PROGRESS ON PULVERIZED BIOMASS GASIFICATION IN A 25 KW ENTRAINED FLOW REACTOR

Roger Khalil, Morten Seljeskog, Jørn Bakken

Content

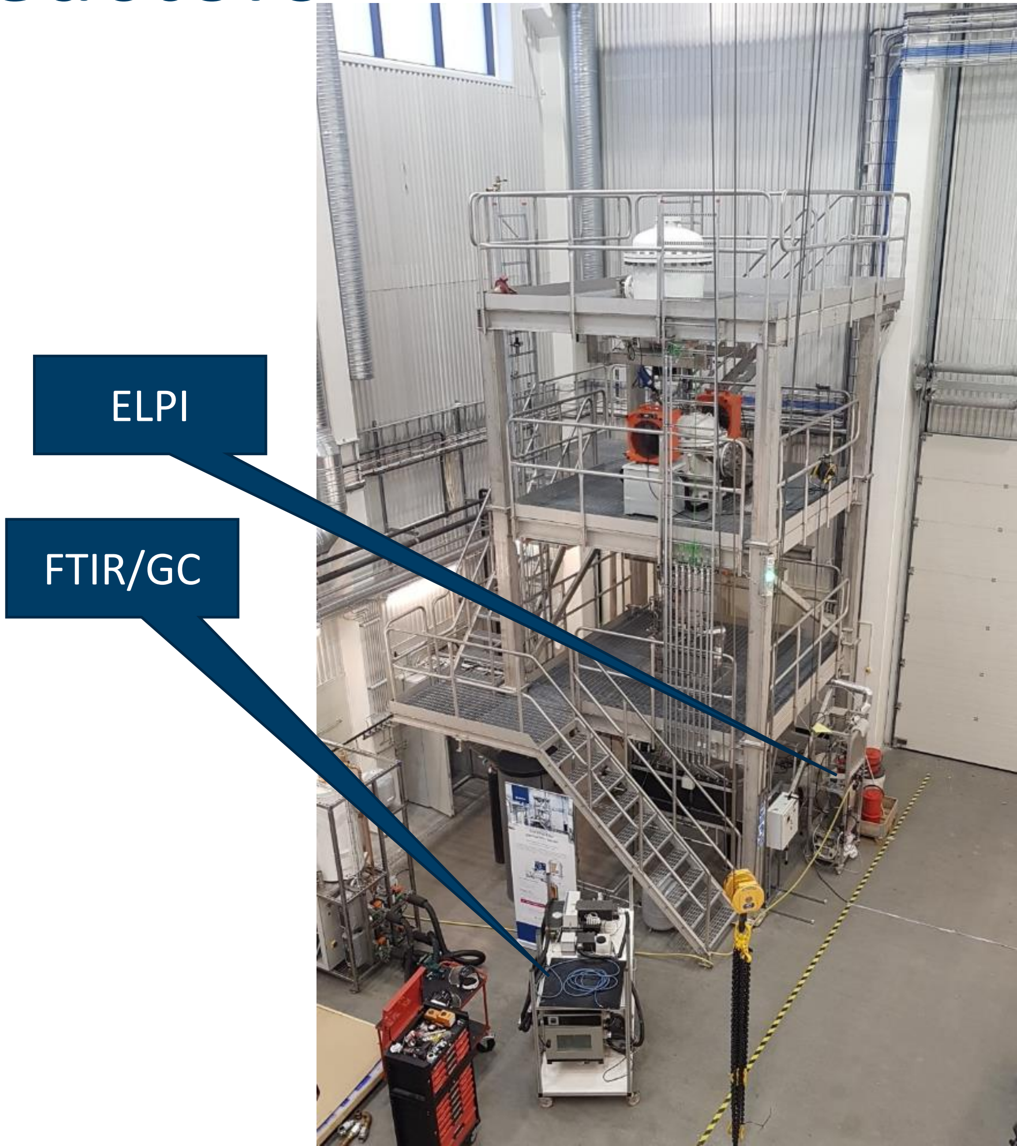
- Introduction
- Challenges with the SINTEF EF reactor
- Results
- Conclusions
- Future work

Introduction-Why Entrained flow gasification?

- Allows for the conversion of biomass and other low-value feedstocks to an energy carrier
  - Syngas, Hydrogen, Biofuels (through FT)
- Contribute to the mitigation of green house gas emissions in a different energy sectors (Heating, Electricity generation, transport fuels)
  - Can be a short-term solution for GHG mitigation in aviation sector
- Allows large scale production of energy carriers, which is a must for energy intensive sectors such as aviation transport

Challenges with the SINTEF reactors

- The SINTEF reactor is a lab scale reactor that is designed with full flexibility, allowing the total control of all inputs and outputs
- A complexity that is necessary for the detailed parametric study of the Entrained flow gasification
- However, with large complexity challenges arise



