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Gasification activities at USN and strategies for implementation of full-scale plants in Norway

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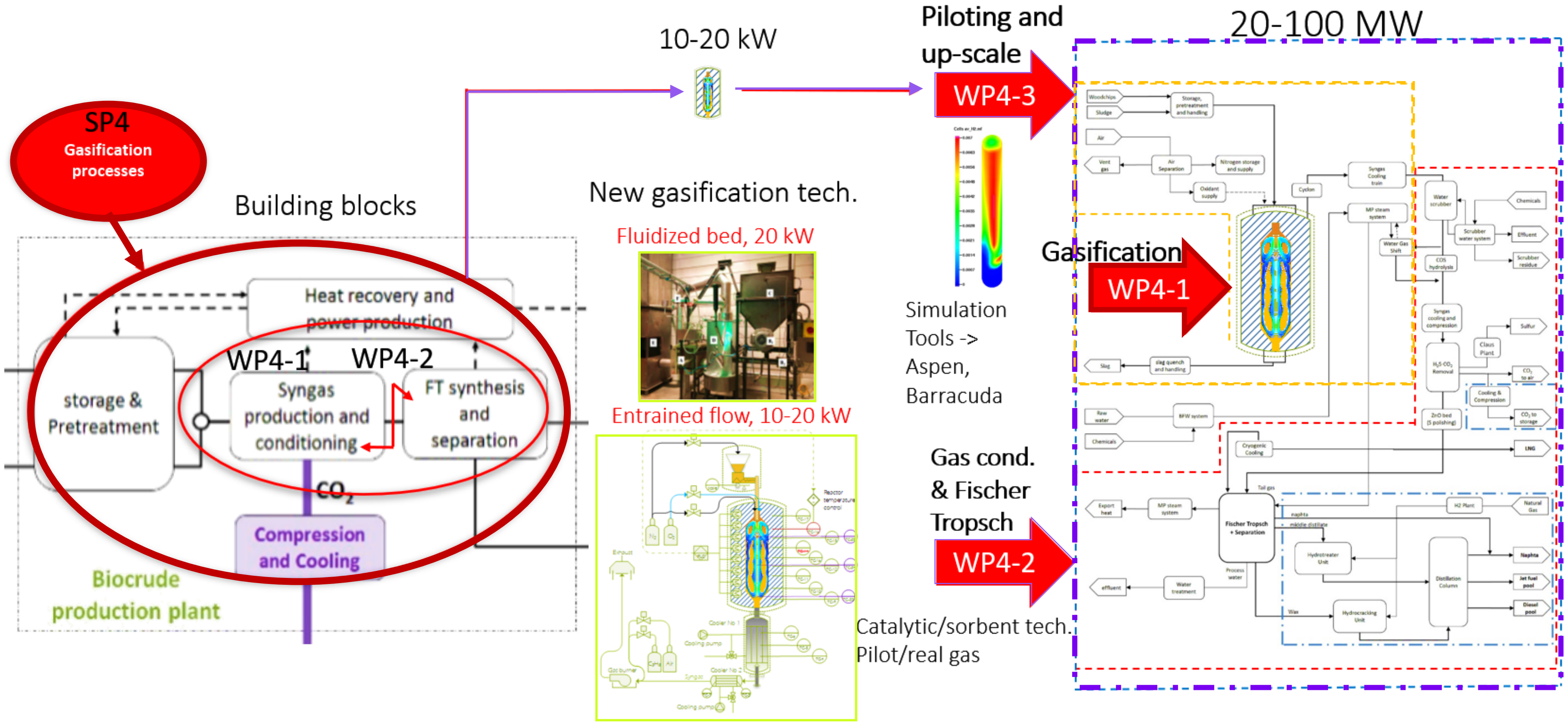
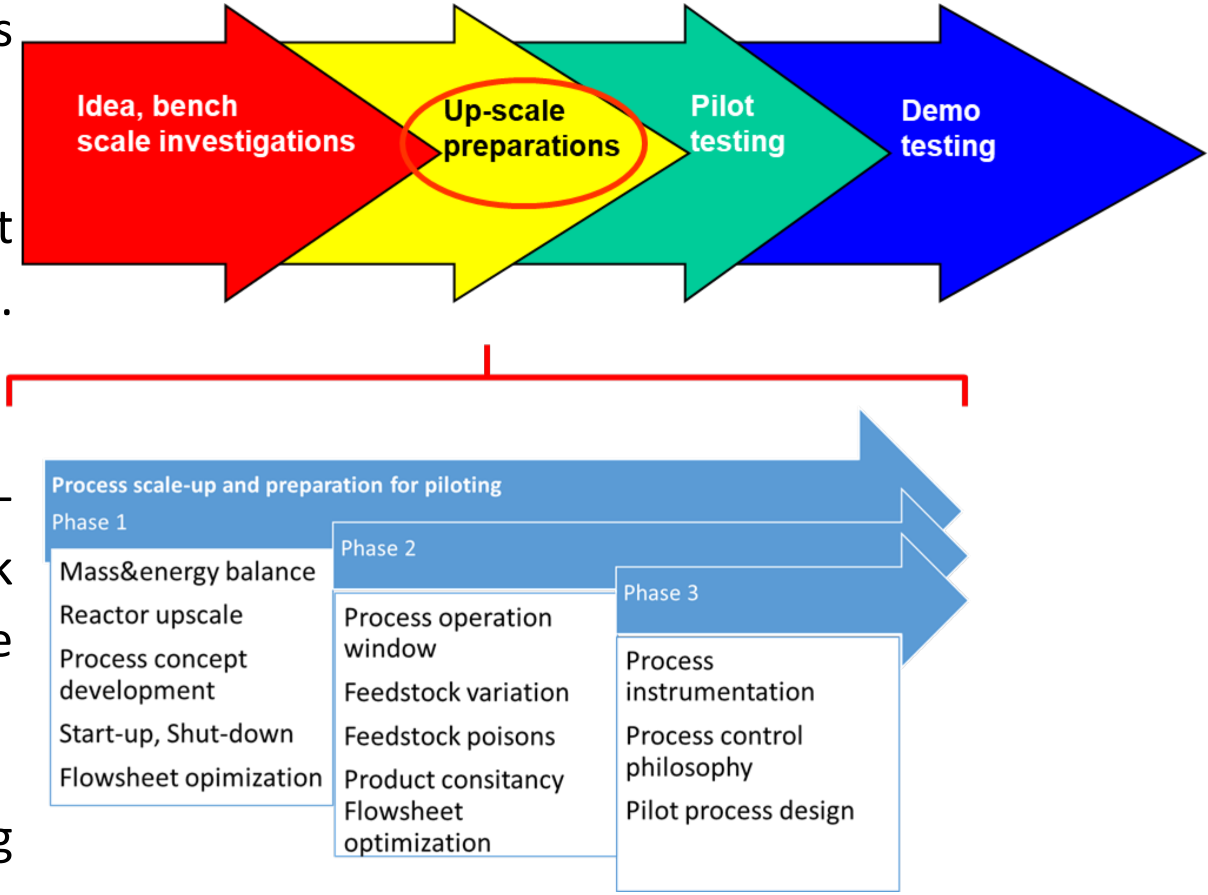
Overview of the project



