Chair of Energy Systems
TUM School of Engineering and Design
Technical University of Munich

Demonstration of a Decentralized Disposal Concept for Sewage Sludge by Torrefaction and Subsequent Entrained Flow Gasification for Gas Engine Use

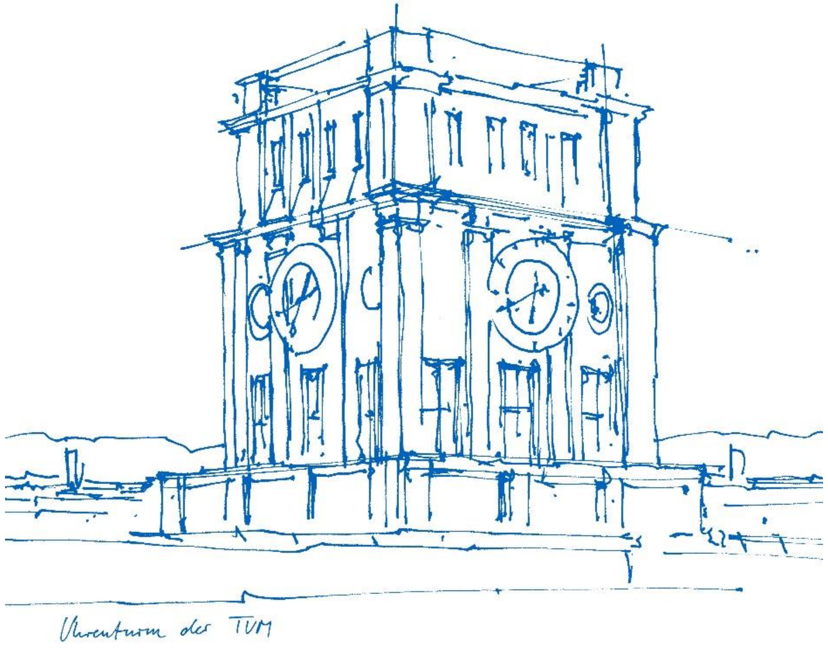
PyroGas Research Project

Technical University of Munich

TUM School of Engineering and Design

Chair of Energy Systems

Bologna, 5th June 2023



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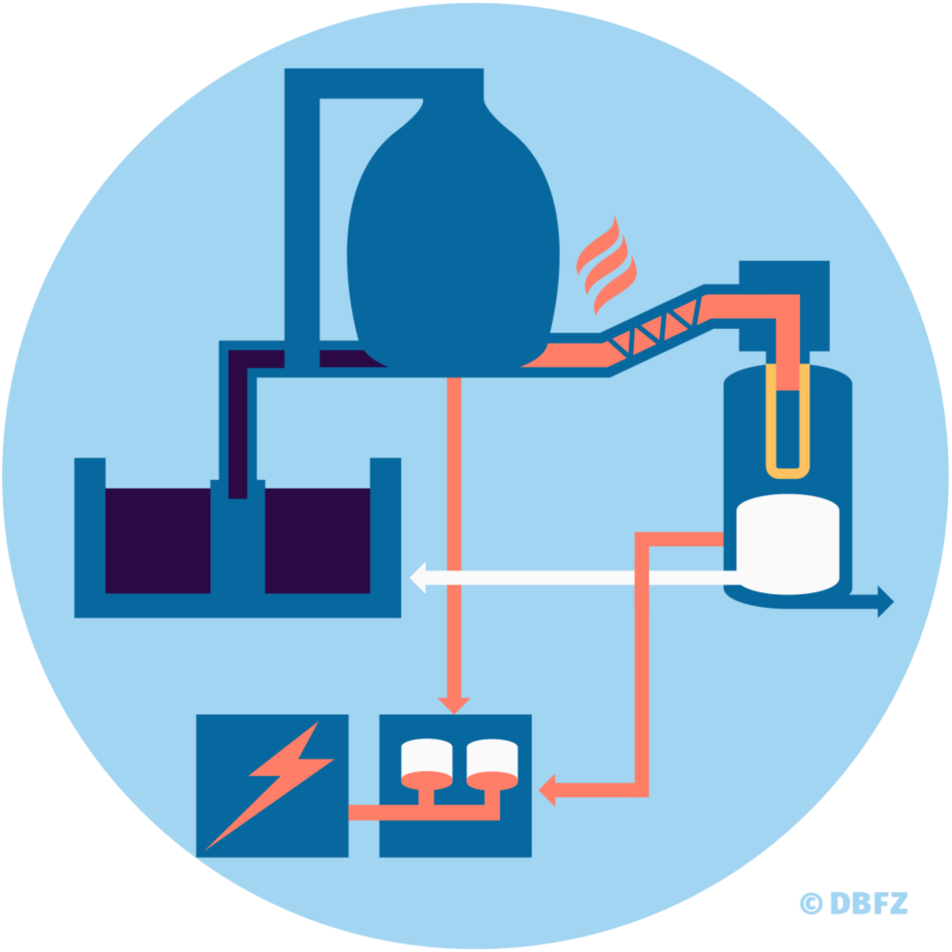
Agenda