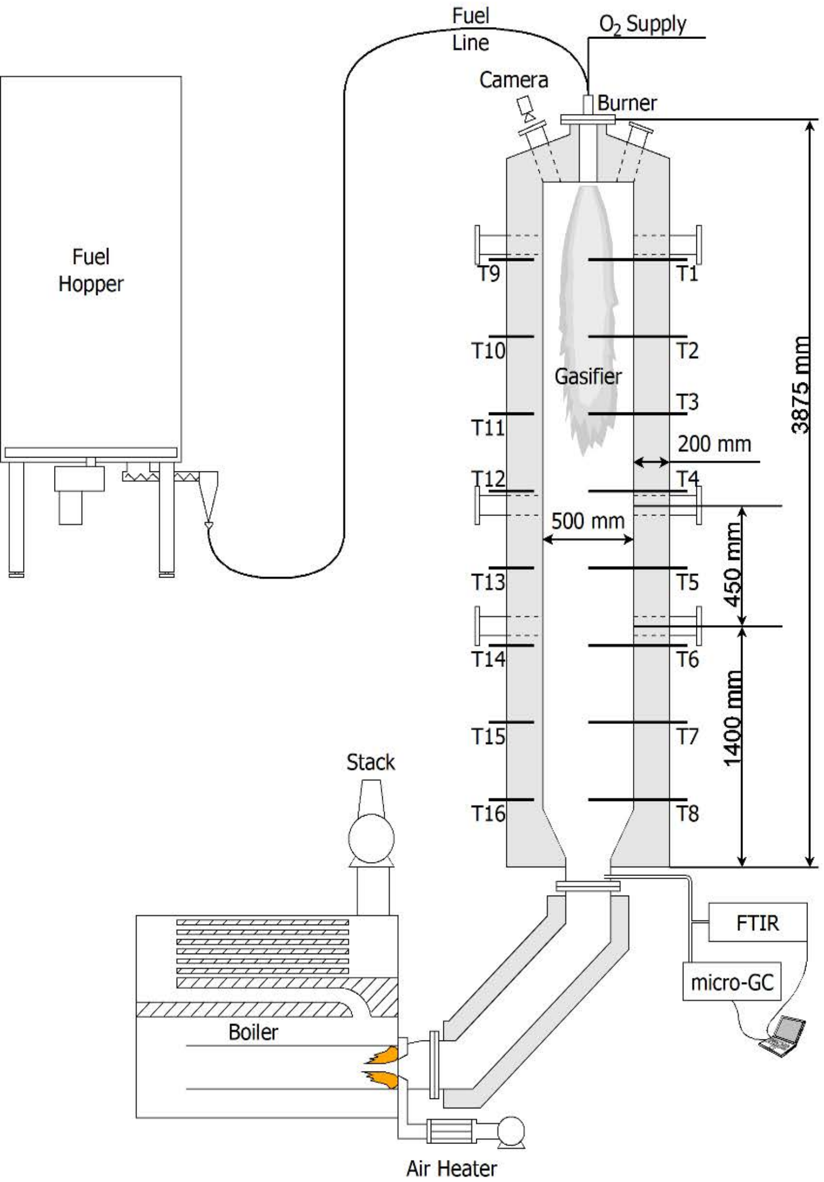
Challenges with the SINTEF reactors?

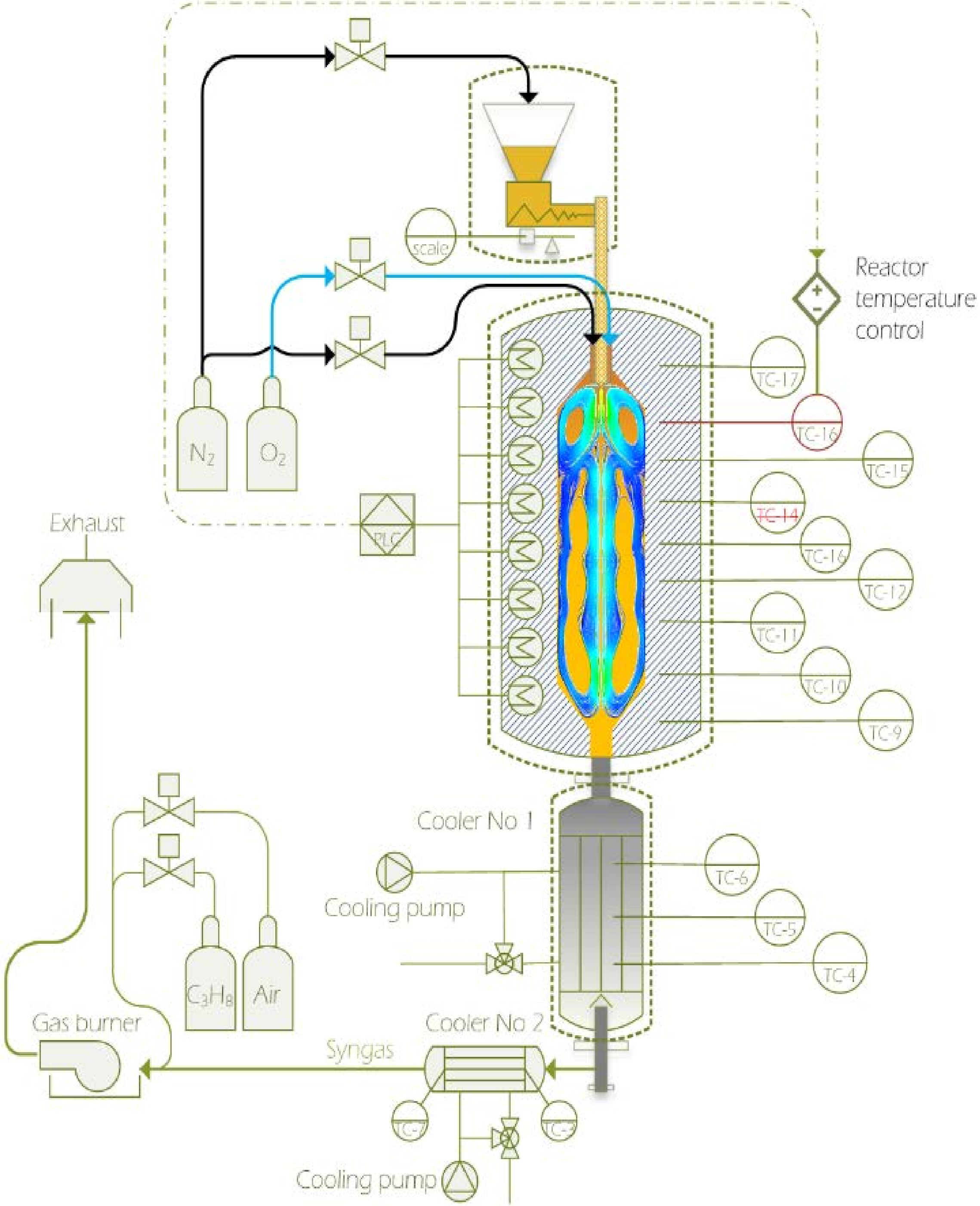
- Sampling system, temperature ELPI
- Cooling water regulator
- Feeding system stability
- Pressure regulation
- Sampling system to gas analysis (dirty syngas)
- Reactor leakage

- Reactor temperature/overheating
- Syngas burner
- Blockage of syngas pipe prior to burner
- Feeder error due to faulty installation
- Buggs in the logging system
- Hot syngas sampling and sampling under pressurized conditions