WP 4.3 Preparing for Piloting and Up-scale

- The cooperation with SINTEF Energy, who is responsible for the gasification; PFI, who is responsible for the pyrolysis, and NTNU, who is responsible for the gas conditioning
- An advanced biomass gasification process concept development using industrial flow sheeting software (e.g. ASPEN-HYSYS, ASPEN PLUS).
- The work includes detailed reactor studies using state-of-the-art software such as BARACUDA experimental work and simulations; reliable process models will be developed
- Data from pilot systems form a basis for up-scaling procedures.



The process development chain

Conceptual design

M&E balances

Process concept development

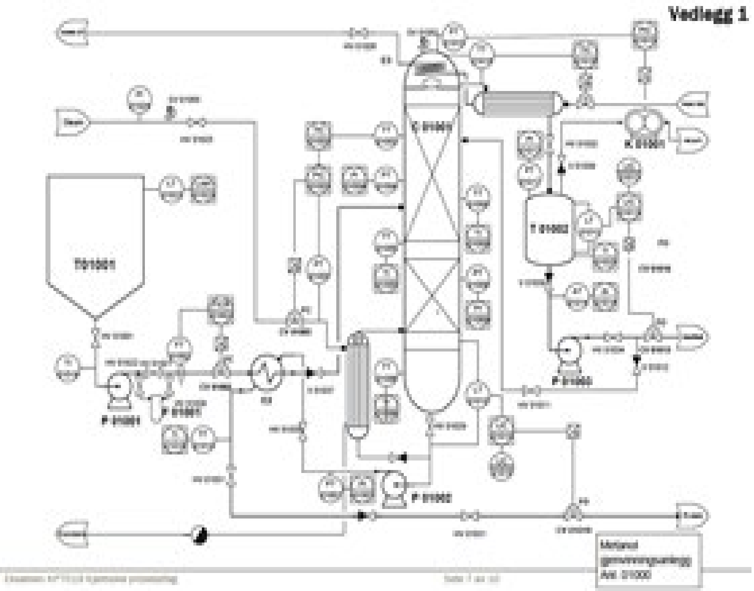
-reactor & apparatus design, scale-up

process intensification, -flowsheeting,

-modelling, energy and cost optimization

process control, instrumentation

Preliminary P&ID



Preparing for piloting - gasification

Ramesh Timsina

Bio4Fuel / USN

Disputas:24.02.2022

Modeling and simulations of bubbling fluidized bed and entrained flow biomass gasification reactors

https://openarchive.usn.no/usn-xmlui/handle/11250/2976140

- Experimental and computational study of the biomass gasification process.
- Experiments were performed with wood chips, wood pellets, and grass pellets at different airflow rates and biomass feed rates.
- The Computational Particle Fluid Dynamics (CPFD) models were validated against the experimental results and gave an acceptable performance as compared to experimental results.
- The results from the developed CFD models are of practical importance for the commercialization of bubbling fluidized and entrained flow biomass gasification reactors.

Preparing for piloting - gasification

- The gasification reactor systems, the Bubbling Fluidized Bed reactor at USN and the Entrained Flow reactor at SINTEF Energy, will be investigated.
- The primary goal is to establish computational particle fluid dynamics (CPFD) and process simulation models to generate insight into the framework needed for process design and pilot plant planning.
- The models will be used as a basis for the successful piloting of gasification technology for the production of syngas, which can be used to produce biofuels or valuable chemicals.
- The project will establish the optimal plant operating parameters for these two reactor designs.

Nastaran Ahmadpour Samani

Bio4Fuel/ USN

Start: 01.05.2021

Computational particle fluid dynamics (CPFD) and process simulations modeling of biomass gasification reactors.

