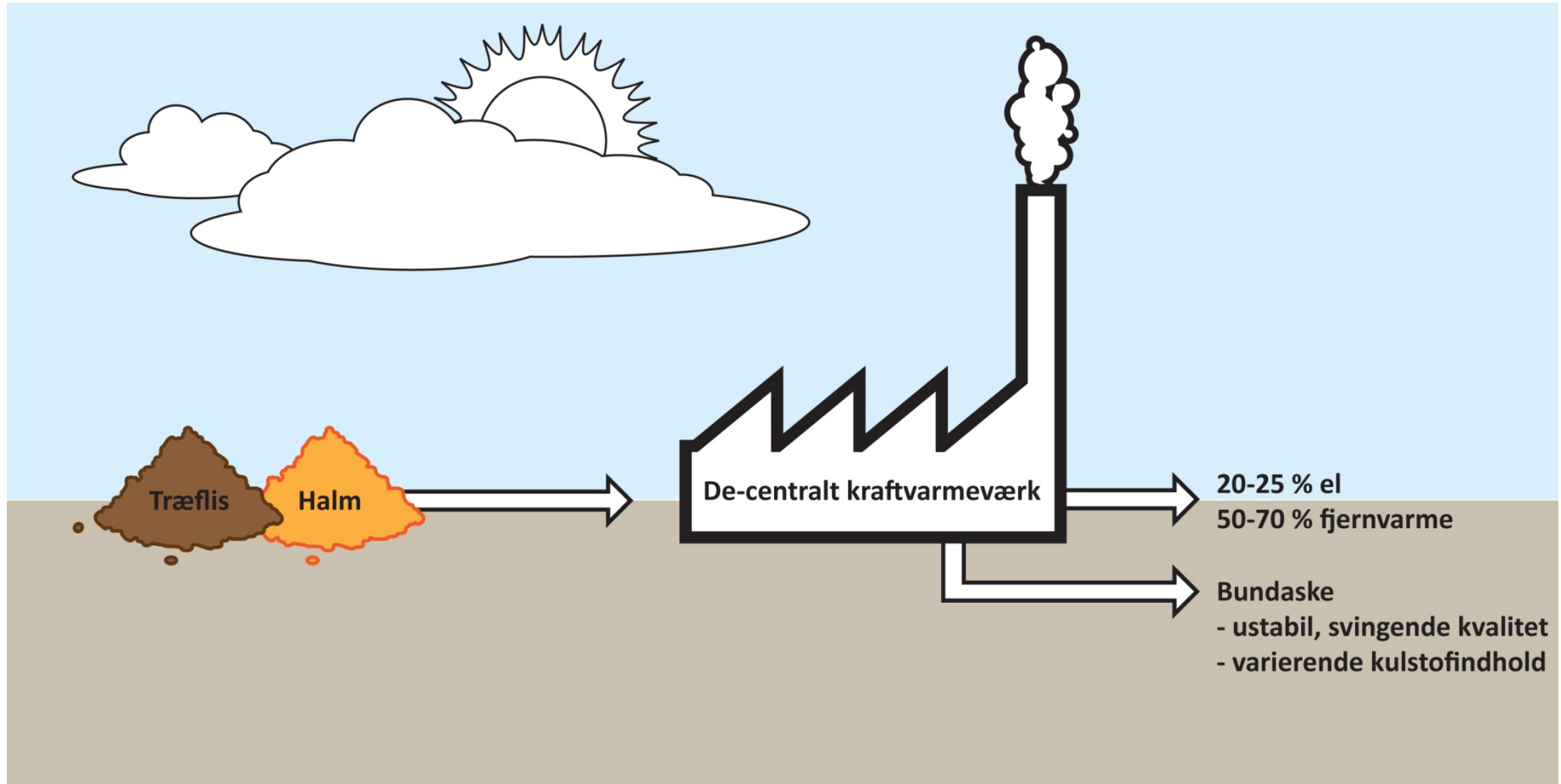
# Introduction of **the LT-CFB gasifier**



