Developments in farm-scale pyrolysis of agricultural residues for heat, power, and fertilizer

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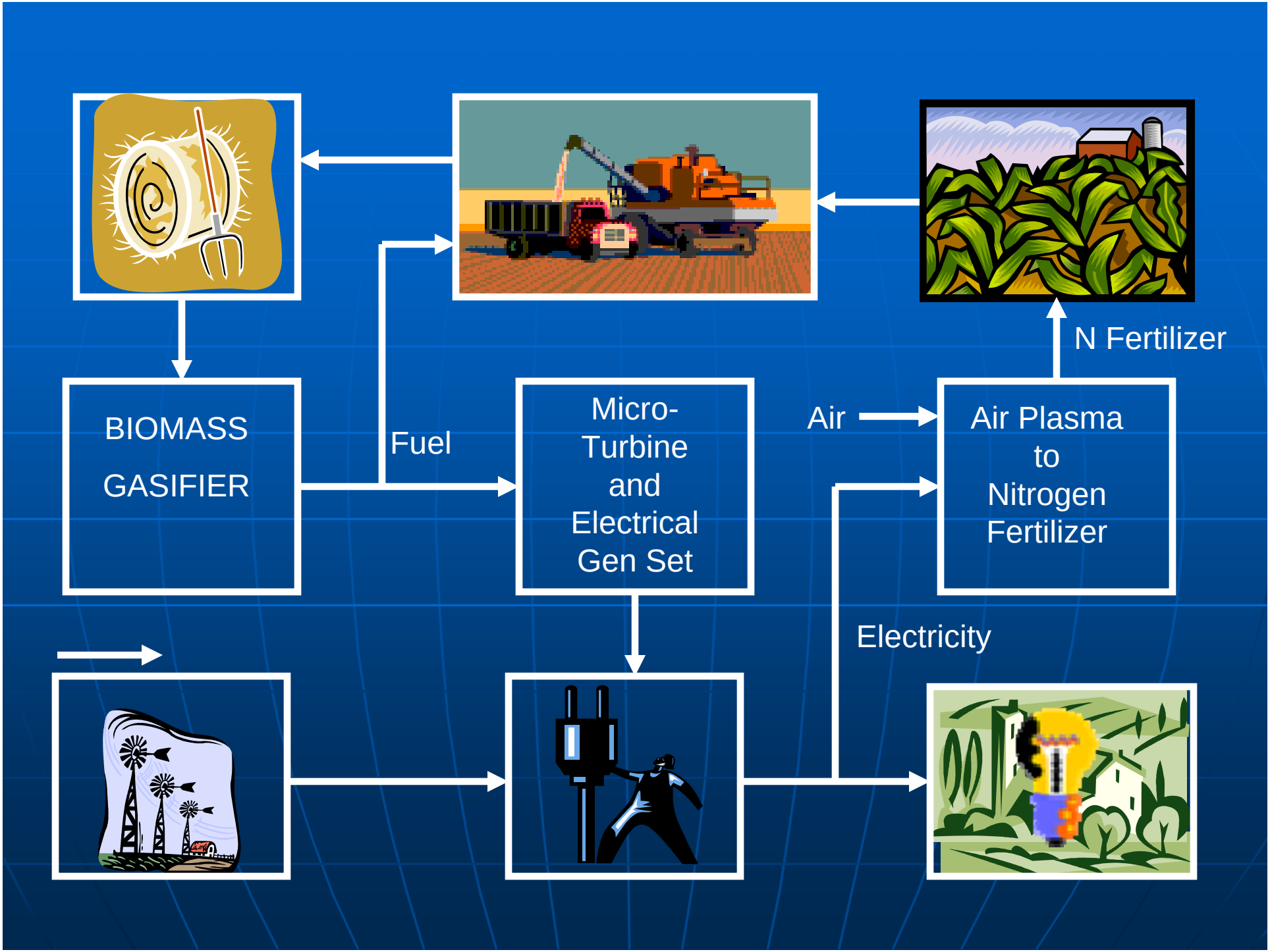
Peter J. Schubert, Ph.D.
Senior Director for Space, Energy & Education Research
Packer Engineering, Inc., Naperville, Illinois

The Problem: Agricultural Dependence on Foreign Energy

- Diesel Fuel Costs increased 400% in 5 years.
- Rural Electricity Costs up 25% in 5 years.
- Nitrogen Fertilizer up 400% in 4 years.
- Fertilizer imports now at 75% of US needs!

