A Mobile Pyrolyzer for Converting Agricultural and Forestry Residues into Liquid Bio-Oil and Bio-Char

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Motivation: why convert biomass?

- Alternative to fossil fuels
- Energy independence
- Global demand for:
  - alternative sources of renewable carbon dioxide neutral (or negative) energy and for green chemicals.
  - increased utilization of agricultural products, co-products and residues.
  - reduced emissions from combustion or composting of residues from agricultural and forestry materials.

Issues with biomass conversion

- Competition with food use.
- Requires land, energy, fertilizer.
- Fertilizer and pesticides bring extra pollution.
- Processing requires energy.
- Low energy density.
- Expensive and polluting transportation to a central processing location.
- Seasonal.

Residual Forestry Biomass

- Low value, bulky biomass is commonly left on site and flared due to cost of transport
- Drop-and-leave is a fire hazard
- Piling and burning is costly, releases gaseous pollutants, and wastes energy

But…..Biomass Removal

- Productivity may decline with excessive removal
- Sustainable bioenergy means <u>avoiding</u> nutrient removal!

Residual Agricultural Biomass

- Available only during a short time of the year
- Often source of pollution and diseases
- Often required landfilling
- Composting generates CO_2 and methane





Residual Agricultural Biomass

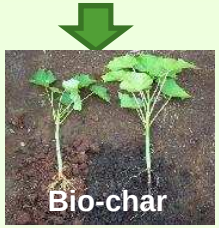
- …burning is not an option!!!

How can we handle biomass?

- Option 1:

Gathering and transportation of low energy density and bulky biomass

- Option 2: Distributed "oil wells"



Gathering and transportation of high energy density bio-oil

Our Approach

• ***Small Scale In-Situ*** Conversion of Agricultural Crops, **Residues** & other Biomass sources into Bio-Oil via **Fast Pyrolysis**.

Agri-Therm unit: Mobile Pyrolysis

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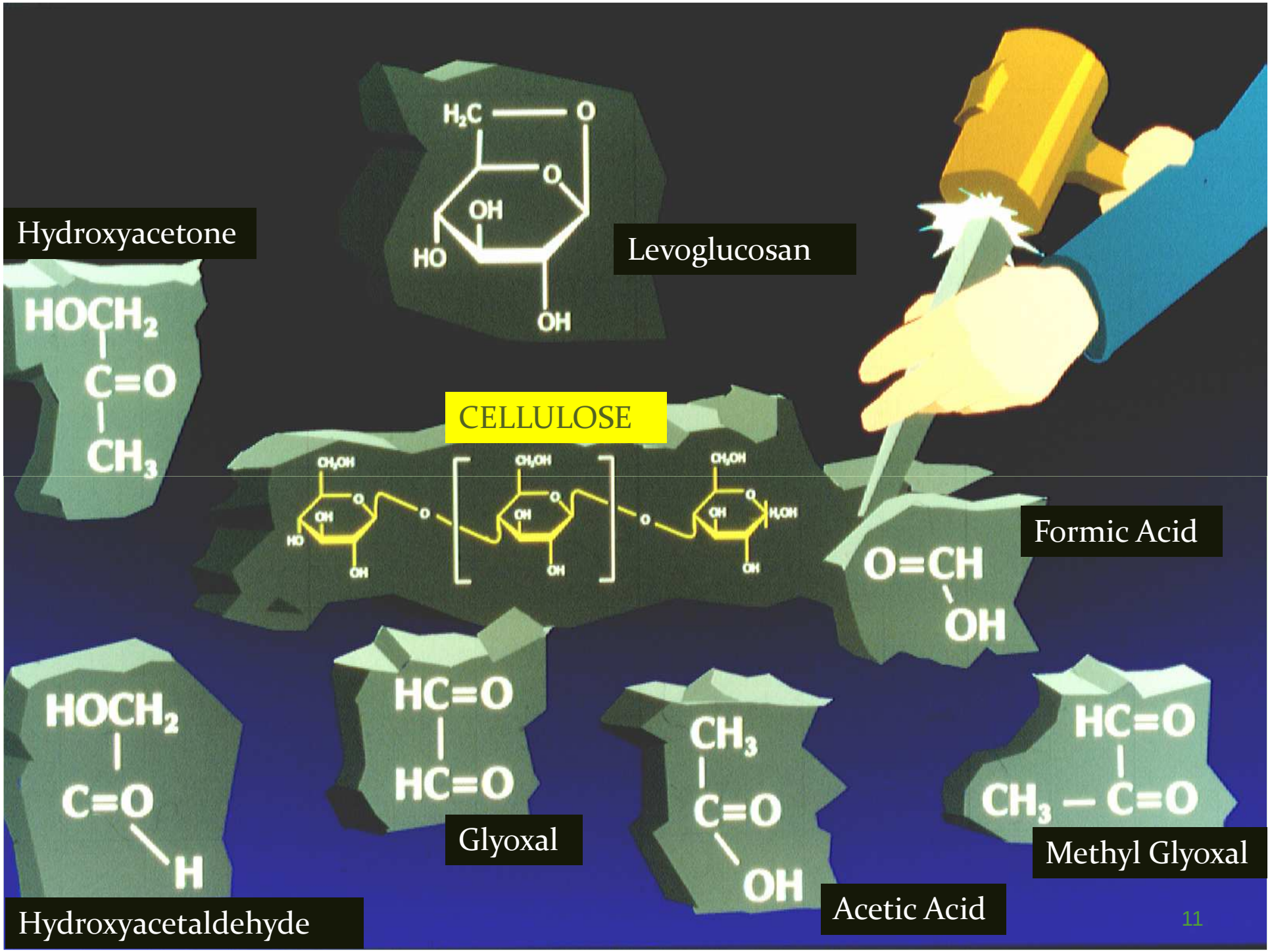
- 10 t/day of biomass feed
- Inexpensive
- Easy to Operate
- Easy to Maintain
- Single Person Operation
- Single User or Cooperative

Pyrolysis

- Chemical decomposition of any organic materials in the absence of oxygen

- Products:
  - Gases (non-condensable vapors)
  - Liquid Bio-oils (condensable vapors)
  - Solids: char and ash


