Enabling Entrained-Flow Gasification of Blends of Coal, Biomass and Plastics

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Blended Fuel Gasification

Coal

Biomass

Plastic Waste

Blended feedstock for entrained-flow gasification

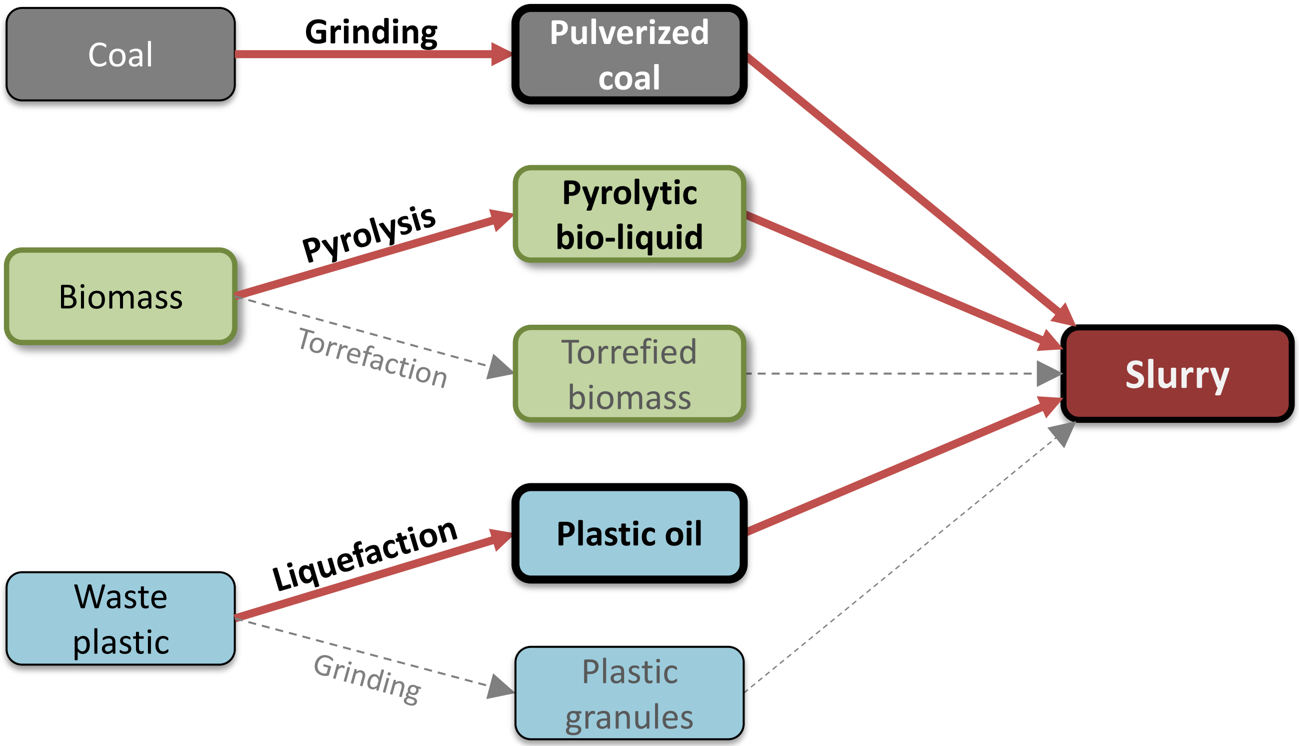
Dry feeding of biomass and plastic difficult at high temperature and pressure

