Gasification Research at OSU

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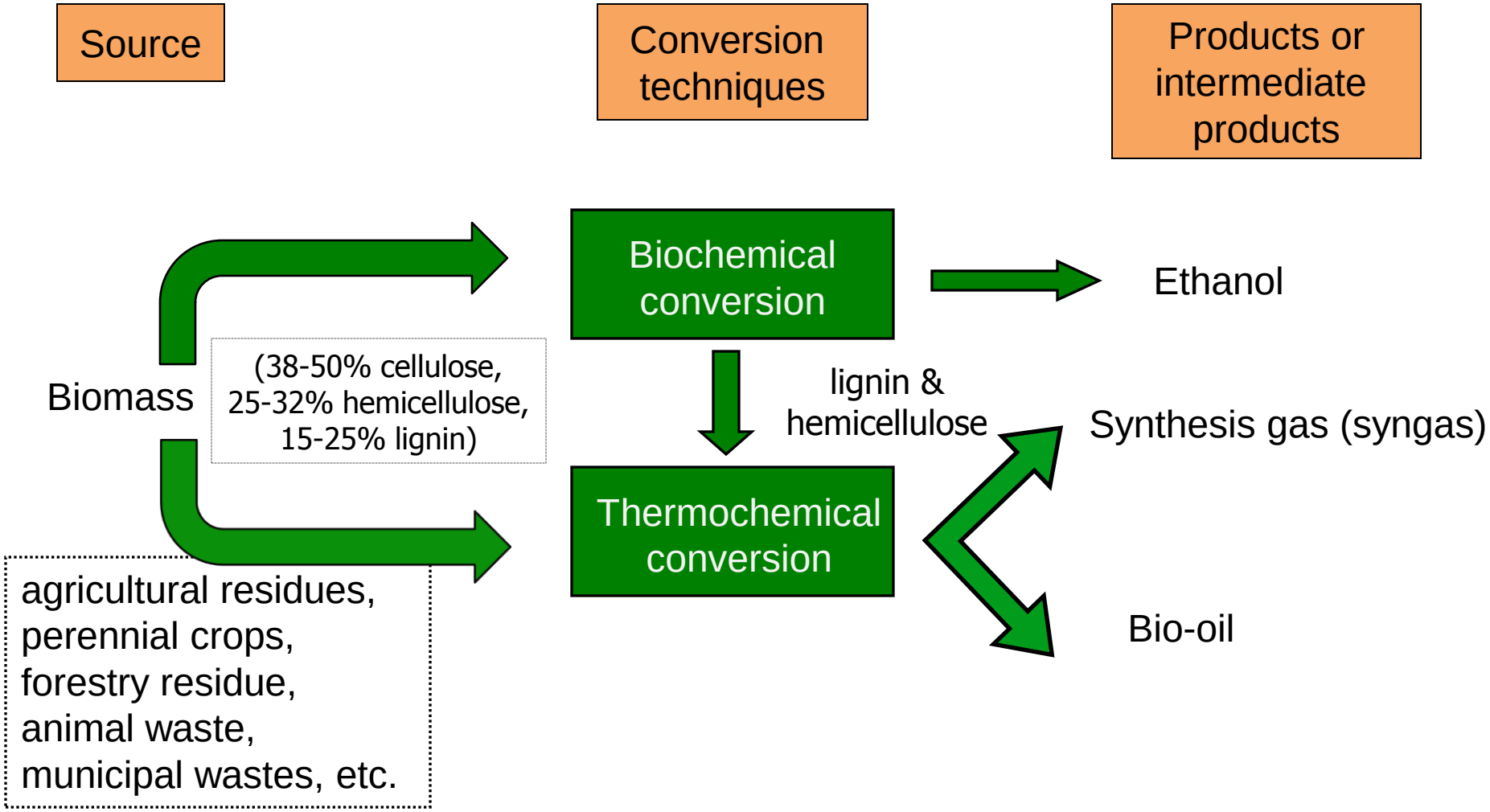
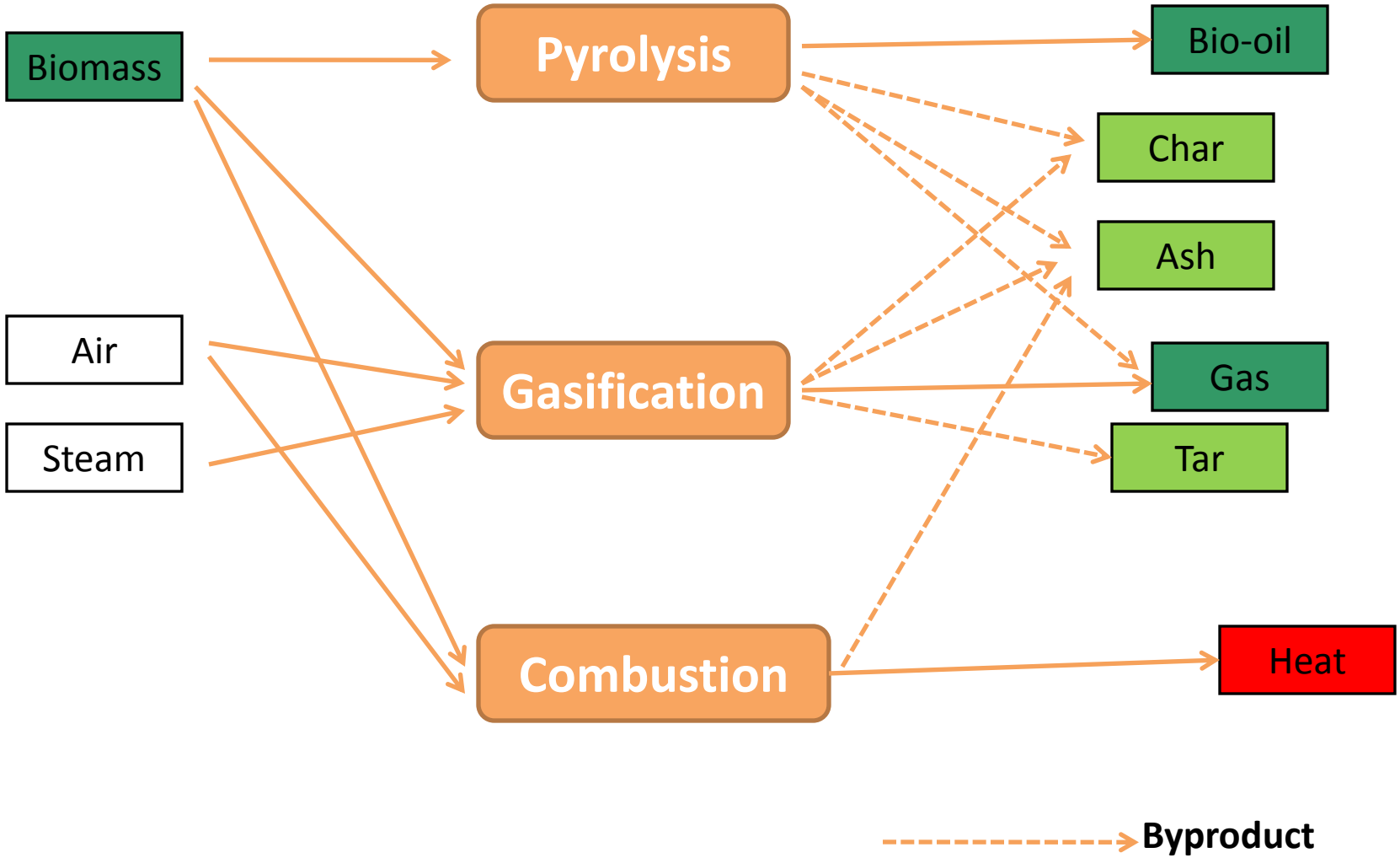
Energy conversion pathways