Hydroxyacetone
Levoglucosan
CELLULOSE
Formic Acid
Glyoxal
Methyl Glyoxal
Hydroxyacetaldehyde
Acetic Acid

Integrated Biorefinery

Distributed Production
"Oil Well"

Mobile Pyrolyzer
In-situ processing

Crude
Bio-Oil

Bio-Char

Centralized Processing
"Refinery"

INTEGRATED BIOREFINERY

MATERIALS

ENERGY

CHEMICALS

FUELS

Food waste, agro residues, non-food crops, grasses

Agri-Therm unit: Mobile Pyrolysis

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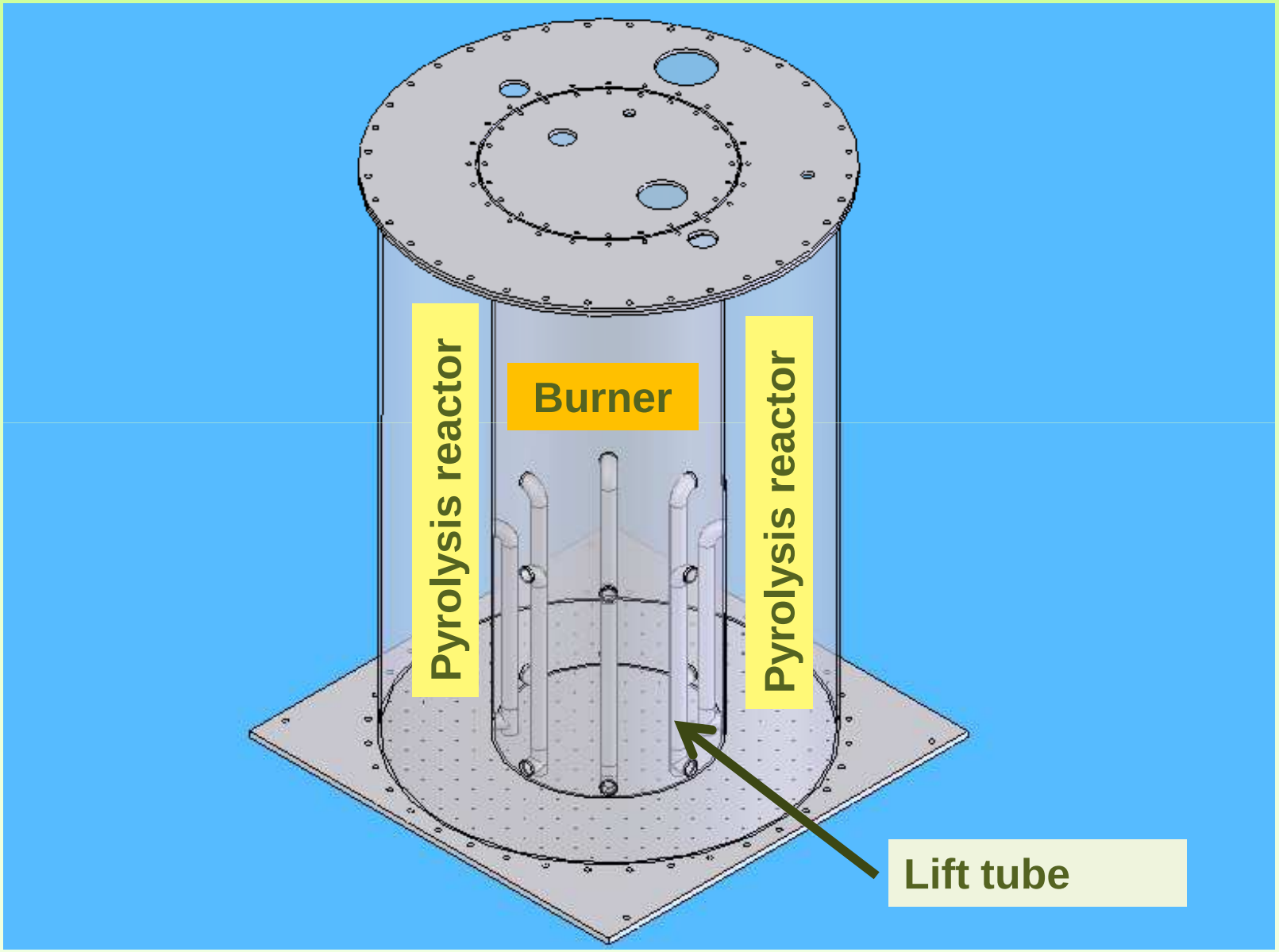
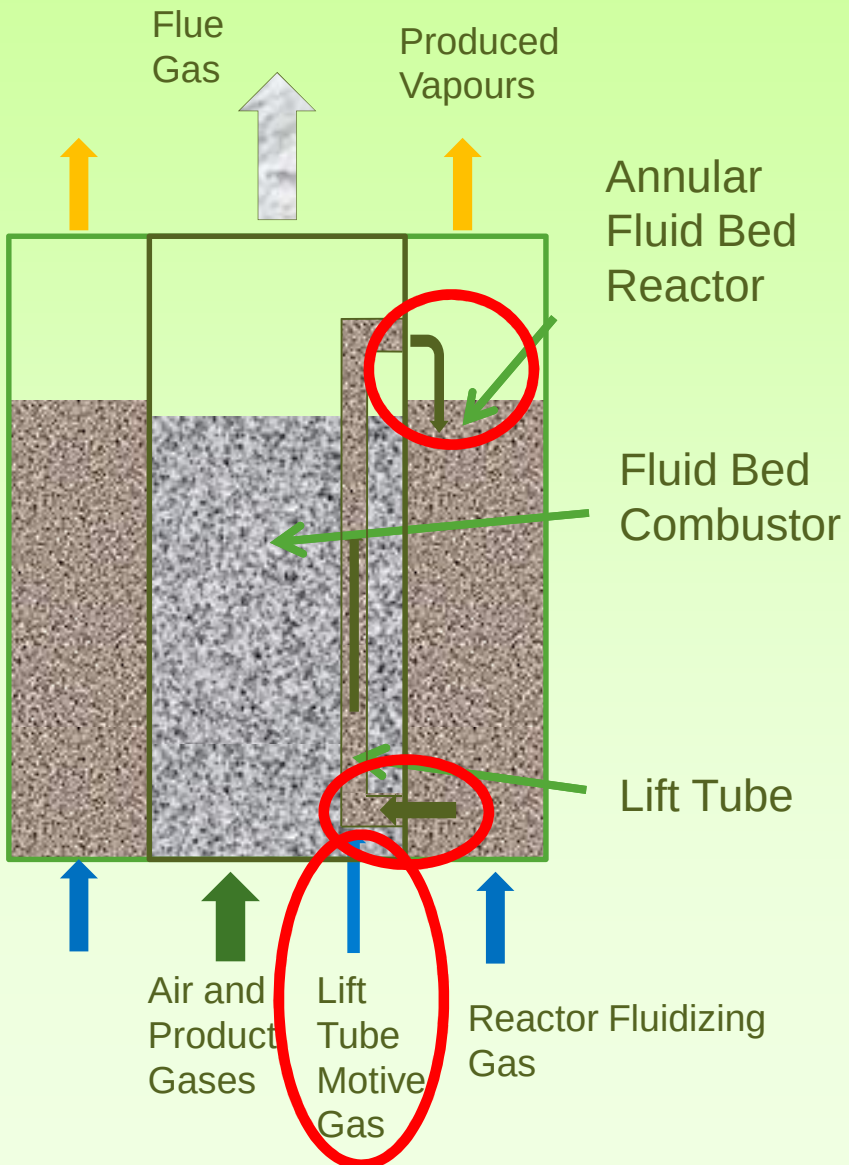
Mobile Pyrolysis Unit: Reactor