Biomass very heterogenous and mixes poorly in water-based slurry

Plastic and biomass milling is very energy intensive

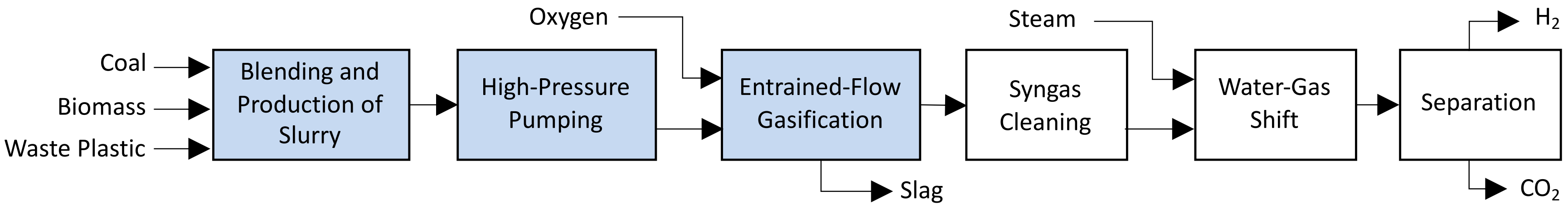
Solution: Prepare biomass and plastic as liquids

Technical Approach



Technical Approach

- *High pressure, entrained-flow* gasification of blended fuel
  - EFG has proven track record
  - Should have good conversion, syngas quality
  - Can be used with existing coal gasification facilities
  - Integration with downstream synthesis is straightforward
- Biomass and plastic fed as liquids
  - Biomass as pyrolytic bio-liquid from Ensyn's process
  - Plastic as oil from Renewlogy process



Project Partners

- **University of Utah:**
  - Gasification R&D since 2001
  - Both lab-scale fundamentals and pilot-scale development
- **Eastman Chemical Co:**
  - Manufacturer of chemicals, plastics, advanced materials
  - Gasifying coal at Kingsport, TN facility since 1983
- **Ensyn Technologies**
  - Pyrolysis-based technology to turn biomass into liquid
  - Commercial process since 1980s
- **Renewlogy**
  - Salt Lake City-based company turning waste plastics into liquids
  - Commercial units approx 10 ton/day
- **Linde Inc**
  - Industrial Gas supplier
  - Has patented hot oxygen burner (HOB) technology

Technical Approach – Feedstocks

- Biomass – Biomass pyrolysis liquid (Ensyn)
  - Condensation of vapors from fast pyrolysis
  - 80-85% energy retention
  - Sand-based bed material (no catalysts)
- Plastic Waste – Plastic oil (Renewlogy)
  - Liquefication via catalytic thermal depolymerization
  - Very low energy requirement
  - Can handle unclean plastics and challenging 4-7 types
- Coal (University of Utah)
  - Bituminous coal – Illinois number 6
  - Pulverized for ease of feeding

Project Objectives

- **Overall objective:** Demonstrate technical feasibility of gasifying blends of coal, biomass and mixed waste plastics in entrained-flow gasifier for production of H_2 with potential for net negative CO_2 emissions

- **Specific objectives:**
  1. Determine compositions of coal-biomass-plastic mixture that produce stable slurry suitable for pumping to high pressure
  2. Design and test novel burner to effectively atomize slurry in high pressure gasifier
  3. Acquire first-of-a-kind performance data for pressurized O_2-blown, entrained-flow gasification of slurried blends of coal, biomass and plastic waste

Project Structure – Tasks

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1. Project management and planning
2. Preparation and characterization of mixed feedstock slurries (year 1)
   - 2.1 Procurement of feedstock materials
   - 2.2 Preparation of mixed feedstock slurries
   - 2.3 Physical and chemical characterization
3. Transport and atomization of mixed feedstock slurries (year 1)
   - 3.1 High pressure pumping studies
   - 3.2 Design and construction of HOB gasifier burner
   - 3.3 Characterization of burner atomization
4. Entrained-flow gasification of mixed feedstock slurries (year 2)
   - 4.1 Gasifier modeling and selection of operating conditions
   - 4.2 Baseline and parametric gasification testing
   - 4.3 Measurement of syngas composition and contaminants
   - 4.4 Evaluation of slag characteristics

