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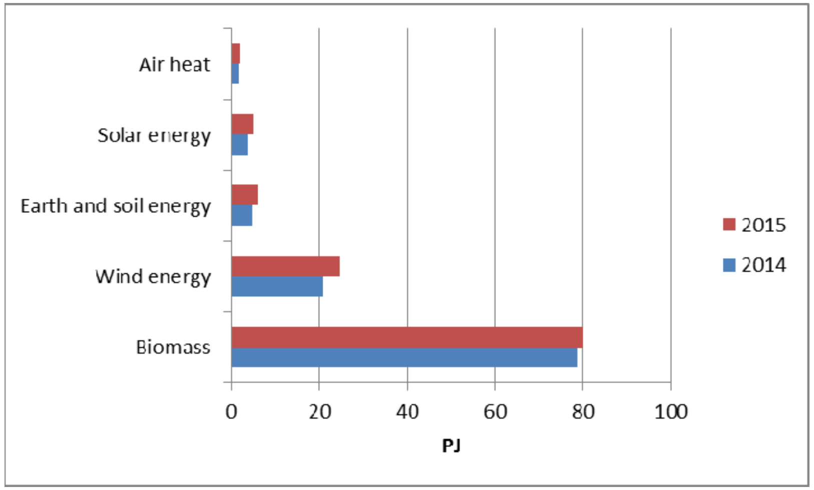
THE NETHERLANDS COUNTRY REPORT

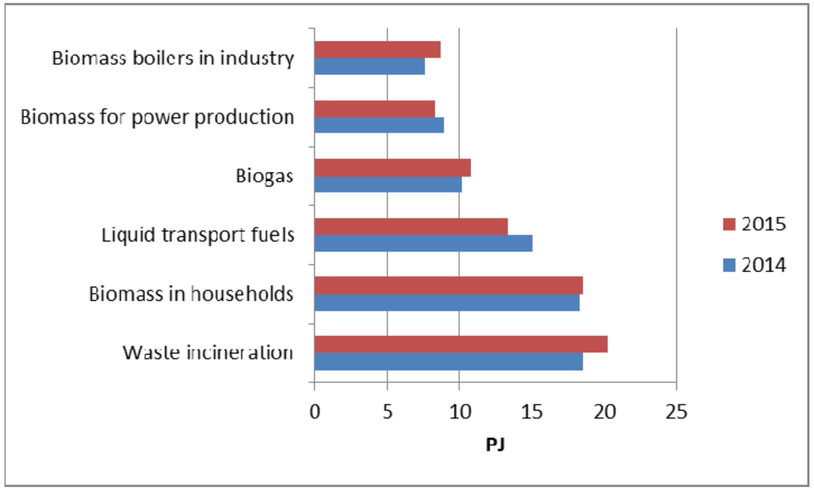
Berend Vreugdenhil

Luzern, Switzerland
24th of October 2016

www.ecn.nl

Status Renewable Energy

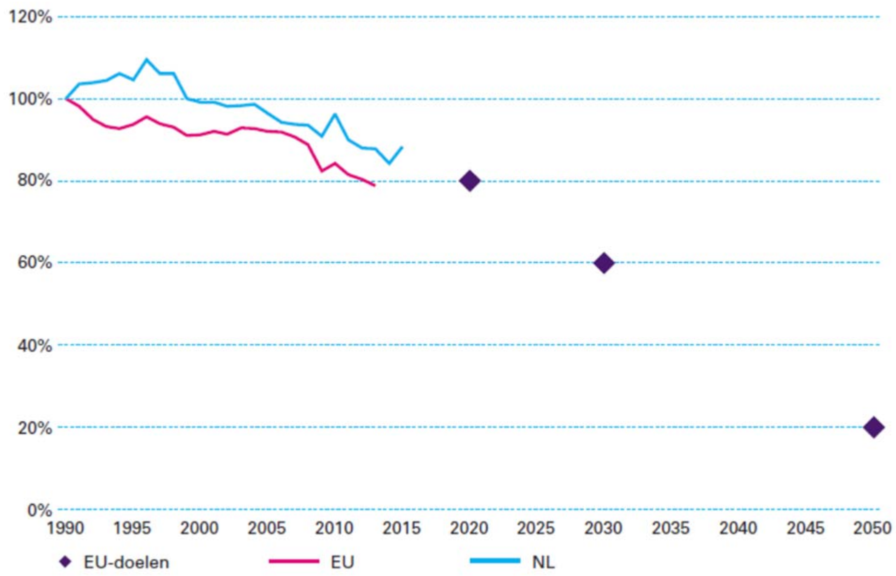




Sustainable energy increased to 5.8%
Biomass growth just 2%, but accounts still for 70% of the total

Biomass used per sector; Waste incineration and biomass boiler increase due to more heat production and distributed heat expansion

Status CO_2 reduction



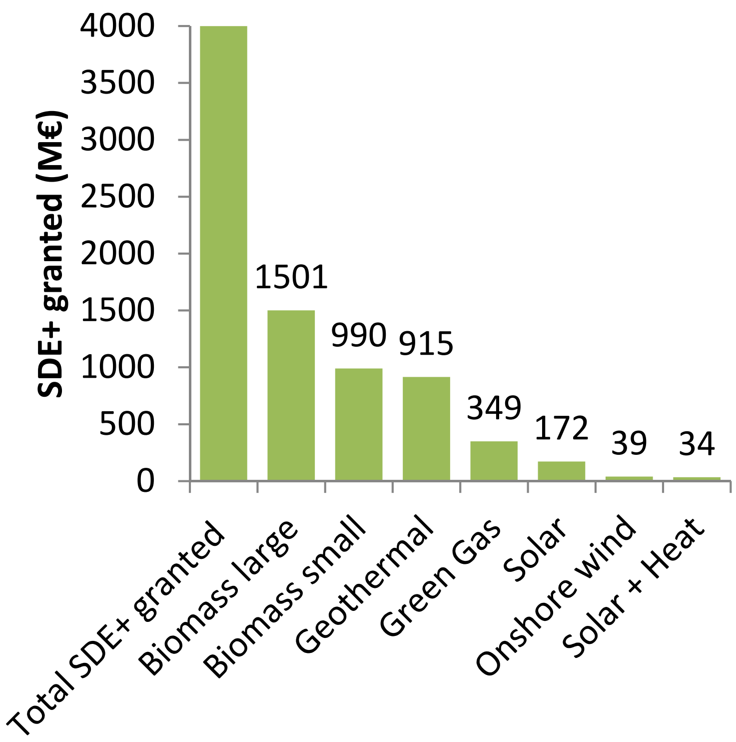
CO_2 emissions compared to 1990 level
EU targets in 2020, 2030 and 2050
Dutch target is 30% reduction in 2020

- Minister is considering shutting down 2 additional coal fired power plants, should become clear Nov-2016
- Gas fired power stations are being mothballed or taken off grid
  - 5 in total for RWE
  - 4 in total for Engie

- SDE$^+$ increased to 9 billion € in 2016

(in 2015 3.4 billion € was allocated)

Status of SDE^+ 2016



- Most SDE^+ into biomass projects
- 1500 M€ for 2 power stations
- Biomass small is CHP applications, operated on digestion gas or biomass
- Green gas is mostly via digestion, one project via gasification 83 M€ (SCW)
- Off shore wind is a separate subsidy programme (5 billion €)

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Status update gasification developments

ESKA

torrgas

- Air blown CFB gasifier for paper rejects
- Pyrolysis reactor coupled with a high temperature zone for syngas production, operated on torrefied biomass

gasunie

- AMBIGO Alkmaar
- BAVIO/BMC (Oss and Zutphen)
- SCW Alkmaar
- Green Gas involvements