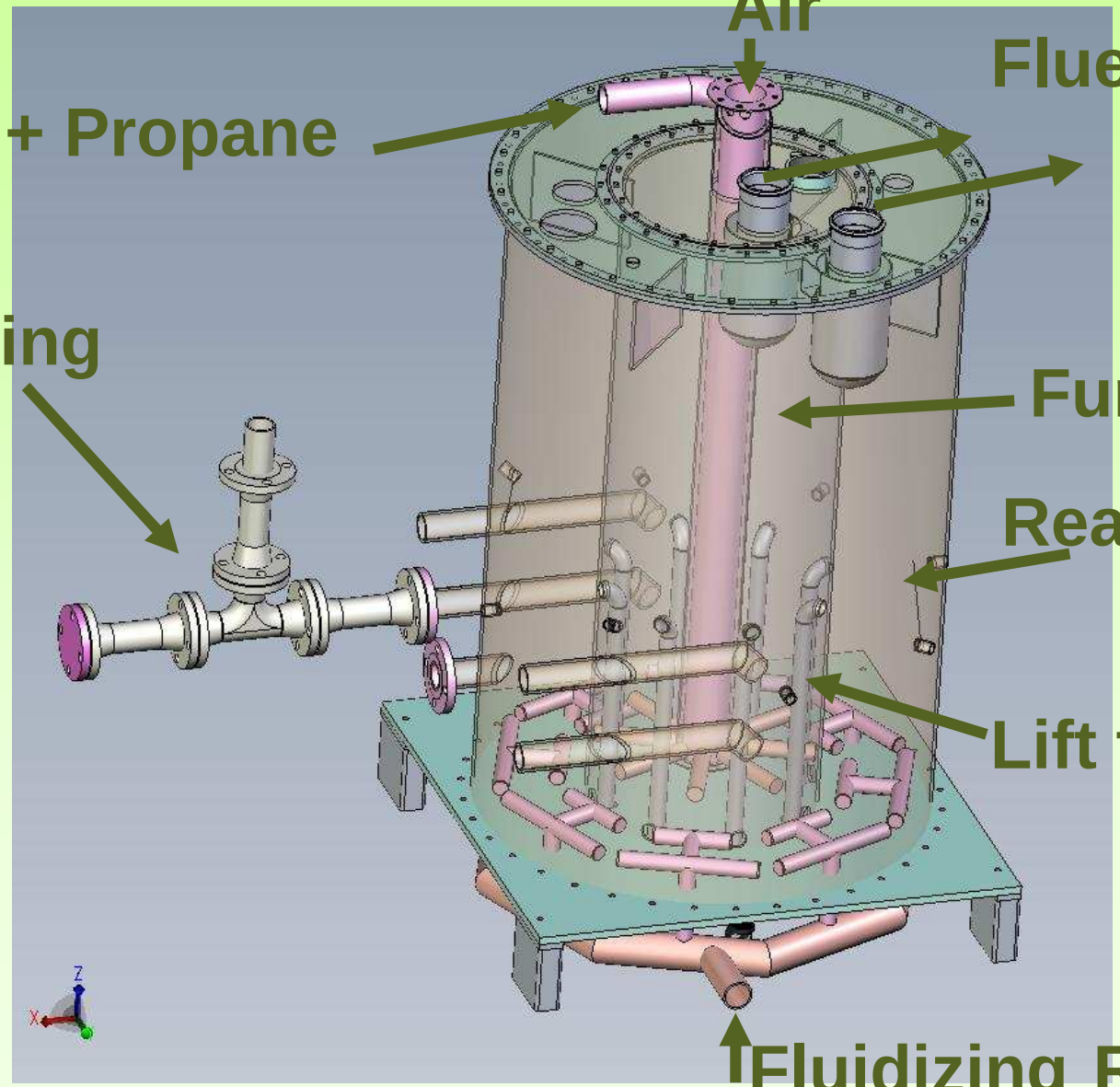


New patented technology

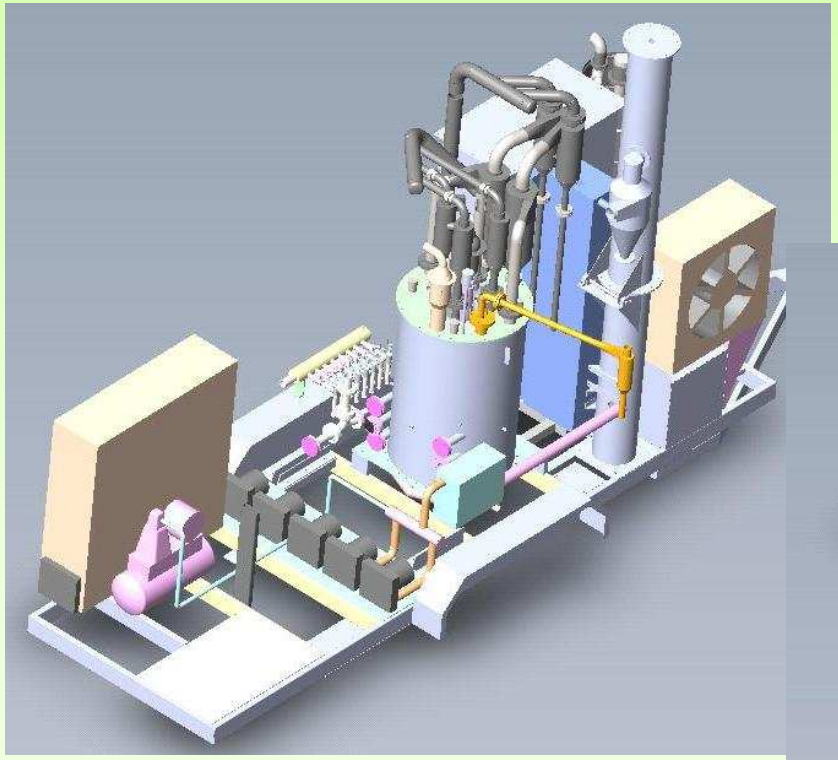


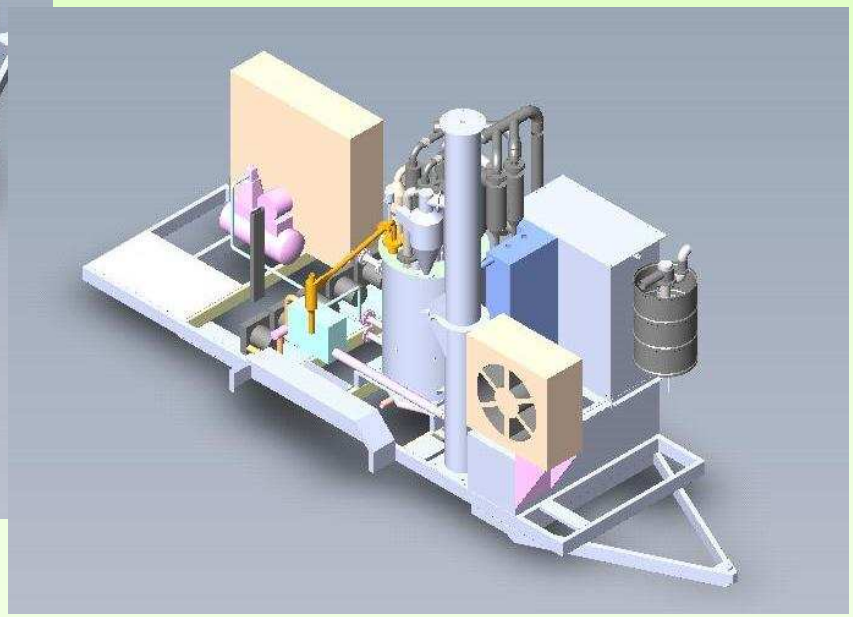
- Fluidized beds of sand
- Annulus for pyrolysis
- Central furnace for combustion of gases
  - Provides the energy needed for pyrolysis
  - Fuels:
    - ✓ Propane for pre-heating,
    - ✓ recycled pyrolysis gases in steady state conditions.
- Lift tubes used to increase heat transfer
  - Experiments: 16 tubes increase heat transferred by 1 order of magnitude