Task 2 – Creation of Mixed Feedstock Slurries

- Subtask 2.1 – Procurement of Feedstock Materials
- Subtask 2.2 – Preparation of Mixed Feedstock Slurries
  - 12 baseline slurries
  - Qualitative assessment complete
  - Favorable slurries Identified
- Subtask 2.3 – Physical and Chemical Characterization
  - Separation tests, proximate analysis, viscosity

IKA Rotavisc Viscometer

Shimadzu Thermogravimetric Analyzer

Task 2 – Mixed Feedstock Slurries

- Mixture requirements per FOA (HHV basis):
  - Biomass: 25, 40, 60%
  - Remainder: 25, 50, 75, 100% coal
- Result is 12 mixtures

Mixture	Heating value basis			Mass basis (wt%)		
	Coal	Bio-liquid	Plastic oil	Coal	Bio-liquid	Plastic oil
1	75	25	0	68.0	32.0	0.0
2	56	25	19	54.6	34.4	10.9
3	37	25	38	39.1	37.3	23.7
4	19	25	56	21.8	40.4	37.8
5	60	40	0	51.5	48.5	0.0
6	45	40	15	40.8	51.2	8.0
7	30	40	30	28.8	54.2	17.0
8	15	40	45	15.3	57.6	27.1
9	40	60	0	32.1	67.9	0.0
10	30	60	10	24.9	70.2	4.9
11	20	60	23	16.9	71.6	11.5
12	10	60	30	8.9	75.4	15.7

Best properties: less than 45 wt% coal, less than 20 wt% plastic oil

Task 2 – Mixed Feedstock Slurry Properties

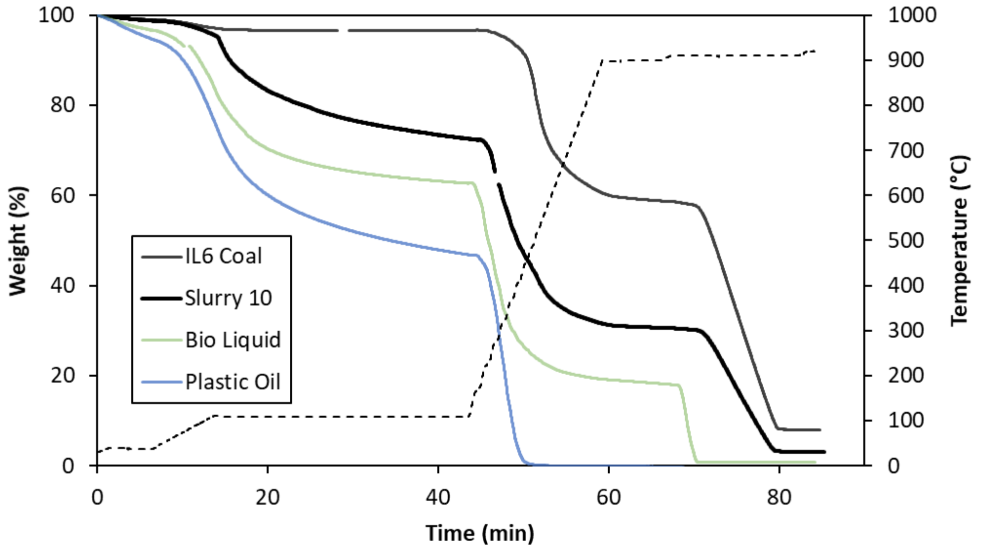
Mixture	Mass basis (wt%)		
	Coal	Bio-liquid	Plastic oil
1	68	32	0
2	54	34	11
3	39	37	24
4	22	40	38
5	52	48	0
6	41	51	8
7	29	54	17
8	15	58	27
9	32	68	0
10	25	70	5
11	17	72	11
12	9	75	16