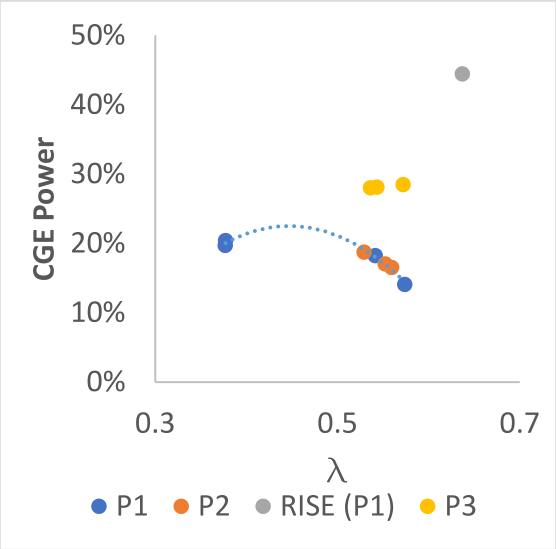
Satisfactory CC (CGE)

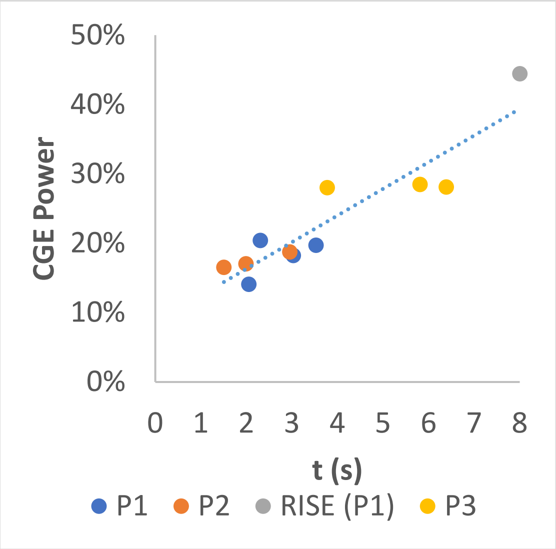
The gasifiers





Results



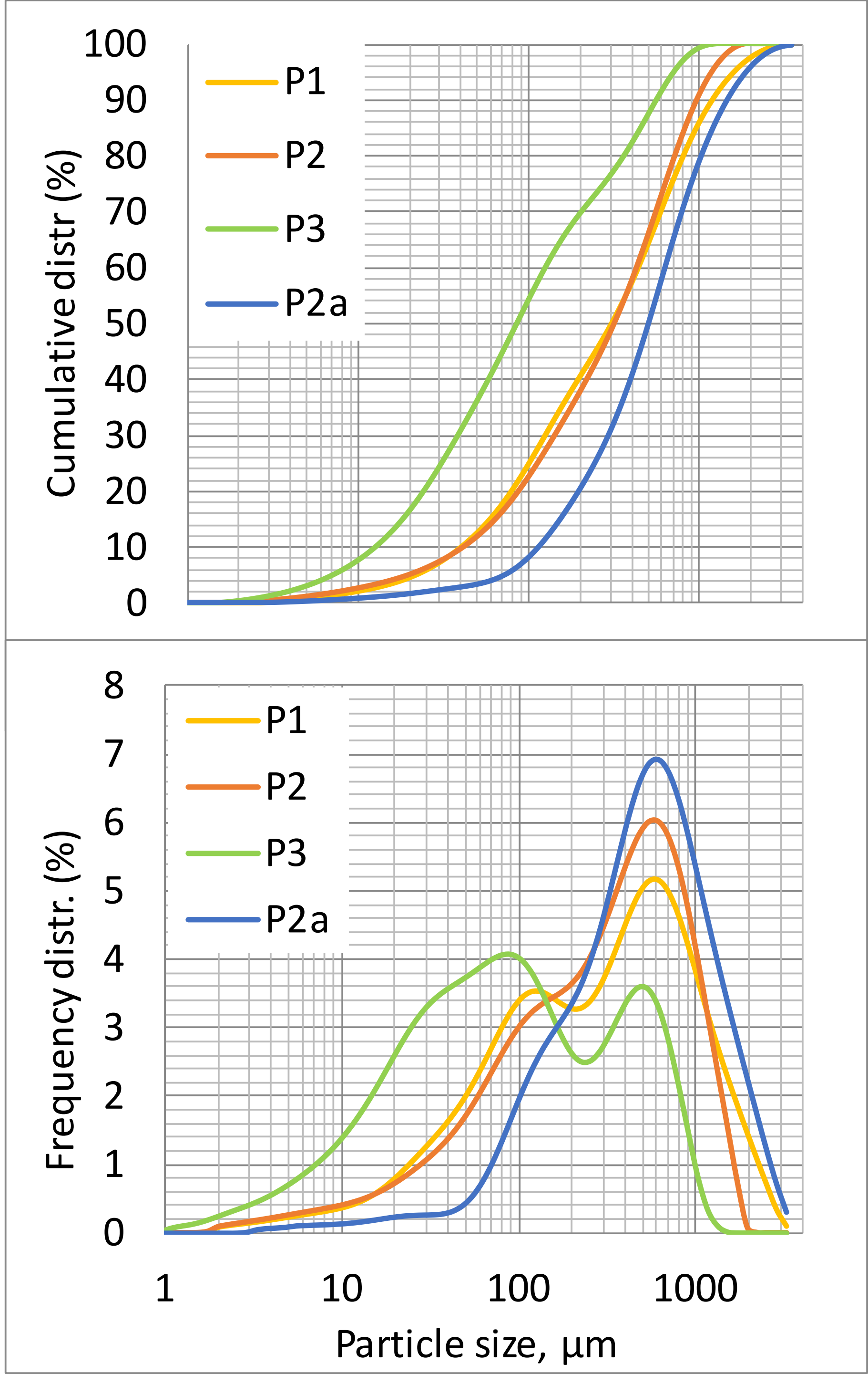


- Have run a number of experiments where results have been compared to a reference experiment performed at the "RISE" gasifier, a 250 kW thermal input setup (the grey dot in the figure)
- As can be seen the conditions are still not optimal
- However, we have been working systematically in order to improve the gasifier cold gas efficiency (CGE)
- Parameters that have been varied:
  - Lambda, particle size (P1> P2> P3), residence time (has been varied through changes in thermal input and changes in reactor pressure (yellow dots)