Thermochemical Conversions



Gasification process

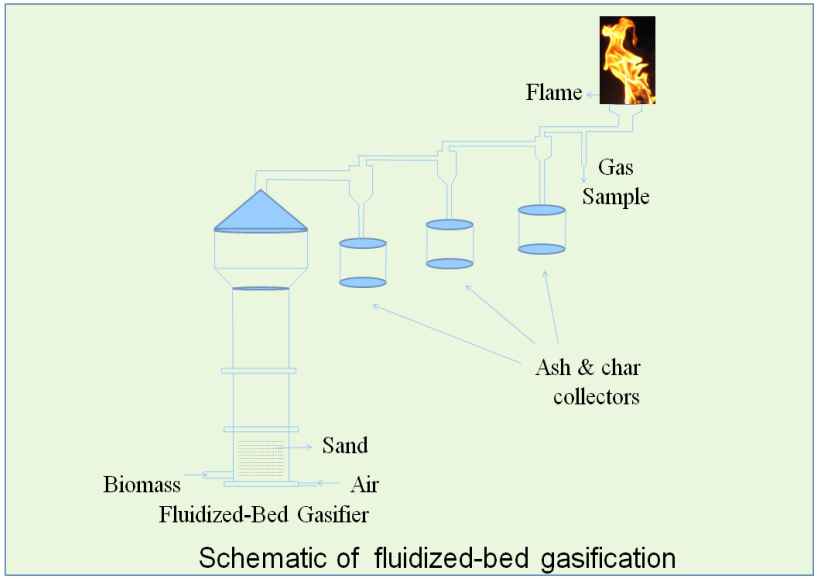
Sorghum

Switchgrass

Biomass

Air

Steam



Gas

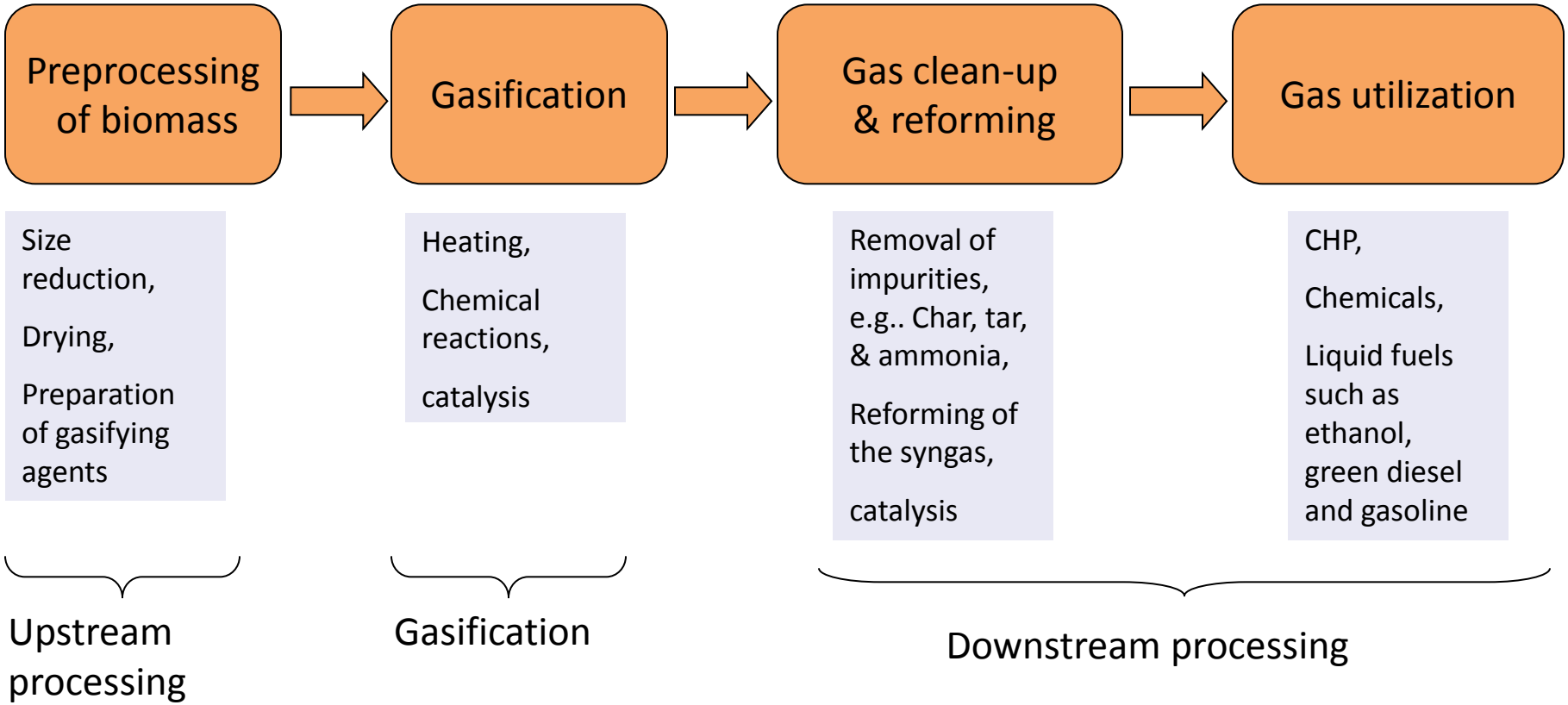
Tar

Char

Ash

- Required: high temperature & oxidizing agent
- biomass + air + H_2O ⇨ C (char)+ CH_4+ CO + H_2 + + CO_2 + N_2 + H_2O (unreacted steam) + ash + tar

Gasification – operations Involved



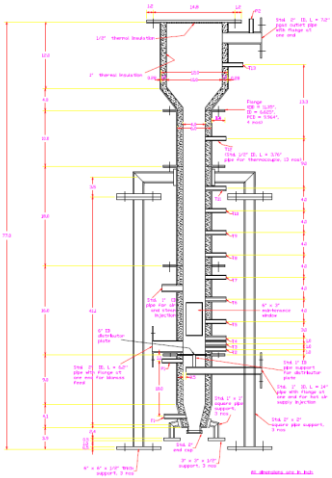
Gasification process - factors

Gasification

Heating,

Chemical reactions,

catalysis



Biomass properties

- Particle size
- Bulk density
- Proximate analysis
- Elemental analysis
- Energy content
- Cellulose, hemicelluloses & Lignin contents

Product properties

- Syngas composition
- Syngas energy
- Carbon conversion efficiency
- Energy conversion efficiency
- Overall energy efficiency
- Amount of tar
- Amount of char

Operating conditions

- Biomass flow rate
- Temperature profile
- Flow rates of oxidizing agents (equivalence ratio (ER), steam to biomass ratio, (SBR))
- Amount and type of catalyst

Gasification: technical challenges

- Experimental challenge
  - Understand and predict the effects of gasification conditions and biomass properties
  - Reduce level of tar and impurities in the producer gas
    - Optimize gasification operating conditions & gasifier design
    - Improve cold gas cleaning technique
    - Improve hot gas cleaning technique
  - Increase percentage compositions of CO and H_2
  - Increase net process energy efficiency
  - Obtain data for developing gasification reaction kinetics for a wide variety of feedstock

- Computational challenge
  - Develop gasification reaction kinetics
  - Incorporate reaction kinetics to develop gasification model to reliably predict gas composition, flowrate and contaminants

Ongoing Projects

- Study of fluidized-bed biomass gasification at near pilot-scale level.
- Study of downdraft biomass gasification at near pilot-scale level.
- Design and performance evaluation of a new lab-scale fluidized-bed gasifier.
- Evaluation of commercially-available catalysts for cracking tar and improving gas composition with toluene as a “model” tar compound.
- Design and development of catalytic reactor for cracking real tar and improving gas composition.
- Characterization of biomass for thermochemical conversion, and
- Development of reaction kinetics and mathematical model for predicting products of gasification

