Distributed Biomass Conversion

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Biomass Conversion

- Direct use of conversion products
  - Heat and Power
  - Bioethanol
  - Syngas
  - Bio-oil
- First step in utilization of biomass
  - For upgrading
  - Feedstock for other processes

Challenges faced by large processing facilities

Initial Capital Investment

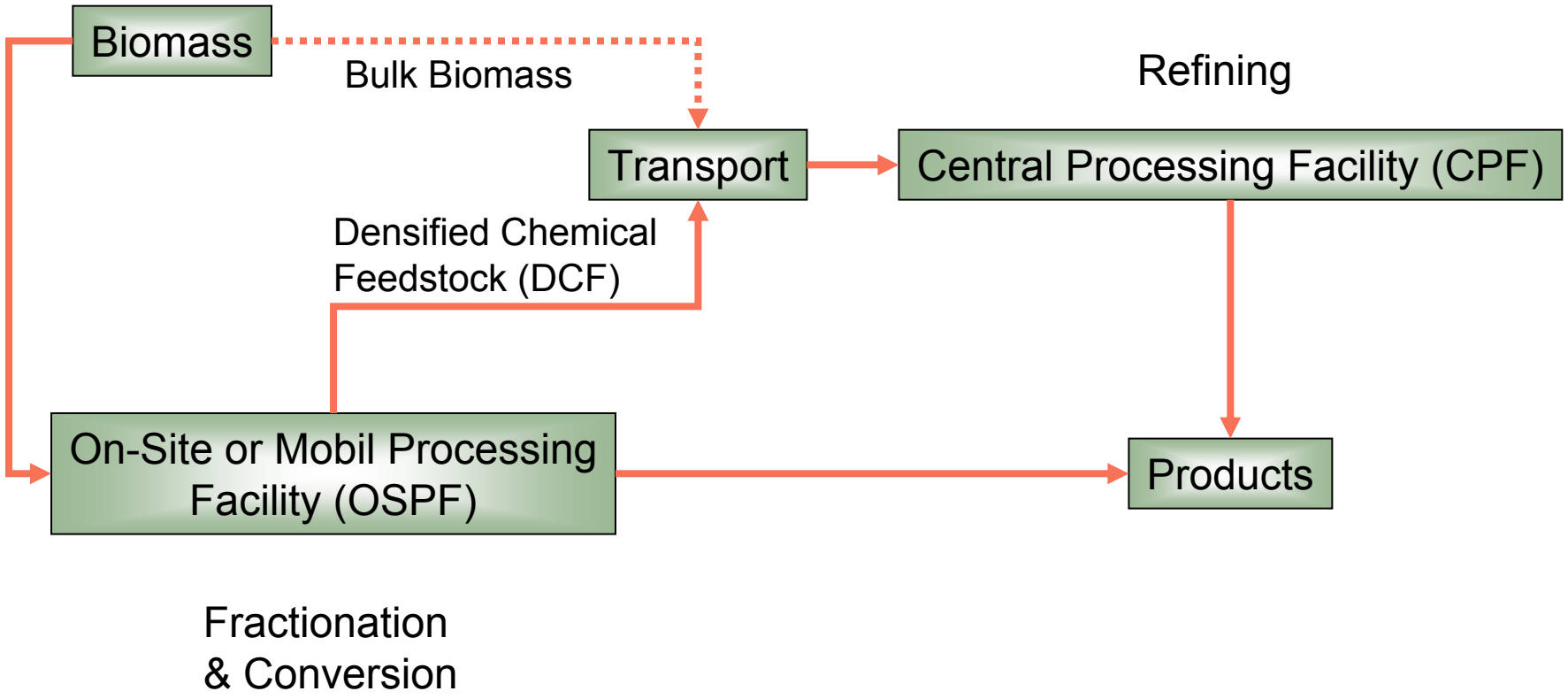
Technicality

Auxiliary Equipment/Facility

Feedstock Transport

Income for Biomass Producers

Distributed Conversion/Refining System