SINTEF

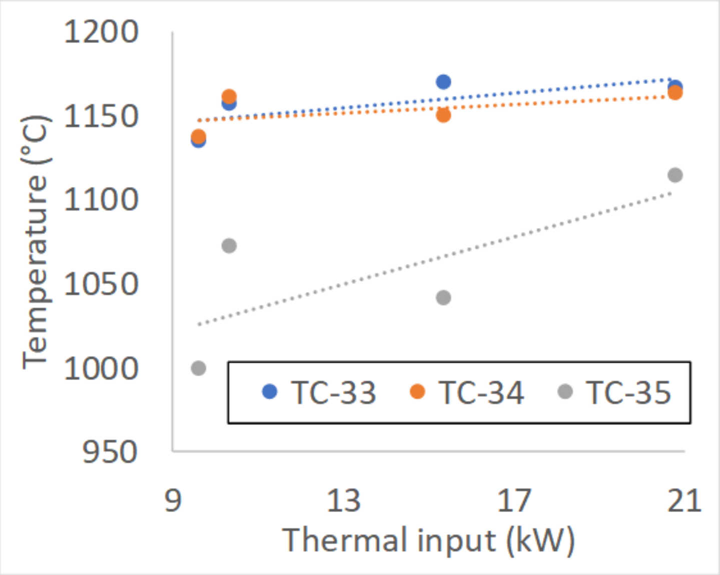
PSD of fuels tested

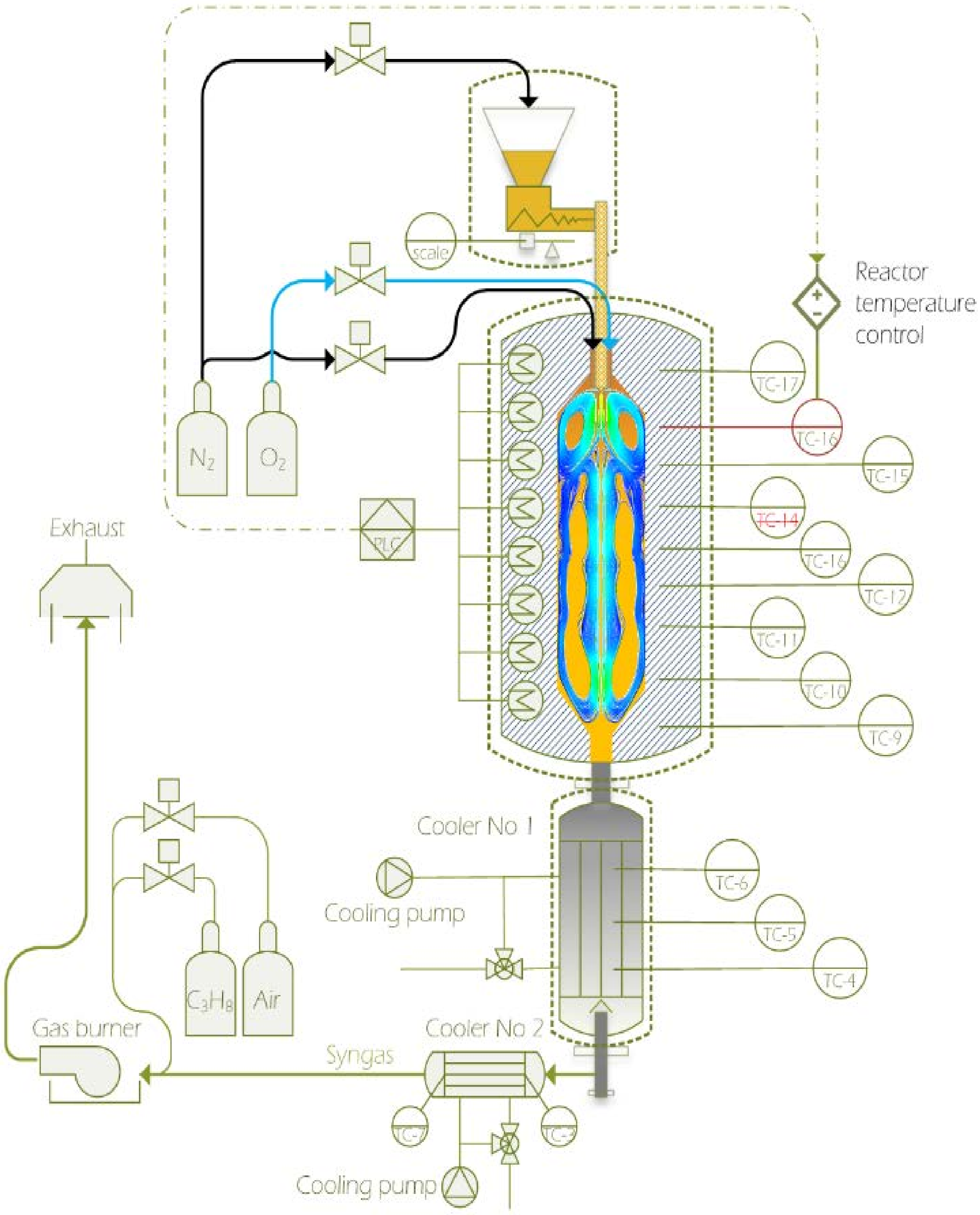
- P1 was prepared by grinding pellets in a hammermill with a 0.75 mm sieve installed
- P2 is P1 sieved with a mesh size 0.63 mm
- P3 is P1 grinded once more in an attritor type mill
    - The mill was operated in a batch mode at 460 rpm for 10 minutes. The mill container was filled with 3 liters of P1 particles in addition to 20 kg of 6 mm balls of steel



Temperature, gas phase

kW	TC9	TC10	TC11	TC12	TC13	TC15	TC17	TC33	TC34	TC35
9.6	87	88	73	1008	964	1189	1098	1135	1137	999
10.3	44	57	57	1004	958	1187	1107	1156	1161	1072
15.4	46	58	59	1005	960	1194	1105	1170	1149	1041
20.8	80	85	72	1009	964	1192	1106	1166	1163	1114