Plant details

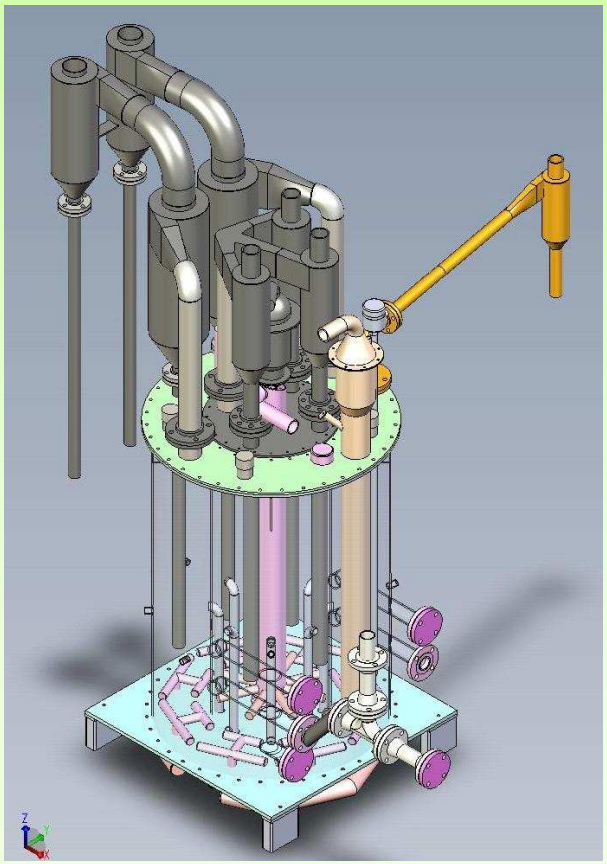


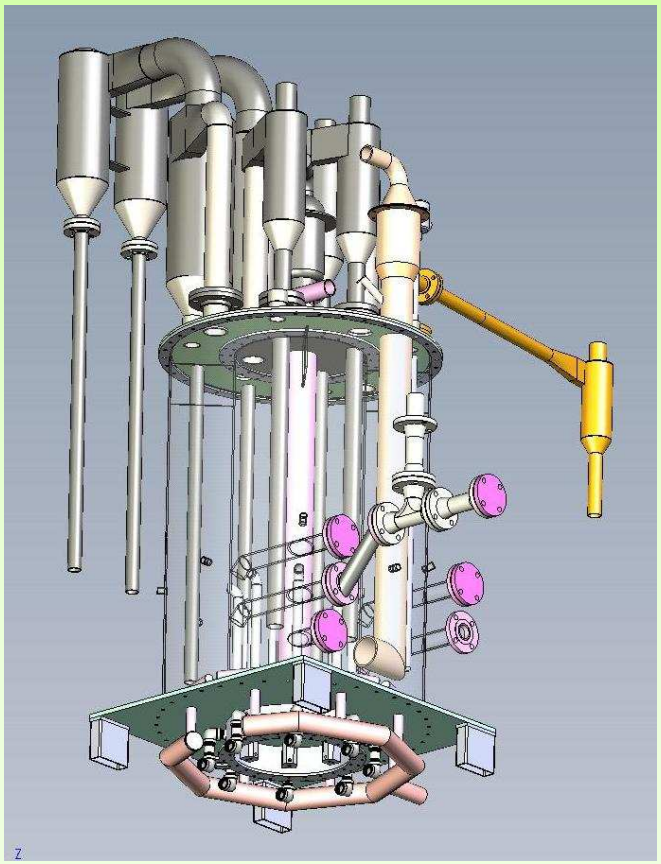
The Plant on the Trailer (8 m x 2.4 m)





The Reactor System





Opportunities

Wine Grape

Corn

Sugarcane

Forest Resources

Wine

Bio ethanol

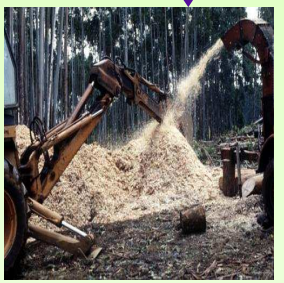
Sugarcane Juice

Pulp and Paper

Grape Skins and Seeds
12.2 million tonnes worldwide

Dried Distiller's Grains
35 million tonnes in North America

Sugarcane Field Residues and Bagasse
800 million tonnes worldwide



Forestry Residue
Several hundred million tonnes worldwide

Residues of Bio-Diesel Industry