Bale to Barrel

As fertilizer back to field for biomass production

Power for conversion

One round hay bale
diameter = 5ft
length = 5ft

1,000lb, 100ft³
10lb/ft³
7,500,000BTU
75,000BTU/ft³

Conversion

H_2 CO
Gas CH_4

2,250,000BTU

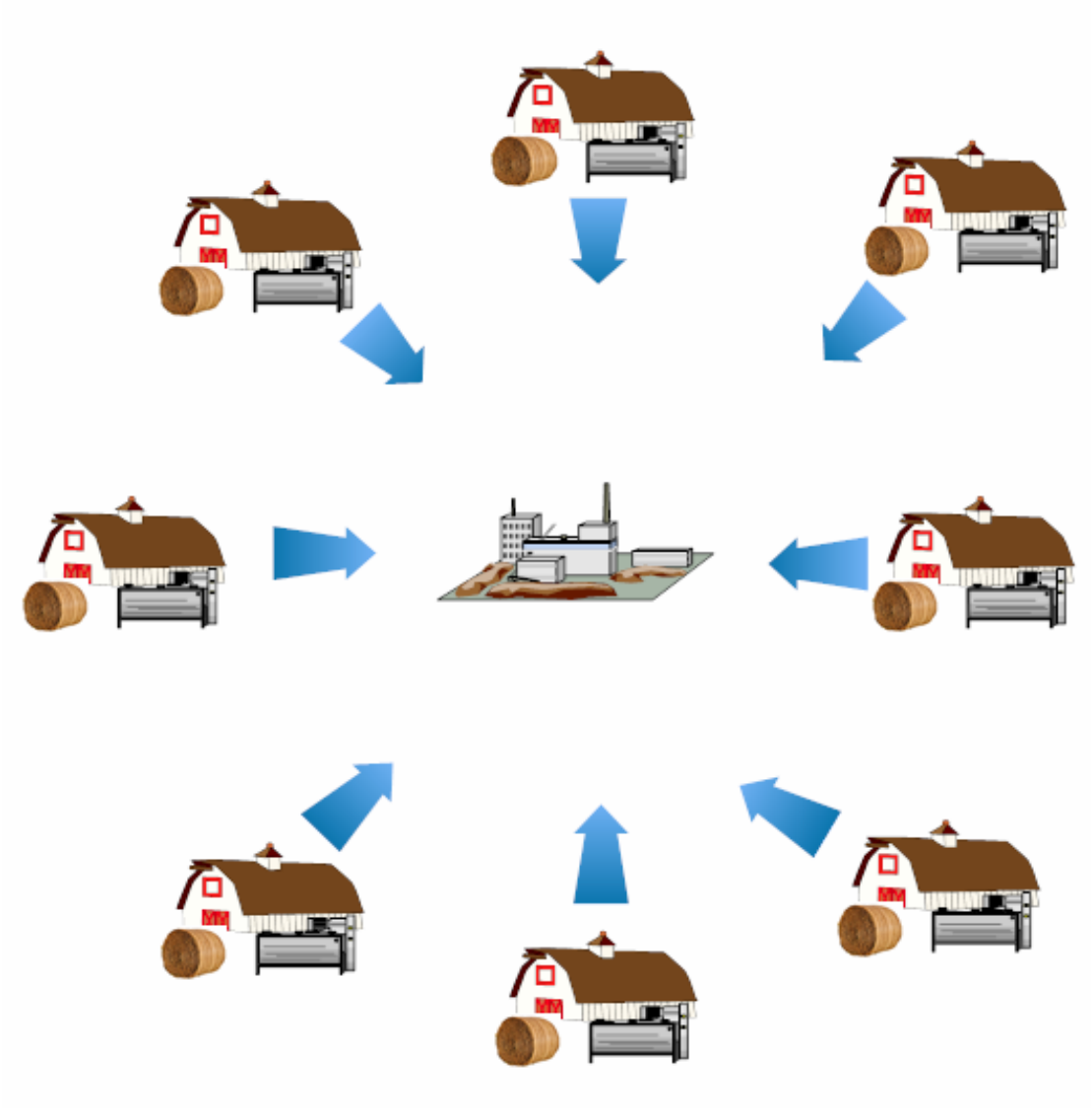
Char

1,500,000BTU

Biocrude

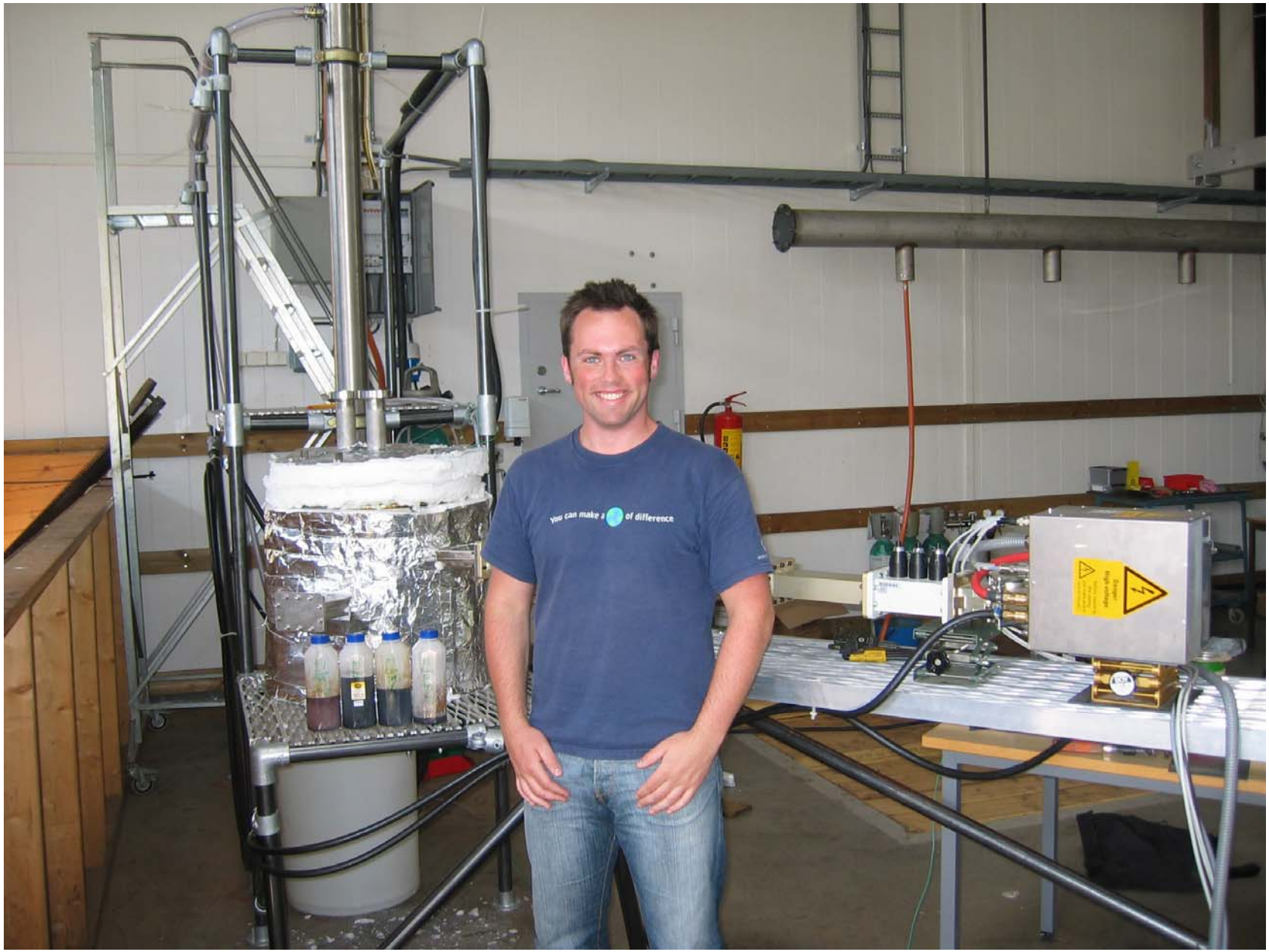
1.2 barrel
500lb, 6.7ft³,
75lb/ft³
3,750,000BTU
562,500BTU/ft³

Distributed biomass processing scheme



Scalable distributed thermochemical conversion technologies

- Processes
  - Microwave assisted pyrolysis
