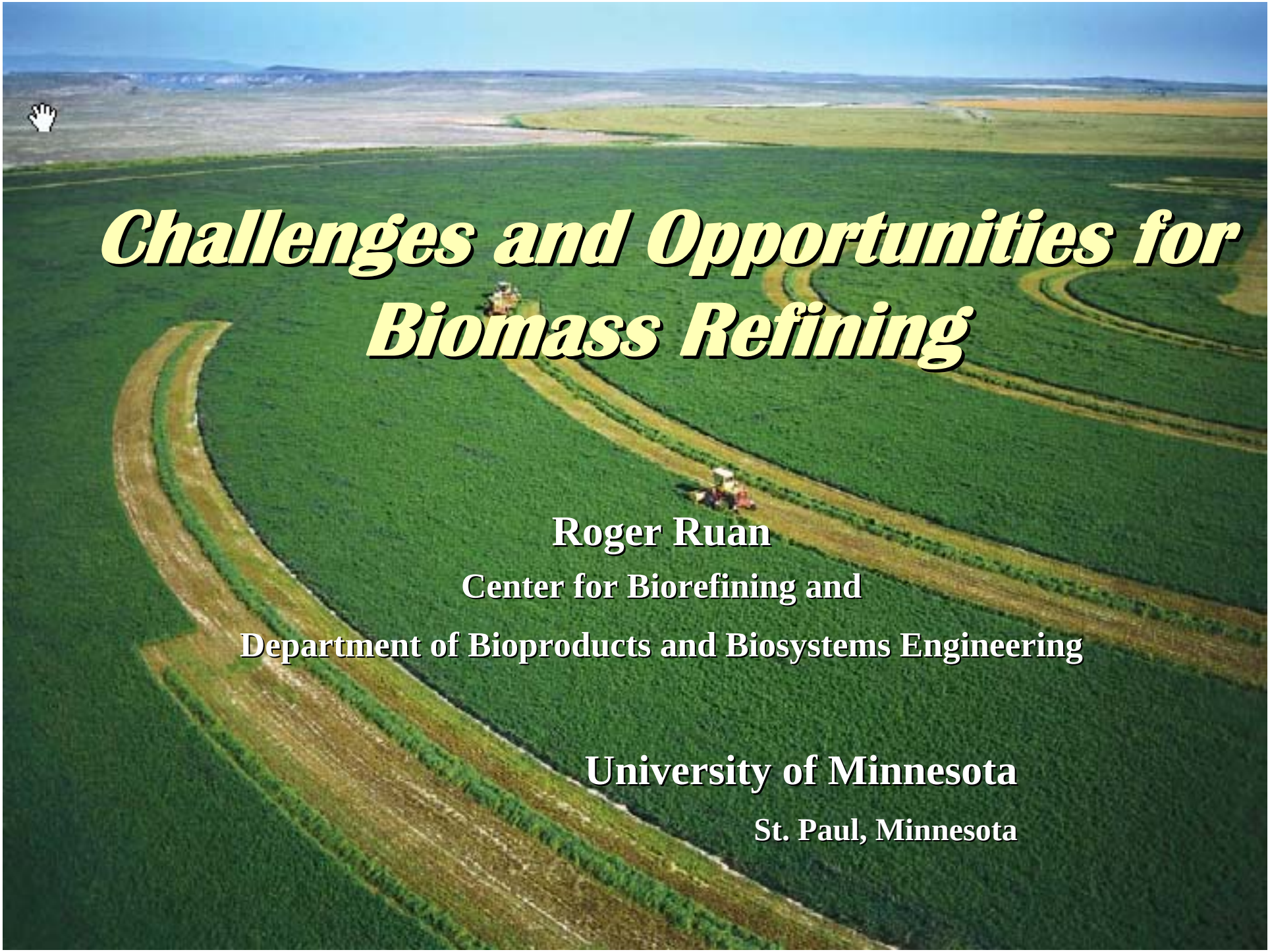
Challenges and Opportunities for Biomass Refining