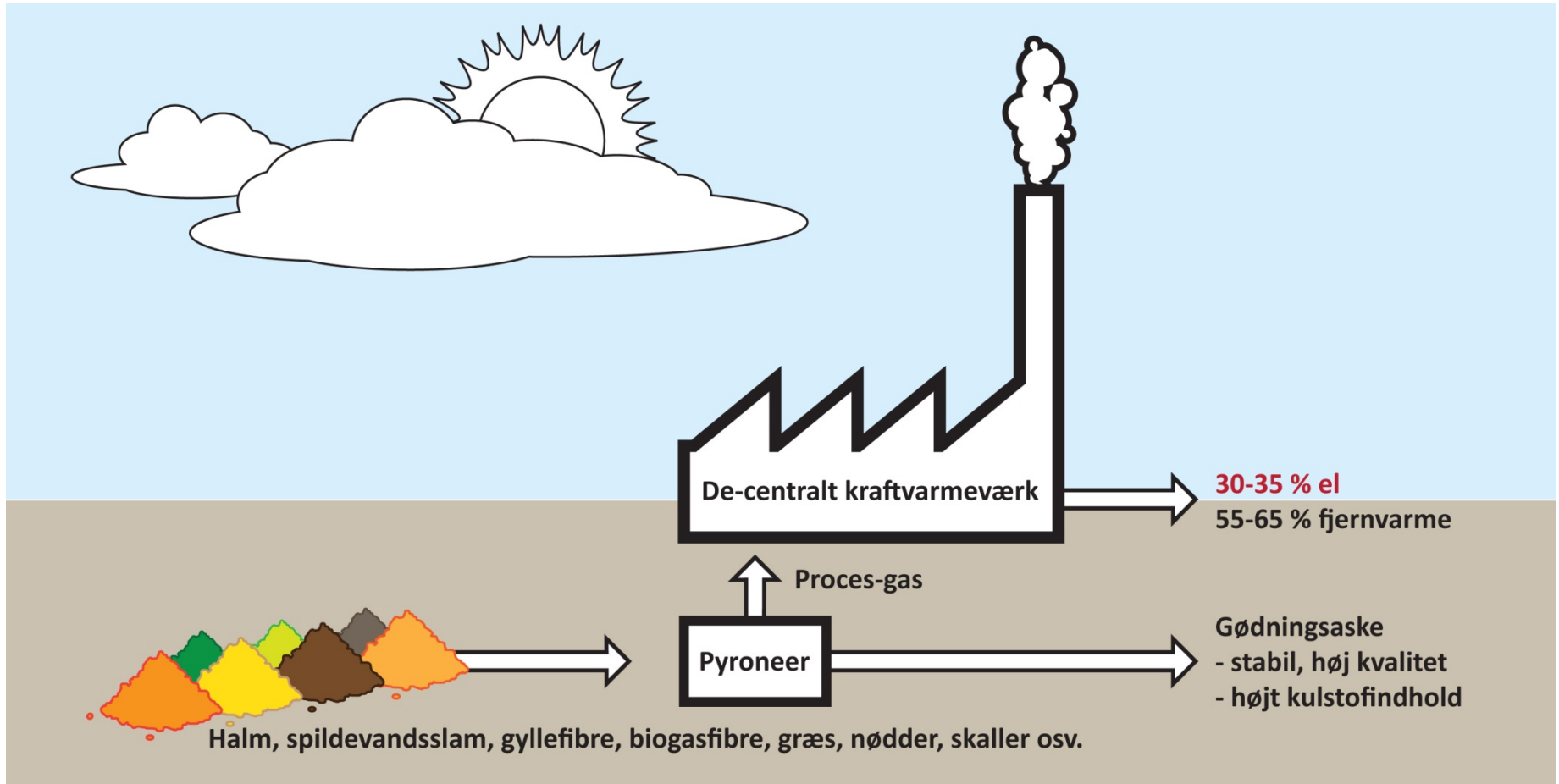
# Introduction of **the LT-CFB gasifier**