Content of This Presentation for EUBCE 2023

- The PyroGas Concept
  - Scheme
  - Pictures
- Setup
  - Entrained-flow Gasifier
  - Cogeneration Gas Engine
- Operating Conditions
  - Procedure
  - Results
- Conclusions



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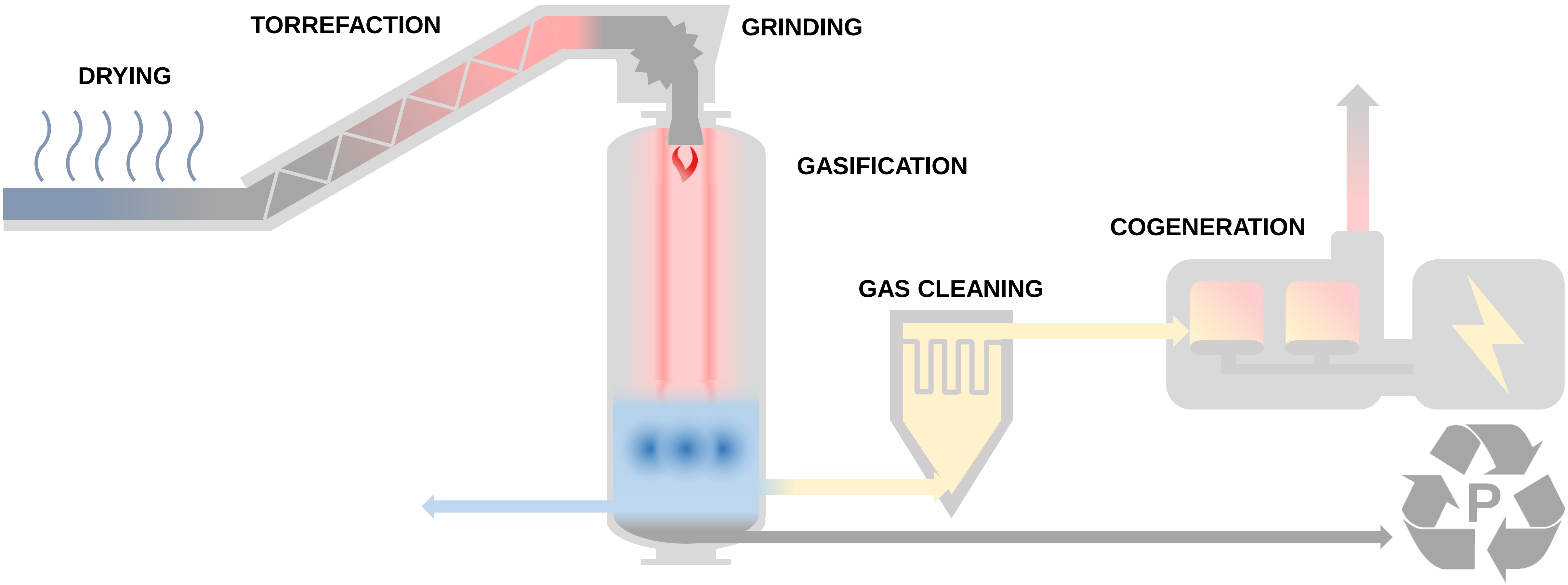
The PyroGas Concept