WP 4.3 Preparing for piloting and upscaling

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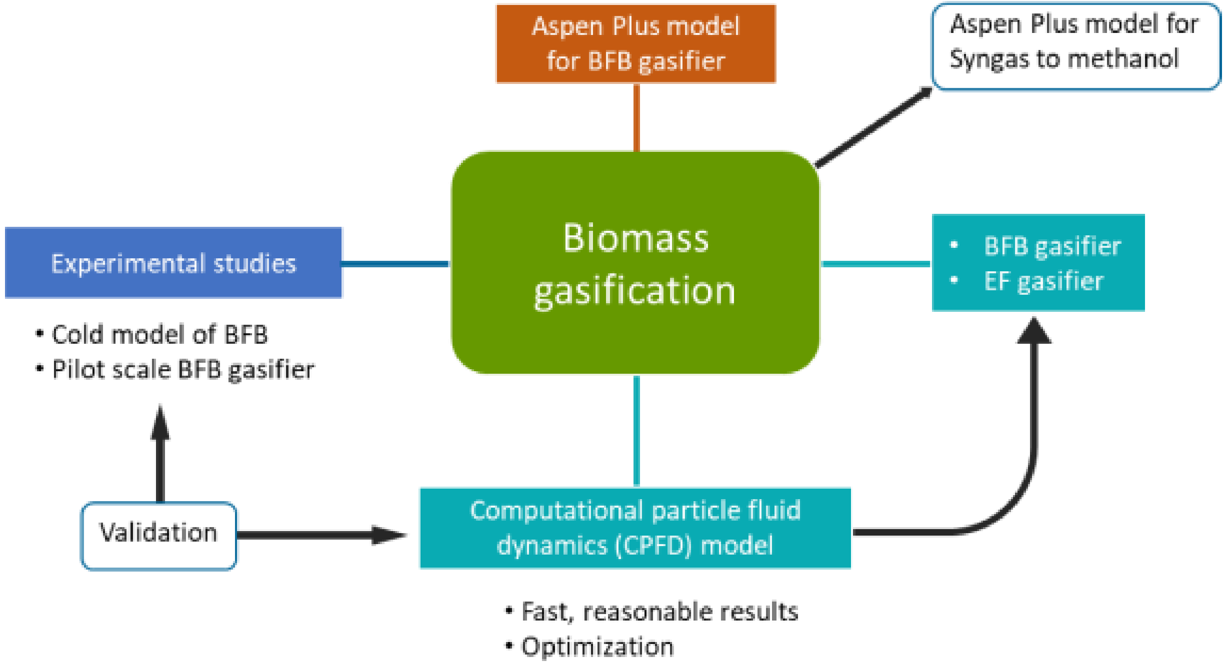


Figure 1-3. Summary of the project work

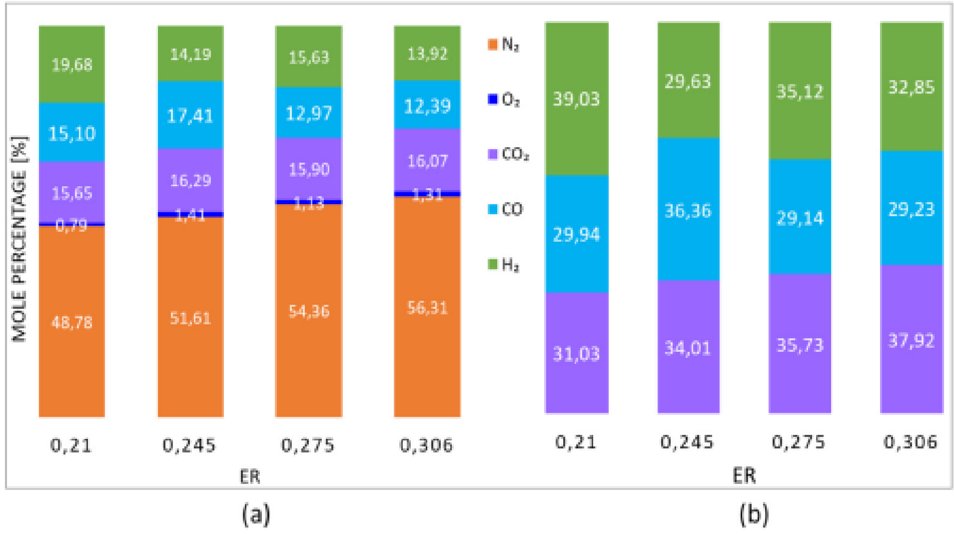


Fig. 5. Product gas composition at different ERs (at 5.4 kg/h feed rate) for wood pellets. (a) with all the gas components (b) recalculated without N_2 and O_2.