Using biomass residues that are waste products from already existing processes

Palm tree's fruit harvested for palm oil production

Produces empty fruit bunches which are a bio-residual waste

Can be converted to a high energy bio-oil

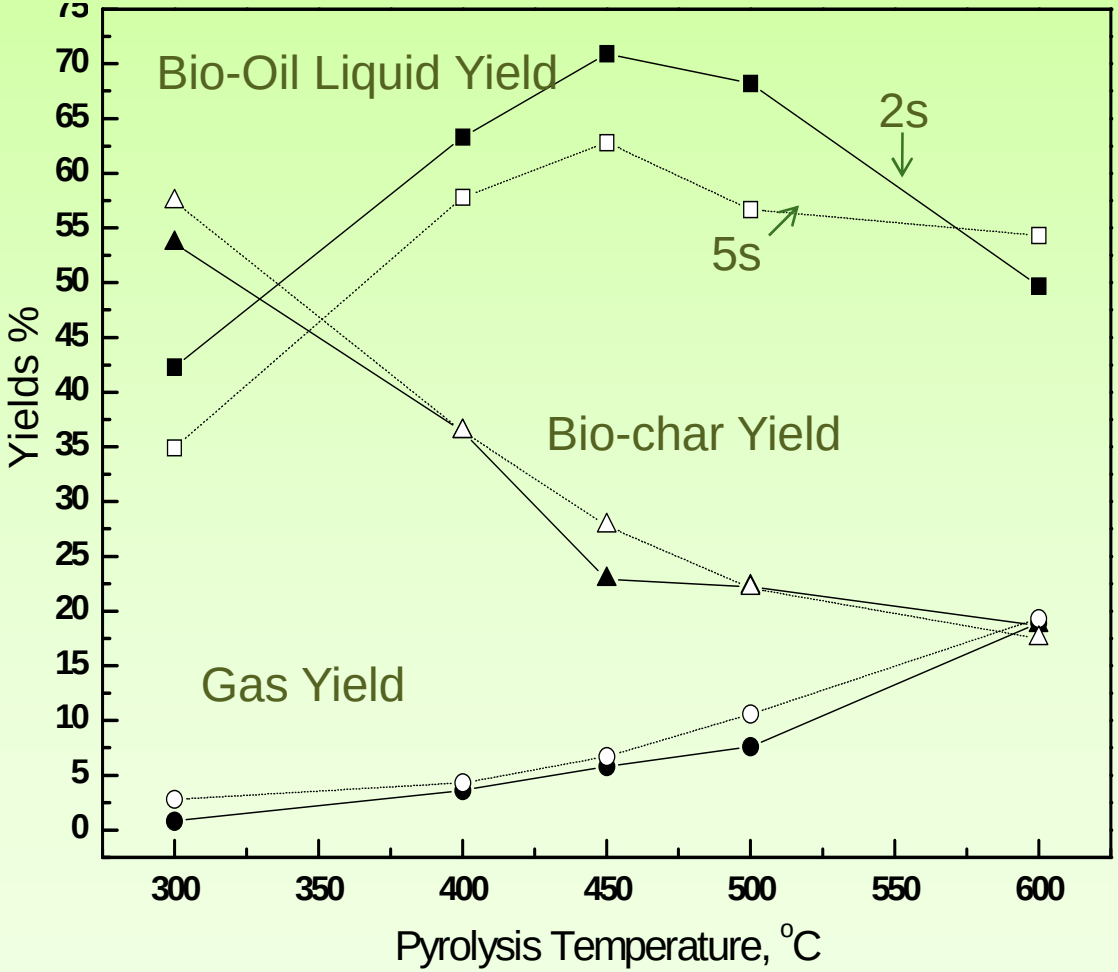
Feedstocks

- **Canada**
  - Forestry residues
  - Tobacco
  - Hemp
  - Distillers' grains & corn stover
  - Chicken litter
  - Apple pomace
  - Grape residues
  - Flax straw
  - Food waste
  - Coffee grounds
  - Wastewater treatment plant sludge
- **Rest of world**
  - Sugarcane plant and bagasse
  - Rice straw
  - Coffee husks