PyroGas as a Scheme



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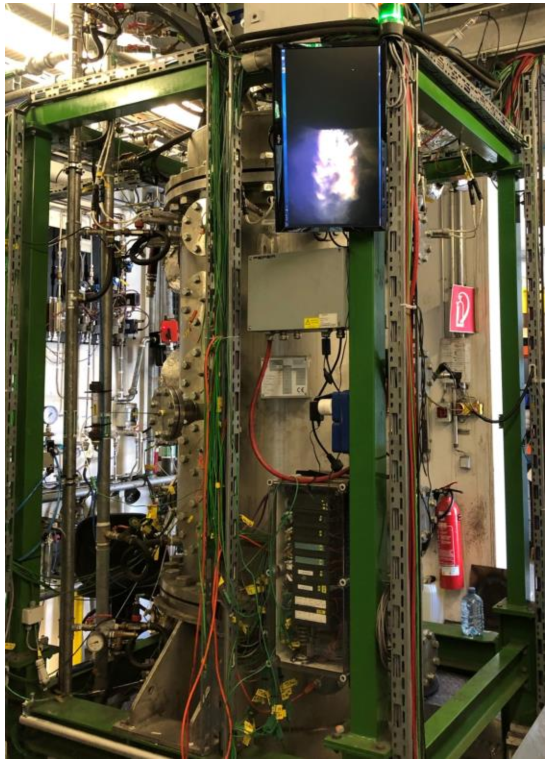
The PyroGas Concept

PyroGas in Pictures

TORREFACTION



GASIFICATION

GAS CLEANING

COGENERATION

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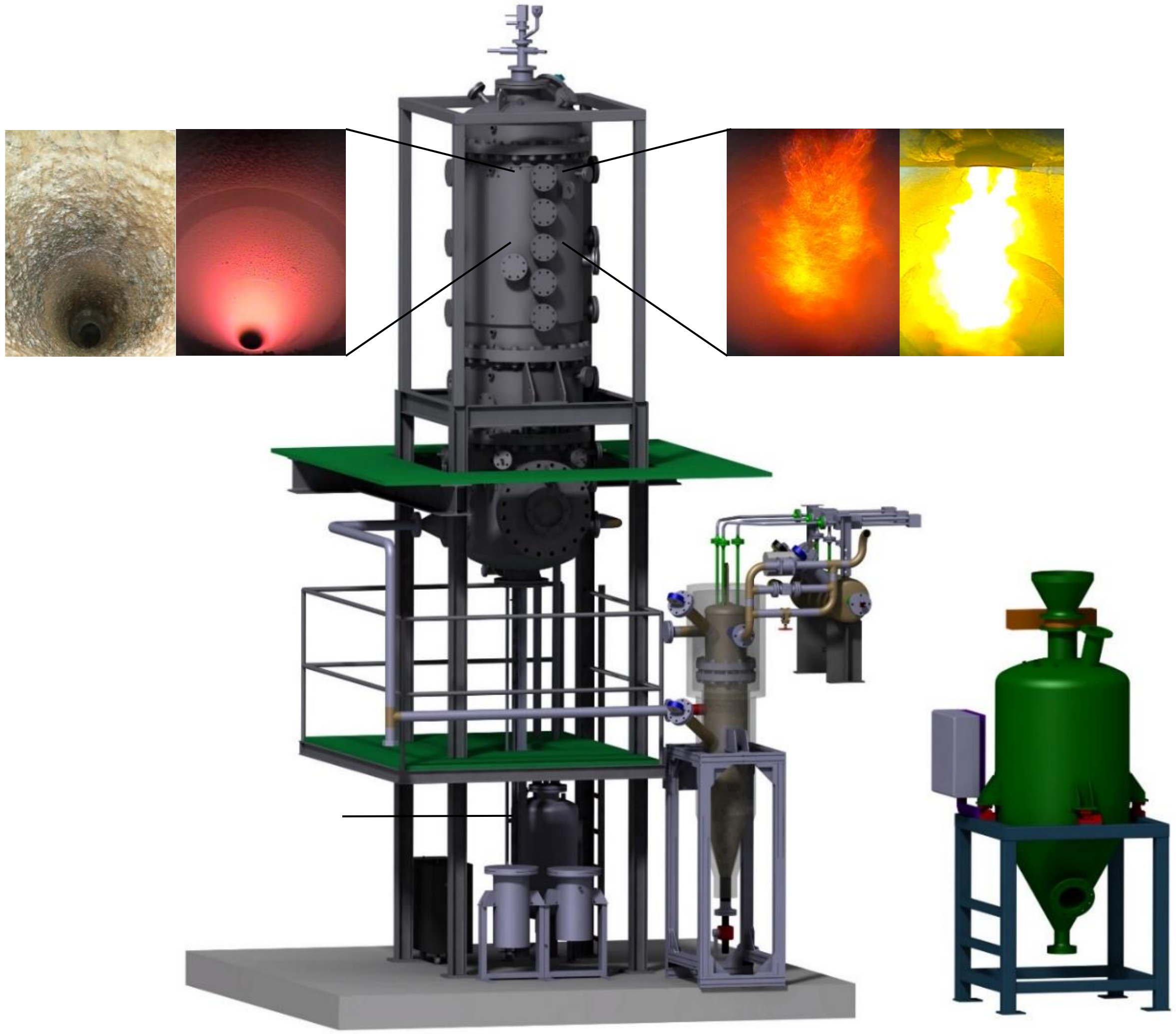
Setup