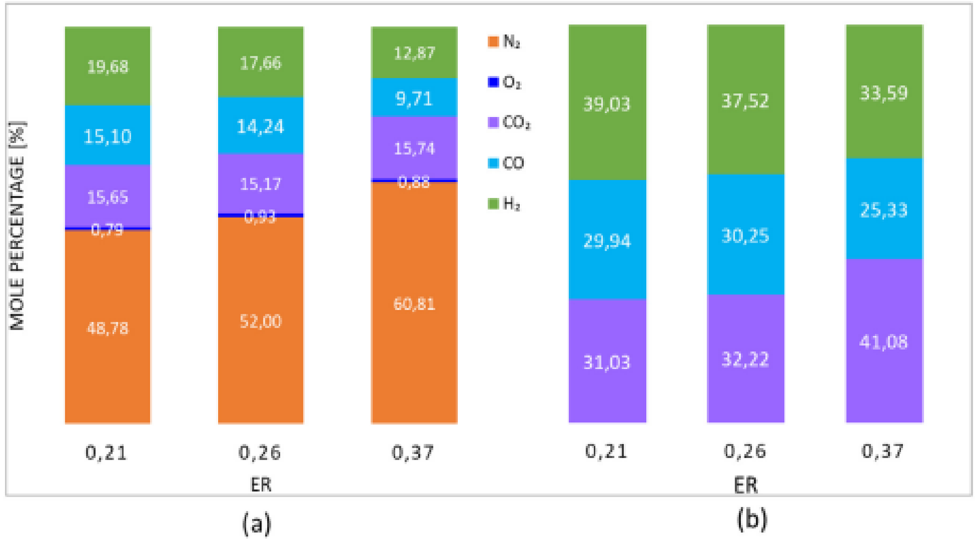
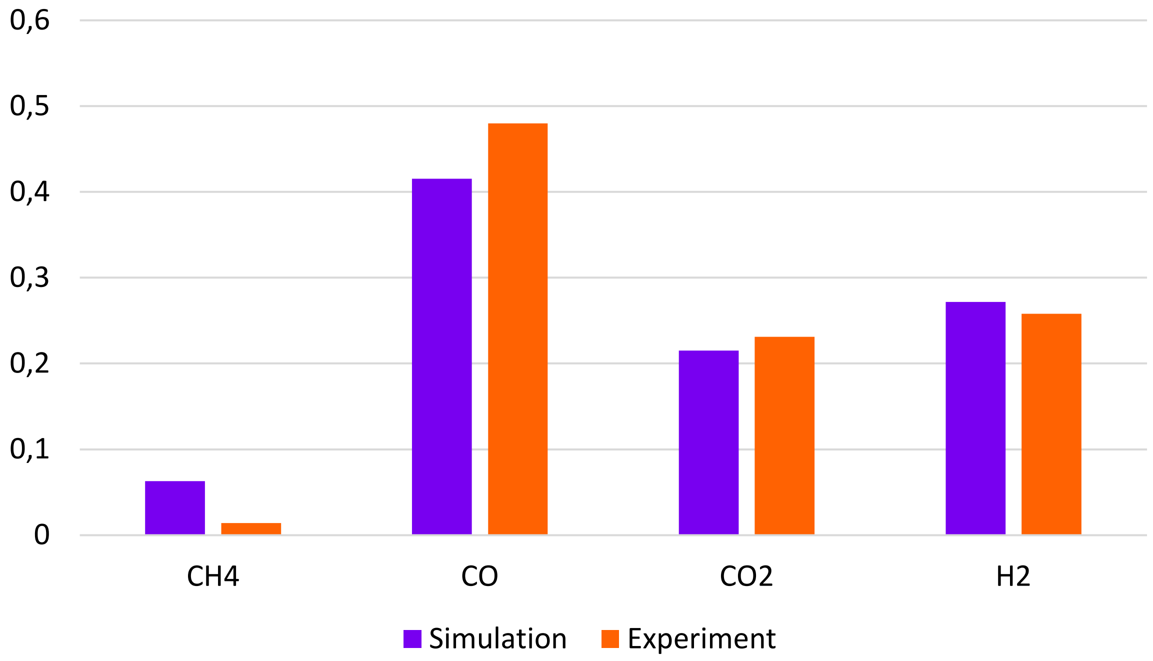


Fig. 6. Product gas composition at different ERs (at 7 kg/h air flow rate) for wood pellets. (a) with all the gas components (b) recalculated without N_2 and O_2.

Syngas composition validation



Comparison of product gas (N_2-free)

Table 3. Syngas Characteristics for the Four Experimental Campaigns

dry syngas	unit	12 Jan[a]	14 Feb	16 Feb	17 Feb
syngas LHV	MJ/kg[b]	7.7 ± 0.3	7.3	7.0	6.2
syngas mass flow	kg[b]/h	69.9 ± 10.6	74.6	75.2	79.5
N_2 content	mol %	18.1	21.1	18.0	25.2
H_2/CO		0.57 ± 0.04	0.57	0.54	0.54
N_2 Free Dry Gas Composition					
H_2	mol %	27.8	27.8	25.8	25.4
CO	mol %	48.7	48.5	48.0	47.3
CO_2	mol %	20.4	21.1	23.1	23.9
CH_4	mol %	2.3	2.3	1.4	1.4
C_2H_4	mol %	0.1	0.1	0.1	0.1
C_2H_2	mol %	0.3	0.3	0.2	0.2

Experimental results

Understanding the Ash properties

- Understanding the ash properties is essential; otherwise, it could lead to operational interruptions, reduced efficiency, equipment damage

- Understanding ash properties helps in designing efficient gasification processes by predicting slagging and fouling behaviour

- Knowledge of ash behaviour enables optimization of thermal systems to enhance energy efficiency and reduce maintenance costs