Experimental Results

Product Yields

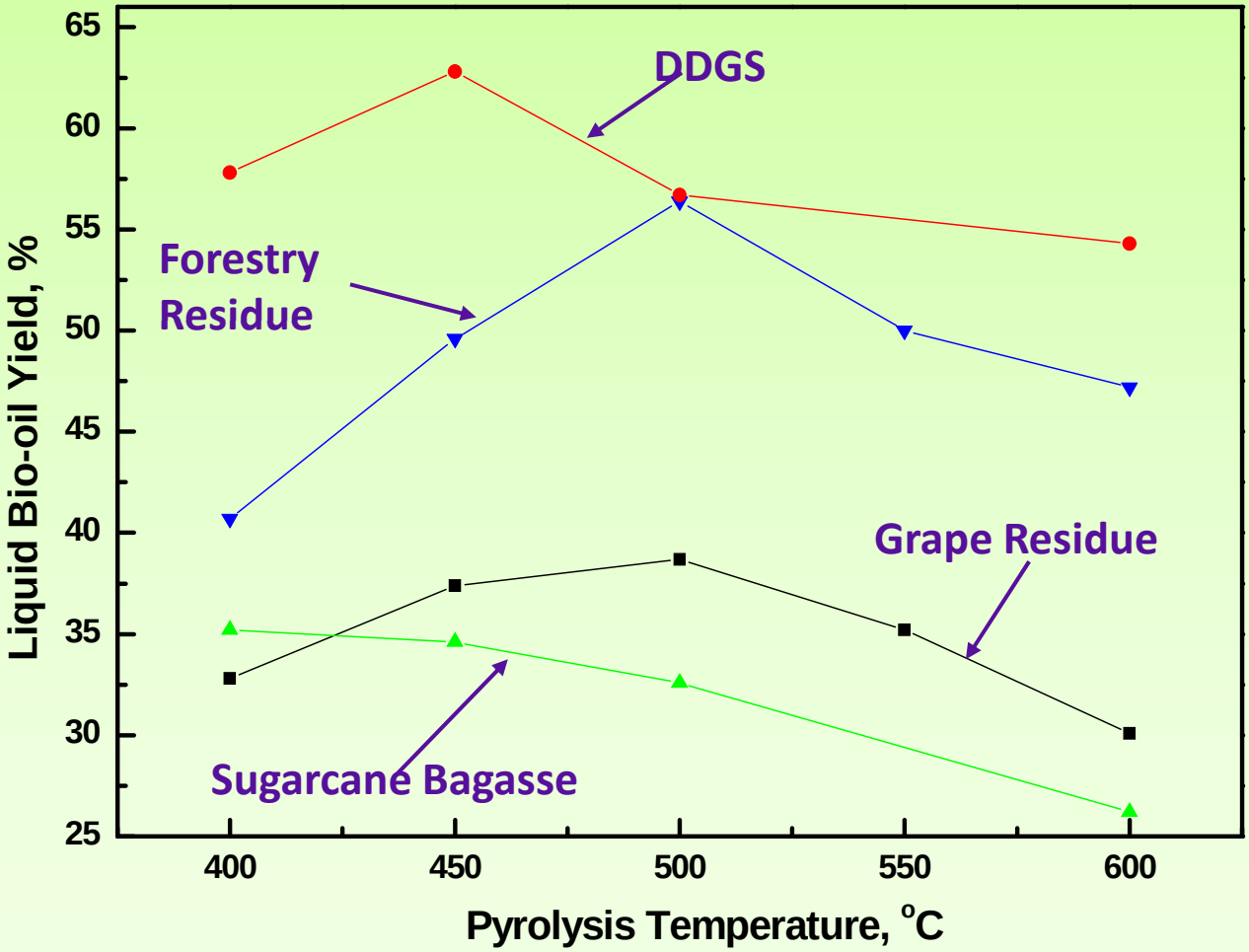
Bio-oil Yields from Dry Distillers' Grains versus Temperature at 2 different vapour residence times



Experimental Results

Product Yields: Liquid

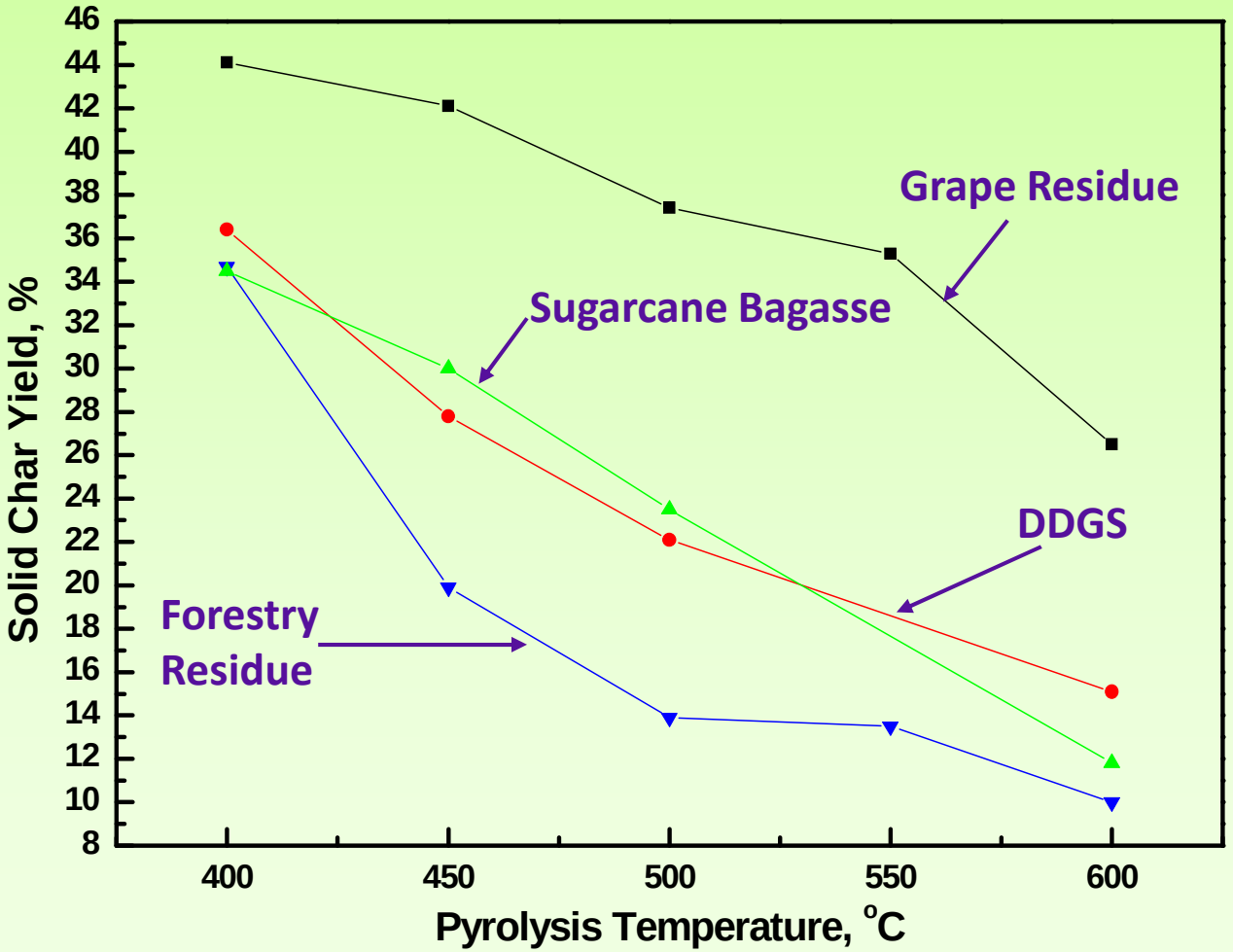
Liquid Bio-oil Yields of Different Biomass Resources
Residence Time: 5 seconds