Biomass Pilot-scale Entrained-flow Gasifier (BOOSTER)

Conversion of the solid fuel to a combustible product gas;
Cracking of organic impurities (pathogens, drug residues, …)

Technical data:

- Operation: autothermal
- Temperature: up to 1500 °C
- Pressure: 0 to 5 barg
- Fuel input: 100 kW (+/- 25 %)
- Dosing system: pneumatic
- Gasification media: Air, O_2, H_2O, CO_2
- Operation time: ~10 h



Research focus:

- Industry-like design (realistic conditions)
- Investigation of cold gas efficiency
- Gas quality (ammonia, hydrochloric and hydrocyanic acid)
- Tar formation and ash melting behavior

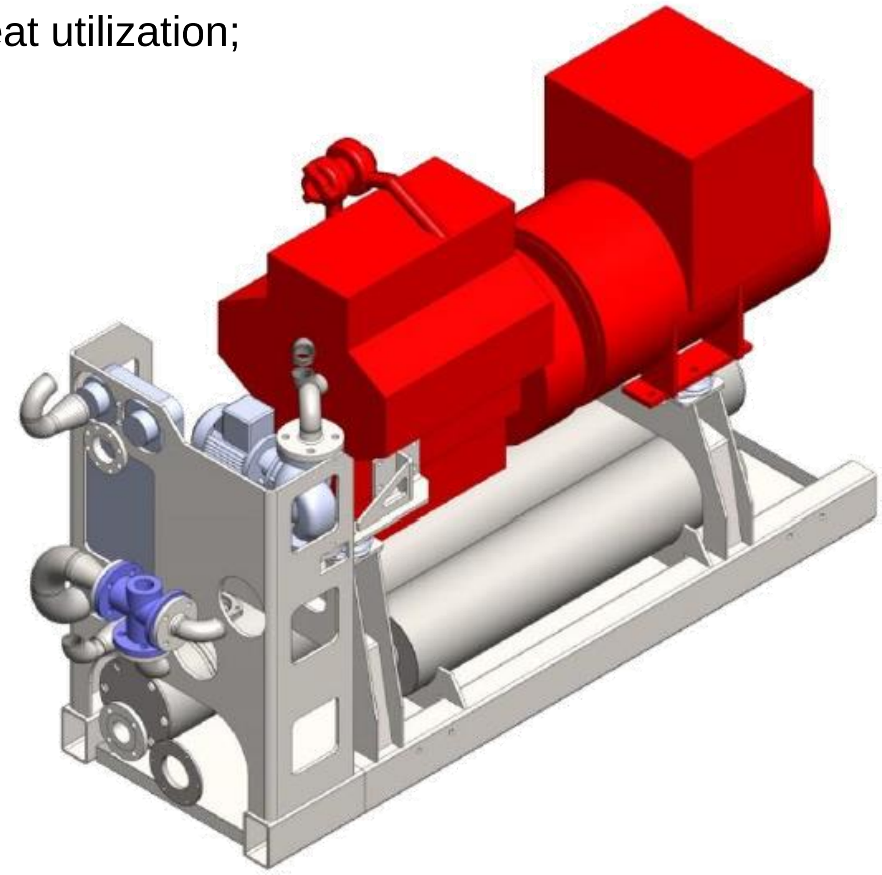
Setup

Cogeneration Gas Engine

Product gas utilization by combustion; Combines engine and exhaust gas heat utilization; Reduction of exhaust and noise emissions