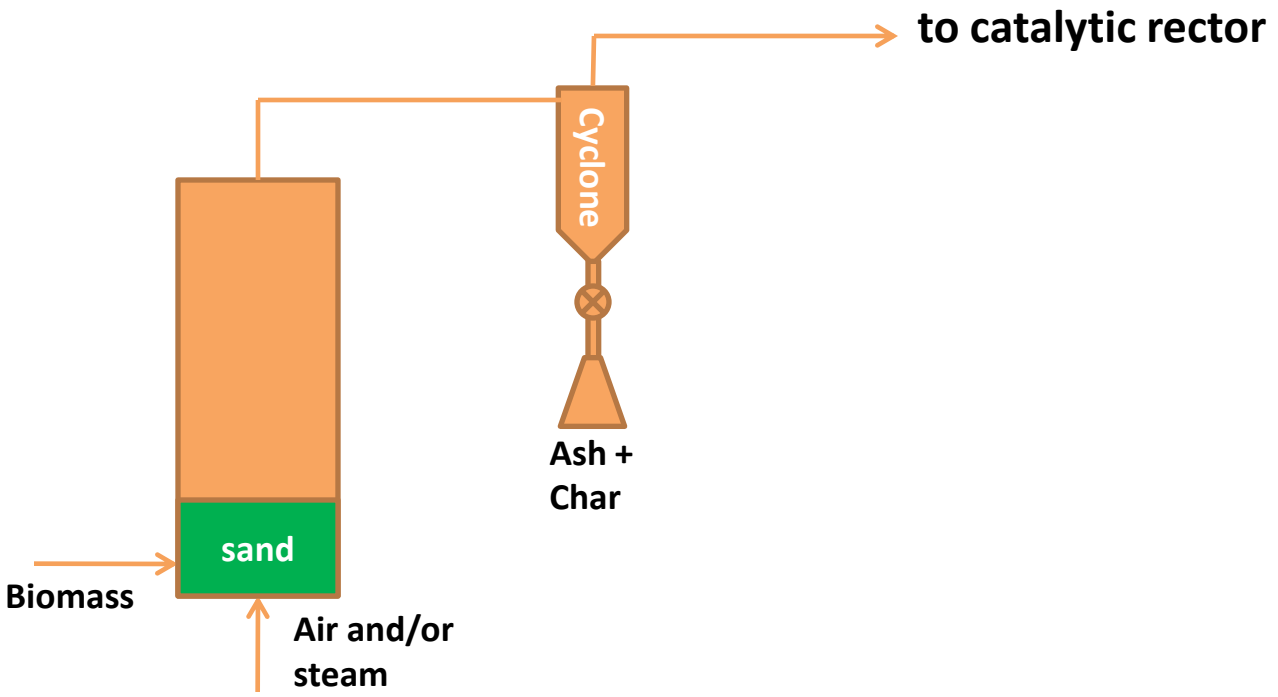
Study of FBG system at near pilot-scale

•Fluidized-bed Gasifier (FBG)

•Gas scrubbing system

•Biomass feedrate – 15-30 kg/h

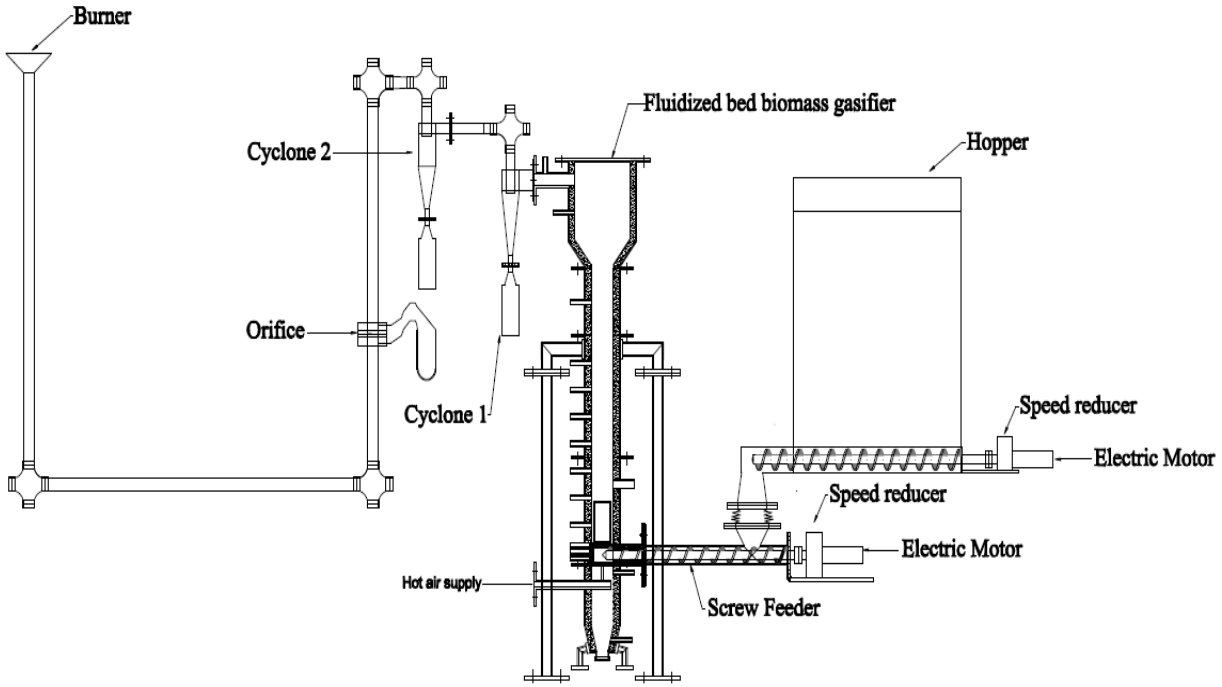
Design and performance evaluation of new lab-scale FBG



Objectives

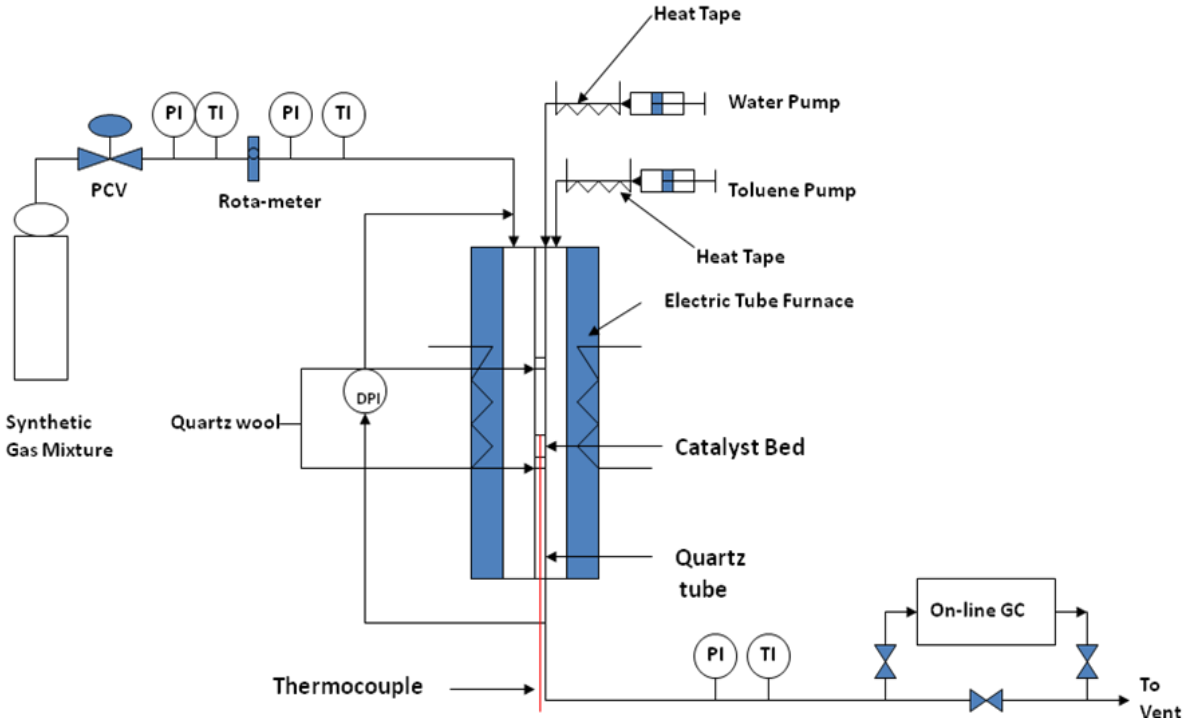
- **Design a new lab-scale FBG with many instrumentation and control**
- **Supply producer gas with tar to tar cracking catalytic reactor**
- **Utilize this FBG reactor serve as a platform for studying catalytic degradation of tar and effects of numerous variables**