# Introduction of **the LT-CFB gasifier**



# Introduction of **the LT-CFB gasifier**





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

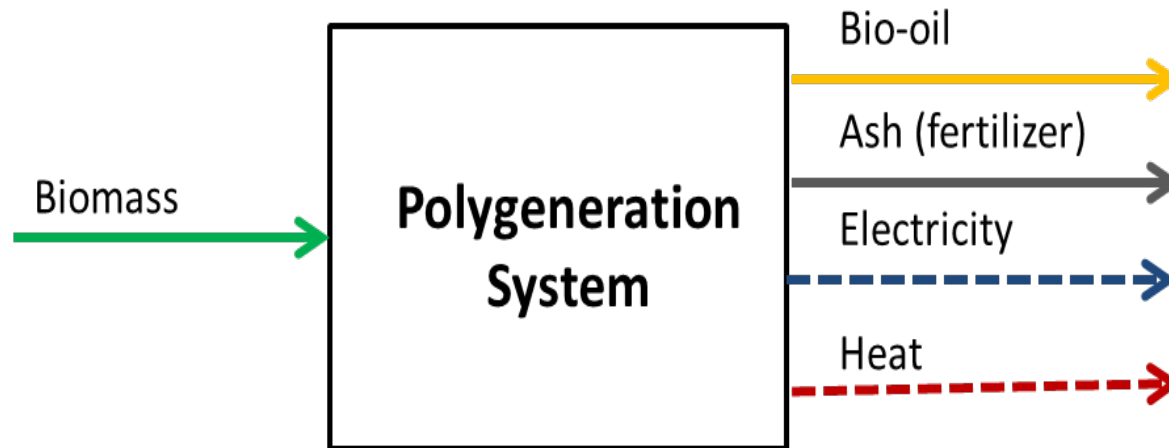


Thermal capacity: 6000 kW  
Location: Asnæs power plant  
Owner: DONG Energy



# LT-CFB gasification **perspectives**

Biomass Gasification Polygeneration:

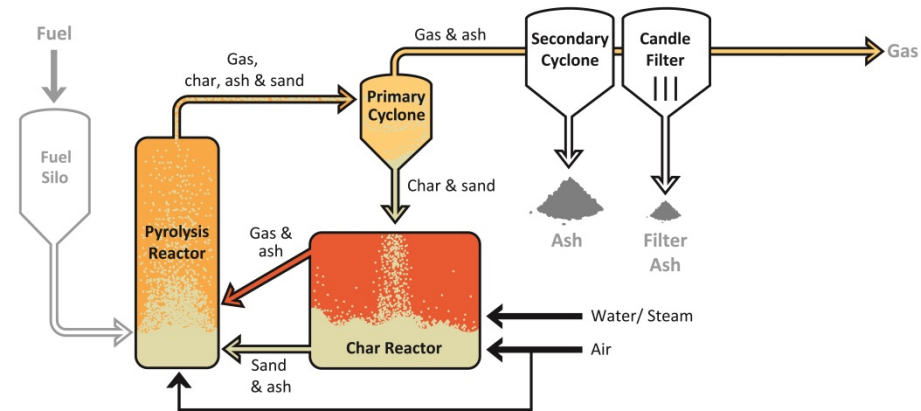


- Tar deoxygenation and condensation as bio-oil
- Increased fuel flexibility (RDF, Food waste, fuel mixes etc.)
- Enhanced heavy metal release and recapture