2 3 4 5 6 7 8

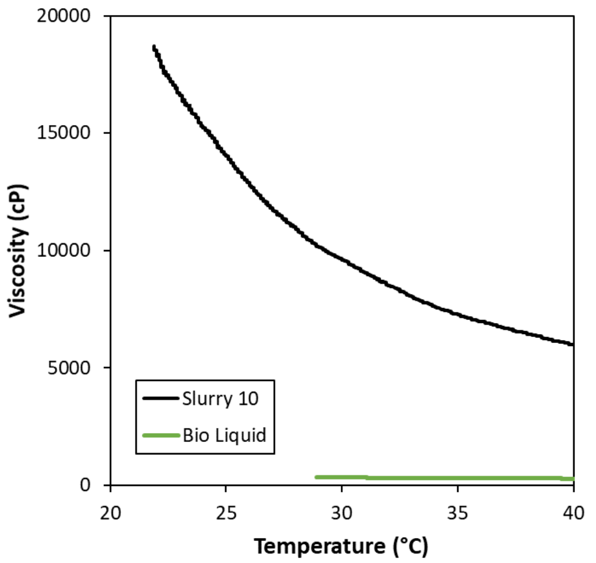
9 10 11 12 1*

Task 2 – Slurry Properties

- Slurry 10
  - 25 wt% coal | 70 wt% bio-liquid | 5 wt% plastic oil



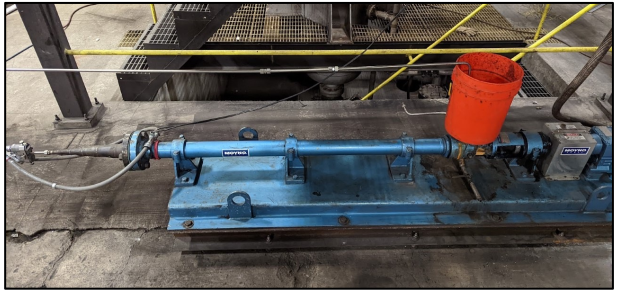
Proximate analysis by TGA



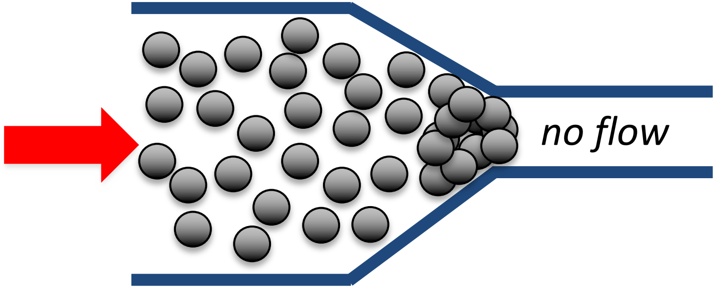
Rheology

Task 3 – Slurry Pumping Studies

- Subtask 3.1 – High Pressure Pumping Studies
  - Ensure reliability of slurry feed
  - Low- and high-pressure studies using progressive cavity pump
  - Identify minimum usable channel diameter



Moyno progressive cavity pump



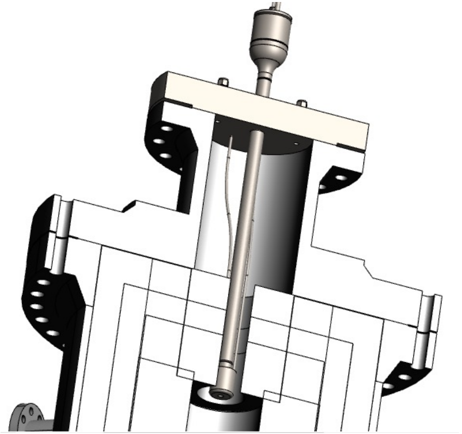
Plugging occurs if channel diameter is too small

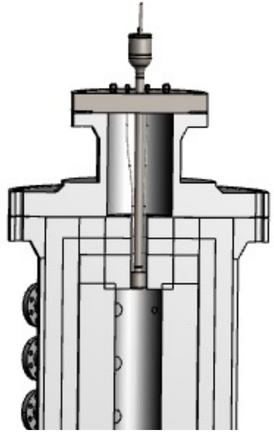
Minimum channel diameter impacts HOB design