  - Hydrothermal pyrolysis
  - Liquefaction
- Product possibilities
  - Bio-oils
    - Heating oil, transportation fuels
    - Bio-polymers
    - Adhesives
  - Syngas
    - Gas turbine to generate electricity
    - Fermentation to produce high value chemicals
    - Reforming to produce fuels


You can make a of difference

Commercial Scale MWP Reactor

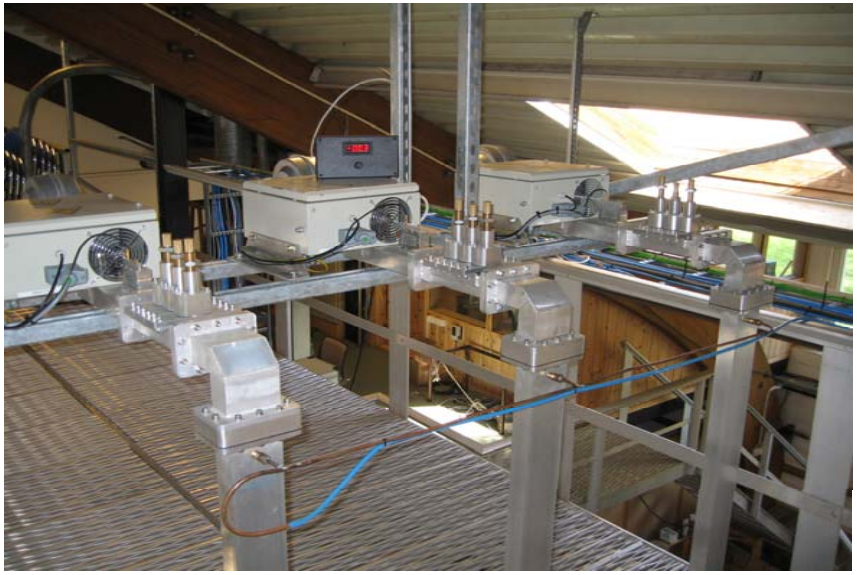
UMB-IMT & X-Waste International

- 4.5 kW power
- computer central controlled process
- 10 kg/h through-put
- various input materials