The Solution: Make Fertilizer, Electricity, and Fuel at The Farm

- Biomass, Wind & Sunlight as Energy Sources
- Make Power, Heat & Fertilizer
- No Transportation Costs
- Farm-ready equipment


BIOMASS
GASIFIER
Fuel
Micro-
Turbine
and
Electrical
Gen Set
Air
Air Plasma
to
Nitrogen
Fertilizer
N Fertilizer
Electricity

Farm Needs Shift

	POWER	FERTILIZER	FUEL	HEAT
Current Source	Electric utility $$$	Agribusiness $$$	Petrochemical $$$	Gas utility $$$
Alt. Source A	Biomass gasifier	Mineral ash	Hydrogen separation	Gasifier reactor
Alt. Source B	Windmill	Nitrogen arc	Biofuels	Turbine exhaust
Export potential	Sell to grid (net metering)	Sell/barter to co-op	Broker through distributors	Barns, silos, homes.

Income Shift

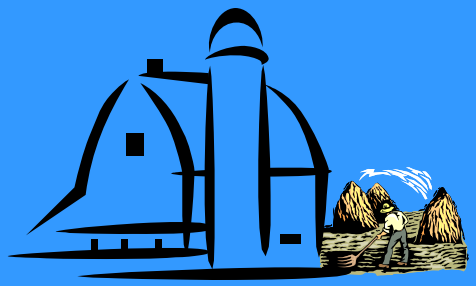
NOW

Electricity
Diesel Fuel
Ammonia
Natural Gas

PAY

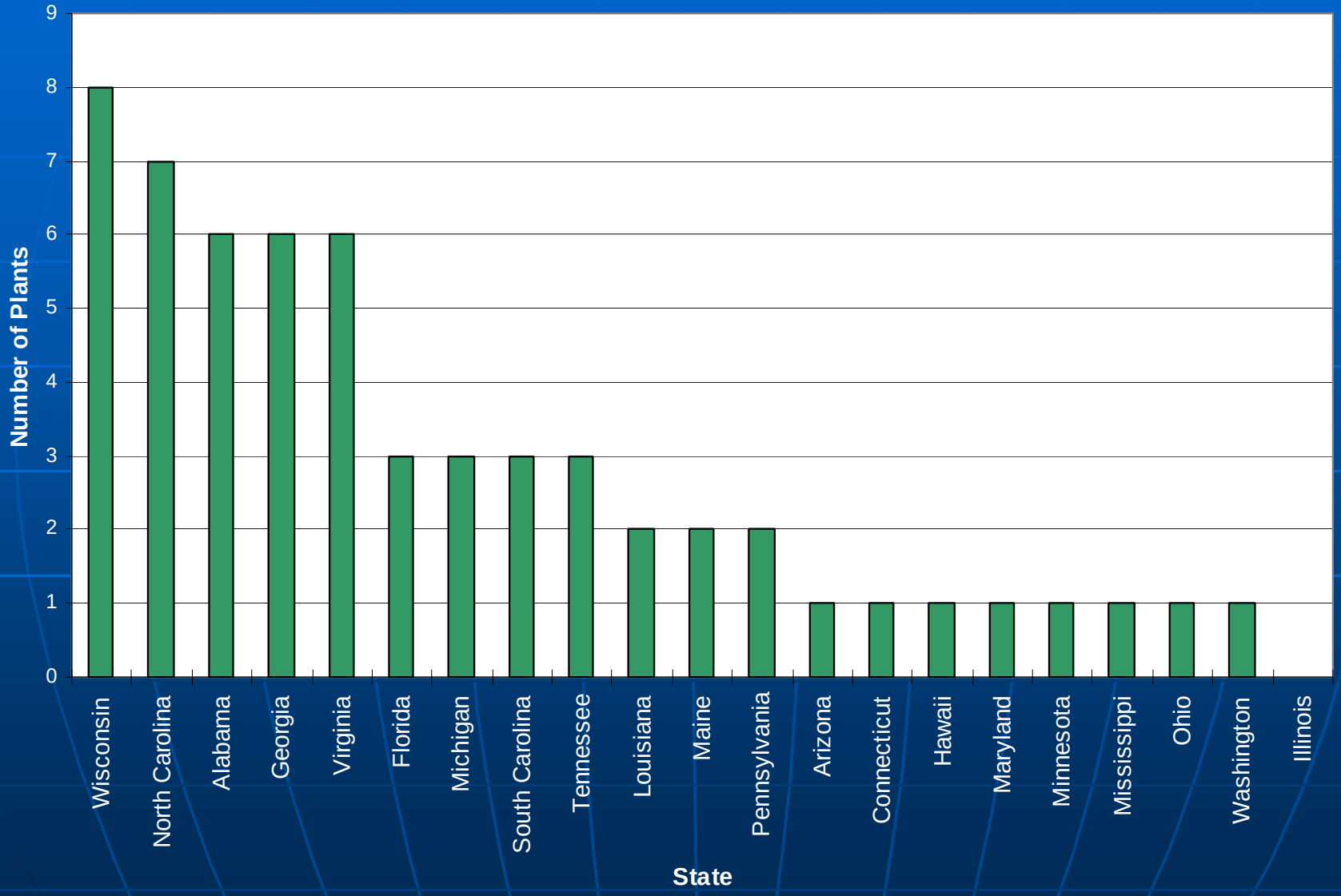
SOON

EARN



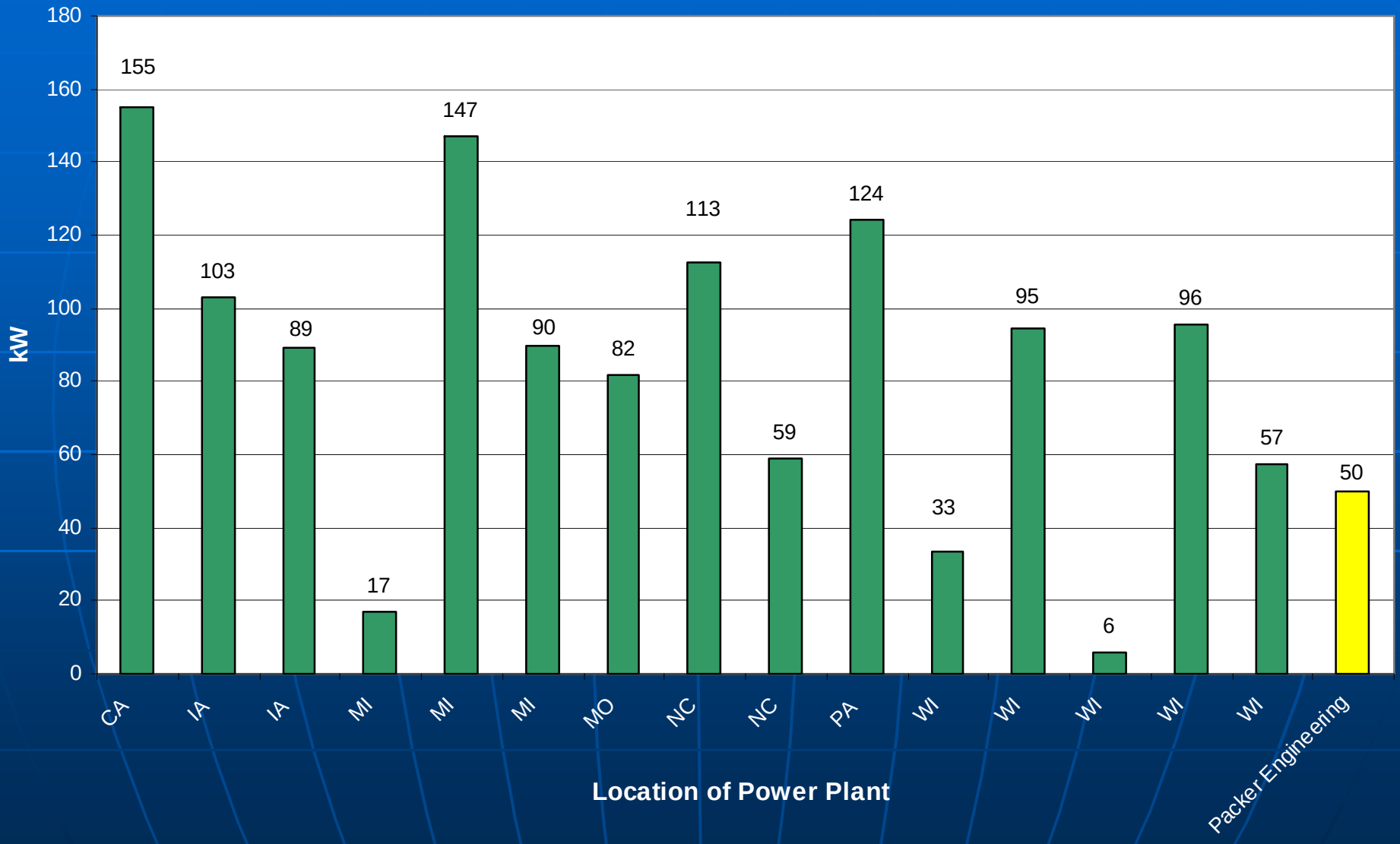
Power
Fertilizer
Biofuels
Hydrogen

Power Plants Consuming >10% Energy from Biomass (using coal and biomass)



Source: Energy Information Administration, Form EIA-860, "Annual Electric Generator Report," and Form EIA-906," Power Plant Report."