Experimental Results

Product Yields: Solid Char

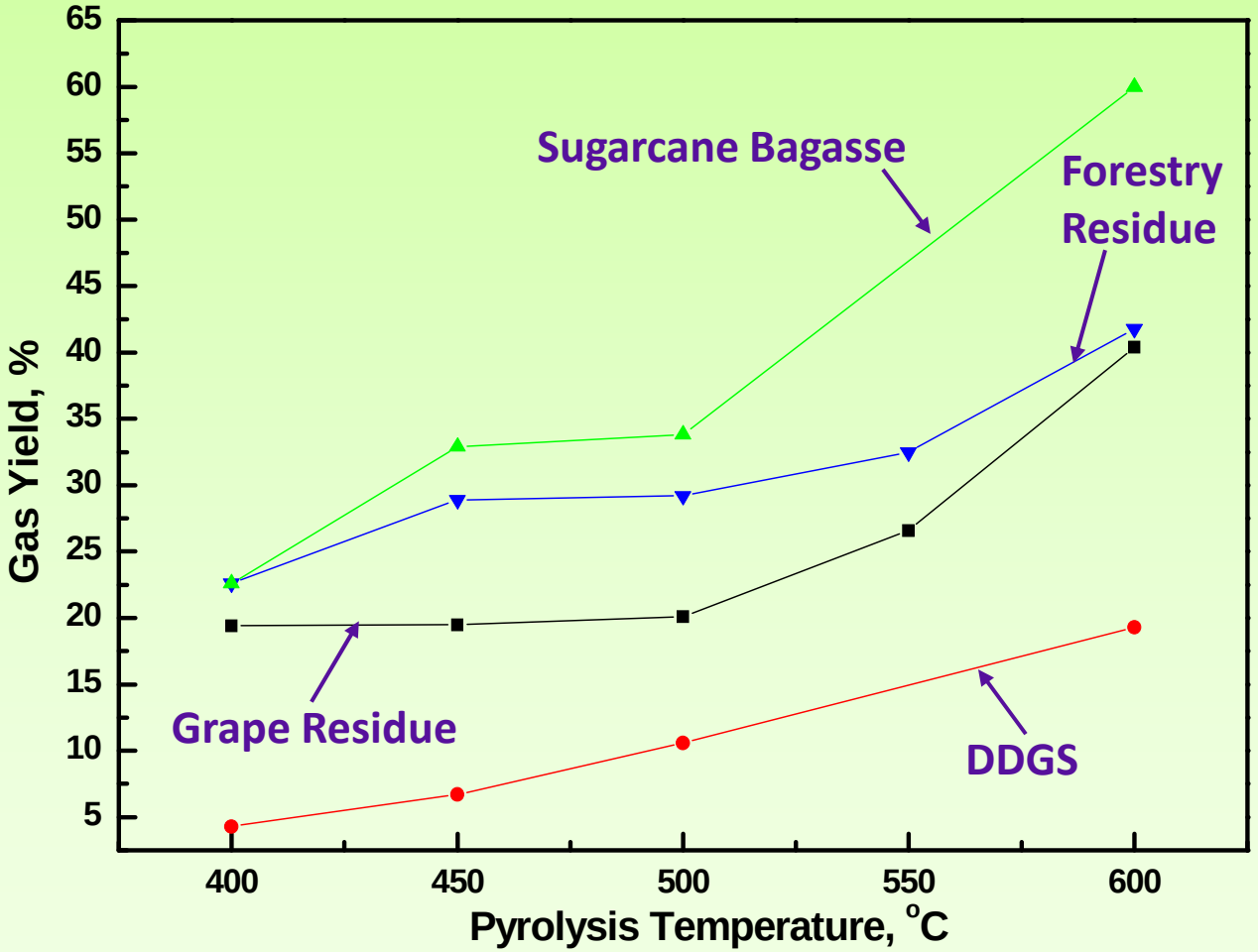
Solid Char Yields of Different Biomass Resources
Residence Time: 5 seconds