Synvalor

synova

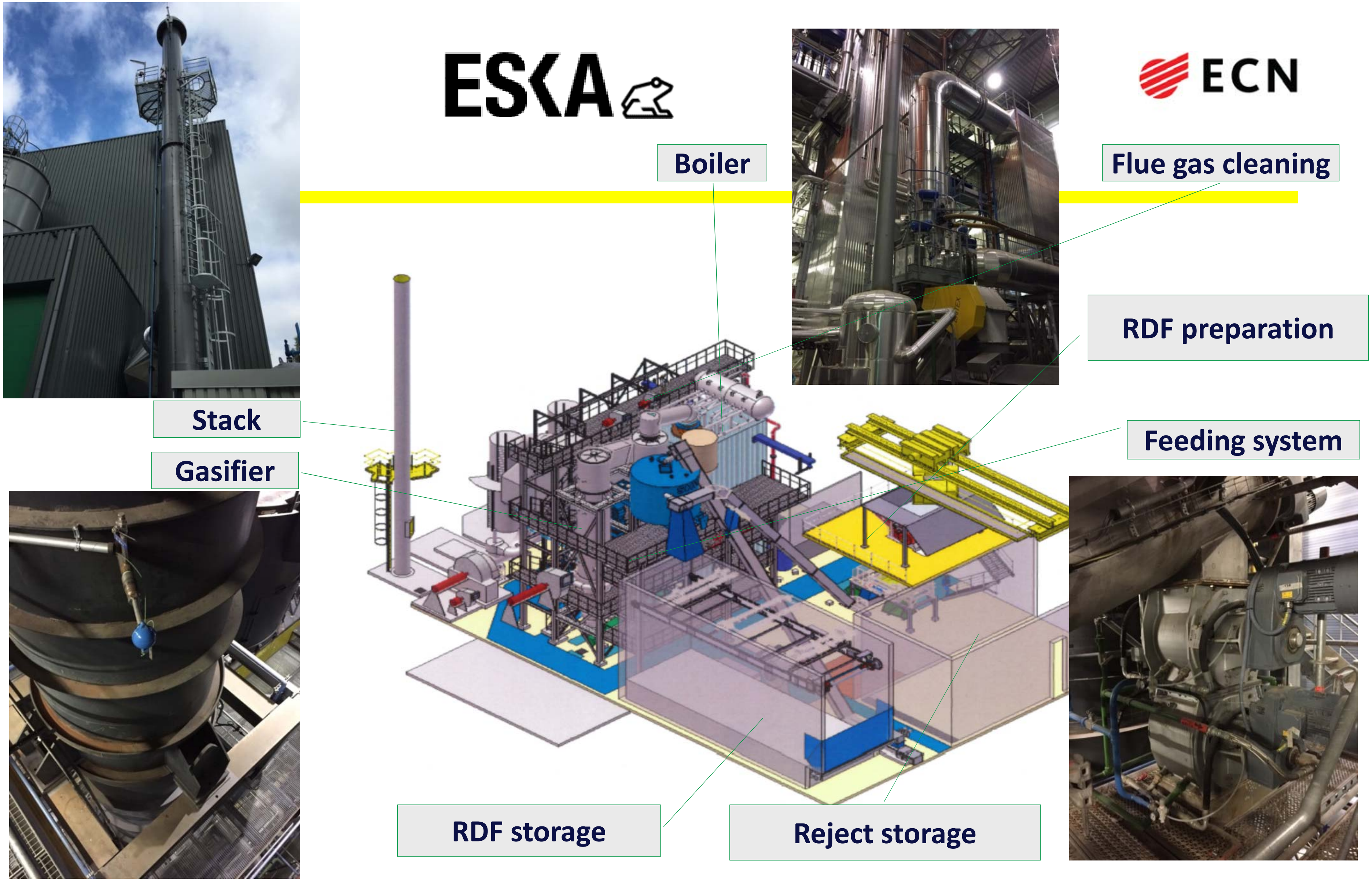
- Synvalor
- Synova

- Research at Universities and ECN

CFB Gasifier of ESKA

- Fuel: 25 kton/y rejects
- Airblown CFB gasifier coupled to a steam boiler
- Saturated steam production @ 16 bar
- Fuel load 12 MW_{th}
- Thermal efficiency ~ 85%
- Installation is in commissioning phase
- Gasification is going according to expectations
- Feeding is causing dust issues
- Q4 2016 a 4 week duration test is planned after which the installation will be taken into full operation

Start in 2015


ESKA
ECN
Boiler
Flue gas cleaning
RDF preparation
Feeding system
Stack
Gasifier
RDF storage
Reject storage

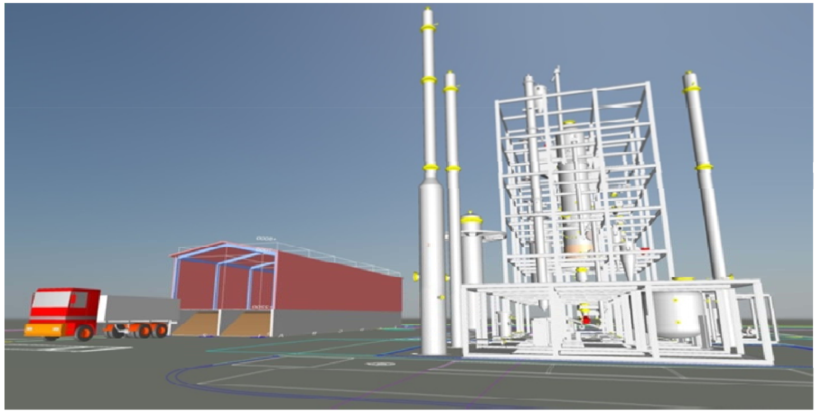
Torrgas installation in Groningen

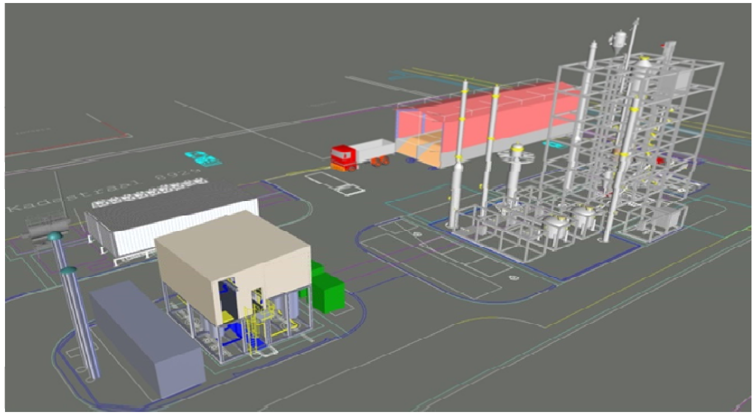
Torrgas is currently in the Basic Engineering fase for a 10 MW_{th} installation

Green Gas developments - AMBIGO

Alkmaar demonstration

- 4 MW_{th} MILENA OLGA ESME
- Basic Engineering finished
- Working on financial close in Q4 2016
- Next fase is detailed engineering and construction to be finished end of 2017





Participatiefonds
Duurzame Economie
Noord-Holland

Green Gas Developments (BAVIO/BMC)

BMC (Zutphen) / BAVIO (Oss)

- 14 MW_{th} wood to SNG plant
- Repeat to reduce costs, 5 environmental permits granted
- SDE^{+} subsidy granted for the project in Zutphen and Oss
- Working towards financial close

-Ellomay Capital started a cooperation with Ludan Energy Overseas

-Ludan Energy Overseas has been active in the Netherlands with Biogas-CHP application

-Ellomay provides a capital injection of 200 M€ for green gas projects in the Netherlands, gasification is within this scope

Gasification

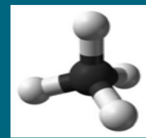
MILENA

Cleaning
(tar removal)

OLGA

Methanation
and gas
upgrading

ESME

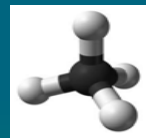


4 MW installation demonstrating the biomass to SNG process in Alkmaar is planned to go on stream in 2017.

ambigo

gasunie

SCW Systems
clean energy technology
developing
Super Critical Water Gasification



2 MW installation demonstrating the wet biomass to SNG process in Alkmaar is planned to be constructed in 2017, scale up to 20 MW after successful demonstration

torrgas

ambigo

gasunie

Synthesis gas
$CO + H_2$
(syngas)

0,7 MW demo installation is now being tested. 10 MW plant in Delfzijl is planned for construction in 2018.