Technical data:

- Mitsubishi diesel engine converted into an otto engine
- Fuel input: 79 kW
- Mechanical performance: 21.5 kW
- Generator efficiency: 93.2 %
- Electric power: 20 kW
- Electrical efficiency: 25.3 %
- Thermal power: 50 kW
- Thermal efficiency: 63.3 %
- Overall efficiency: 88.6 %



Research focus:

- Engine performance for low calorific value product gases
- Exhaust gas compostion (CO, NO_X, …)

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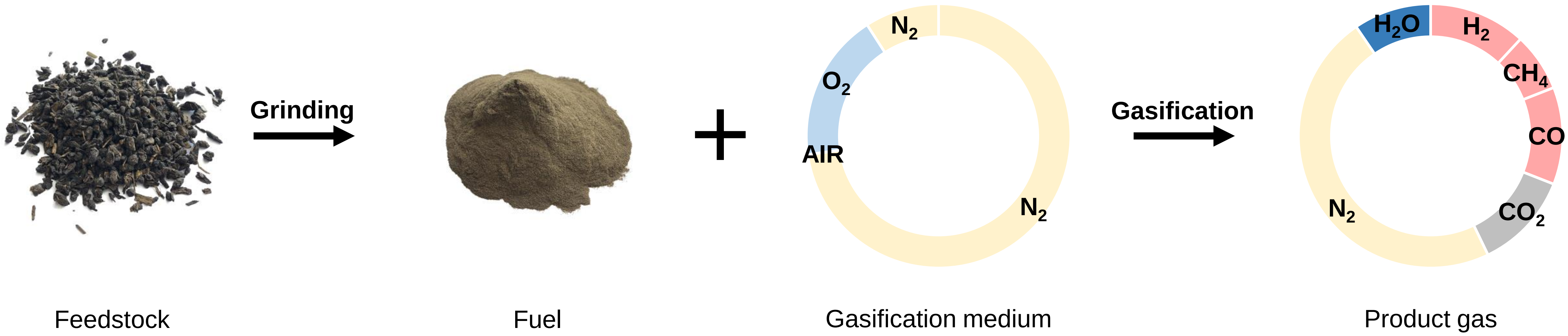
Operating Conditions

Procedure

Varying operating conditions such as fuel input and gasification medium:



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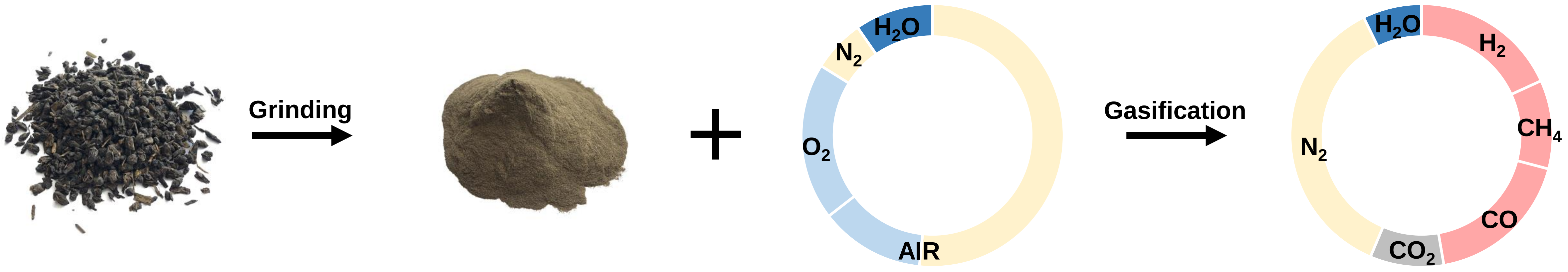
Operating Conditions