Subtask 3.2 – Design and Construction of HOB

HOB = Hot Oxygen Burner

- Design based on other hot oxygen burners for liquid fuels
- Adaptations include adjustments for increased pressure, lower firing rate and using particulate-containing slurry
- HOB design will also allow for natural gas feed, simplifying operation
  - Enables use as a warmup burner
  - Allows system to start gasification mode on NG and line up analytical systems, enabling focus during liquid feeding
- Design work nearly complete
  - Long lead materials have been ordered
  - Confirming University of Utah reactor configuration works





Task 4 – Entrained Flow Gasification

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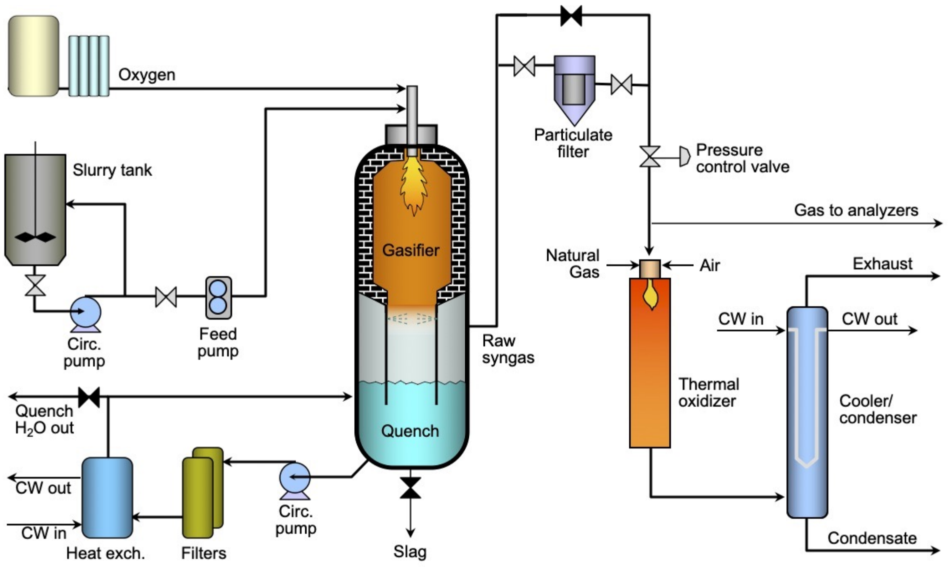
Subtask 4.1 – Gasifier modeling and selection of operating conditions

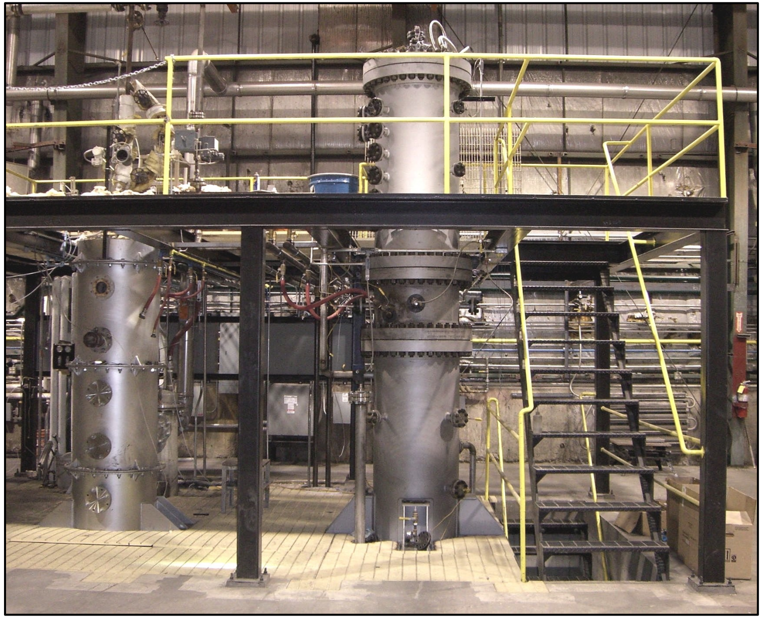
- Modeling performed using FactSage™ thermodynamic modeling software
- Used compositions of coal, biomass, plastic to determine compositions of mixtures
- Assume gasification with 35% of stoichiometric O_2
- Calculate flame temperature and equilibrium gas composition