Other developments

Synvalor

- Developing a project to produce 700 kW_{el} and 1000 kW_{th} for a nursery garden.
- Demonstration unit moved to Latvia. Operated on woodchips connected to 250 kW_{el} engine. Heat is used for additional drying onsite.

synova

- Thailand project: Gasification of RDF to produce power with a gas turbine and gas for a furnace.
- Client: Siam Cement Group
- Location is Saraburi Province, Nong Khae Industrial park
- Currently working towards FID

Biomass gasification research at TU Delft

Prof.dr.ir. Wiebren de Jong,
TU Delft, faculty 3mE (mechanical, maritime and materials engineering

Supercritical Water Gasification

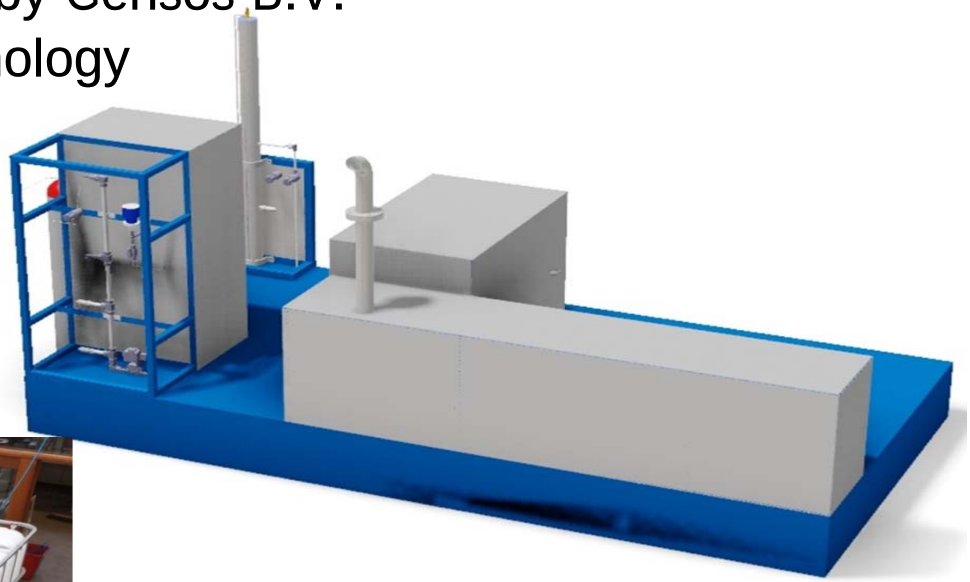
of wet biomass (model components)

PhD student O. Yakaboylu

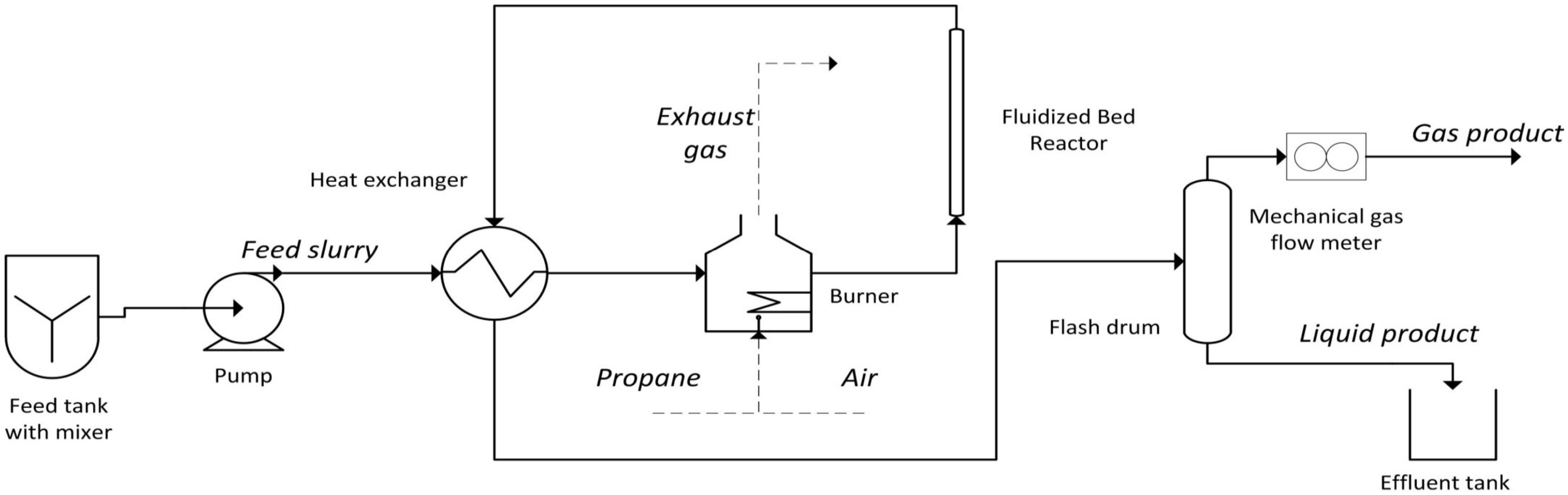
Acknowledgement to RvO for cofunding the research in the framework of the Dutch EOS-LT project
“Superkritische vergassing van natte reststromen” (contract EOSLT10051)

Experimental setup

- Designed with and manufactured by Gensos B.V.
- A novel reactor with a novel technology
  - 50 l/h feed capacity
  - Bubbling fluidized bed reactor
  - Capable of performing real wet biomass experiments such as manure, algae



Simplified process flow diagram



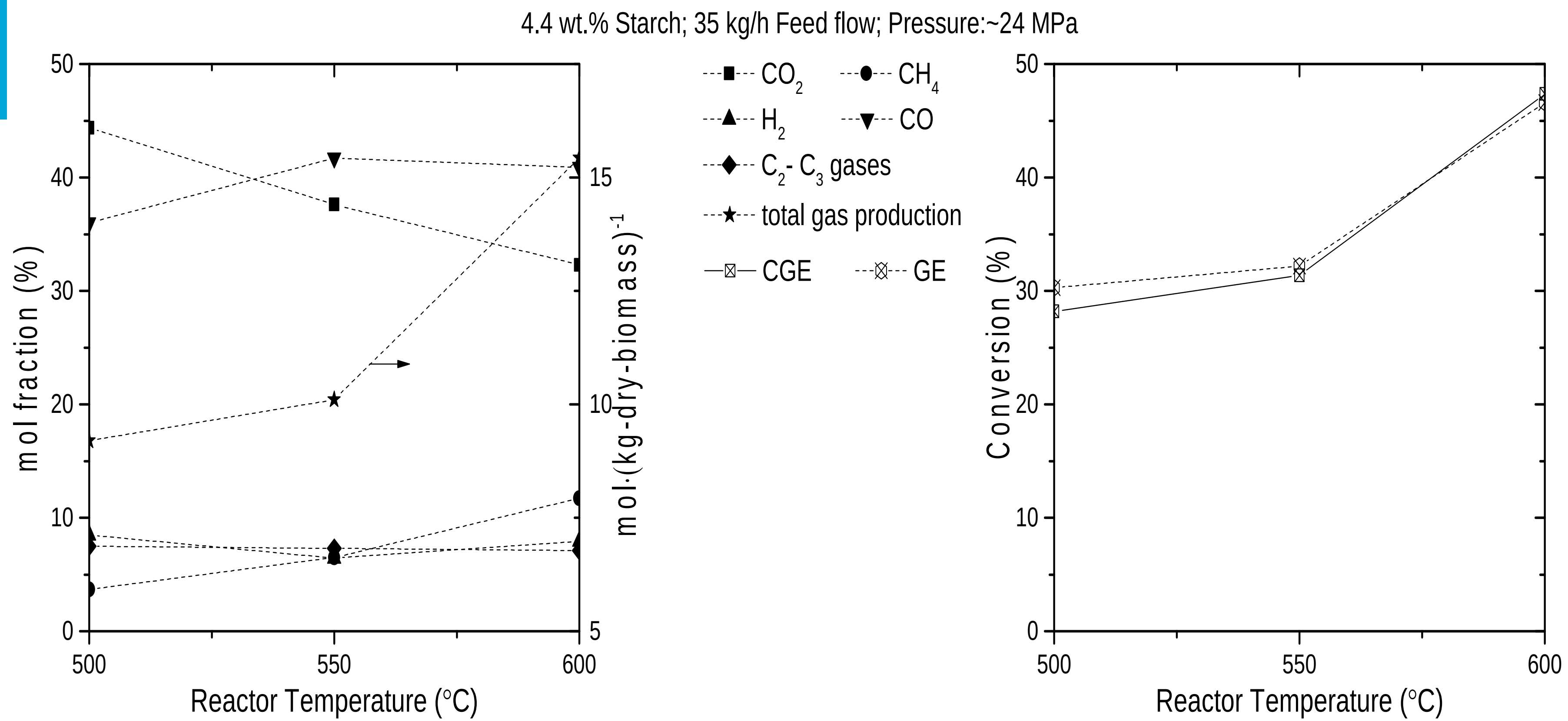
First experiments

- Gasification of starch
  - 4.4 wt. % concentration in the feed
  - Pressure of ~ 240 bar