Pyrolysis Chamber

- air tight hopper system w. 1 m^3 capacity
- horisontal-, cyclindrical reaction chamber
- w. auger transport system
- microwave inlets x 3
- ventilation/under-pressure
- vapour outlet
- dry fraction outet/collection
- w. heating
- inert gas lines
- temperature measurement

Microwave Generators



- 1.5 kW magnetrons x 3
- reflection indicator (selectable)
- tuning device x3
- inert gas inlets CO_2, h_2
- vertical microwave guides ca. 5m ↕

Condensing Column & Liquid Collection

- 5 fraction distililation column
- 2 x gas scrubbers
- Collection tank for distillate
- w. Heating element
- Dry gas flare

Logging Capabilities

as functions of time

Feedstock

- Temperature [^{o}C]

Reaction

- Vapour temp. [^{o}C]
- Condensing temp. [^{o}C] x 5 pt.

Power

- Emitted and reflected

Laboratory MWP Reactor

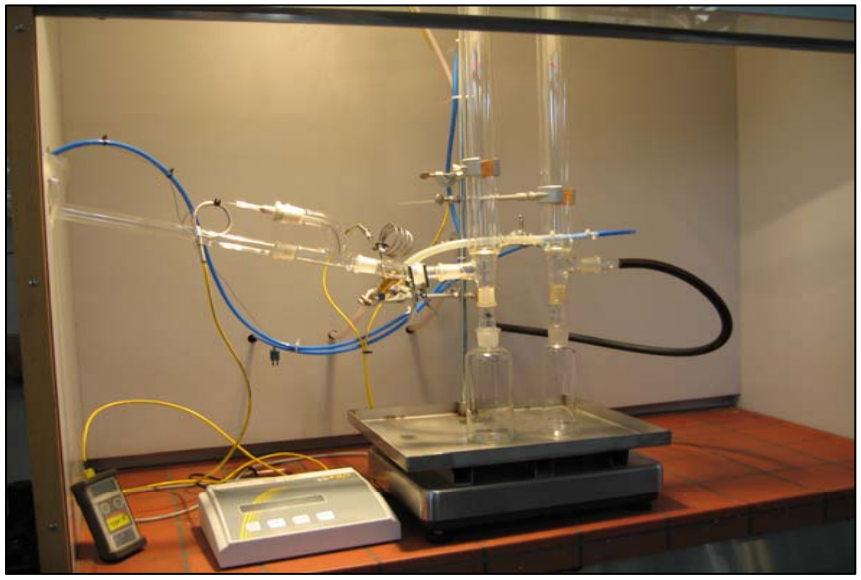
- Batch operation
- 1-2 l input material capacity
- near limitless input materials capability
- ≤ 1200 ºC
- in-time gas sampling and analysis (06.07)
- Insured safe working environment (microwave, gas leakage)

Reaction Chamber

CEM - Max

- 1.5 kW magnetron
- ≤ 1200 ºC
- programmable (start, running, cool-down)
- Aluminum oxide furnace chamber
- silica-carbide arch
- built-in scale (± 0.1 g)
- thermocouple
- computer terminal connections

Condensing Column & Liquid Collection



- 2 x tube-in-tube heat exchangers
- Stage 1 - air cooling
- Stage 2 - water cooling
- Liquid sample collection
- Scale
- Thermocouple
- Vapour inlet
- Gas outlet (to FTIR)

Logging Capabilities

as functions of time

Feedstock

- Weight loss [g & %] (± 0.1 g)
- Temperature [ºC]

Reaction

- Vapour temp. [ºC]
- Condensing temp. [ºC] x 2 pt.