Energy Consumed from Biomass for Power Plants Consuming >5% from Biomass



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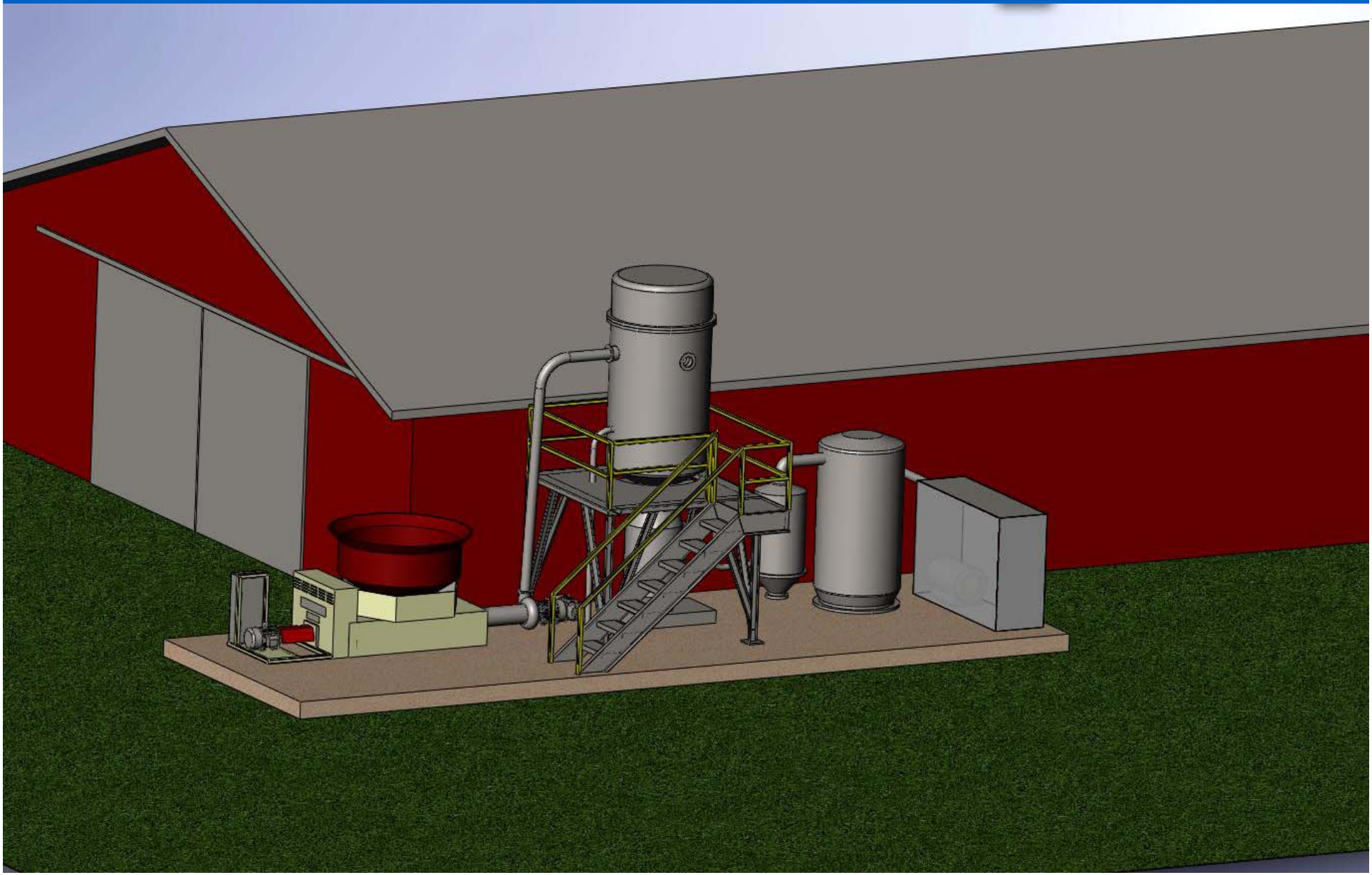
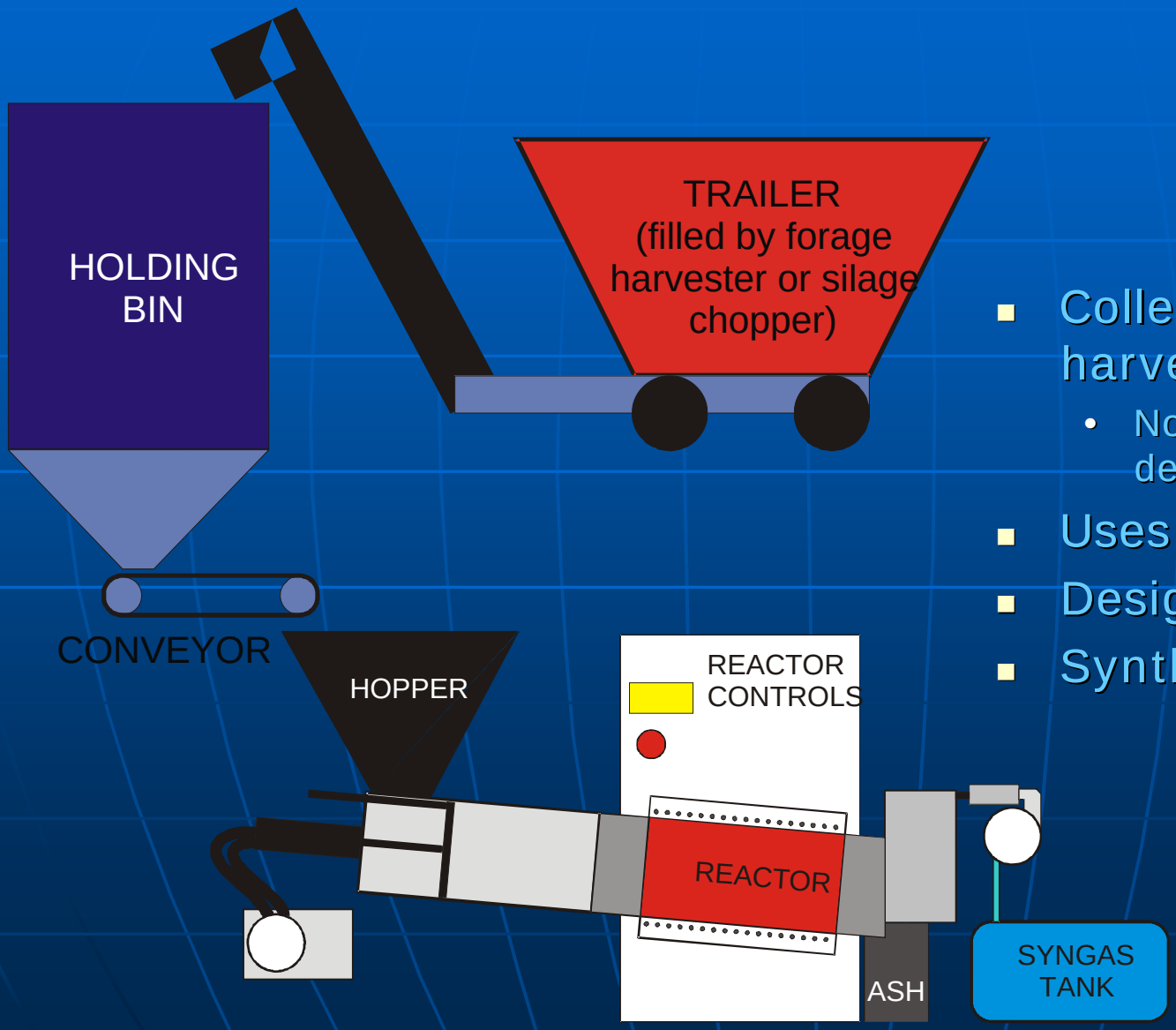
Packer Engineering Stalk Stoker