- Investigation of the influence on the gasification efficiency and gas composition of:
  - Temperature
  - Feed flow rate
  - Presence of salts

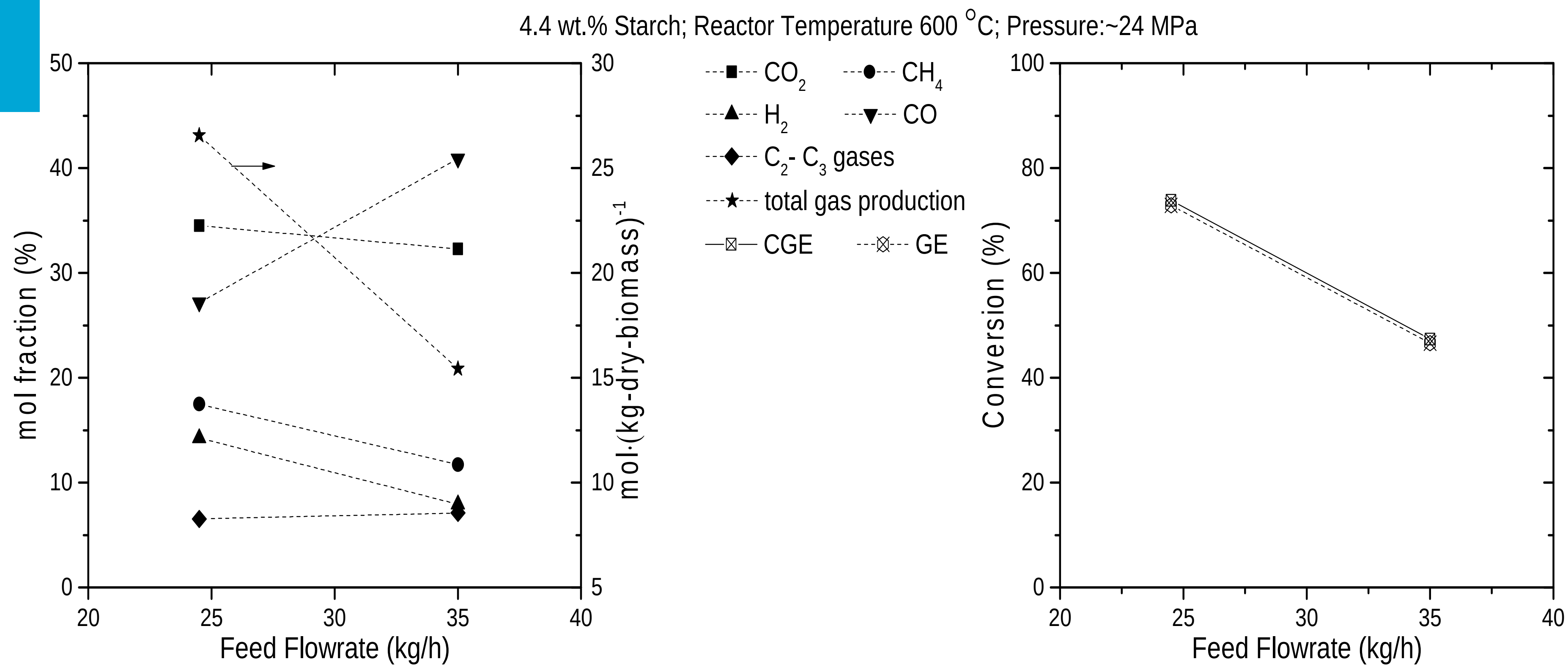
Results

- The influence of reactor temperature



Results

- The influence of feed flow rate on gas composition and CGE



Conclusions

- Supercritical water gasification is attractive for converting low value wet biomass streams, like manure

- Depending on process conditions either methane-rich or hydrogen-rich gas is predicted to be produced

- Process modelling of a system including SCWG can benefit from our applied approaches, both
  - constrained equilibrium as engineering model
  - kinetic model for obtaining more insight in effects of temperature/time and reactor dimensioning