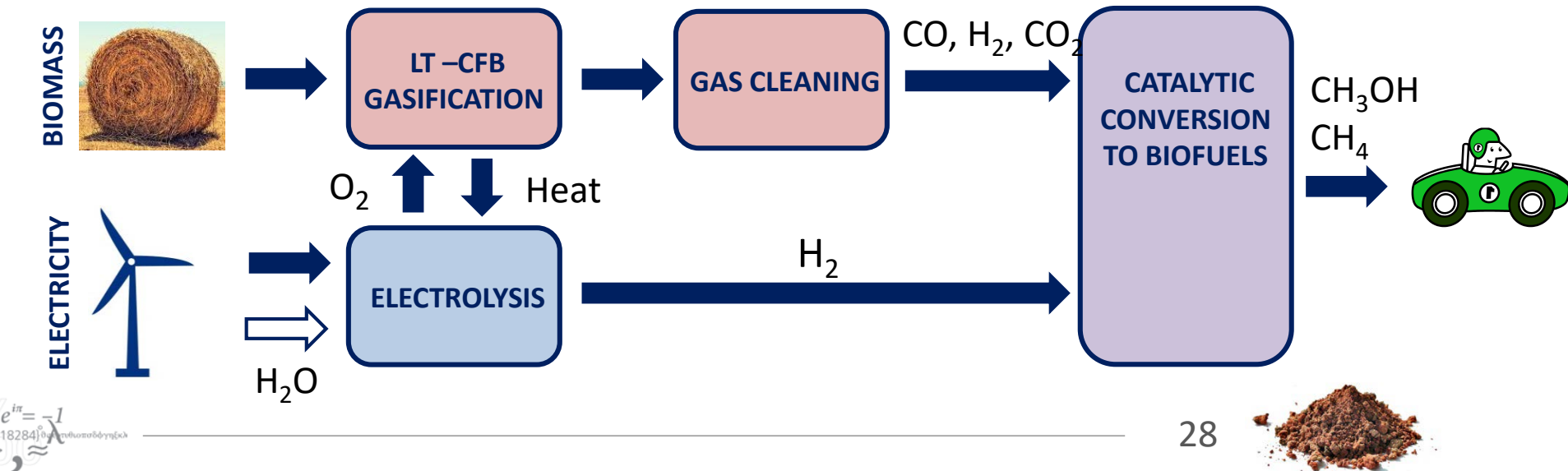
# LT-CFB gasifier integration

- Double stage fluid bed; max process temperature  $\approx 750^{\circ}\text{C}$
- Suitable for low quality (high ash) feedstock such as straw, sludge, biogas residues, manure fibers
- High tar content in the producer gas (up to  $30\text{ g/Nm}^3$ )



LT-CFB gasifier process diagram [1]

## Synfuel concept



# LT-CFB gasification **perspectives**

- Highly efficient utilization of problematic low grade biomass and waste for large scale power plants
- Co-firing of biomass in existing coal fired power plants without slagging and corrosion problems
- Conversion of gas/oil fired power plants to 100% biomass
- More biomass based energy production – Now!
- Increased flexibility of fuel and products
- High export potential



# 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**

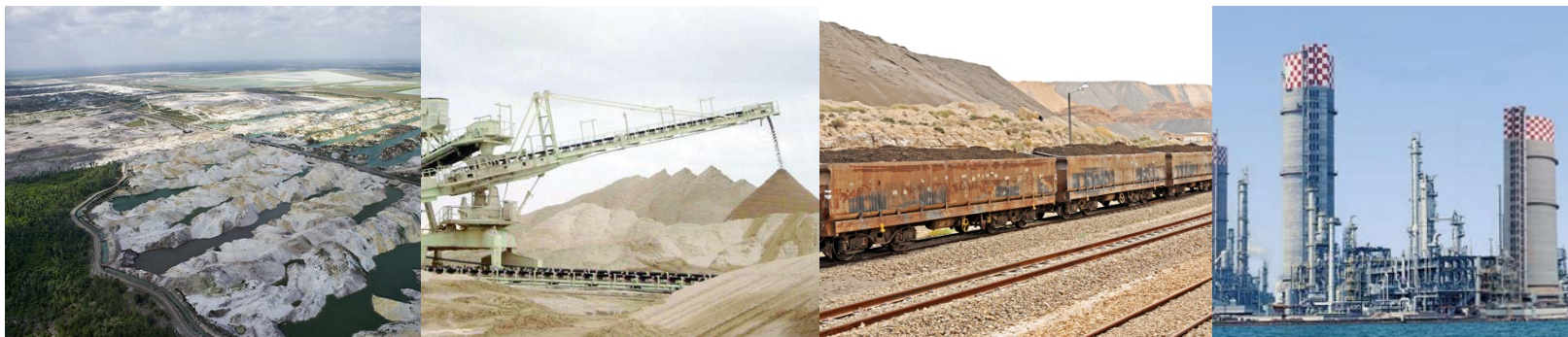
## 2) Improve feasibility of thermal gasification in a circular economy:

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



# BGG Focus: Increase P security

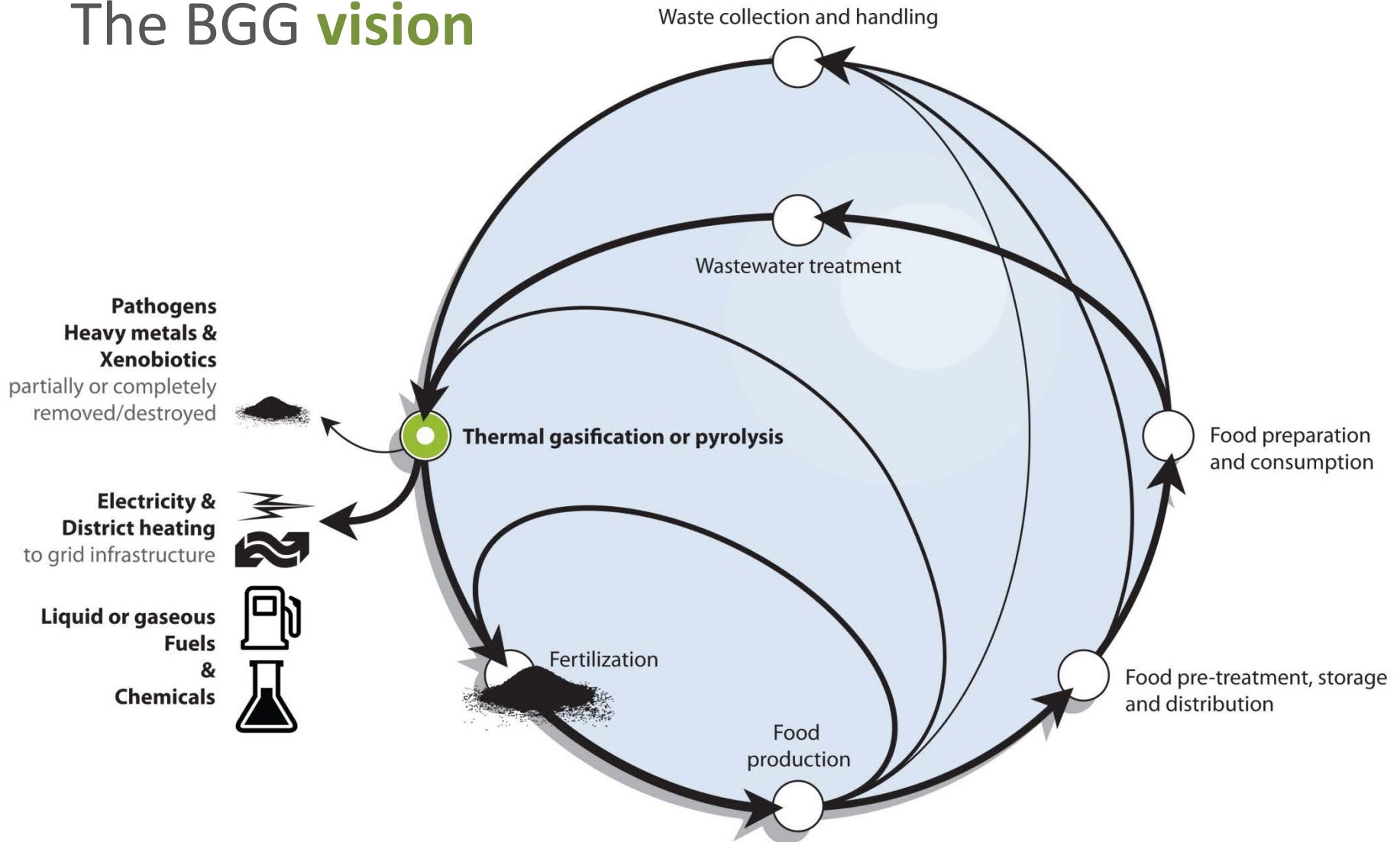
- P is a **pre-requisite for all life as we know it** and irreplaceable in DNA, ATP, phospholipids etc.
- P consumption is increasing rapidly while the commercially available P-stocks are depleting and likely to **reach a peak within the next 50-100 years** (Cordell et al., 2009).
- Phosphorus on **EU's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

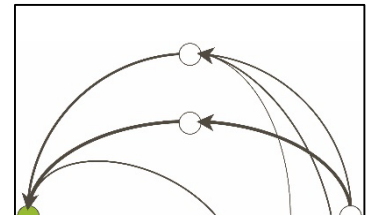
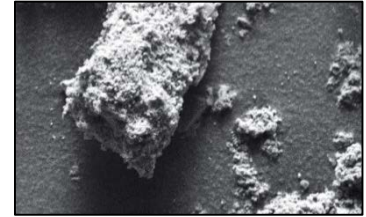


# The BGG vision



# Ash investigations: **How?**

- **Fuel and ash characterization**
  - Elemental content, solubility and speciation
  - Content of PAH and other organic toxins
  - pH
  - Morphology and structure
- **Application and handling test**
  - Pelletization and granulation properties
  - Storage and transportation losses
  - Distribution and field application
- **System analysis**
  - Energy- and mass-balances
  - Carbon footprint assessment
  - Full life cycle analysis



# Ash investigations: **How?**

- **Soil incubation studies**
  - P & K fertilizer quality
  - Heavy metal solubility
  - pH of soil/substrate mixtures
  - Carbon stability
  - Water holding capacity
- **Plant experiments (pot and field trials)**
  - P and K uptake
  - Plant growth response (P and K)
  - Heavy metal uptake
  - Nutrient and heavy metal leaching
  - Soil structural changes, SOC, respiration and eco-toxicology
  - Liming effect



# Ash investigations: How?



# Biomass Gasification Group