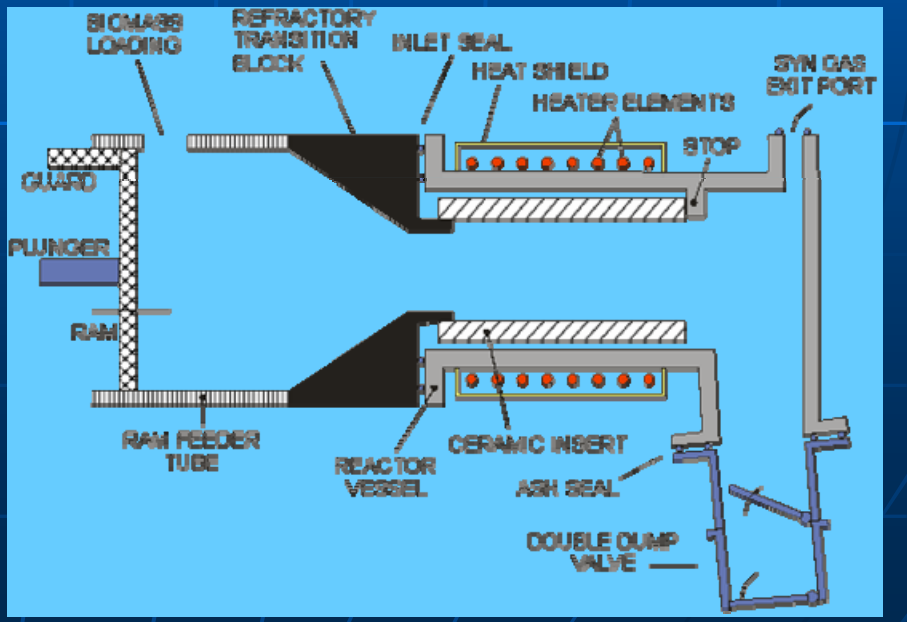
Biomass to Syngas



- Collect residue <u>after</u> harvest
  - No “Food versus Fuel” debate
- Uses existing farm tools
- Designed for farm use
- Synthesis gas out