- First experiments show promising carbon gasification efficiency potential

100 kW$_{th}$ CFBG TU Delft

Gasification of wood and torrefied wood pellets

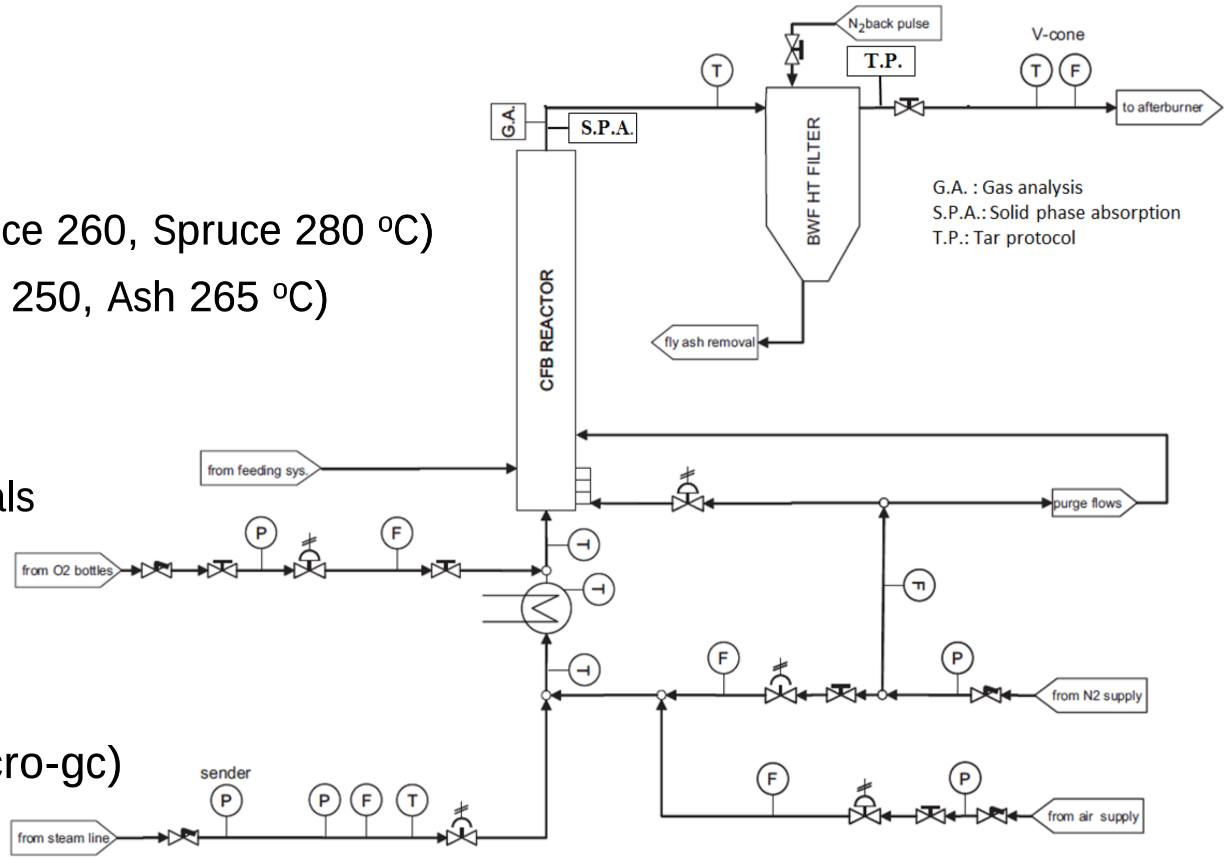
PhD student G.A. Tsalidis

Postdoc M. di Marcello

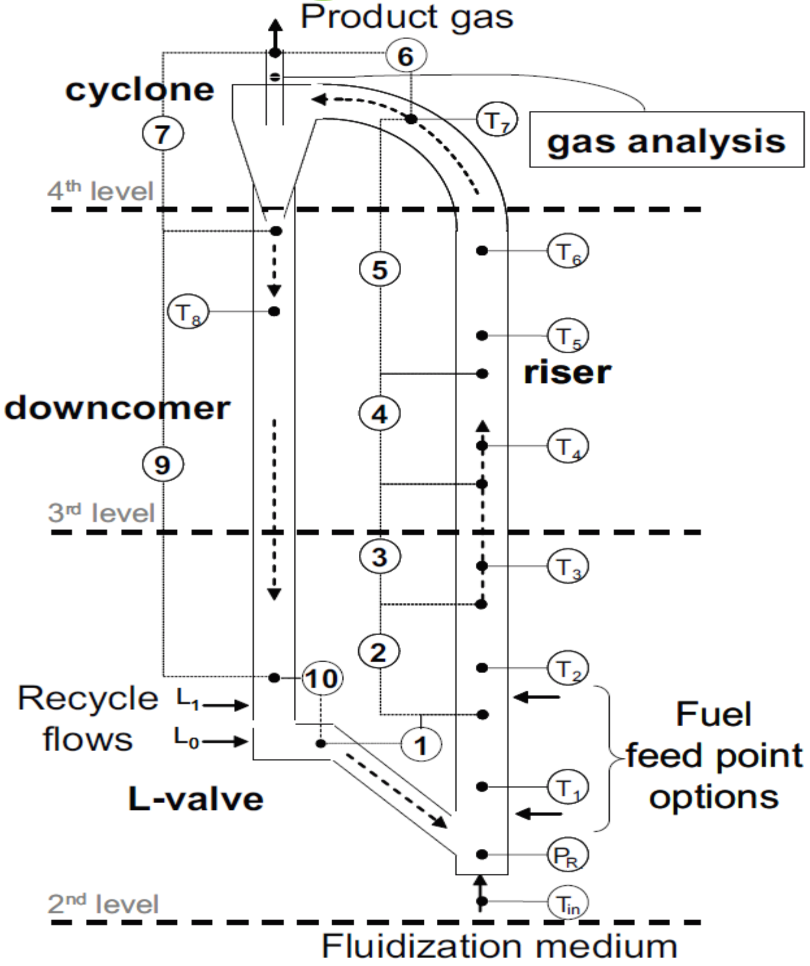
Acknowledgement to RvO for cofunding the research in the framework of the Dutch National TKI project “INVENT Pretreatment”, project no. TKIBE01011

Materials and methods

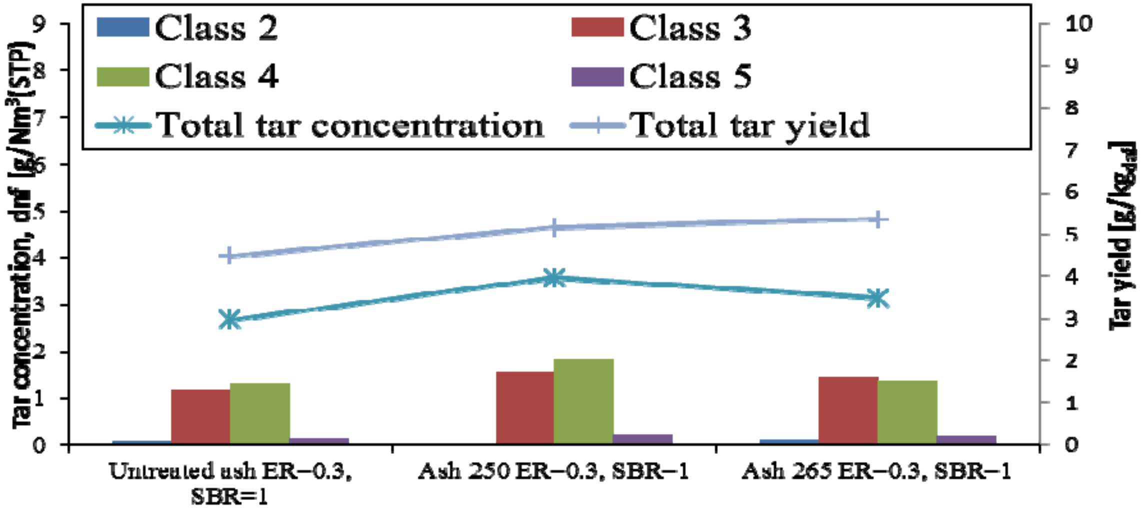
- Steam-oxygen blown, atmospheric CFBG, all tests at 850 ºC
- Steam-O_2 blown
- Magnesite as bed material
- Pelletized fuels:
    - Torrefied softwood (Spruce 260, Spruce 280 ºC)
    - Torrefied hardwood (Ash 250, Ash 265 ºC)
    - Topell black
    - Torrcoal black
    - Untreated parent materials
- Permanent gas composition
- Tar analysis (tar protocol)
- Benzene quantification (micro-gc)



Gasification rig at TU Delft – CFB

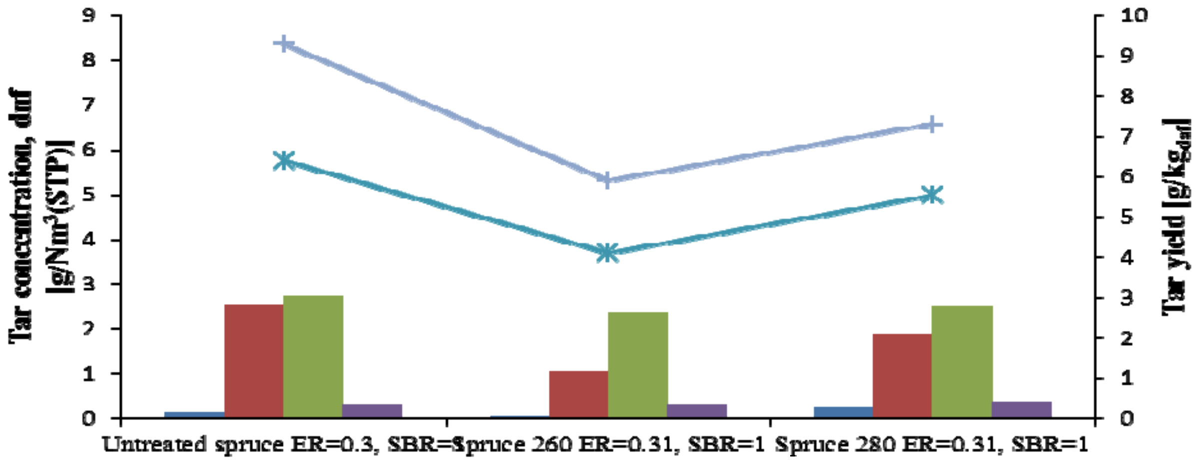


Softwood (spruce) and hardwood (ash)



- Minor changes in permanent gases, H_2, CO_2, CO and CH_4
- Small changes in benzene, toluene and xylenes