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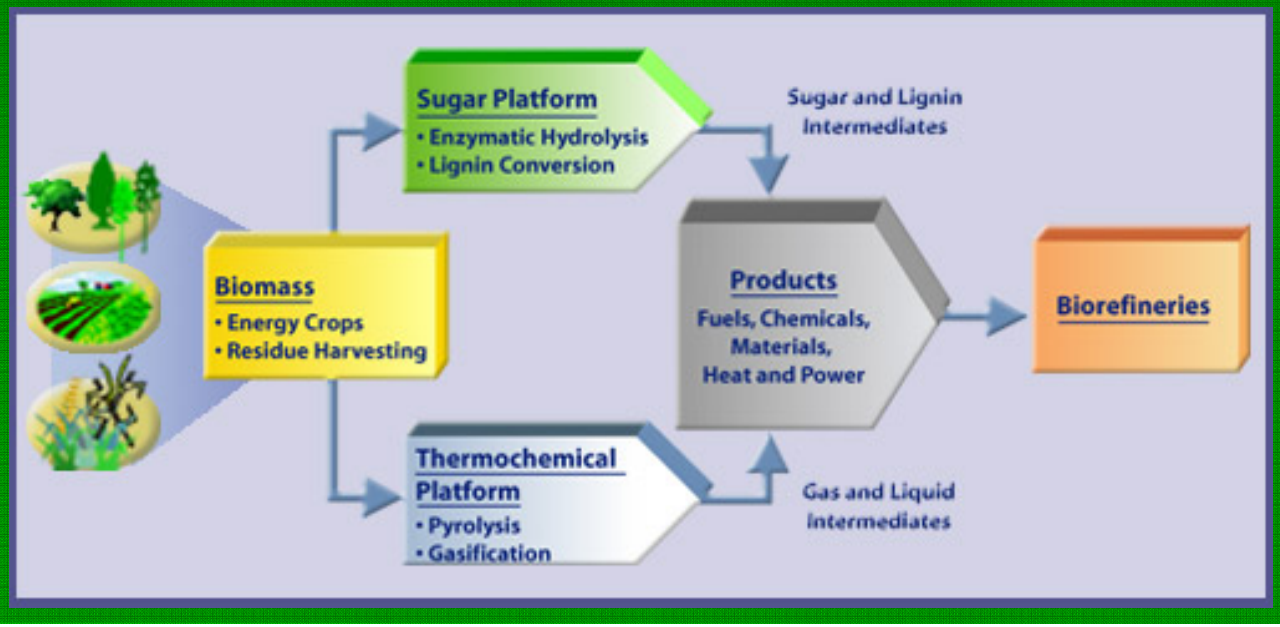
Biomass Conversion