Syngas Reactor

- Unique Approach
  - Ram-fed tube design is patent pending
  - Cost-effective even at farm-scale
- Challenging but Feasible
  - Sludge removal
  - Gas composition
- Existing Market
  - Demand for gasifiers



Syngas to Electricity

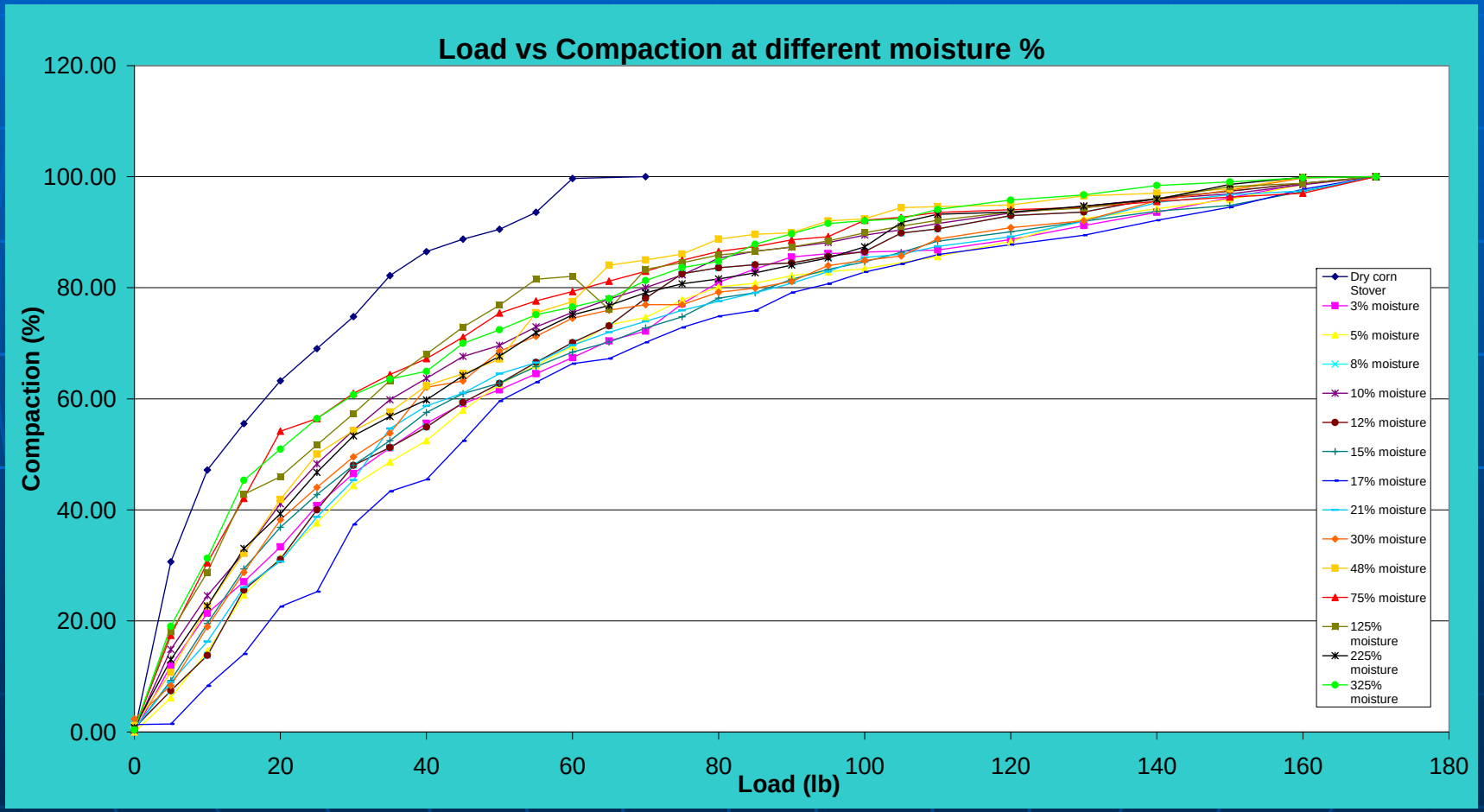
- Microturbines burn syngas directly
  - No costly, messy gas scrubbers or sorbent beds required
  - Low methane content requires modifications
- Turbine runs Generator
  - Electric power out
- Hot exhaust, too
  - Dry a grain silo
  - Heat a hog barn
  - Hot water heater

“Net metering” to Utilities

- Small systems can “net-meter”
  - Must be smaller than 40 kW
    - Enough for 15 average households
  - Obtain credit, <u>not cash</u>, for power
    - Expires each year
  - Meter cost can be significant!