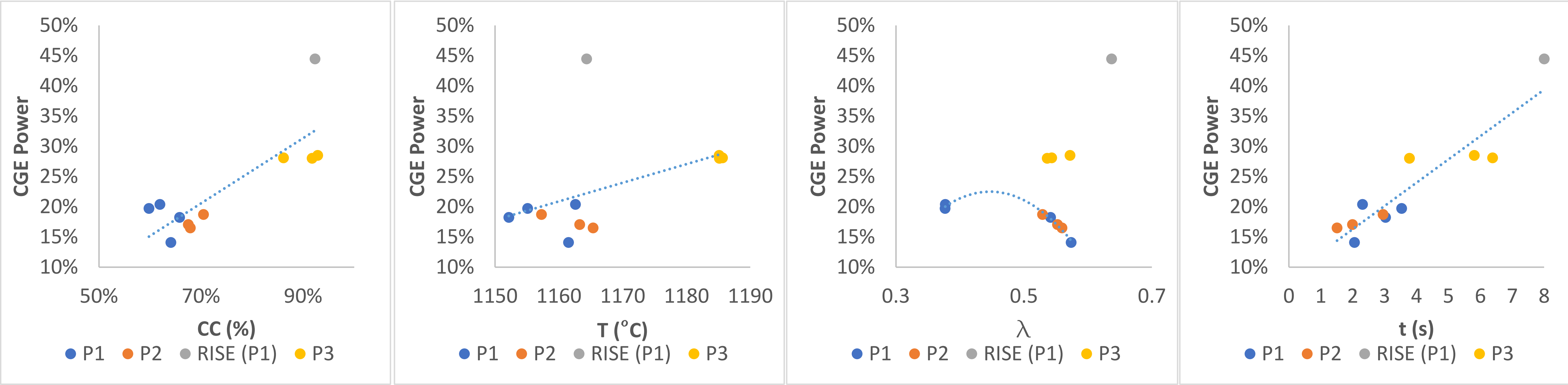


Top (TC35), Middle (TC34) and Bottom (TC33)

Conditions of performed experiments

Exp. #	PSD	Input (kW)	I	Burner velocity (m/s) (oxidant)	Burner velocity (m/s) (fuel)	Reactor T (°C)	Residence time (s)
1	P1	12.7	0.38	8.1	2.3	1155	2.7
2	P1	19.0	0.38	15.6	2.3	1163	1.8
3	P1	10.7	0.54	12.2	2.3	1152	2.3
4	P1	15.5	0.57	21.8	2.3	1162	1.6
5	P2	11.0	0.53	12.2	2.3	1157	2.2