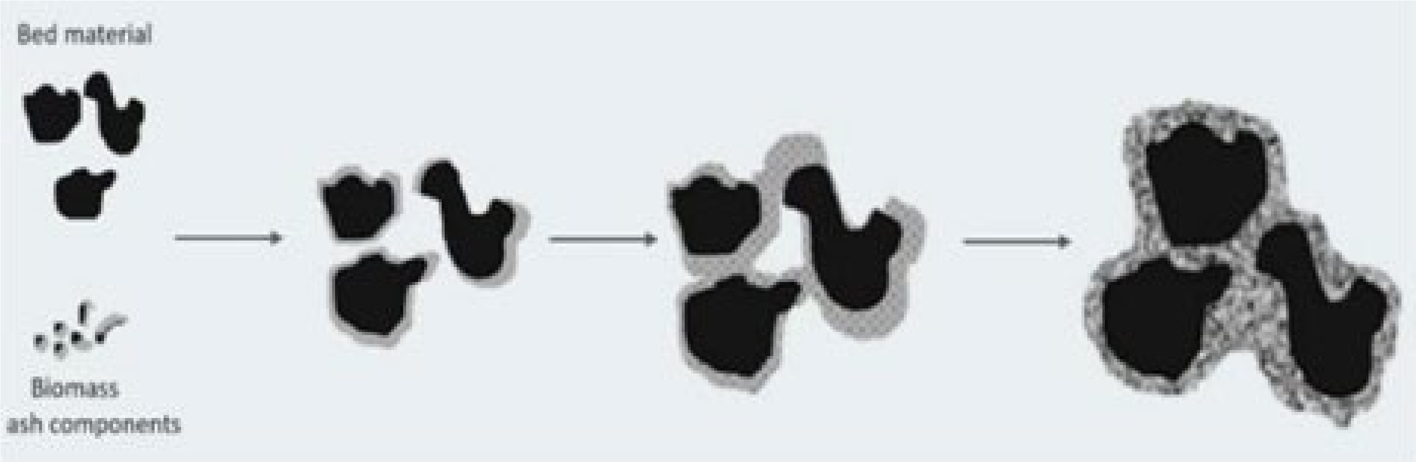


Fig:- A) Straw pellet B) agglomeration of bed materials

FLASH Project to predict ash behaviour

Predicting the FLow behaviour of ASH mixtures for production of transport biofuels in the circular economy

- Increase the fundamental understanding of ash properties and behaviour in thermal systems (e.g. gasification processes)
- Develop methods and models to predict ash behaviour
- Define/test strategies to mitigate ash-related challenges

Project partners:
University of South Eastern Norway, Porsgrunn
SINTEF Energy Research, Trondheim
University of Natural Resources and Life sciences, Vienna
Aalto University, Helsingfors

This study is funded by **The Research Council of Norway, Program for Energy Research (ENERGIX),** Project 280892

FLASH-Predicting the FLow behavior of ASH mixtures for production of transport biofuels in the circular economy - Prosjektbanken (forskningsradet.no)

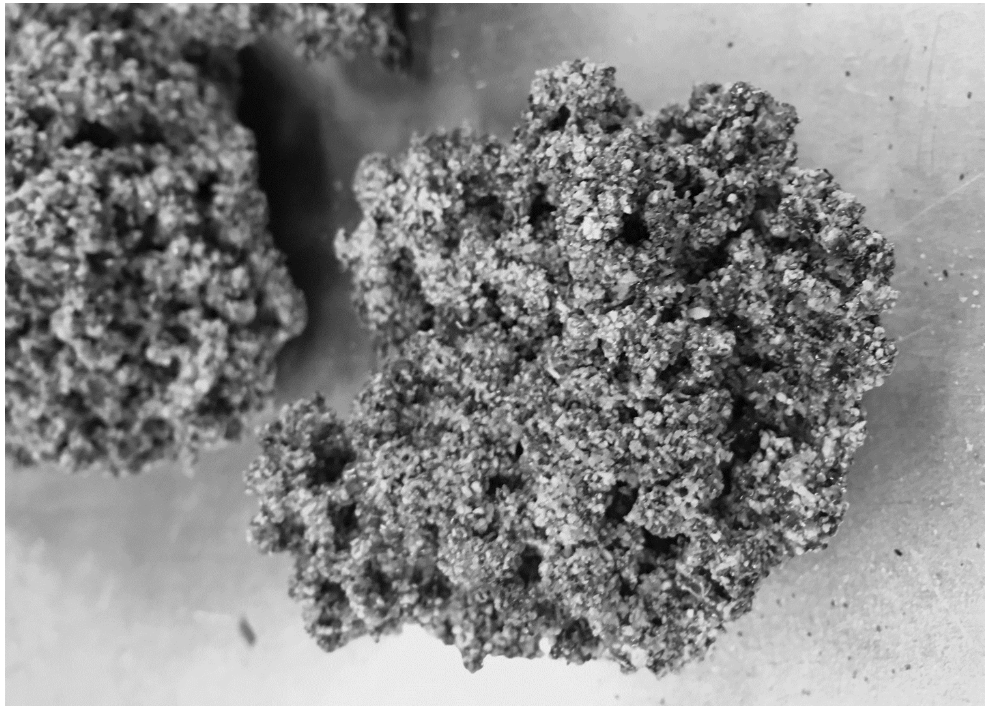
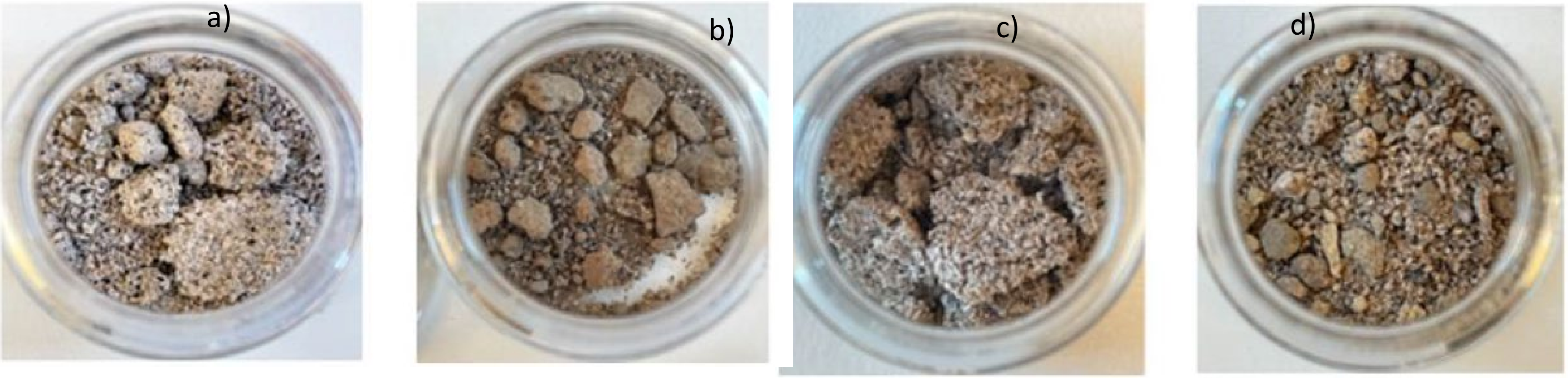