Procedure

Varying operating conditions such as fuel input and gasification medium:



Feedstock | Fuel | Gasification medium | Product gas

→ Finding a product gas composition to run the engine by adding the least amount of pure O_2

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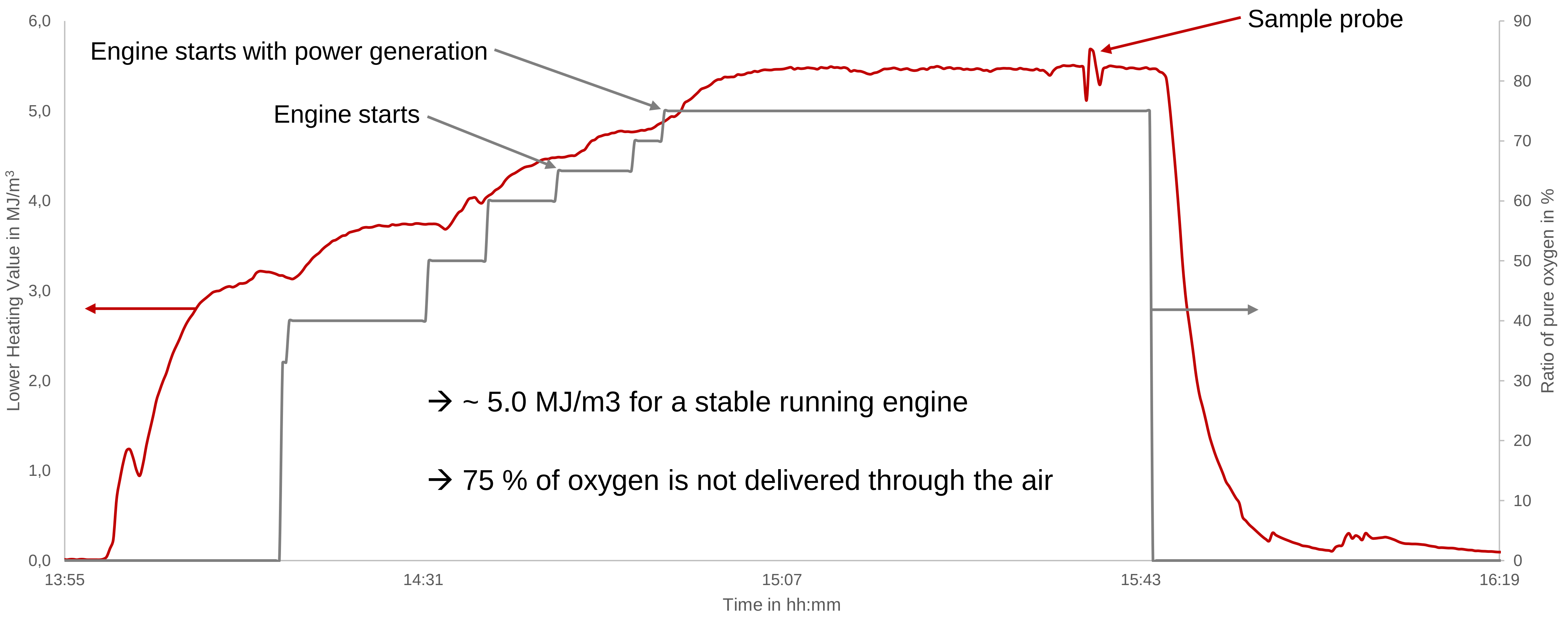
Operating Conditions

Addition of Pure Oxygen to Air as the Main Gasification Medium – Lower Heating Value