6	P2	16.1	0.55	21.9	2.3	1163	1.5
7	P2	21.3	0.56	31.2	2.3	1165	1.1
8	P3	16.2	0.54	21.7	2.3	1185	2.9
9	P3	10.1	0.57	12.2	2.3	1185	4.4
10	P3	10.7	0.54	12.2	2.3	1186	4.9
VAFF	P1	108.8	0.64	37.6	1.8	1164	8.0

Results-CGE



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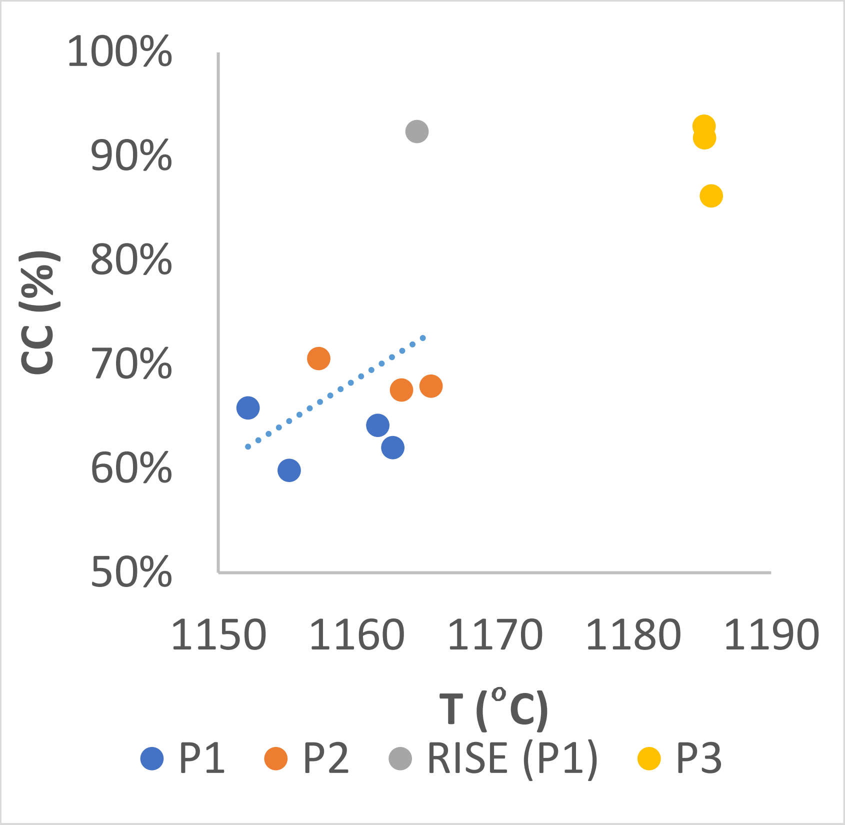
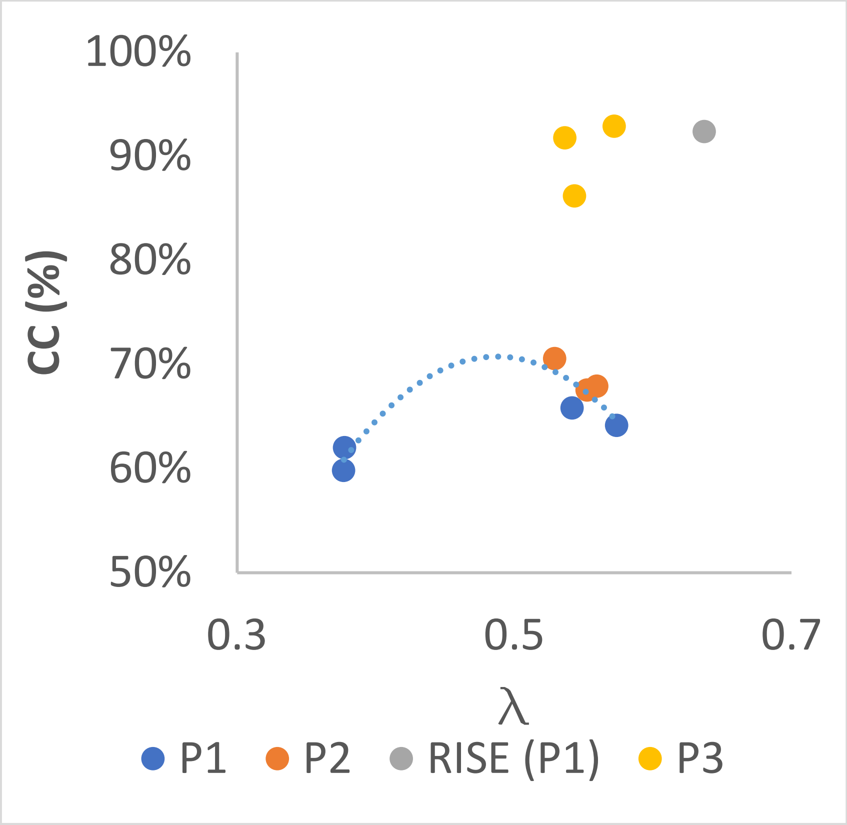
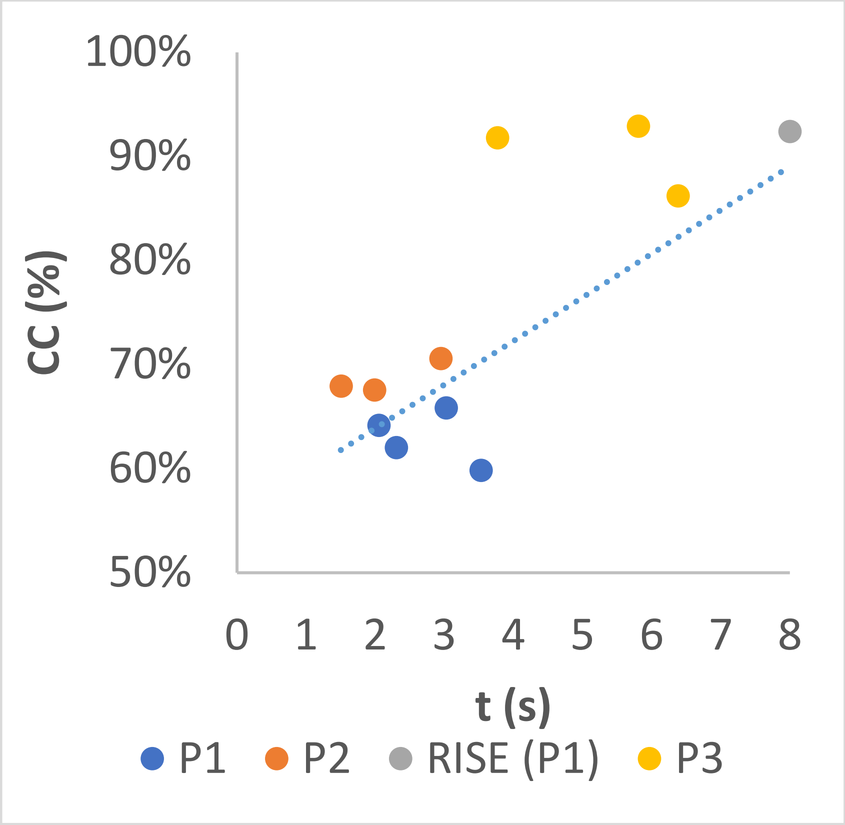
Results-CC