Liquid

- Weight increase [g] (± 0.1g)

Gas

- Planned; volume flow [l/s]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Objectives

- To understand and optimize the processes
- To explore product possibilities
- To develop pilot scale continuous processes and equipment

Work accomplished

- Experiments to investigate product yields and properties under different conditions
- Testing different feedstock
- Burning and engine testing of bio-oils
- Development of bio-polymers from bio-oils
- Development of continuous microwave pyrolysis and hydrothermal pyrolysis systems


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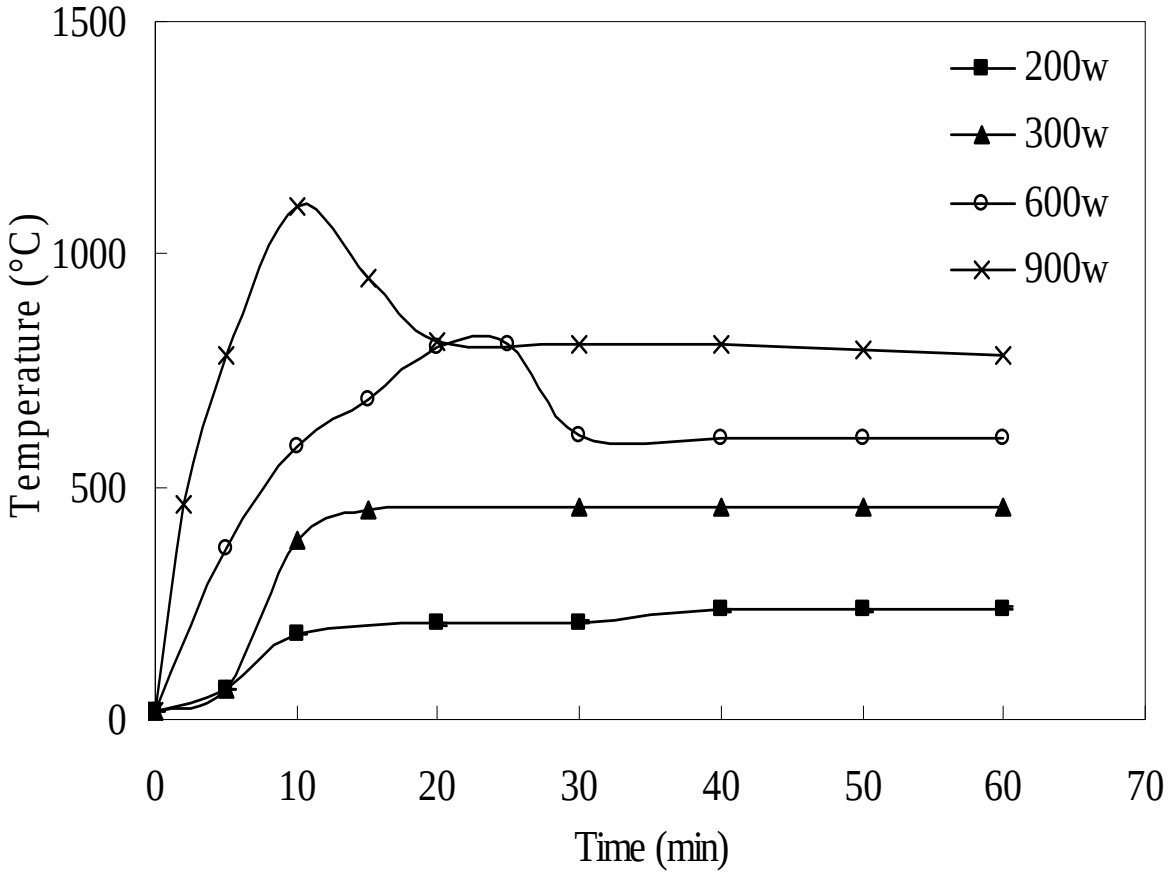
Microwave-Assisted Biomass Pyrolysis System (UMN Generation II)