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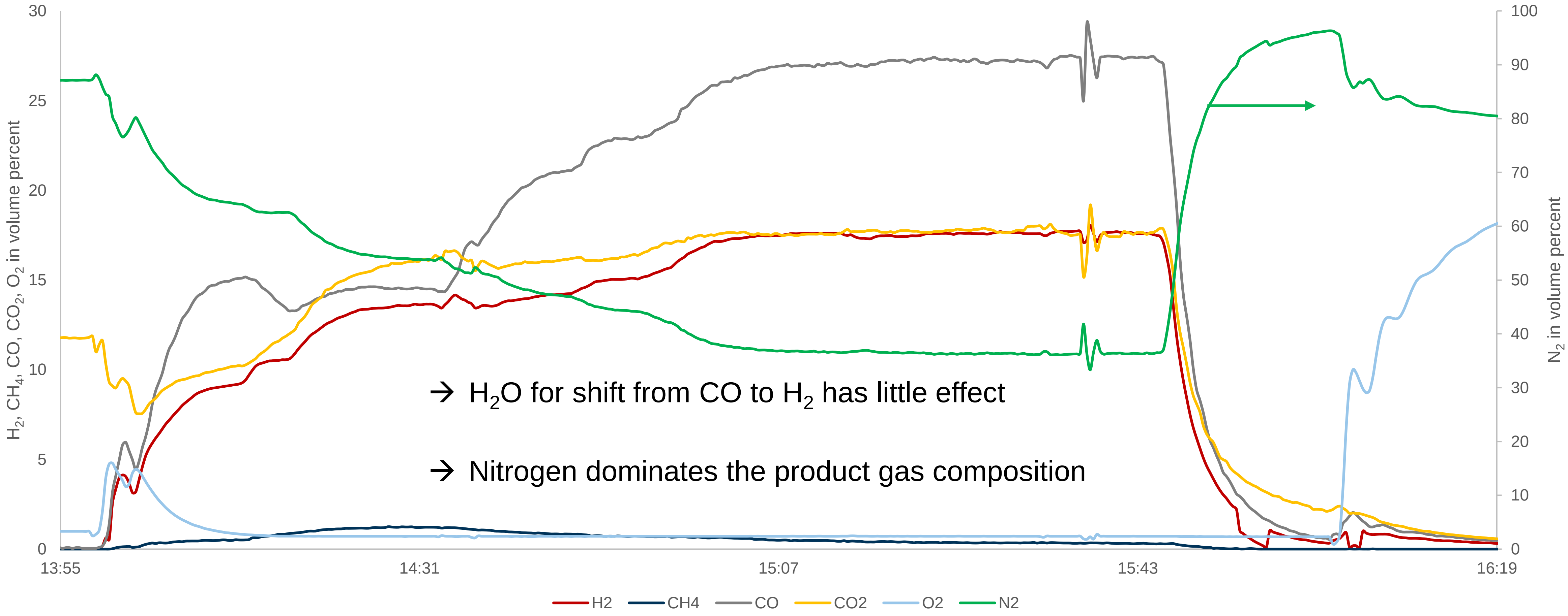
Operating Conditions

Addition of Pure Oxygen to Air as the Main Gasification Medium – Product Gas Composition



→ H_2O for shift from CO to H_2 has little effect

→ Nitrogen dominates the product gas composition

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Operating Conditions

Operating Parameters for Stable Engine Operation

Fuel input measured	122.7 kW
Air ratio λ measured	0.41
Dosing rate measured	34.4 kg/h
Nitrogen addition (cooling, dosing system)	3.7 Nm^3/h (~ 14 %)
Air addition (primary gasification medium)	13.9 Nm^3/h (~ 53 %)
Oxygen addition (secondary gasification medium)	8.8 Nm^3/h (~ 33 %)
Temperature measured at flame height	1318 °C
Temperature measured below flame	1230 °C
Lower heating value of product gas	5.46 MJ/m^3
Carbon conversion rate	82.5 %
Fuel conversion rate	91.8 %
Cold gas efficiency	47.4 %
Electrical power of the cogeneration gas engine	15 kW_{el}
Electrical efficiency	12.2 %

Conclusions

Summary of Results and Outlook

It is possible to operate the engine with sludge product gas from an entrained-flow gasifier.
→ The overall proof of concept was successful

Optimization potential:

Reduction of nitrogen addition
→ Higher heating value of the product gas

Carbon dioxide in the dosing system
→ Higher heating value of the product gas

A higher fuel input (and a more suitable gasifier design)
→ More product gas for the engine and a higher heating value

Final Statement:

Optimization may not be sufficient to eliminate the addition of pure oxygen.
→ Admixture of sewage gas from sludge digestion at the wastewater treatment plant

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Thank you
for your attention.

Don't hesitate
to ask questions!