Slurry	Temperature	Syngas Composition							
Mixture	(°F)	CO (%)	H_2 (%)	H_2O (%)	CO_2 (%)	CH_4 (%)	H_2S (%)	N_2 (%)	COS (ppm)
1	2432	57.31	33.03	5.09	2.96	0.20	1.00	0.35	586
2	2452	55.33	35.59	5.16	2.65	0.21	0.75	0.27	396
3	2481	53.29	38.12	5.28	2.29	0.20	0.50	0.19	239
4	2502	51.33	40.63	5.31	2.13	0.21	0.26	0.11	112
5	2256	53.33	34.13	6.84	4.14	0.45	0.78	0.29	403
6	2271	51.87	35.99	6.99	3.85	0.46	0.59	0.23	282
7	2286	50.39	37.89	7.11	3.57	0.46	0.39	0.16	175
8	2301	48.88	39.83	7.22	3.30	0.46	0.20	0.10	81
9	2084	48.26	34.89	9.20	5.80	1.11	0.50	0.21	227
10	2092	47.37	36.03	9.35	5.56	1.12	0.38	0.17	163
11	2114	46.68	37.45	9.31	5.13	1.05	0.25	0.13	101
12	2109	45.56	38.36	9.66	5.10	1.10	0.13	0.09	49

Task 4 – Entrained Flow Gasification

- Testing planned for year 2 of project
- System modifications complete
- System shakedown in progress

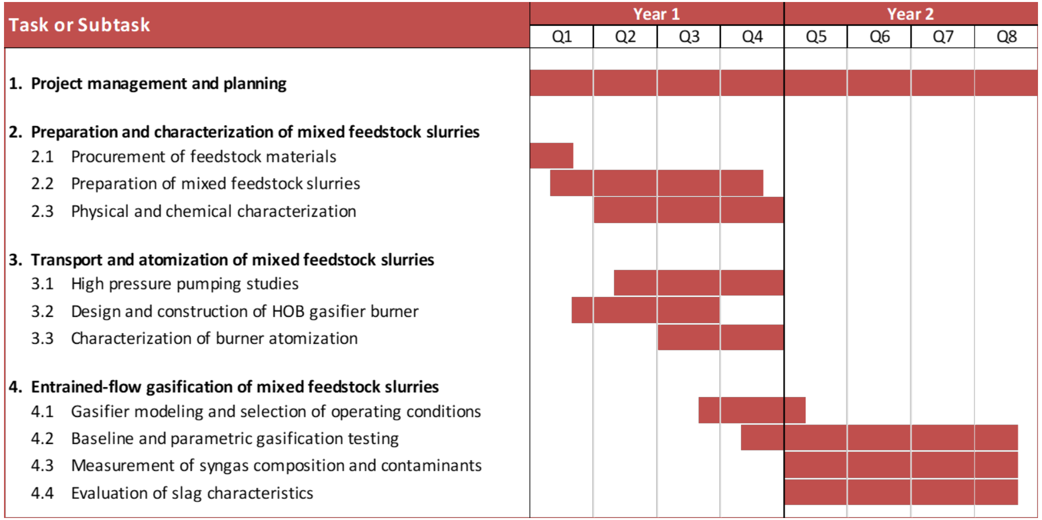




U. Utah pressurized, oxygen-blown entrained-flow gasifier.
Target conditions: 300 psi, 1 ton/day (~300 kW_{th}) feed rate.

Plans for Coming Year

- Continue evaluating candidate slurries
- Construct, test, and install hot oxygen burner
- Evaluate gasification of mixed feedstock slurries
  - Syngas composition
  - Carbon conversion
  - Slag properties



Acknowledgements

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- Project partners
  - Eastman Chemical Company
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