100%
90%
80%
70%
60%
50%
CC (%)
1150
1160
1170
1180
1190
T (°C)
P1
P2
RISE (P1)
P3

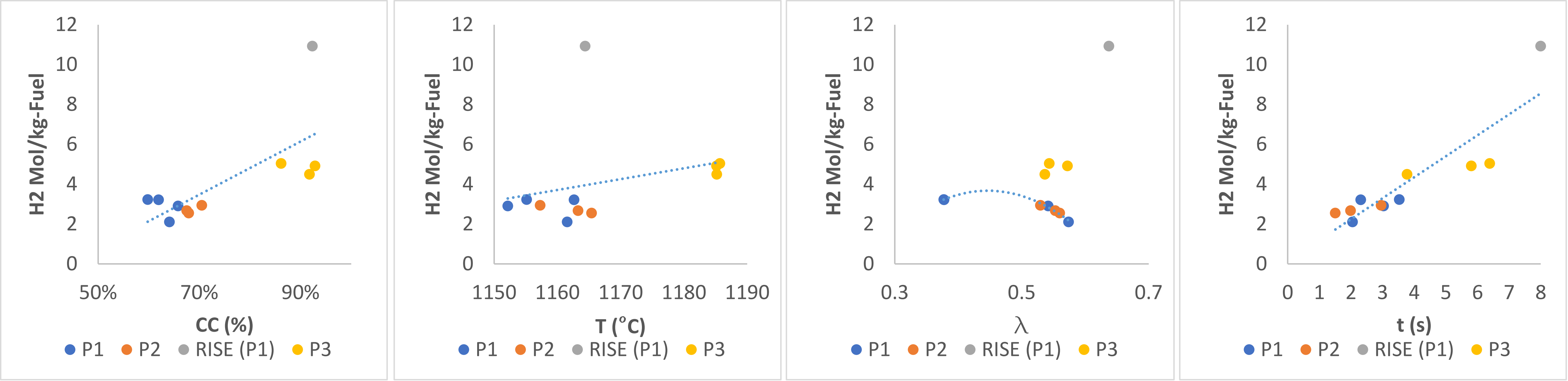


100%
90%
80%
70%
60%
50%
CC (%)
0.3
0.5
0.7
λ
P1
P2
RISE (P1)
P3

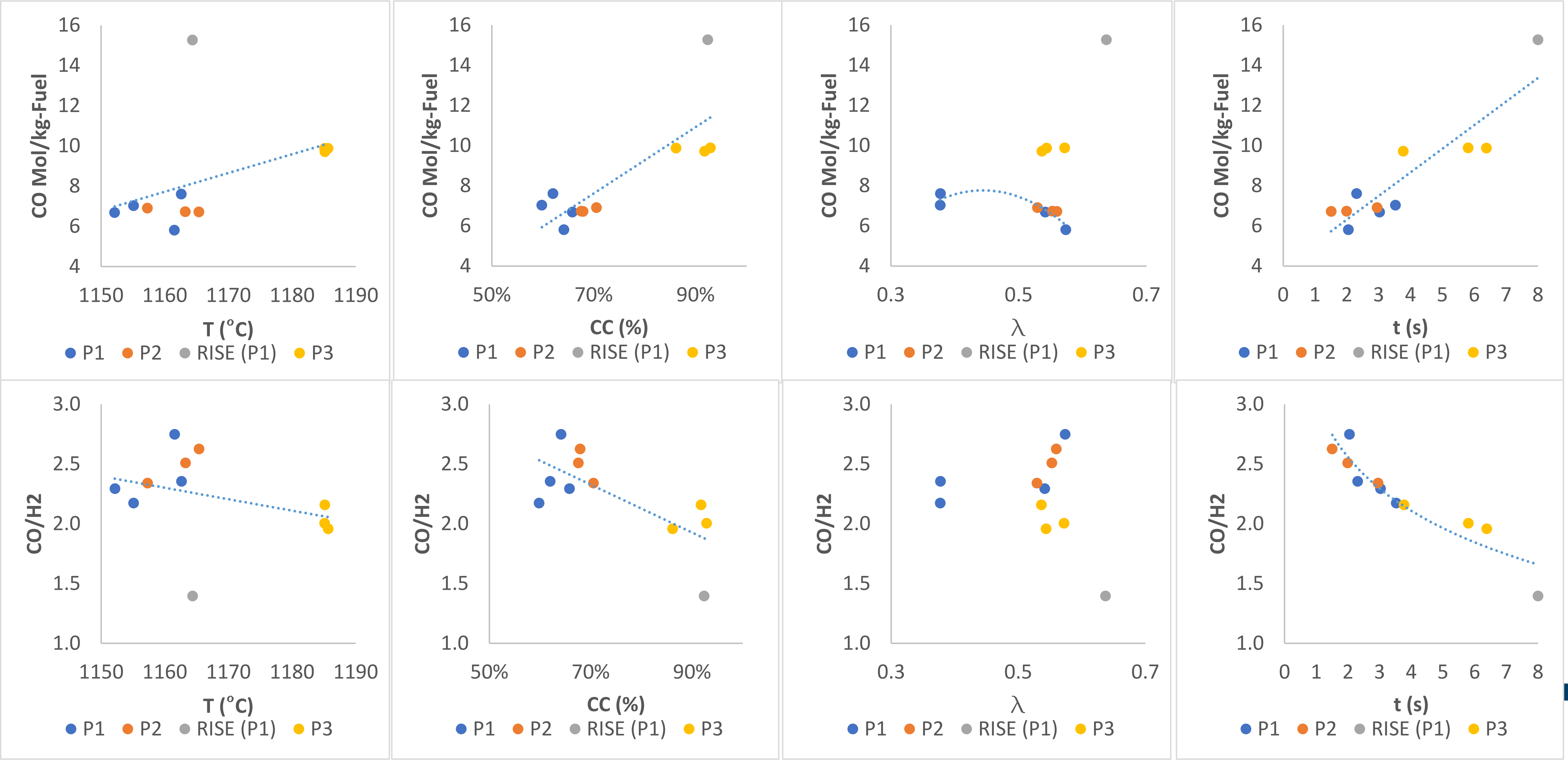


100%
90%
80%
70%
60%
50%
CC (%)
0
1
2
3
4
5
6
7
8
t (s)
P1
P2
RISE (P1)
P3

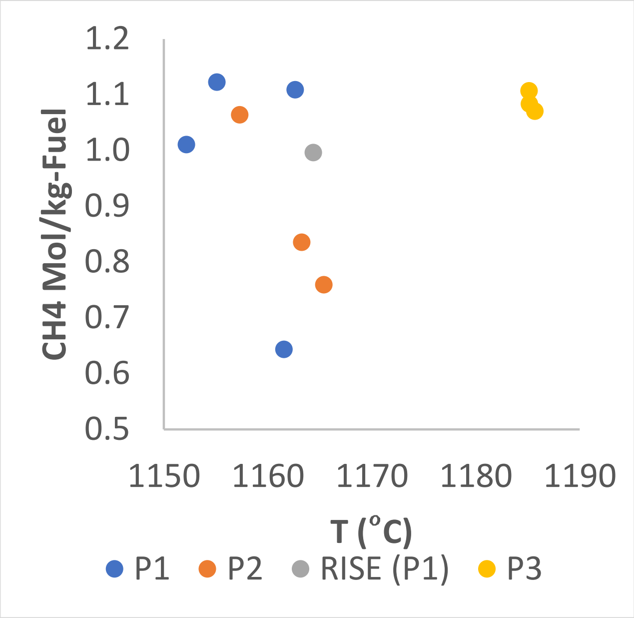
Results-H2

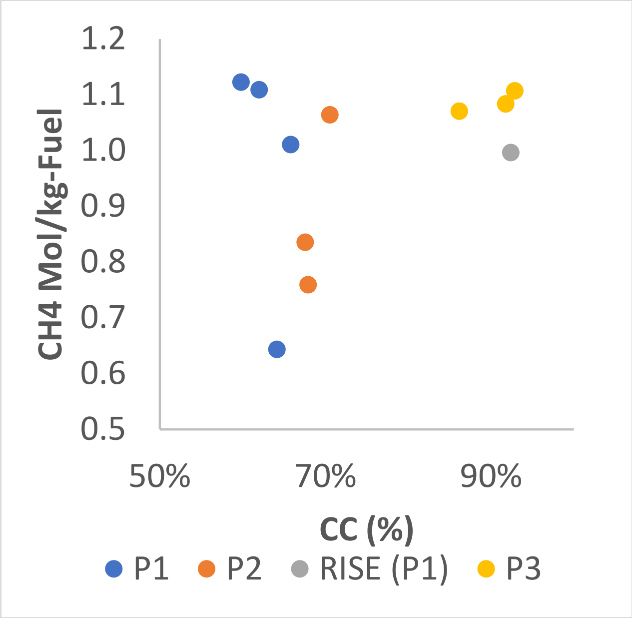

H2 Mol/kg-Fuel
12
10
8
6
4
2
0
50%
70%
90%
CC (%)
P1
P2
RISE (P1)
P3
H2 Mol/kg-Fuel
12
10
8
6
4
2
0
1150
1160
1170
1180
1190
T (°C)
P1
P2
RISE (P1)
P3
H2 Mol/kg-Fuel
12
10
8
6
4
2
0
0.3
0.5
0.7
λ
P1
P2
RISE (P1)
P3
H2 Mol/kg-Fuel
12
10
8
6
4
2
0
0
1
2
3
4
5
6
7
8
t (s)
P1
P2
RISE (P1)
P3