Figure: Agglomeration of ash

FLASH Project to predict ash behaviour

- The developed model and method are new scientific tools for determining the critical amount of ash in fluidized bed systems.
- Thus, they provide the necessary tools to utilize biomass more efficiently and economically in the future Related to the operational challenges with ash melting in fluidized bed systems- e.g. gasification of biomass in fluidized beds.

- Ash-related challenges are the main obstacles to accelerating the implementation and commercialization of the conversion of biomass to biofuels via gasification.



Agglomerates formed during the fluidization experiments with (a) grass, (b) wood (c) straw and (d) bark.

Nora Furuvik

FLASH/USN

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Modelling of ash melts in gasification of biomass

https://openarchive.usn.no/usn-xmlui/handle/11250/2980114

Upscaling of technology and Circular economy

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- Economic analysis is necessary for gasification projects to assess their financial viability, ensuring that the benefits outweigh the costs, and to attract investment by demonstrating potential profitability.
- Life Cycle Assessment (LCA) evaluates the environmental impacts of gasification across its entire life cycle, ensuring sustainable and responsible decision-making.

Zahir Barahmand

USN

Start: 01.05.2023

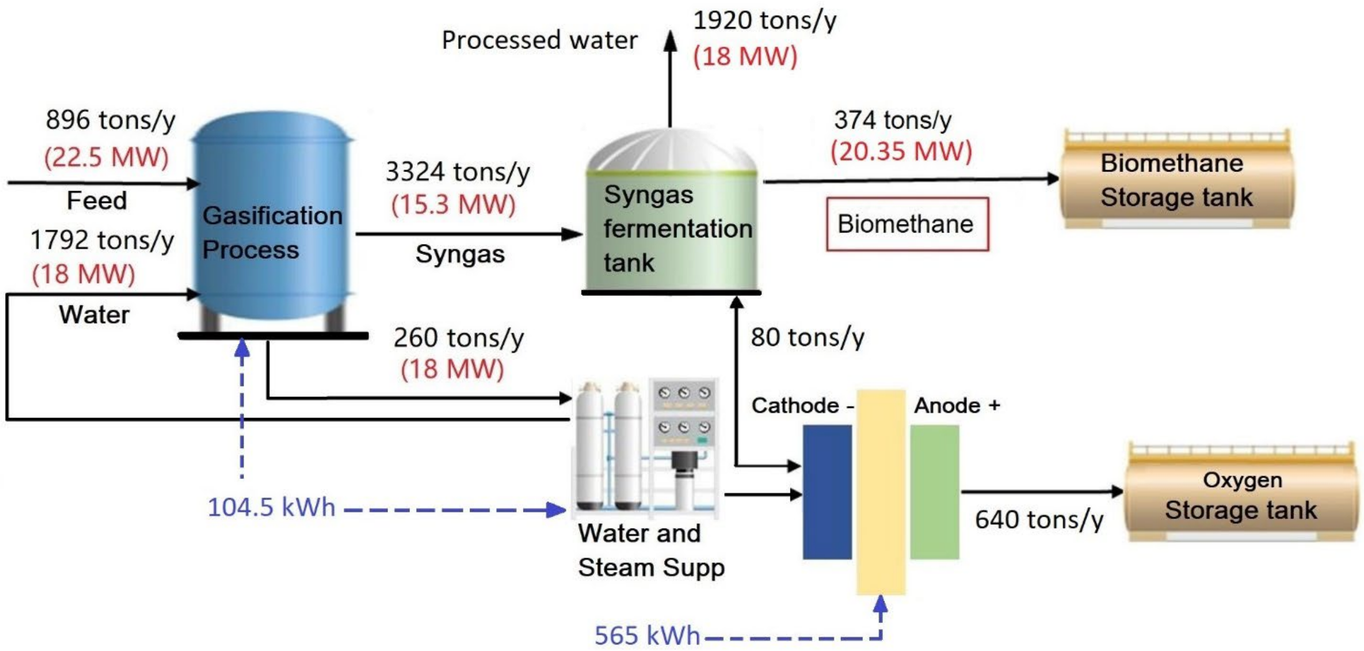
Life cycle assessment of biomass gasification processes from a circular economy perspective