New lab-scale fluidized-bed gasifier (FBG)



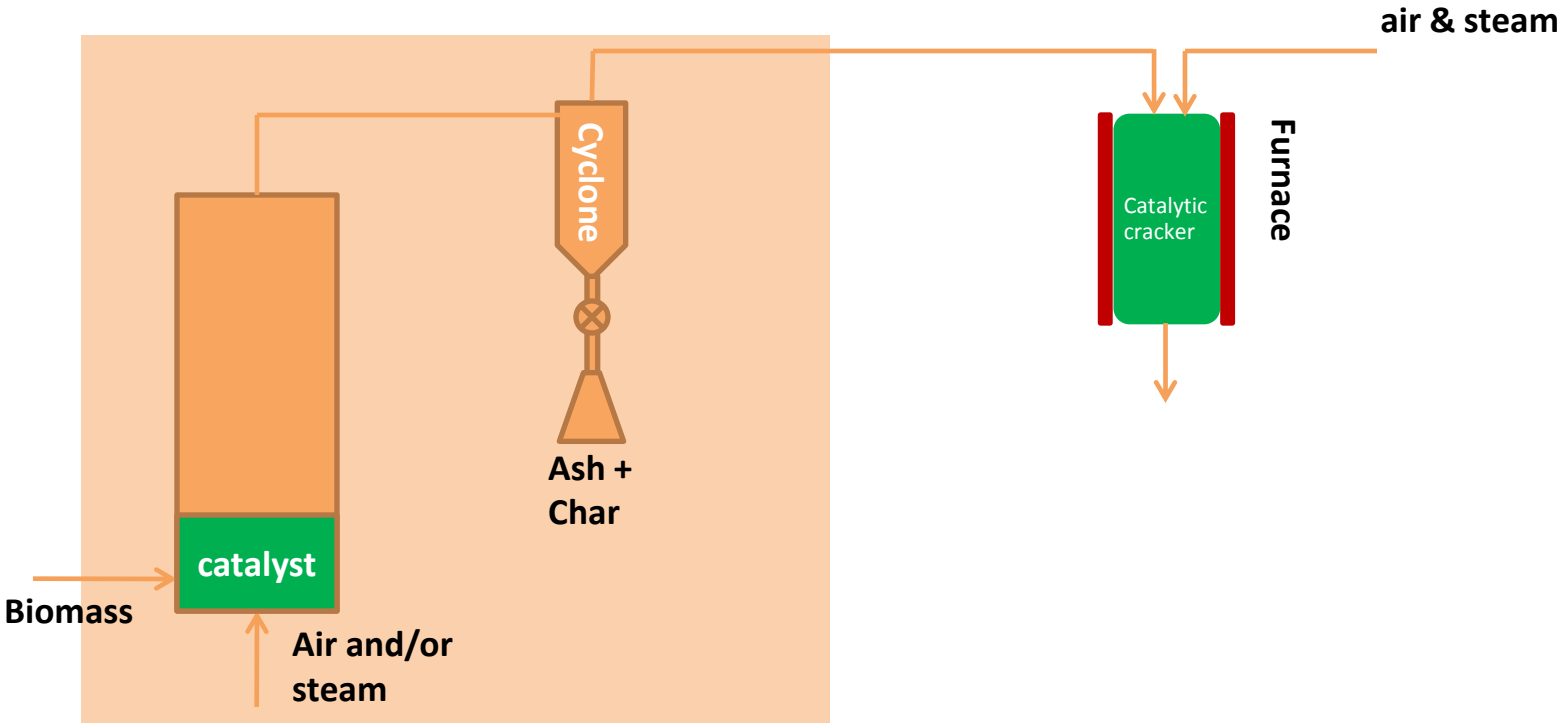
- **Biomass feedrate – 3-5 kg/h**

Evaluation of catalysts with toluene as a "model" tar compound



- **Toluene is used as a model tar compound**
- **Tests are being conducted on selected steam reforming catalysts which are commercially available for cracking tar**

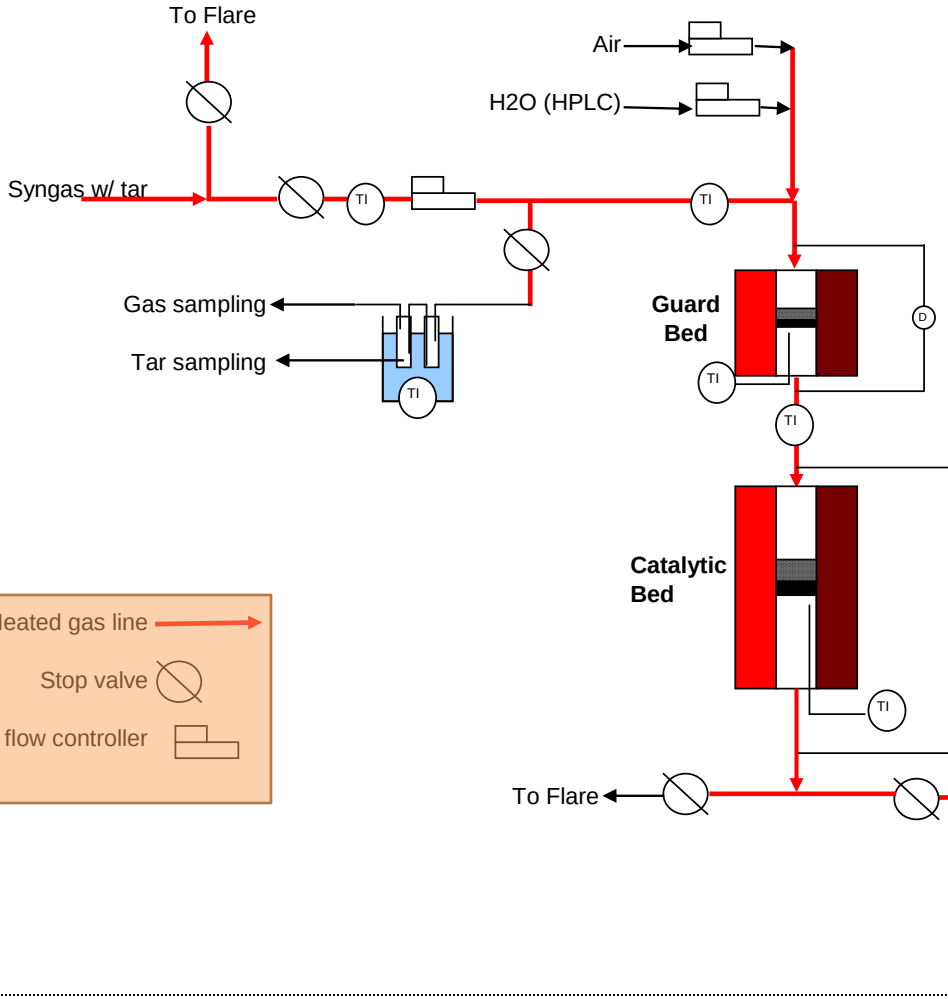
Study of catalysts in a secondary reactor



Objectives

- **Study effects of operating condition of catalytic cracker (air and steam flowrate, temperature, residence time) and selected steam reforming catalysts for cracking tar and improving gas composition from gasifier.**
- **Field-test commercially-available catalysts**