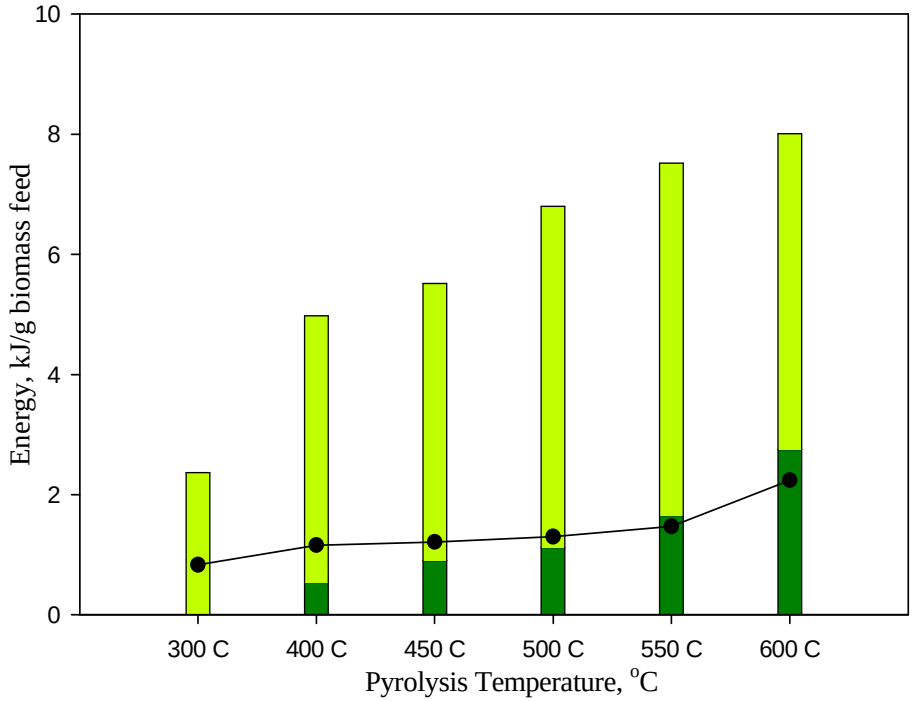
Experimental Results

Product Yields: Gases

Gas Yields of Different Biomass Resources
Residence Time: 5 seconds



Self sustainability: Lab scale testing



Grape skins, energy balance at different reactor temperatures (5s vapor residence time,1 kg/hr feed rate)
(-●-) Heat required for pyrolysis; (■) energy contained in the product gas (□) energy contained in the bio-oil

Possible uses of bio-oil

- Pharmaceuticals and Nutraceuticals
- Food Additives
- Chemicals
- Pesticides
- Fuel

Valuable biochemicals in bio-oil

Chemical	From
Smoke flavor	Wood
Browning agents	Sucrose, cellulose
Paclitaxel (taxol)	Yew, bark, twigs, needles
Betulin	Birch bark
Maltol	Larch bark, Pine and balsam fir needles
Quinine	Calisaya bark
Salicylic acid	Sweet birch bark
Nicotine	Tobacco leaves
Caffeine	Coffee waste

Many more chemicals will be identified in the future

Bio-oils produced by

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Colorado potato beetles

Tobacco waste

Both nicotinic and non-nicotinic fractions are effective

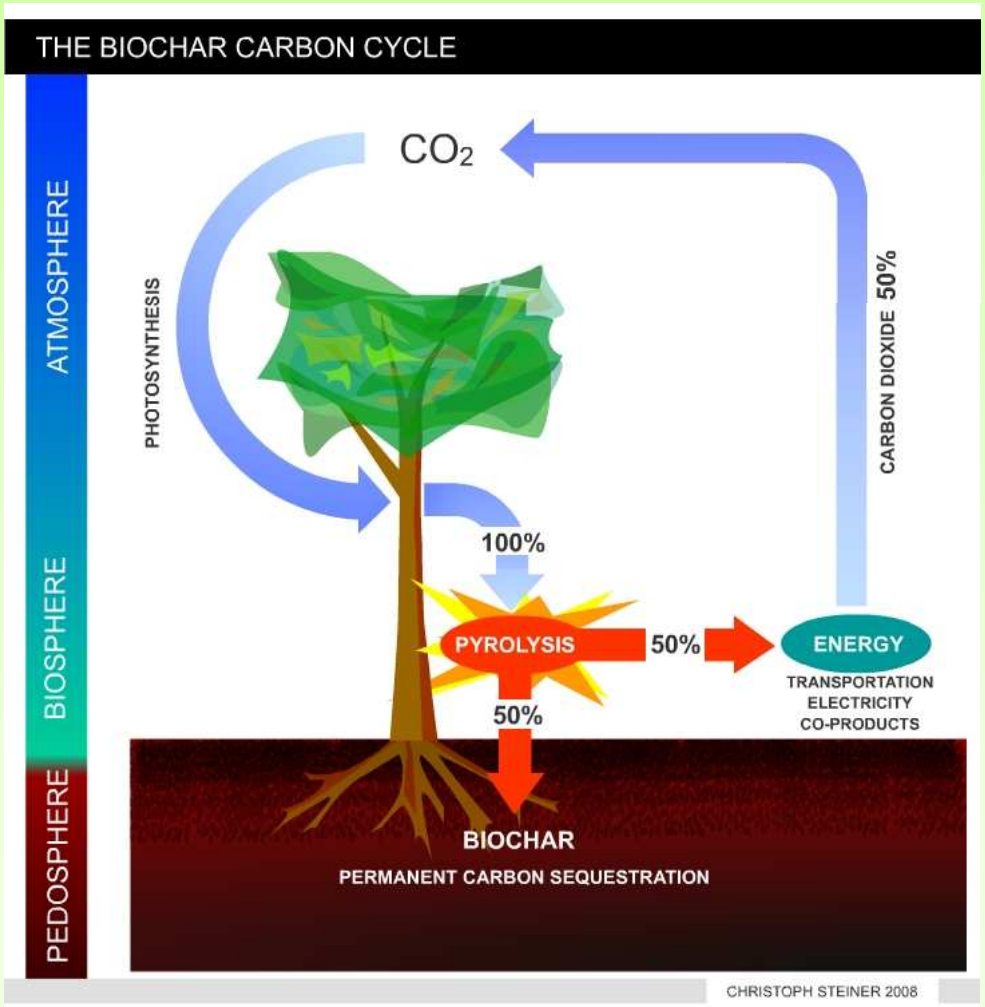
Control

Coffee grounds

Fuel

- Research on making bio-oil compatible with oil refinery streams:
  - Catalytic hydrogenation to remove oxygen
    - Suitable catalyst?
    - If hydrogen comes from natural gas, nearly 50% of the energy content of the upgraded bio-oil will come from a fossil fuel
    - Can hydrogen be generated by reforming low value aqueous bio-oil fractions?
- Research on increasing stability and heating value and reducing acidity

..Pyrolysis as a carbon sequestration process…

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