- Circular Economy Level
- Process Level
- LCA Level

Diversification of feedstocks

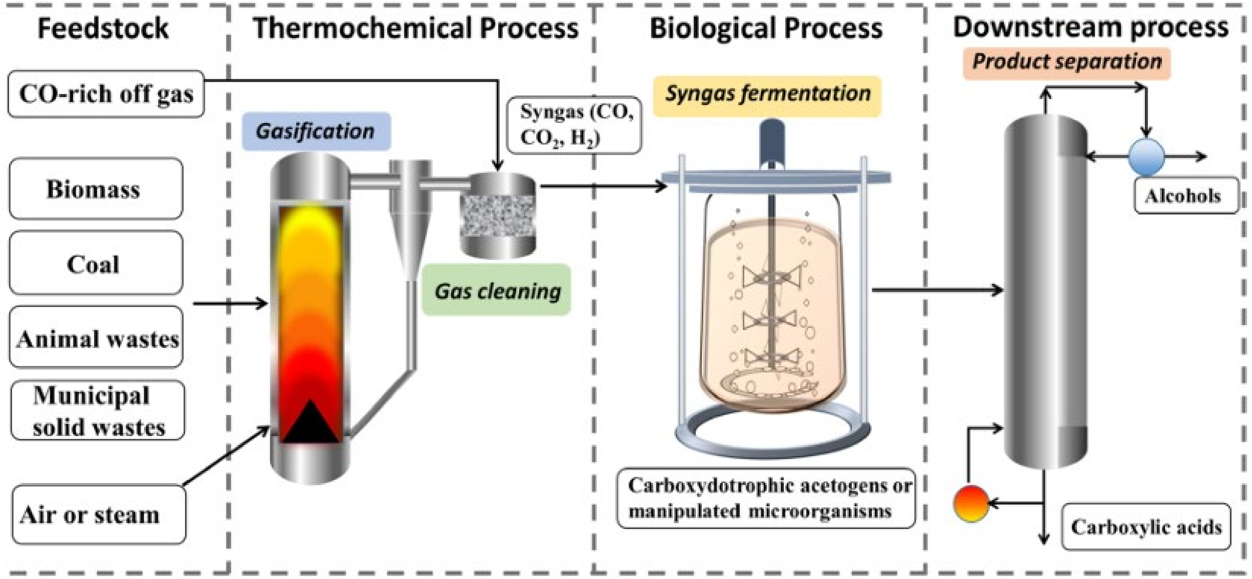
- Diversification of feedstock is necessary to minimize the competition in the bioenergy sector (AD, Gasification)
- Contaminated organic waste might be alternatives in circular economy aspect
- Inorganic waste such as Plastics waste
- Economically competitive downstream process development is necessary

Straw pellet and coffee waste pellet (USN)



SNG production from syngas (USN)

Future work

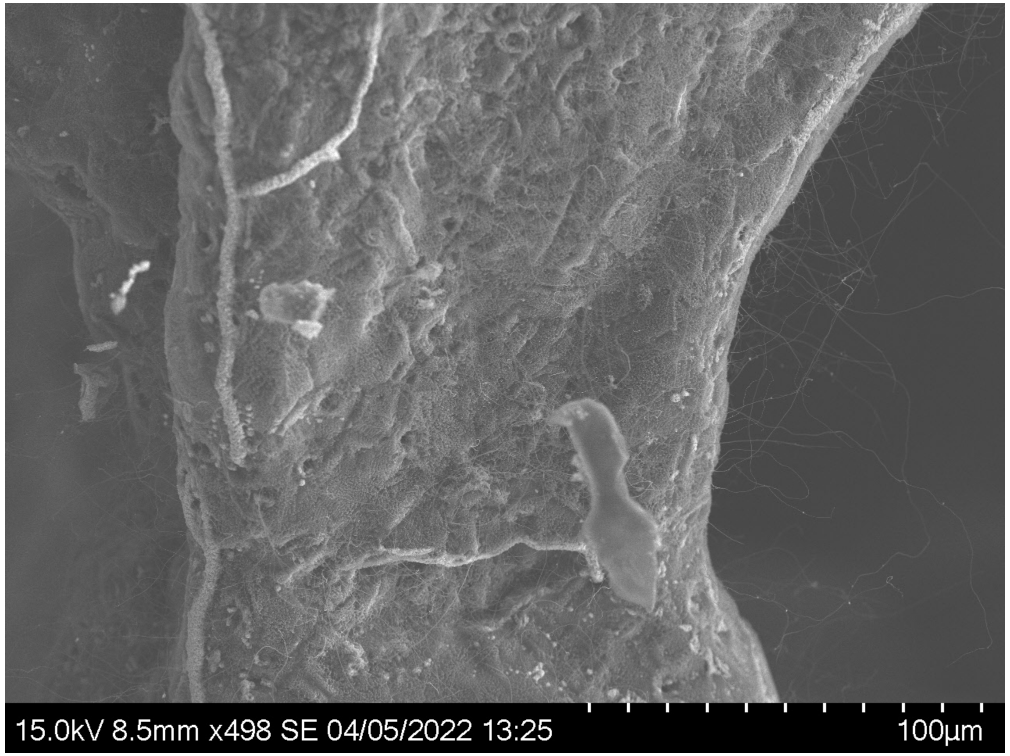


Sun et al, 2019

He et al, 2019

- **Synthetic Fuels:** Syngas from gasifiers can be converted into methanol through processes like Fischer-Tropsch synthesis
- **Chemicals Production:** Syngas is a versatile feedstock for producing chemicals like ammonia, which is essential for fertilizers, and hydrogen
- **Synthetic Natural Gas (SNG):** By further processing, syngas can be converted into synthetic natural gas quality biomethane