New catalytic Reactor for hot gas cleaning

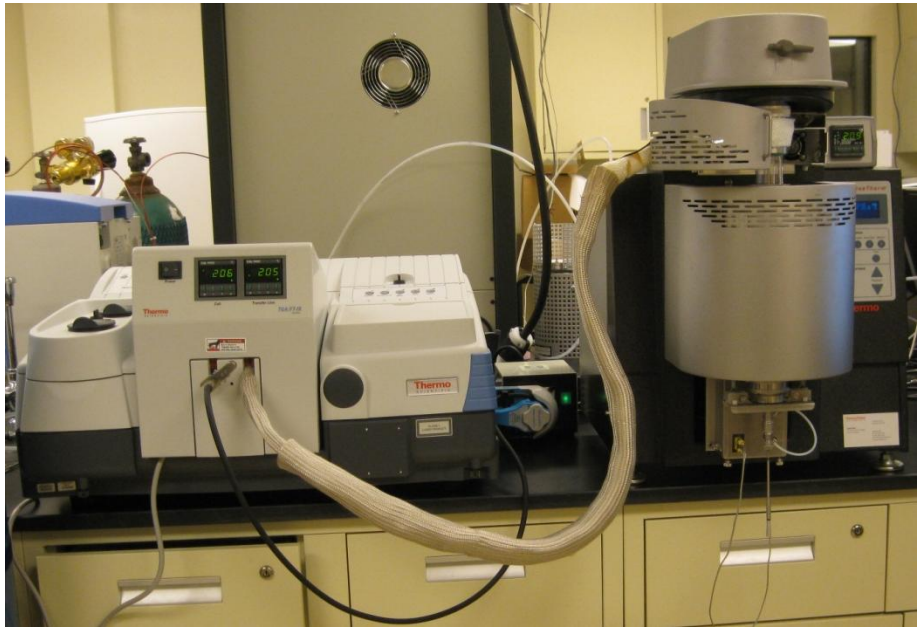


Objectives

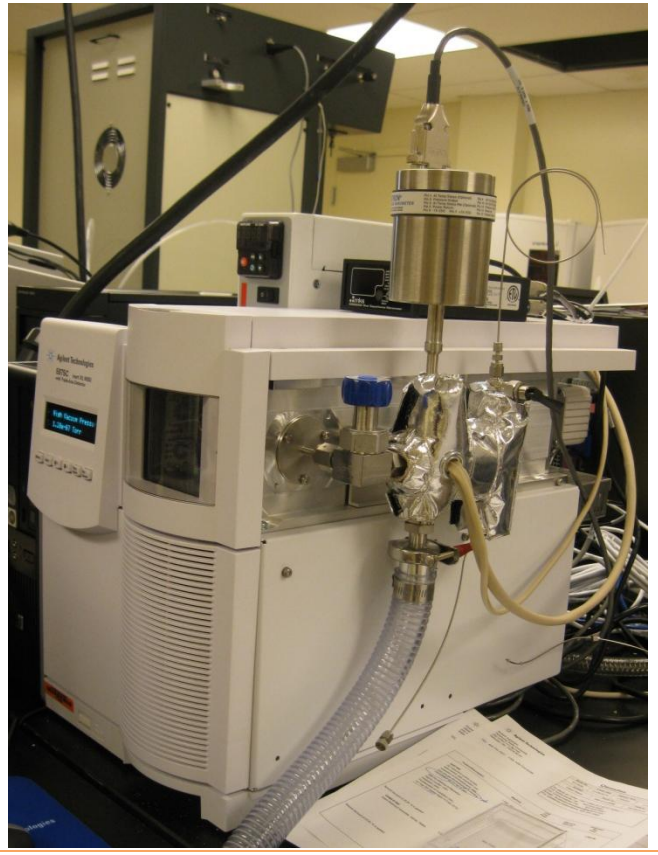
- **Study effects of operating condition of catalytic cracker (air and steam flowrate, temperature, residence time) and various steam reforming catalysts on tar level and gas composition**

Catalysts: commercial Ni-based steam reforming catalysts

Biomass characterization *for* thermochemical conversion

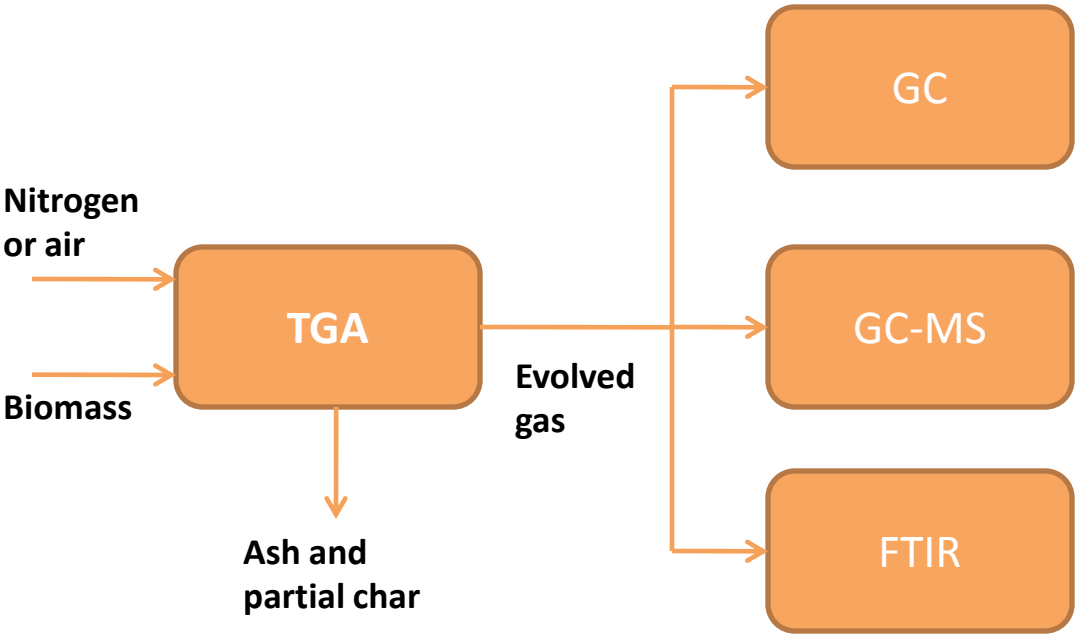


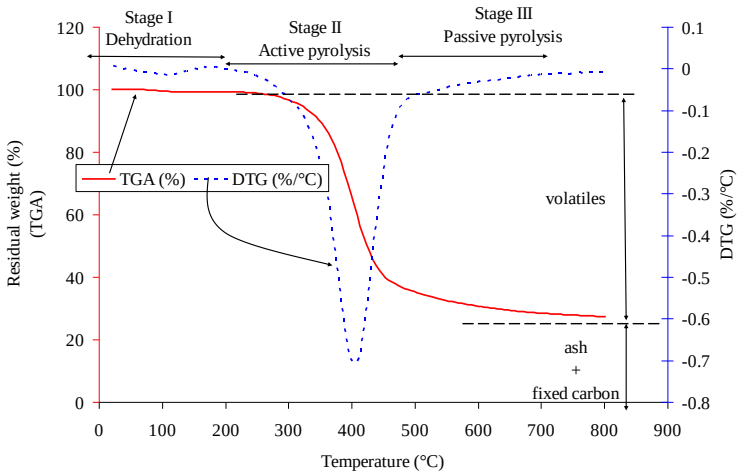
Coupled TGA-FTIR set-up
- Studying reaction kinetics of gasification
- Identifying compounds at various reaction conditions