- Two major platforms
  - Sugar platform – corn and cellulosic ethanol
  - Thermochemical platform – gasification and pyrolysis



Large Scale Processes

- High capital investment
- High operation technicality
- High feedstock transportation and storage costs
- How to overcome these barriers?

Nature of Biomass Production

- Distributed production
- Transporting bulky biomass from scattering production sites to a central processing facility has been a key barrier to biomass utilization

Biomass Delivered Cost

Facility Capacity (dry ton/day)	Delivered Cost ($/dry ton)	Hauling Distance (one-way, miles)
500	43	22
4000	52	62

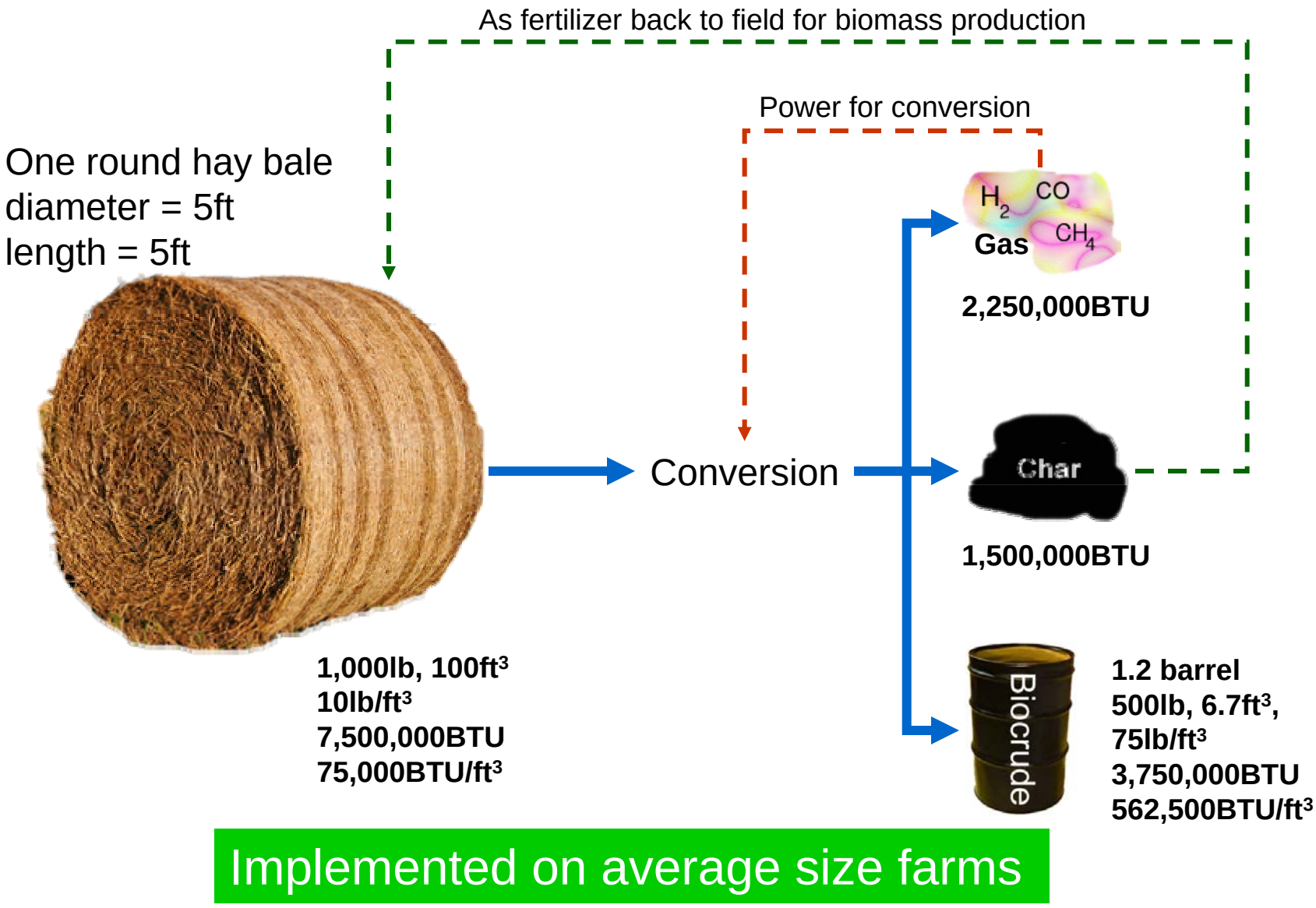
- Research has found that the financial advantage provided by large processing capacity may be offset by high delivered costs of feedstock, and suggests that biomass industry development should include smaller-scale facilities to be economically viable.