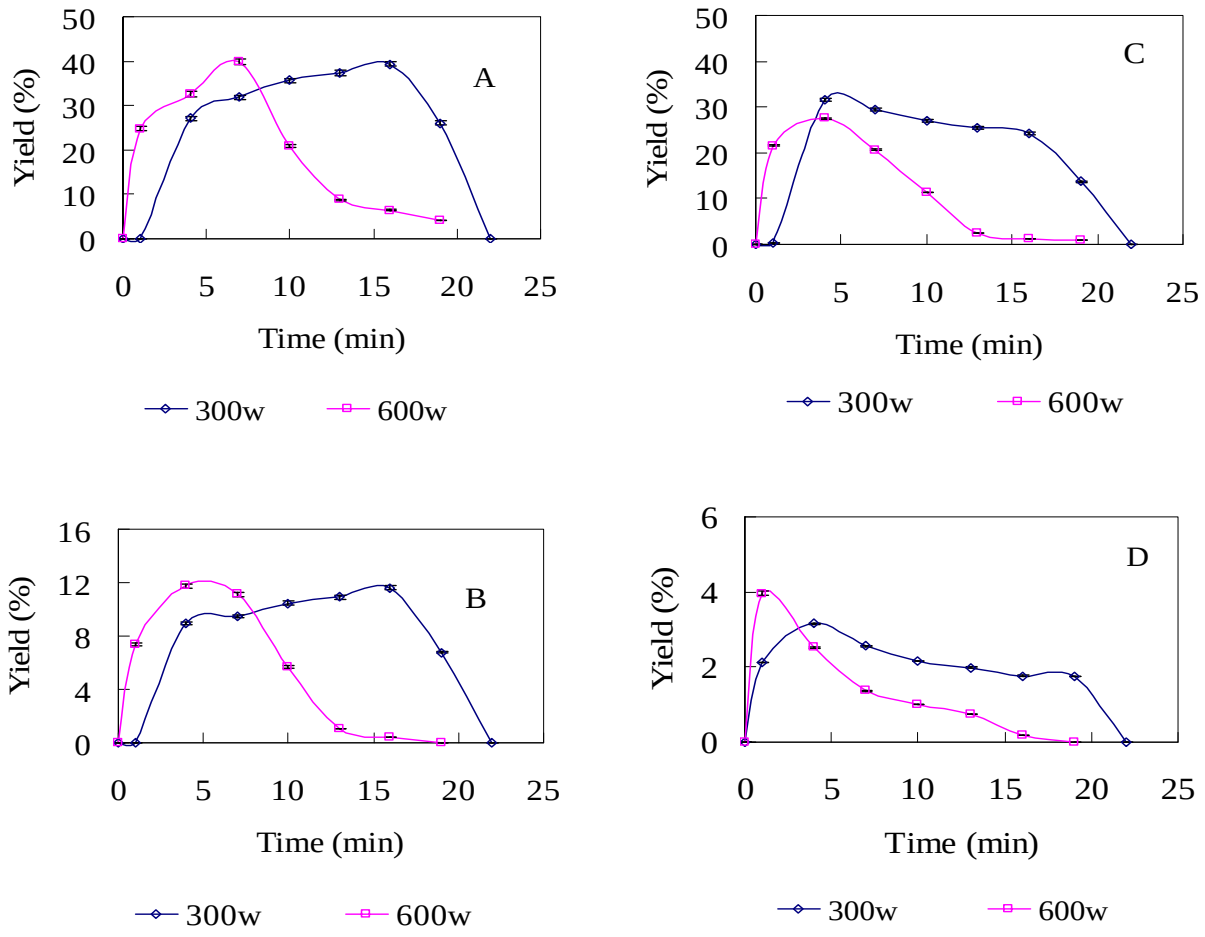
Microwave Pyrolysis



Microwave pyrolysis of corn stover at different input power.

Microwave Pyrolysis of Corncob and Cellulose

	300W		**1000W**	
	Corncob	***Cellulose***	***Corncob***	***Cellulose***
Gases (%)	14.36	7.52	46.88	23.64
Liquid (%)	16.34	13.76	30.16	43.64
Solids (%)	69.3	79.72	22.96	32.72