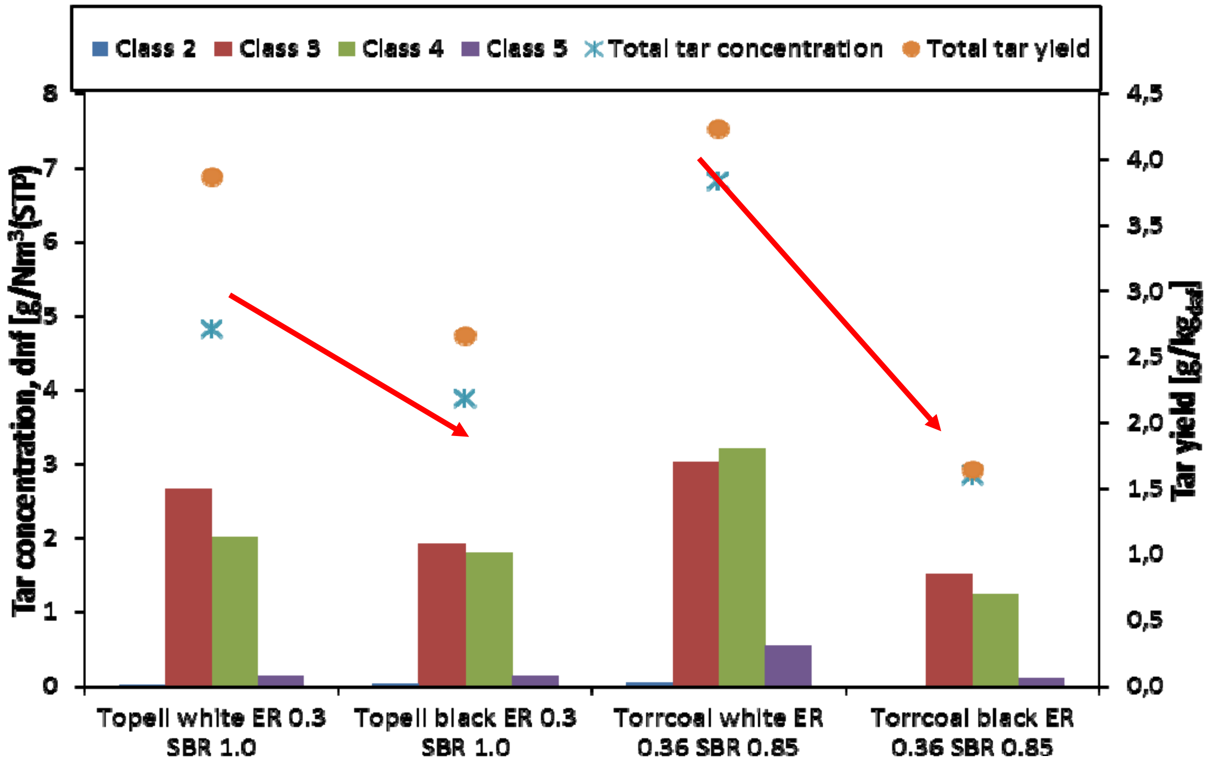
- Influence in tar species
  - Reduction for torrefied spruce
  - Increase for torrefied ash



Topell and Torrcoal pellets

- Minor changes in permanent gases, H_2, CO_2, CO and CH_4
- Small changes in benzene, toluene and xylenes

- <u>Influence in tar species</u>
- Reduction for both torrefied feedstocks
- Torrcoal black mainly from Toluene, Naphthalene and 1-CH_3-Naphthalene reduction



Process benchmarks

CCE: Carbon Conversion Efficiency
CGE: Cold Gas Efficiency

	Untreated ash	Ash 250	Ash 265	Untreated spruce	Spruce 260	Spruce 280	Topell white	Topell black	Torr-coal white	Torr-coal black
CCE	102.1	78.0	90.6	95.6	89.1	81.6	72.0	79.0	100.2	92.5
CGE	62.0	52.1	58.3	60.0	53.4	48.2	45.0	54.4	56.2	56.0
H_2/CO	2.4	2.8	2.5	2.4	2.3	2.4	3.1	2.6	2.4	2.1
Gas yield[a]	1.7	1.4	1.7	1.6	1.6	1.5	1.2	1.5	1.6	1.7
LHV[b]	7.0	6.8	6.6	6.8	6.5	6.5	6.5	6.9	6.5	6.3

[a] in Nm^3/kg_{daf}, [b] in MJ/Nm^3

Conclusions

- Considering the benefits of torrefaction in the biomass supply chain, both commercial torrefied fuels offer benefits in large scale application under the same conditions, Topell black in terms of process benchmarks and Torrcoal black, especially, in terms of tar reduction.
- Torrefied spruce and torrefied ash need to be investigated more. However, torrefied spruce appears to offer benefits in terms of tar reduction.

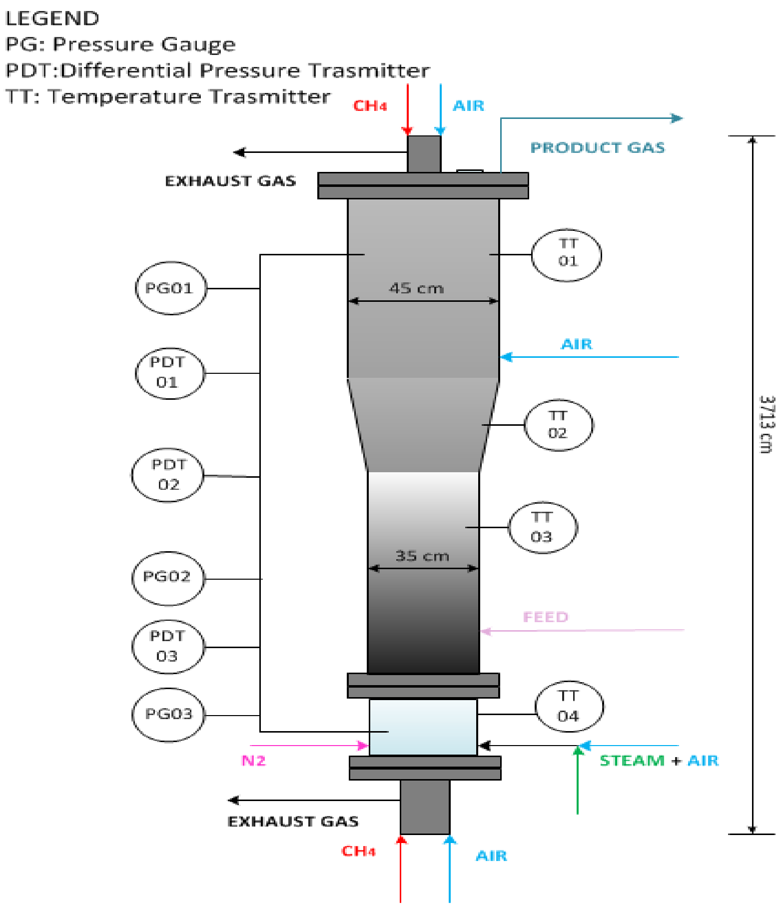
Biomass Gasification in a novel 50kW$_{th}$ Indirectly Heated Bubbling Fluidized Bed Steam Reformer: study on char reactivity in-situ and possible post process applications

PhD student M. Del Grosso

Acknowledgement to Dutch company Petrogas for cofunding the research

Set up description

- **Indirectly heated bubbling fluidized bed steam reformer (HIBFBSR)**



  - Bubbling Fluidized Bed Steam Reformer
  - Self recuperative ceramic burner in radiant tube (bed zone and freeboard)

The tests will be carried out with only steam as gasification agent with the possibility to introduce also air.

No contact between product gas and exhaust gas producing high quality gas.

Material and methods

- **Biomass**
  - A-wood pellets (d≈6mm)
  - B-wood pellets (d≈12mm)
  - Miscanthus pellets (d≈6mm)
- **Bed material**
  - Corundum NK-F046
  - Corundum NK-F054
  - Corundum NK-F060
- **Operating parameters**
  - T= 850°C
  - $0.5 \leq SBR \leq 1.5$
  - $0.15 \leq ER \leq 0.4$
- **Additive**
  - Kaolin

Research focus

- **Experimental part**
  - Biomass – bed material – additive characterization.
  - Study on the heat transfer of radiant tube burners.
  - Study on the effect of this new concept of indirectly heating based on combustion.
  - Evaluation of the performance of different biomasses: study on the effect of feed properties (biomass type, moisture content, ash content…).
  - Study on the effect of the operating parameters (bed temperature, residence time, bed particle size, ER, STBR).
  - Analysis of gas yield and composition, tar content, carbon conversion and mass balances, cold gas efficiency.
  - Char analysis in order to study its reactivity in-situ and its possible post process applications.

- **Modelling part**
  - Model of the gasification process with Aspen Plus™.
  - Model of the heat transfer using CFD.

Catalytic conversion of ethylene into BTX

G. Aranda Almansa, C.M. Lok, Y.-T. Kuo, B.J. Vreugdenhil

Into smart gasification schemes – co-production

- Biomass: only renewable carbon source which can potentially replace fossil fuels for the production of fuels and chemicals.

  → towards synthesis of fuels and chemicals

- Low-medium T gasification: significant amount of CH_4, C_2-C_4 gases, BTX and tars in producer gas.

- Ethylene, BTX: not only harmful in synthesis processes ,but also high economic value.

→ Recovery of valuable compounds from producer gas in co-production schemes: improvement with respect to (costly) conversion to syngas.

What to do with bio-ethylene?

- Ethylene: high value but challenging separation.
- Ethylene separation options:
    - Conventional cryogenic technology: energy-intensive, not economical in biomass gasification applications.
    - Adsorption: under development.
    - Reactive separation → conversion of ethylene into other high-value compounds (e.g. aromatics) which can be more easily harvested from the gas.