Distributed Biomass Conversion Systems (DBCS)

-

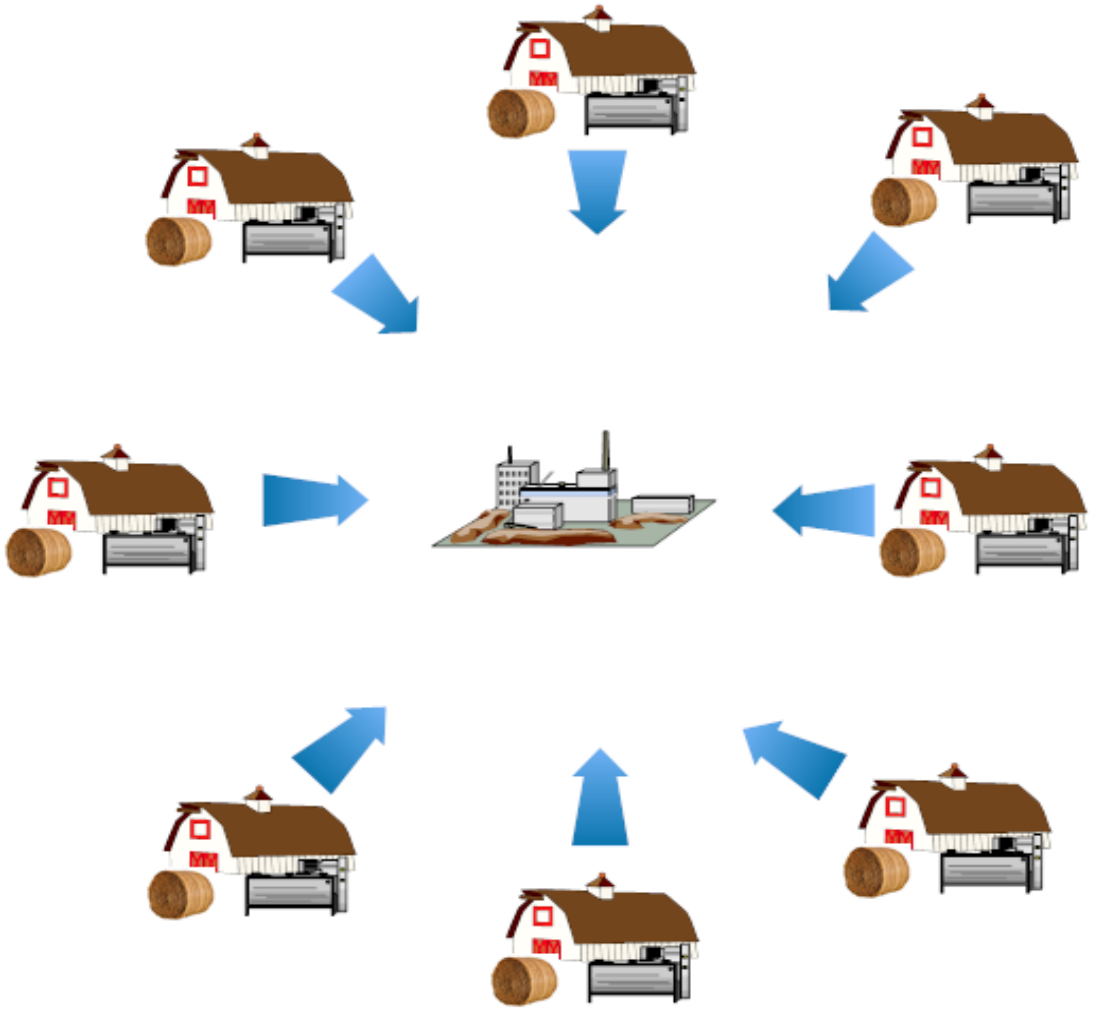
A "Smaller" Solution

Bale to Barrel DBCS



Implemented on average size farms

Distributed Biomass Processing Scheme



Benefits and Criteria for Successful DBCS

- Economic and social benefits for the rural community
- Have affordable capital cost
- Be easy to operate (turn-key) technology

Choose DBCS Technologies

- Cellulosic ethanol
- Gasification
- Pyrolysis
- Total liquefaction

Cellulosic Ethanol

- Cellulosic ethanol plants: 40-50 million gallons/year (~2,000 tons biomass per day), $300 million, technical and management challenges
- Furthermore, compared with corn ethanol production, additional processing costs are needed to convert cellulosic feedstock to fermentable sugars, which would raise feedstock-associated costs to as high as 70–80% of the final product cost.