Mass Spec with precision sampling system
- Online measurement of gas composition

Reaction kinetics of gasification



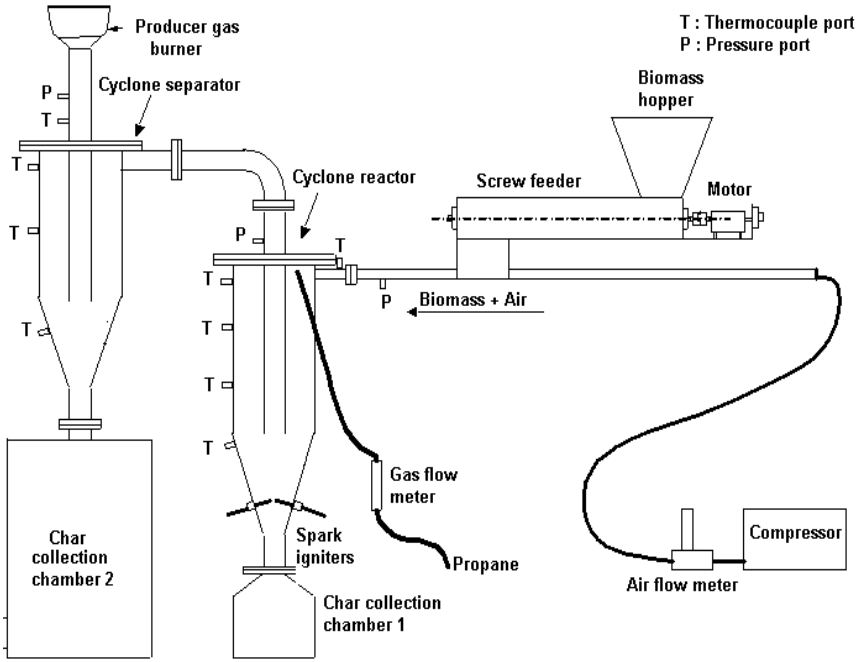


Kumar et al., 2008. Biomass and Bioenergy.

Objectives

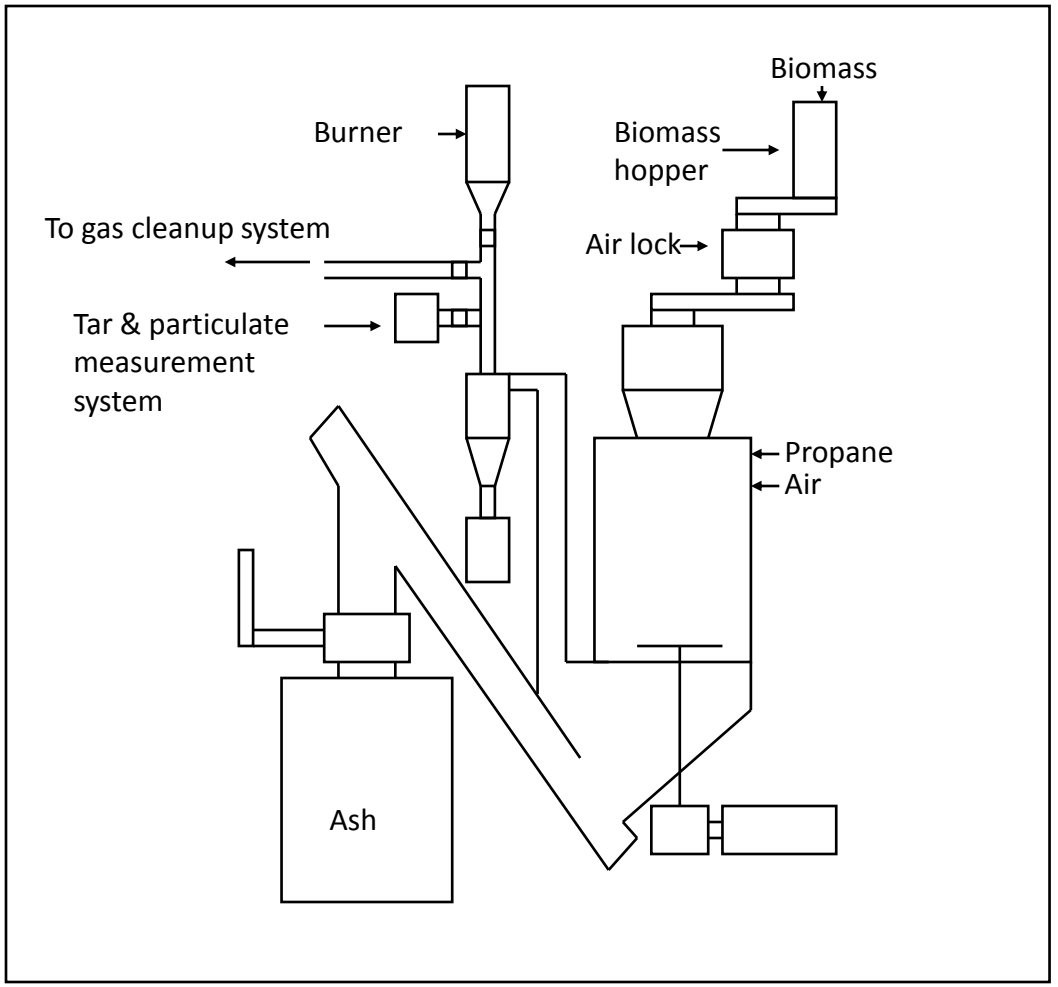
- **Investigate the effects of oxidizing atmosphere, temperature and heating rate on gas and tar composition**
- **Derive volatization kinetics of various feedstocks**
- **Develop gasification model to predict producer gas composition**

Cyclone gasifier



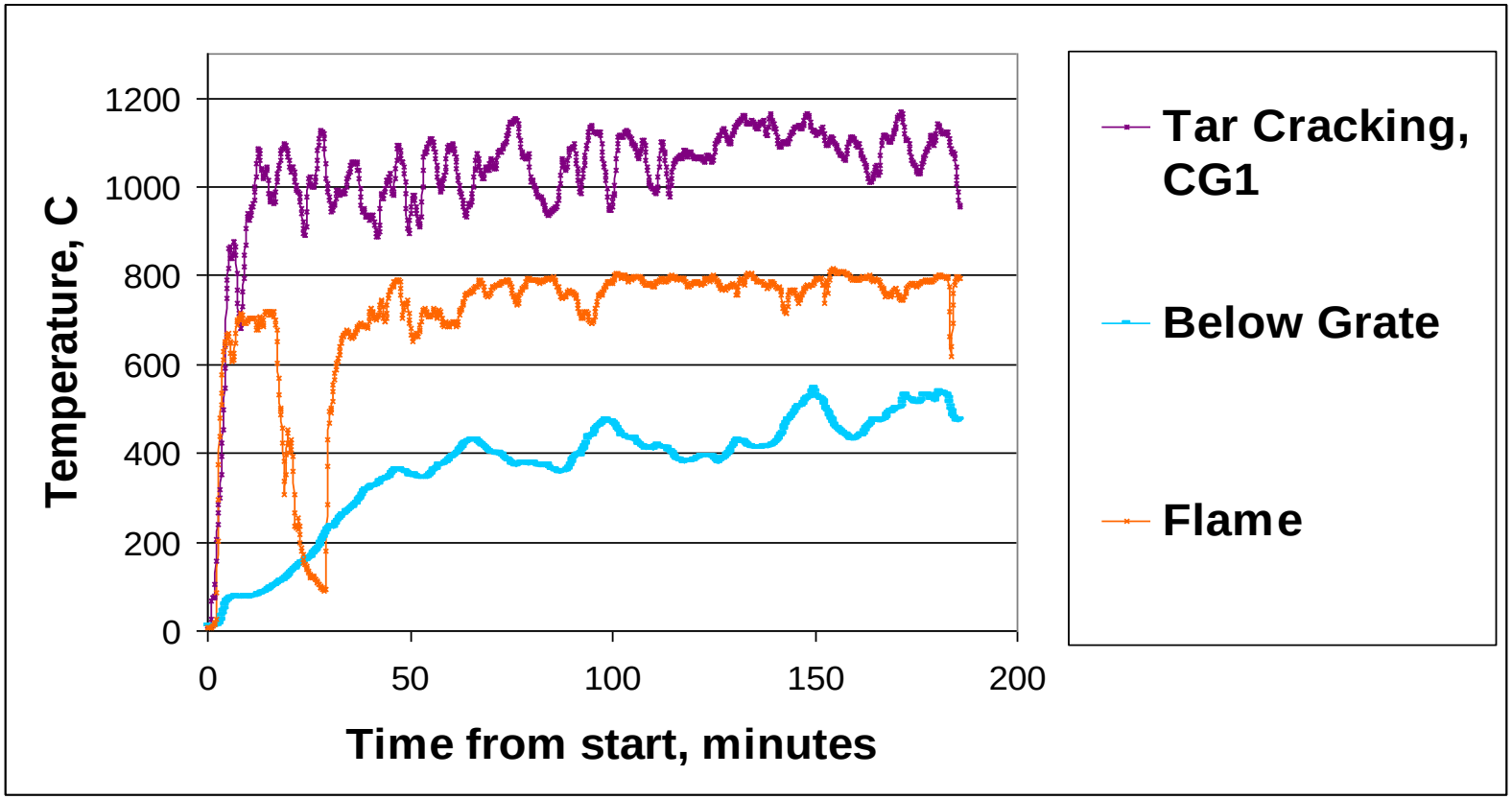
Equivalence ratio	0.12	0.15	0.15	0.15	0.22
Dry gas composition, % volume					
CO	17.5	15.7	19.7	19.9	20.2
H_2	4.2	5.0	5.5	5.8	6.5
CH_4	3.2	3.7	4.1	3.3	3.2
CO_2	16.2	17.8	18.5	14.8	13.4
N_2	57.9	55.3	49.5	53.7	55.0
C_2H_2	Not detected	0.9	0.9	0.8	0.7
C_2H_4	1.0	1.4	1.72	1.3	0.9
C_2H_6	Not detected	0.2	0.2	0.4	0.2
Lower heating value of dry gas (kcal . m^{-3})	1052	1273	1471	1395	1294
Dry gas yield ($m^3 \cdot kg^{-1}$ dry biomass)	0.9	1.1	1.2	1.1	1.6
Char generation, % of fuel input	20	19	16	16	NA