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TKI Green Birds & Blue Bird projects

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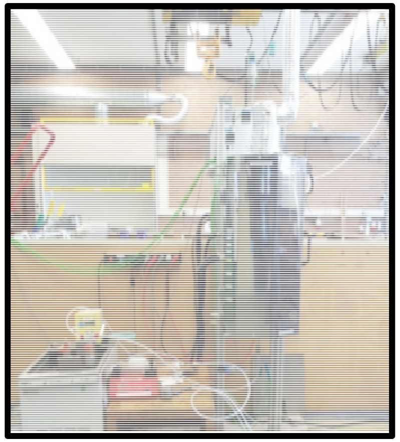
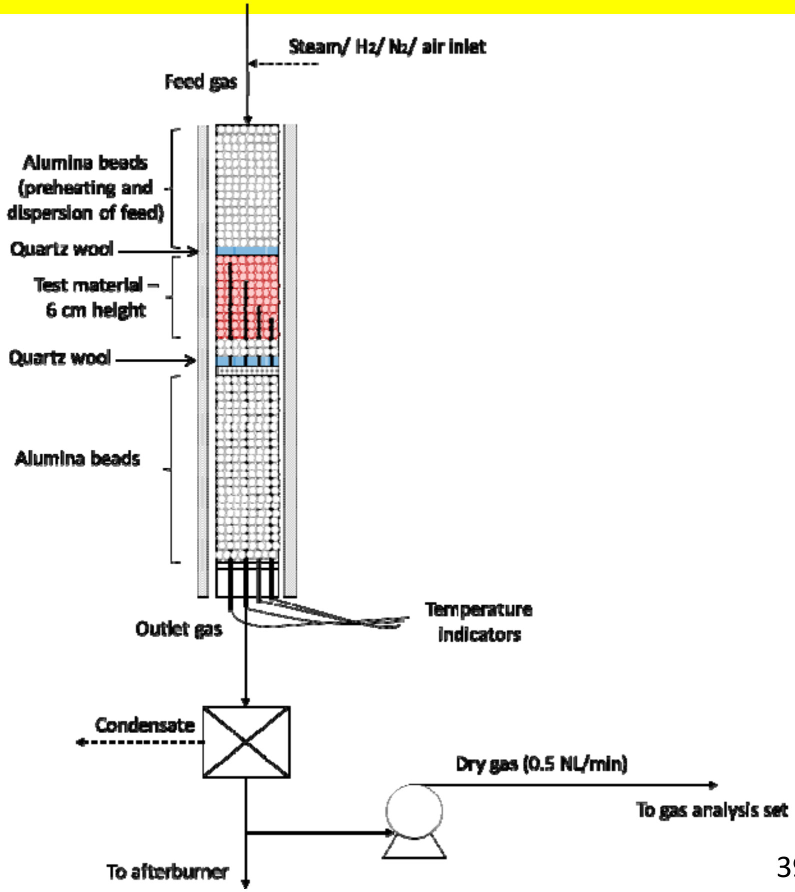
TKI Green Birds & Blue Bird projects

  - **Reactive separation** → conversion of ethylene into other high-value compounds (e.g. aromatics) which can be more easily harvested from the gas.

Experimental setup

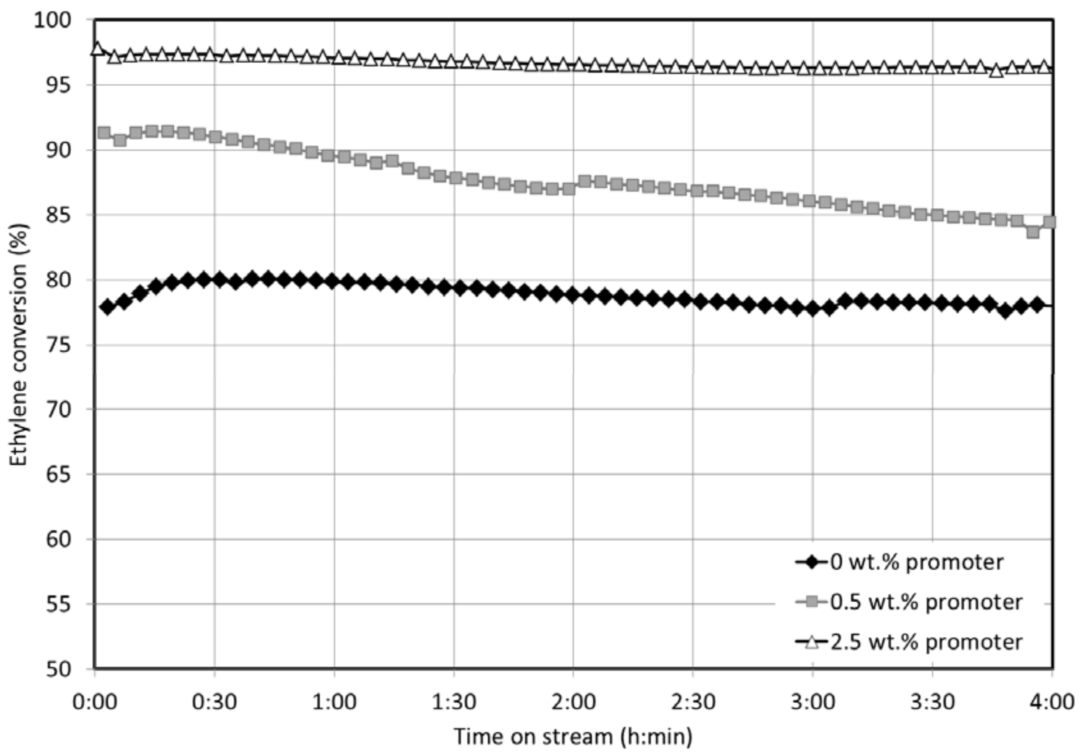
- Performance of promoter-loaded zeolites using producer gas from MILENA indirect gasification as feed gas.
- Effect of operating conditions: temperature, promoter loading, zeolite acidity.