Collaboration beyond Bio4Fuels



Carbon nanotube synthesis on the surface of copper (Developed at USN)

- Methanol production from syngas from a gasifier
- Some selected solid waste, such as sludge from WWTP, digested, contaminated waste, agriculture waste, and residual forest waste, is becoming problematic in Norway
- Proposed research activities: i) Syngas generation by investigating various waste ratios of contaminated waste and agriculture residual waste to derive selected stoichiometry of CO, CO and H_2 in syngas, ii) Copper-based catalyst production to produce methanol

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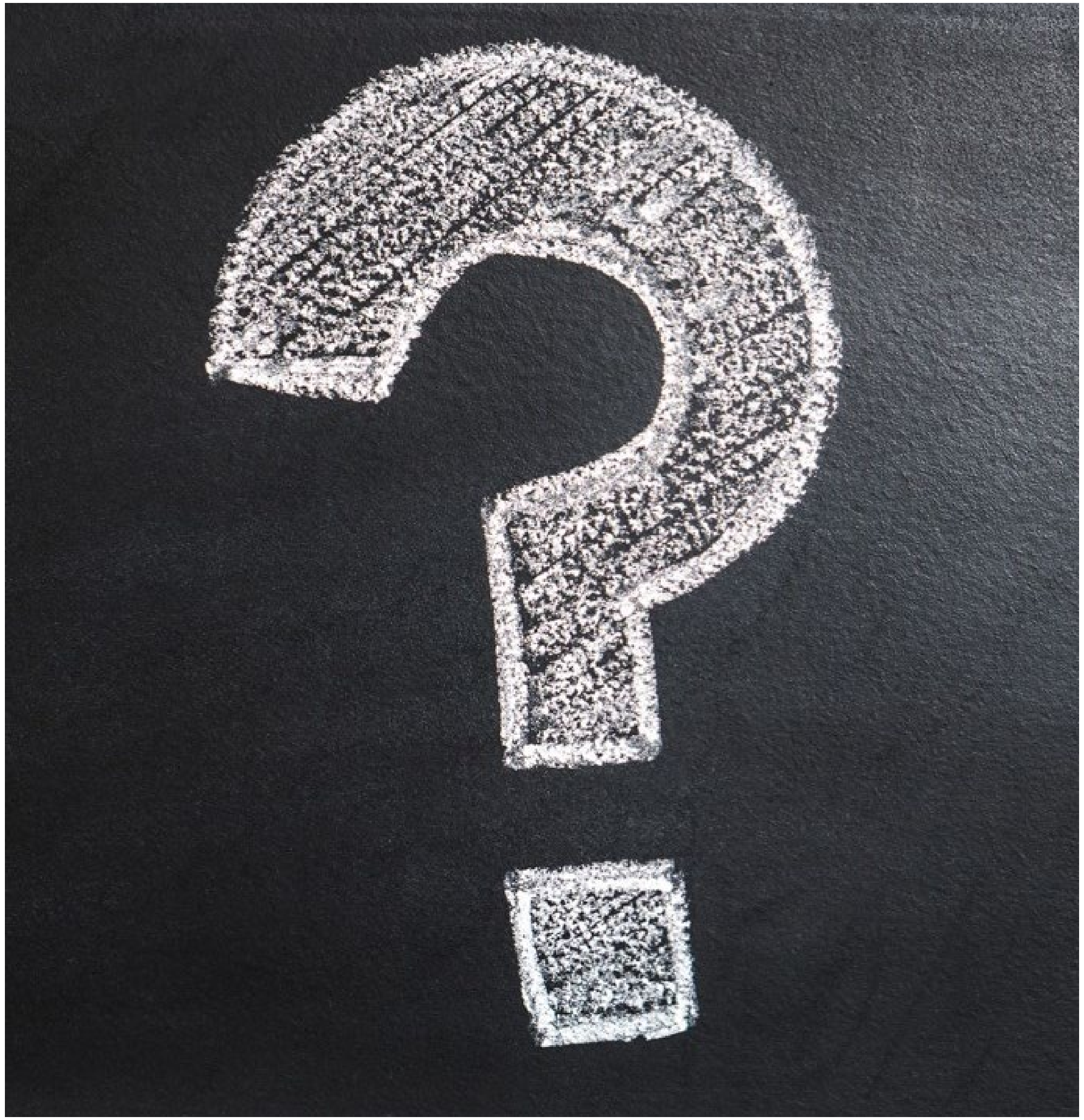
Collaboration beyond Bio4Fuels

- Diversifying the feedstock in the circular economy aspect
- What possible value-added products can be produced from biomass gasification?
- Where do these value-added products fall within the value-added pyramid?
- Downstream processing for synthesised product
- Upscaling and demonstration of gasification plants



Thank you

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NMBU NTNU NIBIO NORSK INSTITUTT FOR BIOØKONOMI IFE USN University of South-Eastern Norway PFI PART OF RISE SINTEF