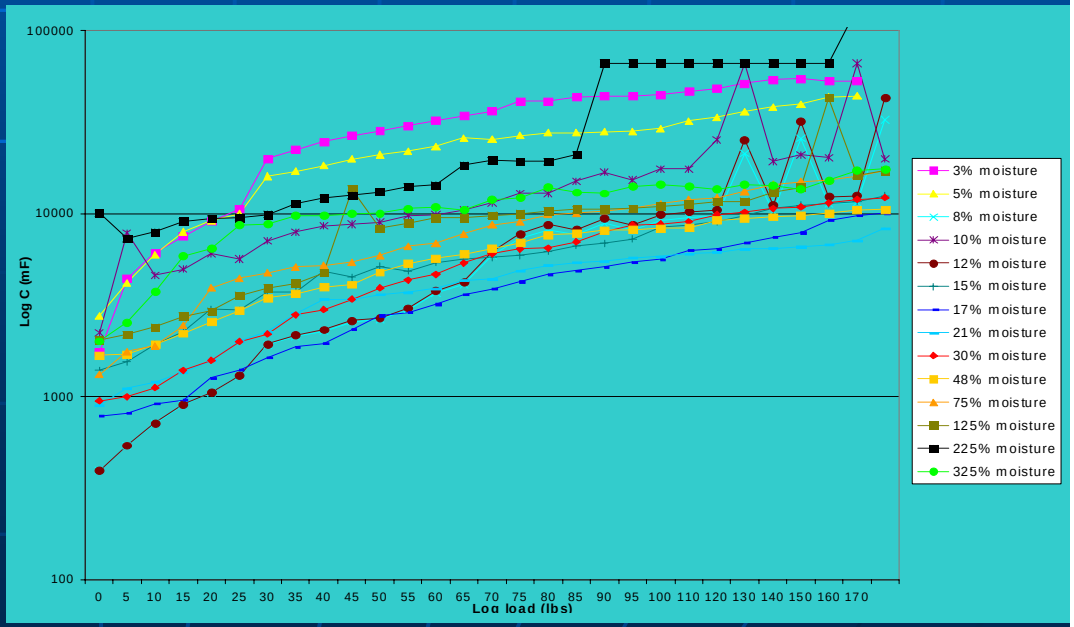
- Larger systems require safety circuits
  - Very costly, very lengthy work with power utilities

Compacting Corn Stover

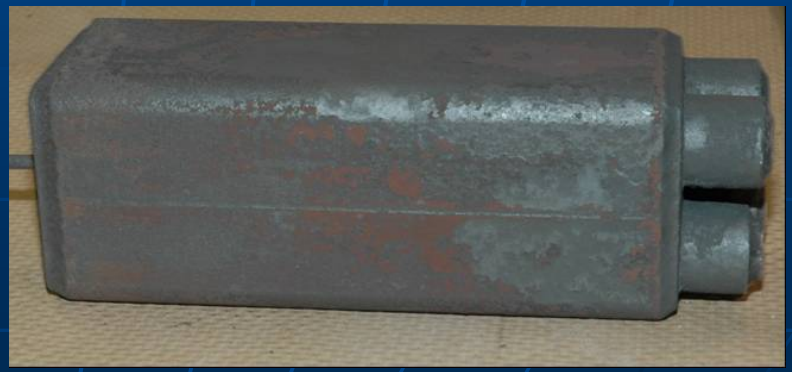


Stover Capacitance vs. Moisture

- Soggy stover dried in batches over many days for each curve
- Results scattered, non-linear across moisture content – useless!
- Hypothesis:
  - ROT!
- Start over.