Gasification

- Gasification plants: 100 tons biomass per day, $5.6 million, challenge bio-oil cleanup (Ensyn Technologies, Inc., DynaMotive Energy Systems Corp., and Renewable Oil International)
- Large biomass feedstock and user base required
- Small gasifiers have better potentials but not without challenges

Issues with Gasification

- Biomass uniformity for certain gasifiers
  - Ground and uniform
- Need to be equipped with gas cleanup facility
  - Particulate Formation
  - Tar Formation
- Unused syngas produced
  - Hard to transport
  - Fermentation is far from practical at this point
  - Syngas reforming

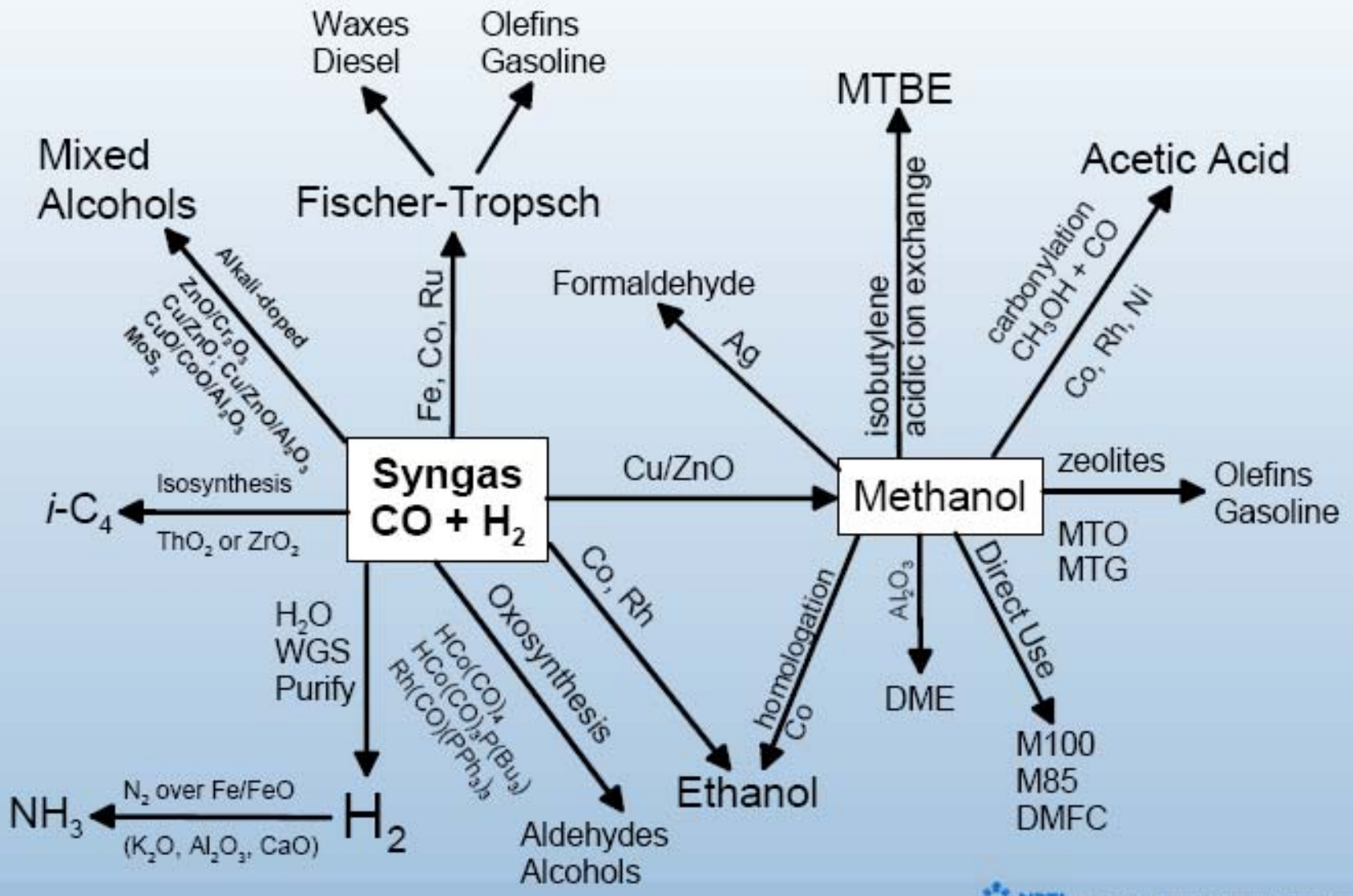
NTP-Assisted Catalytic Reforming

- Catalytic reforming has become a useful way to produce biofuels and other chemicals
- Conventional catalytic reforming usually requires high temperature and high pressure
- Catalysts can perform well at low temperature and pressure with assistance of Non-thermal Plasma (NTP).

Ionizations of Nitrogen and Hydrogen with NTP-Assisted Catalysis

- $N_2 \rightarrow 2N^+$
- $H_2 \rightarrow 2H^+$
- $N^+ + H^+ \rightarrow NH^+$
- $NH^+ + H^+ \rightarrow NH^{2+}$
- $NH^{2+} + H^+ \rightarrow NH^{3+}$

Products from Syngas



Microwave Assisted Pyrolysis (MAP) System

Pilot Scale MAP Reactor

- 4.5 kW power
- Computer central controlled process
- 10 kg/h through-put
- Various input materials

Key components
- **Pyrolysis chamber**
- **Microwave generator**
- **Condensing column**

Pilot Scale Continuous MAP System

Challenges and Counter Measures

- Bio-oil upgrading
  - Fractionation, purification, cracking
- Product development
  - Transportation fuels
  - Heating fuel
  - Biopolymers
  - Chemicals
- Pyrolytic syngas cleanup and utilization
  - Cleanup for gas turbine
  - NTP-assisted reforming to produce fuels and chemicals
- Market development

Total Liquefaction Process

- Atmospheric or low pressure
- Low temperature
- Use cheap bio-diesel glycerol (few cents/gallon) as liquefying agent