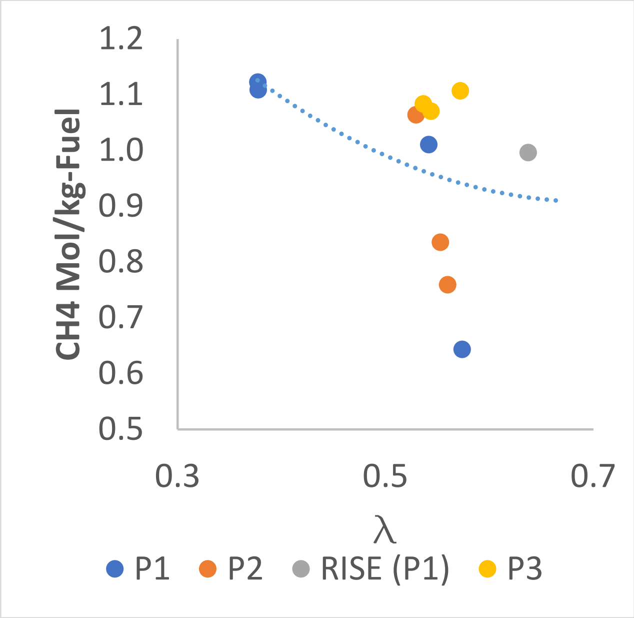
Results-CO & CO/H2 ratio

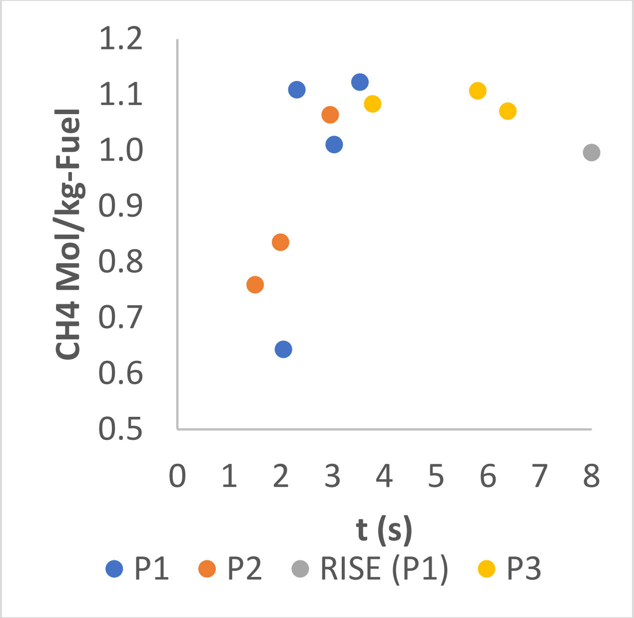


Results-CH4









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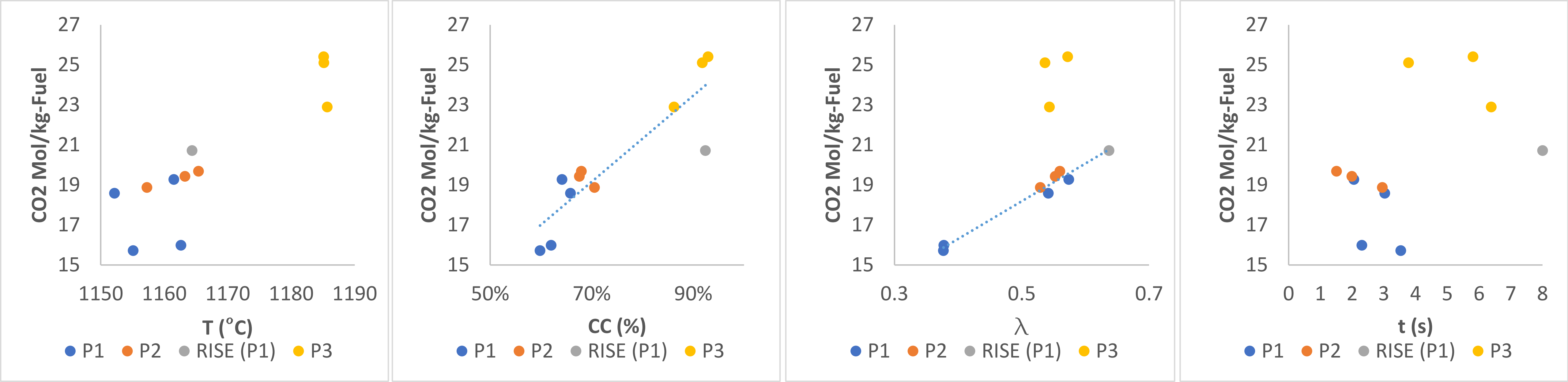
Results-CO2



CO2 Mol/kg-Fuel
27
25
23
21
19
17
15
1150
1160
1170
1180
1190
T (°C)
50%
70%
90%
CC (%)
0.3
0.5
0.7
λ
0
1
2
3
4
5
6
7
8
t (s)
P1
P2
RISE (P1)
P3

Sampling at high pressure

- Continuous gas sampling for both FTIR and GC
- Sampling just at the exit of the gasifier
- Hot gas cleaning
- Temperature regulation (ideally at 180 C)
- Safety?
- More information can be obtained
  - Can perform a hydrogen balance
  - Can measure minor species (nitrogen species such as HCN & NH_3)

Conclusions

- Have looked at the EF gasification of pulverized biomass in 2 different reactors (different scales)
- Studied parameters:
  - Particle size
  - Lambda
- Carbon conversion/Cold gas efficiency still not satisfactory

- To improve CC/CGE, future experiments will investigate:
  - Residence time through increased pressure
  - Burner geometry for increase velocity/turbulence at the entrance of the burner
  - Steam gasification

Teknologi for et bedre samfunn