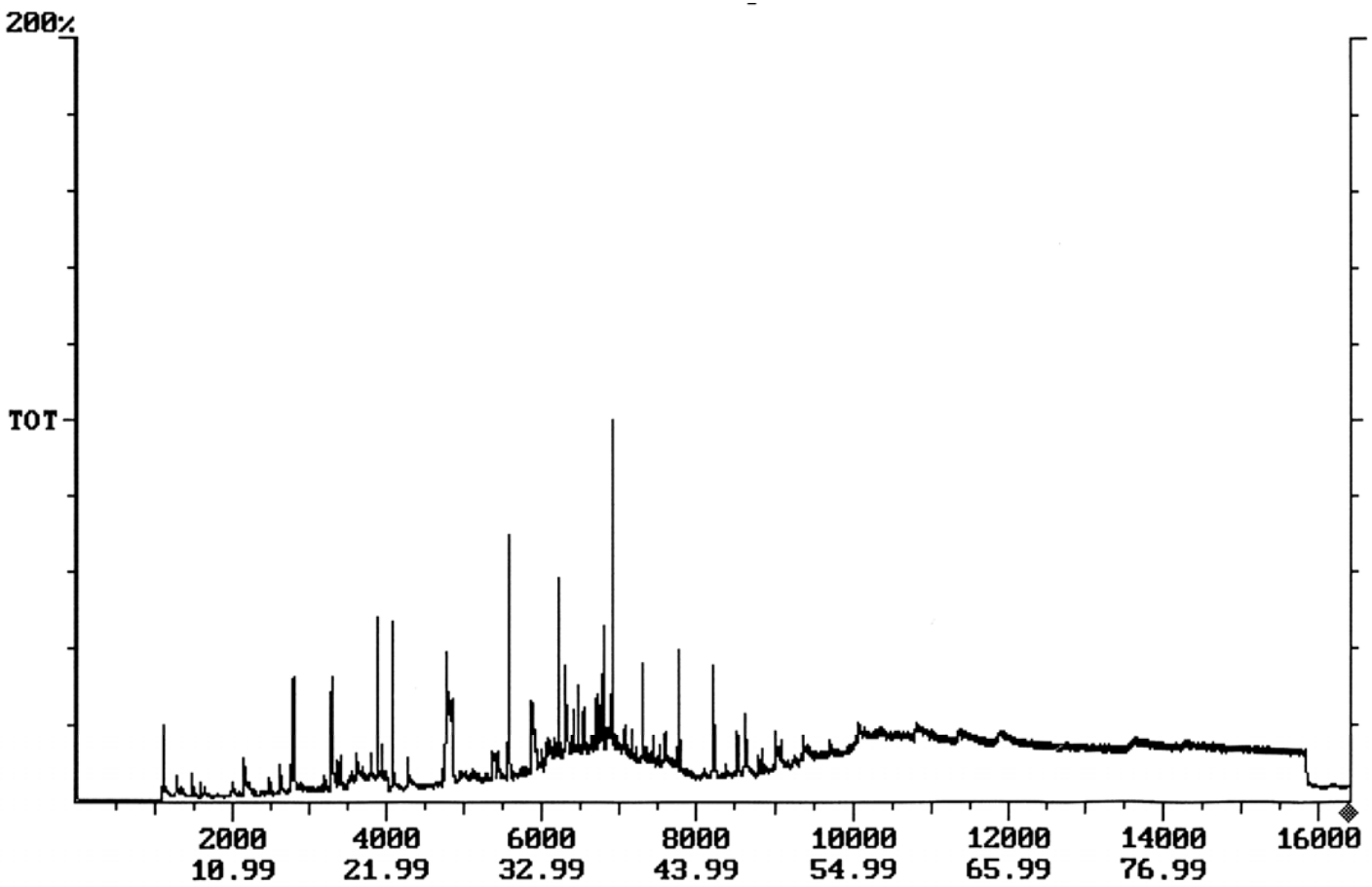
Micro-GC chromatograms of the microwave pyrolysis gas obtained from corn stover at 300W and 600W.

A: H2; B: CH4; C: CO2; and D: CO.

Composition of Pyrolytic Gases

Retention time (min)	Peak Name	Percentage at 300w	Percentage at 600w
Peak Info for Channel A (MS5A)			
0.413	<H2>	6.33	17.68
0.659	<CO>	15.64	15.32
Peak Info for Channel B (PPQ)			
0.365	<CO2>	39.68	32.58
0.382	<C2H4>	0.28	0.90
0.390	Acetylene	0.94	1.15
0.408	<CH4>	3.97	3.76

Pyrolytic Liquid Composition



GC-MS chromatograms of the pyrolysis liquid obtained from corncobs.

Analysis of microwave pyrolytic oils

Analysis	Method
pH	pH meter
Water, wt%	ASTM D 1744, Karl-Fischer titration
Minerals, ppm	ICP
Viscosity (20 °C), mPa • s	ASTM D 445, Rotational viscometer
Ash, wt%	EN 7
Elemental composition, wt%	Elemental analyzer
Heating value, MJ/kg	DIN 51900, Bomb calorimeter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EAI
EAI—EAGLETON ANALYTICAL, INC.

Physicochemical properties of bio-oils

Properties	Value
pH	2.87
Moisture , wt%	15.2
Density , g/ml	1.25
Dynamic viscosity at, mPa • s	
20 ℃	1270
40 ℃	185
60 ℃	60
80 ℃	34
Gross heating value (HHV), MJ/ kg	17.51
Elemental composition, wt%	
Carbon	60.66
Hydrogen	7.70
Nitrogen	2.02
Sulphur	0.15

Minerals of Bio-oils by Inductive Coupled Plasma (ICP) Analysis

Mineral	Al	B	Ca	Cd	Cr	Cu	Fe	K
Content (ppm)	4.922	2.848	6.833	0.059	0.307	0.397	7.589	3.127
Mineral	Mg	Mn	Na	Ni	P	Pb	Zn	
Content (ppm)	1.858	0.034	1.816	0.953	1.518	0.822	0.792	

High heating value of bio-oils and bio-oils with solvent addition

Samples	High heating value (MJ/kg)
Bio-oils	17.51
Aqueous phase	1.2
Bio-oils with 10 wt% methanol	16.21
Bio-oils with 20 wt% methanol	15.96
Bio-oils with 30 wt% methanol	13.47
Bio-oils with 10 wt% ethanol	14.51
Bio-oils with 20 wt% ethanol	12.07
Bio-oils with 30 wt% ethanol	11.98