- Total utilization of biomass
- Easy to operate

Liquefaction Apparatus

Continuous Hydrothermal Biomass Pyrolysis System

Fossil Oil Like Bio-oil

Unlimited Possibilities

- Millions of years work in hours
- Can be implemented on or near farms to convert bulky biomass to easily managed pumpable liquids for transport to refineries

Biorefining of Biooils and Liquefied Biomass

Small Distributed Biomass Energy Production Systems

Summary

- Compared with current large-scale biomass energy systems, DBCS is more technologically feasible, economically viable, and sustainable. The DBCS offers a valid near-term solution to the realistic utilization of bulky biomass, and presents substantial opportunities for greater economic benefits with the biomass energy industry, and smaller-scaled distributed processing facilities.
- The DBCS should also be particularly attractive to developing countries where funds for large-scale plants are scarce, technical management skills are lacking, and the income generated is attractive to the **rural community**.

Summary of R&D Efforts to Overcome the Barriers in Thermochemical Processes

- Biomass
  - Scalable systems which can be implemented on farms
  - Robust systems which can process multiple feedstocks
- Conversion process
  - Optimized to produce bio-oils or syngas at high yield
  - Low capital and operation costs
  - Minimum requirement for water and fossil energy
  - Clean
  - Bring income to both biomass producers and processors
- Product and market development and establishment
  - Produce transportation fuels that meet industrial standards
  - Produce high value chemicals
  - Produce thermoset polymers
  - All is done within the biorefining approach (cleanup, fractionation and purification, upgrading, cracking, reforming, fermentation. …….)
  - Develop markets

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Thank You!

Comments and Questions?

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