Study on downdraft gasifier



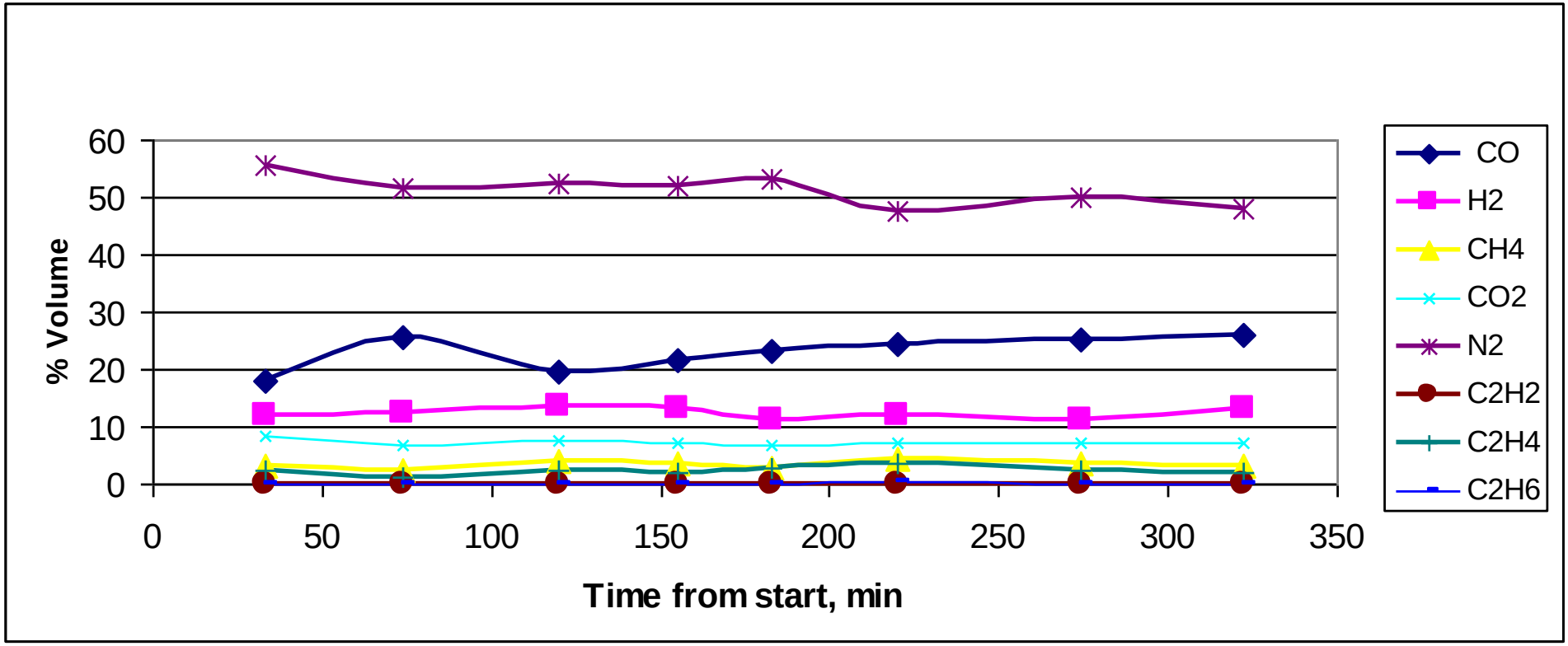
Temperature profile

for switchgrass gasification

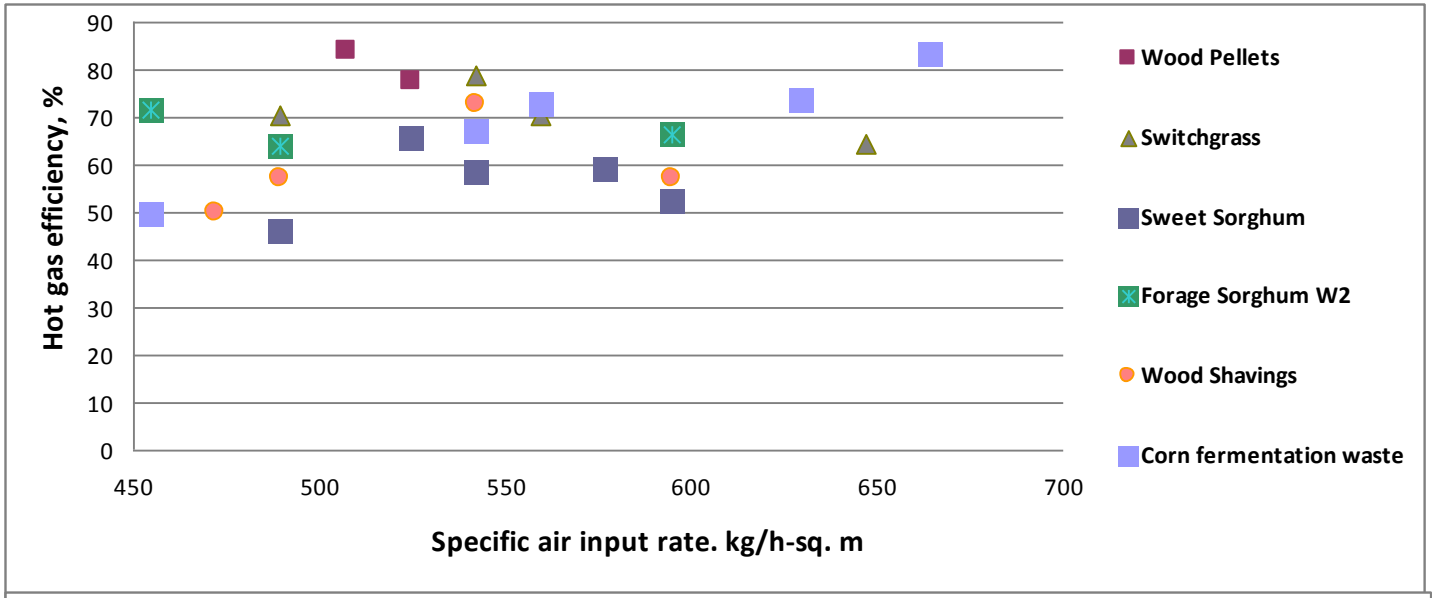


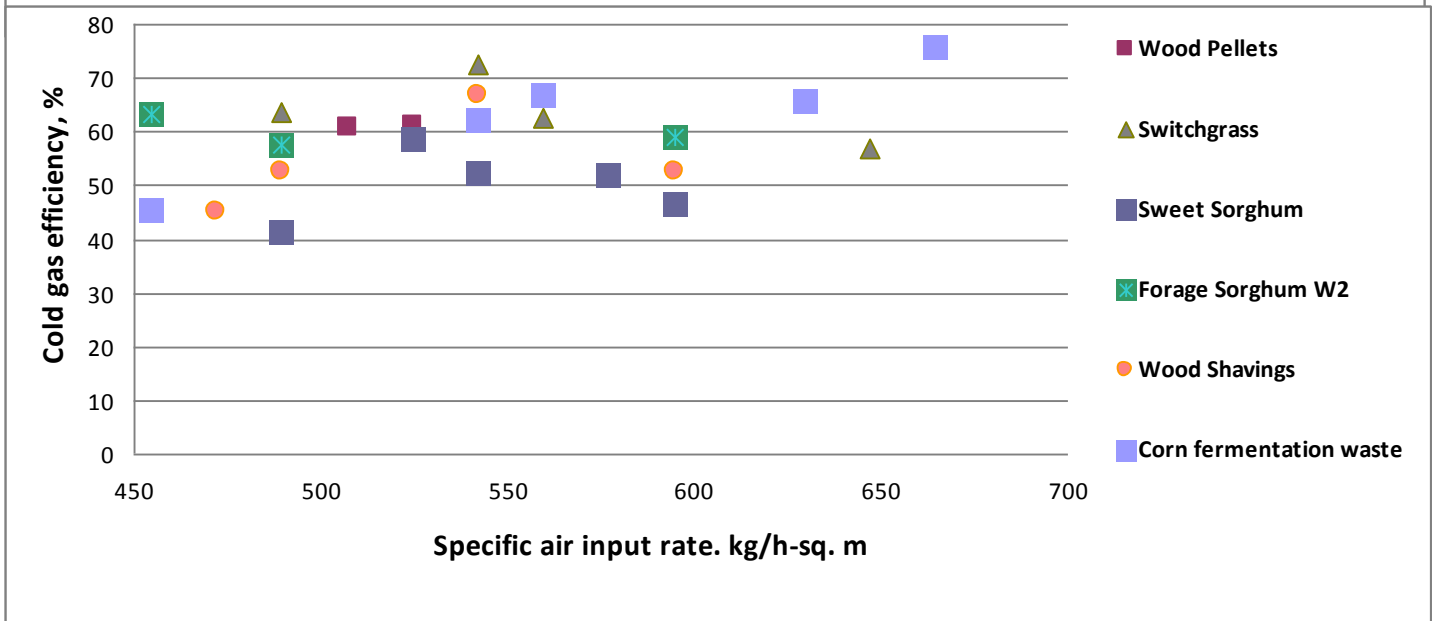
Gas composition

Switchgrass gasification

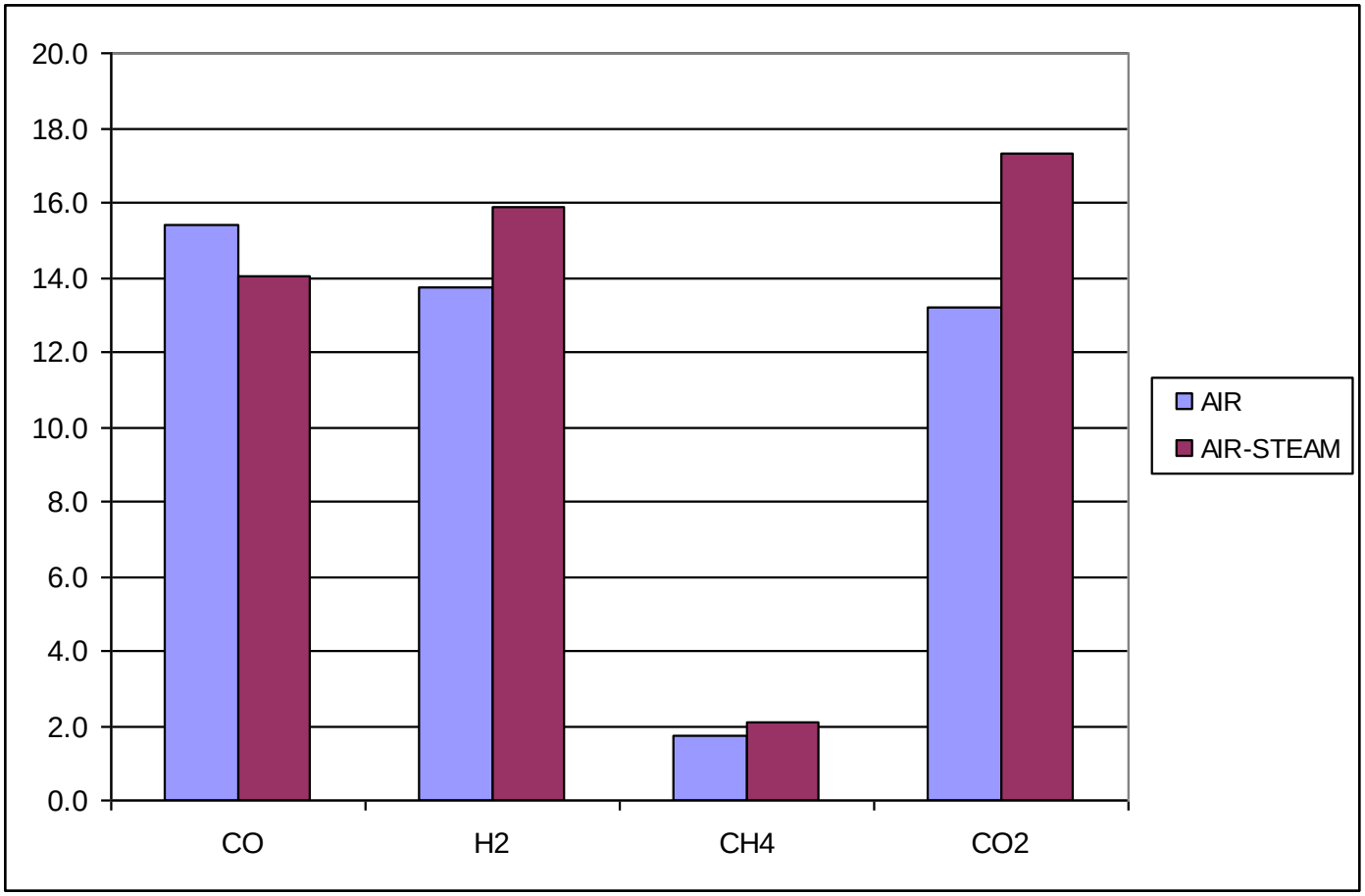


Energy Efficiency





Air and air-steam gasification of chopped forage sorghum



Personnel and Financial Support

PIs:

- **Ajay Kumar**
- **Krushna Patil**
- **Danielle Bellmer**
- **Raymond Huhnke**

Graduate Students/Research engineer:

- Ashokkumar Sharma – Design and study of lab-scale fluidized-bed gasification
- Prakash Bhoi – Study of downdraft gasification
- Vamsee Pasangulapati – Thermochemical characterization of biomass
- Sabre Arrowood – Design and study of new catalytic tar cracker
- Akshata Modinoor – Study on effects of catalytic reactor condition on tar cracking
- Luz Martin - Evaluation of the selected catalysts for tar cracking

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Thank you,

Questions?