Development of Polymeric Products

- Bioadhesives
- Biopolyesters
- Biopolyurathane
- Compressed materials
- Biochemicals

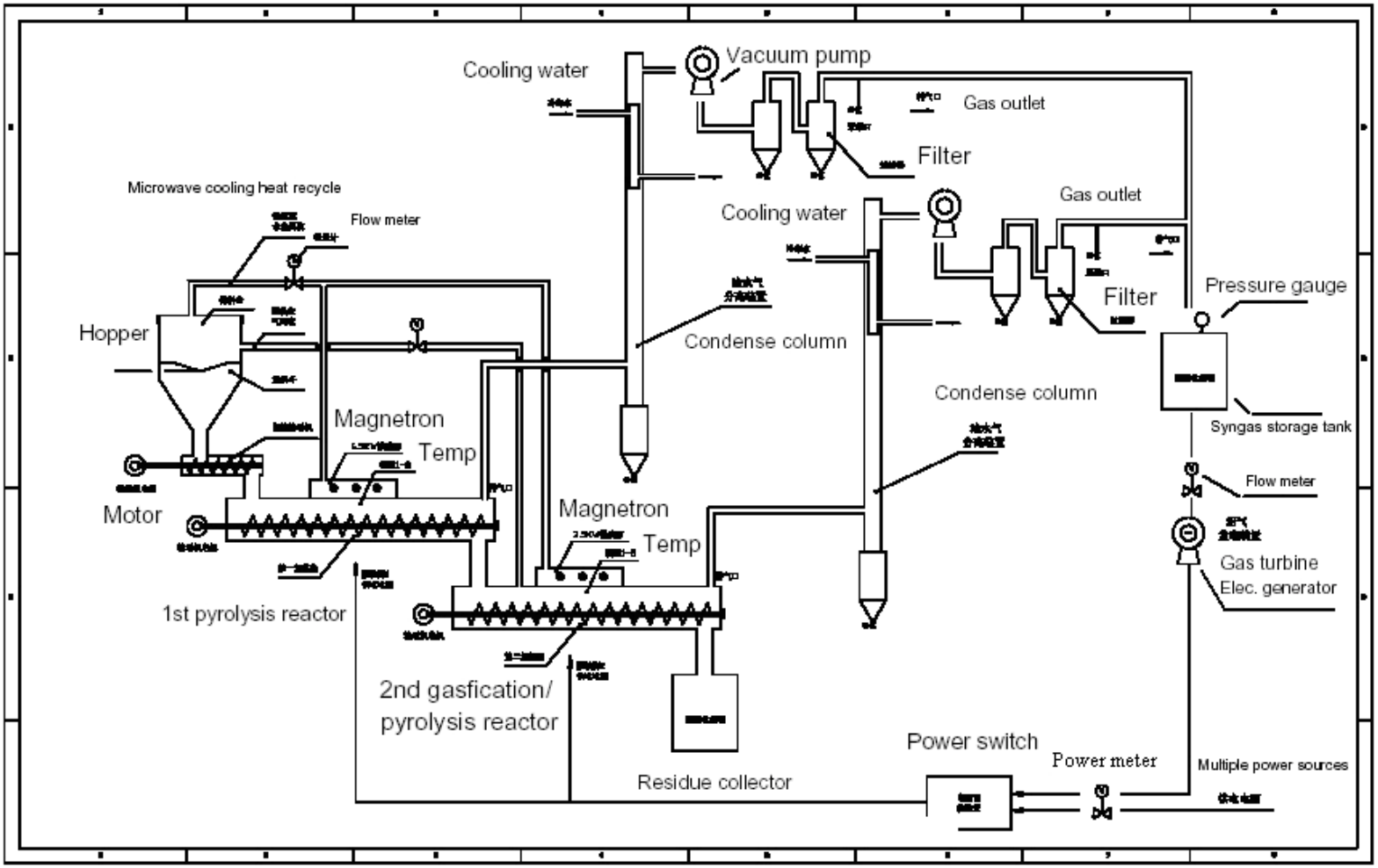
Sample Bioproducts Produced from Biooils

Test of Polyurethane Foams

Generation II Continuous Equipment Development

- Continuous process
- Larger capacity
- Closed-system: gas turbine for electricity generation
- Two-state processes: pyrolysis and gasification
- Completion: estimated in July or August

Schematic Diagram of the Microwave-Assisted Pyrolysis System under Design



Continuous Hydrothermal Biomass Pyrolysis System