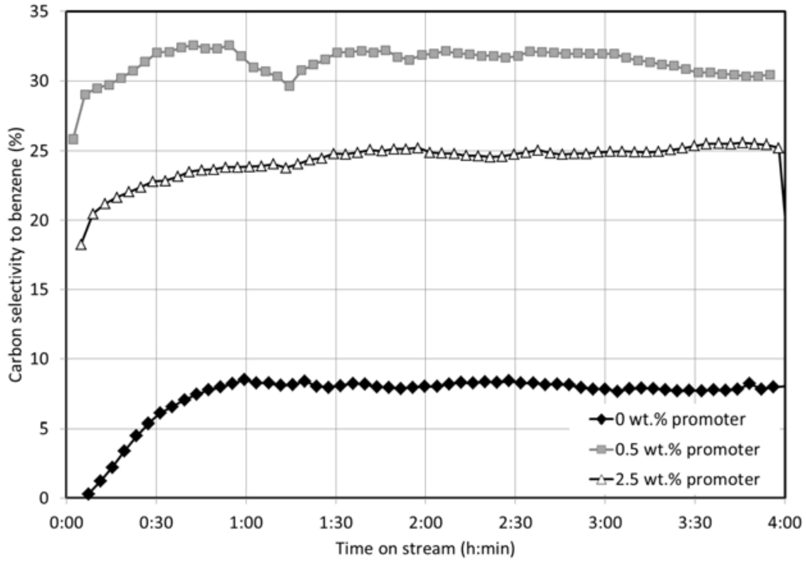


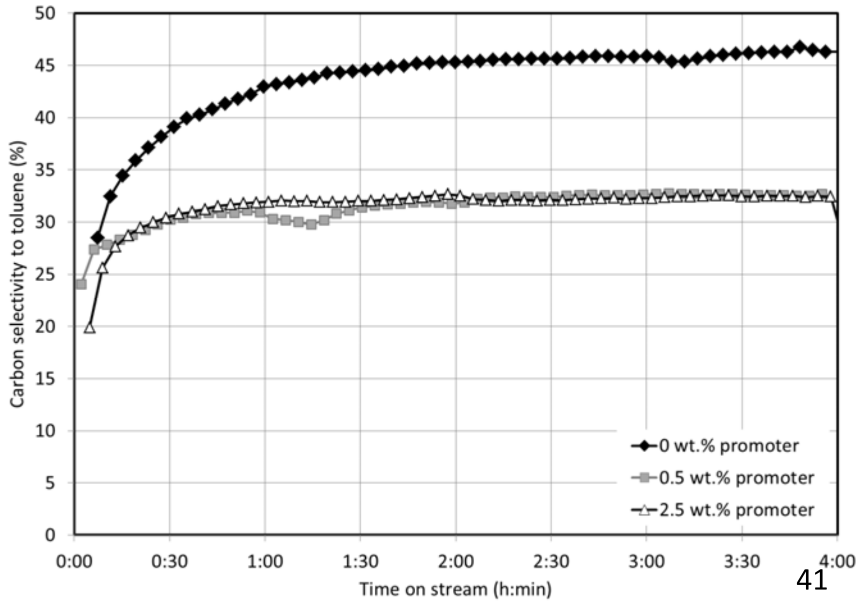
Effect of promoter loading

- 80-97% ethylene conversion.
- Total conversion of C_2H_2.
- ↑promoter loading → ↑ethylene conversion and ↑ carbon selectivity to benzene but ↓ carbon selectivity to toluene
- 0.5 wt.% promoter-zeolite: highest carbon selectivities to benzene (~ 32%) and benzene + toluene (~ 65%).

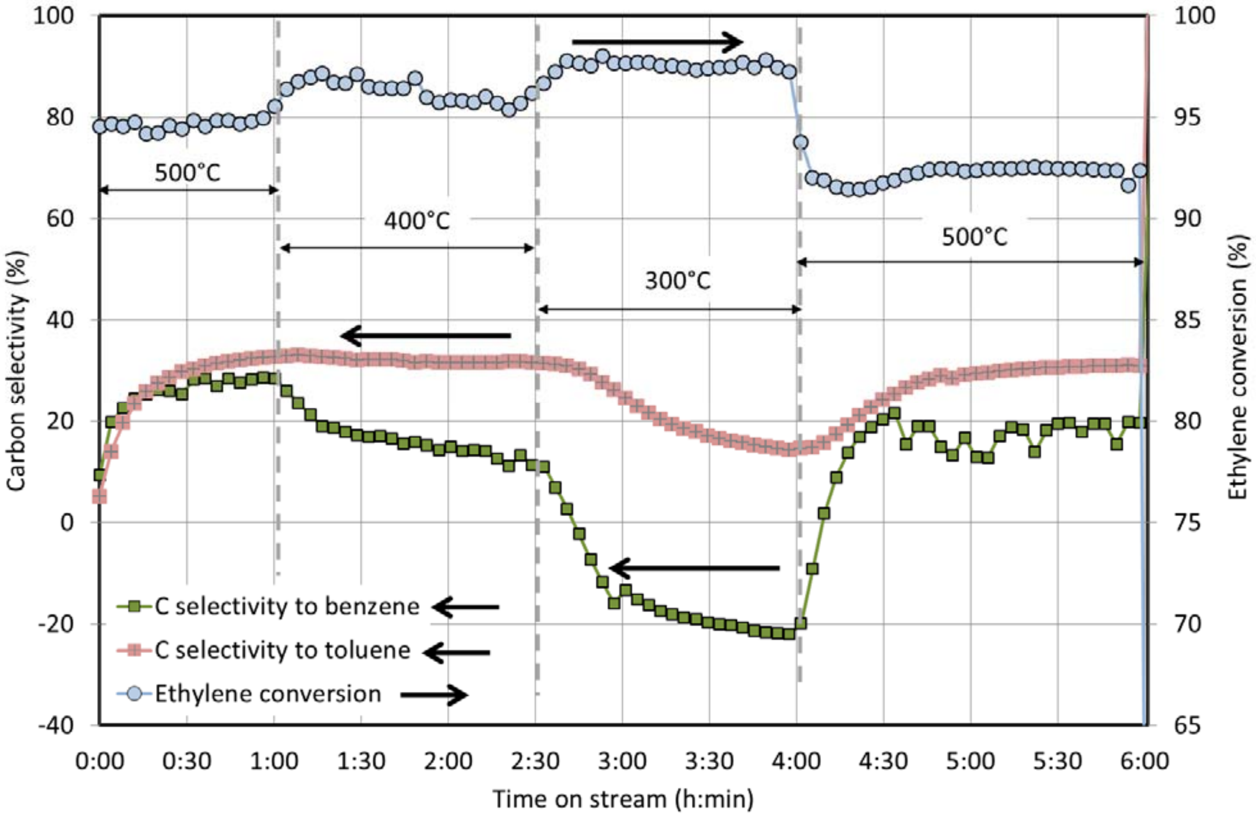


Effect of promoter loading



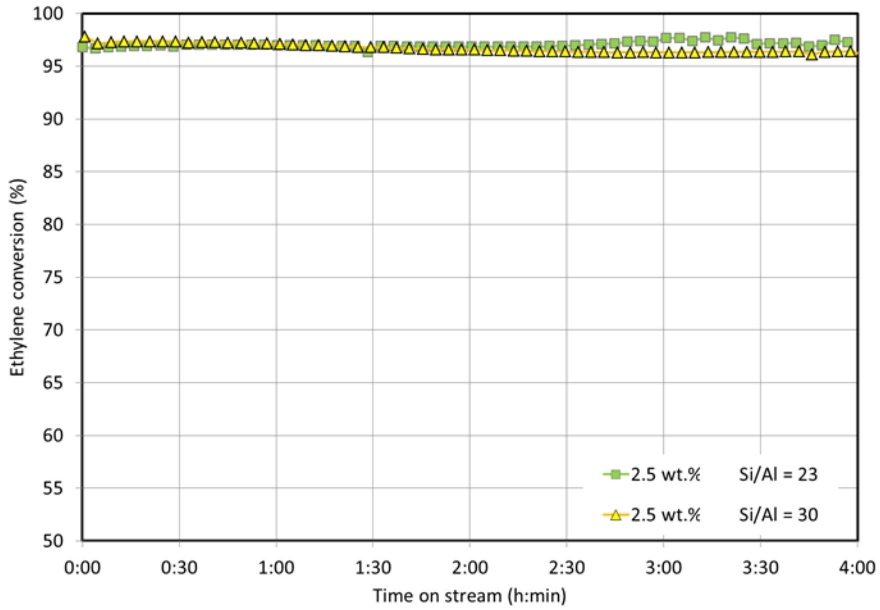


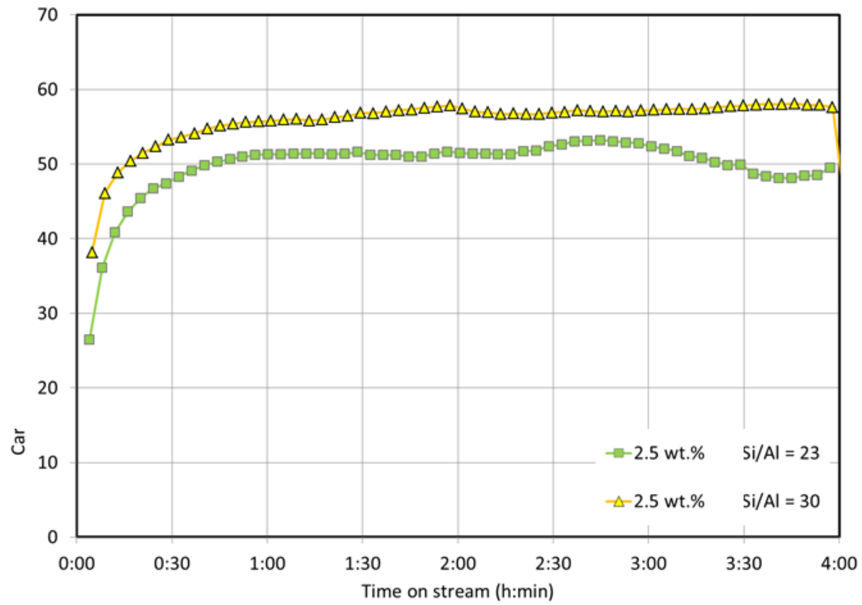
Effect of temperature



2.5 wt.% promoter in zeolite.

Effect of zeolite acidity





MORE INFORMATION

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