Self-gas Pyrolysis Apparatus

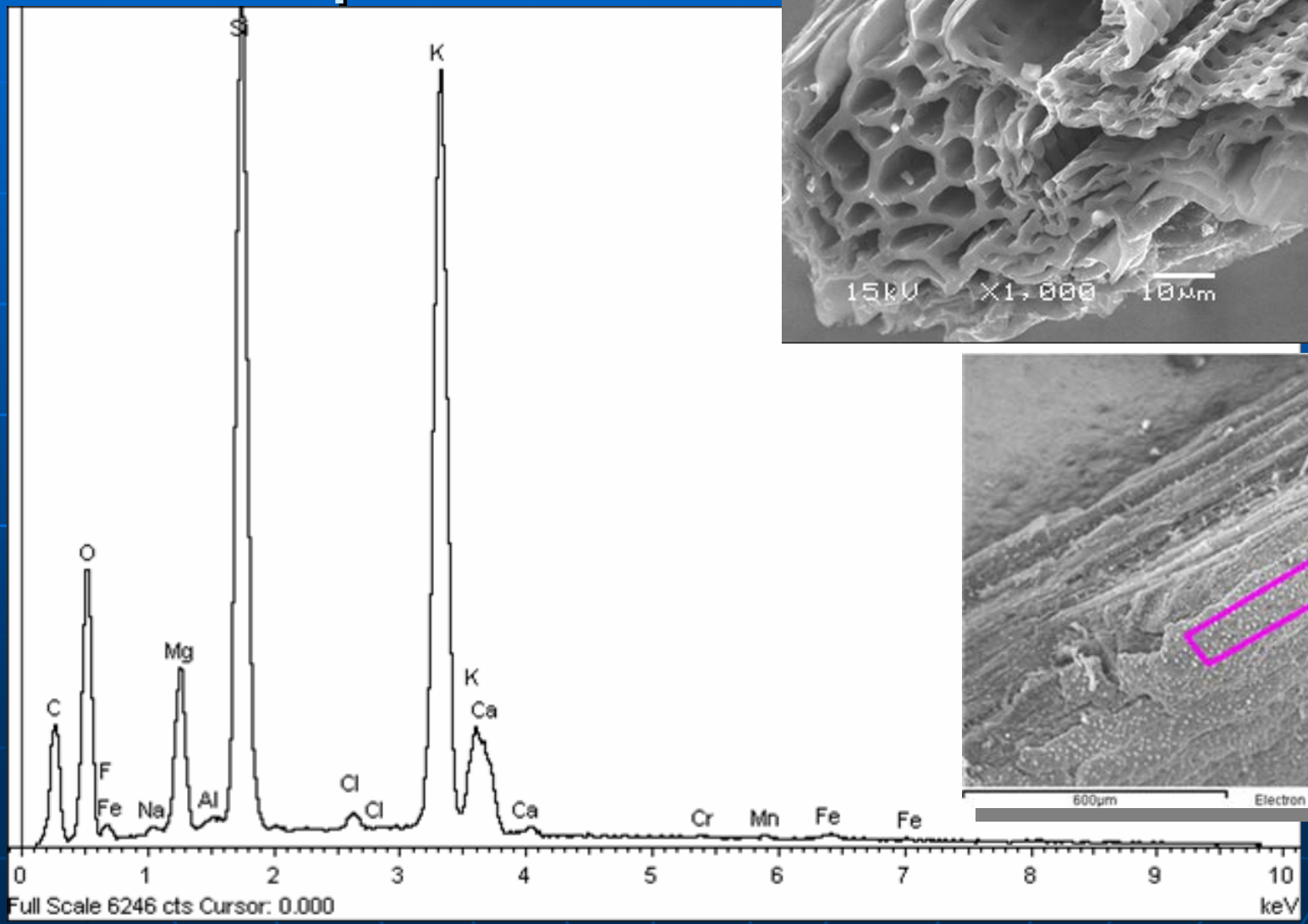


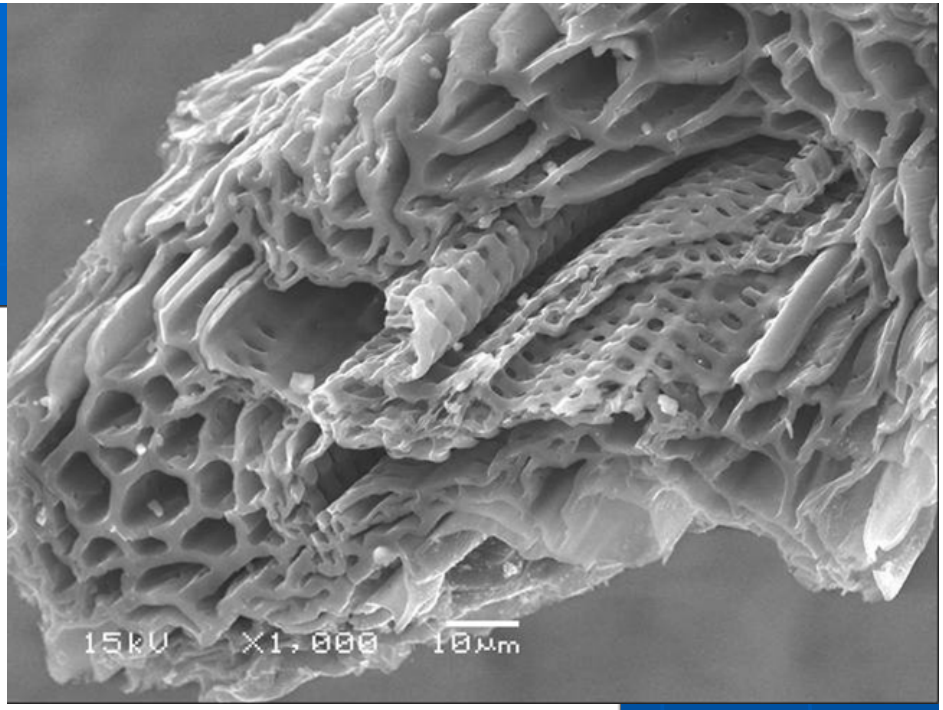
Pyrolysis Gas Composition

- Air-tight chamber evacuated with dry biomass inside.
- Heated to 1130° C
  - 15 minute dwell
- Cooled gas collected into Tedlar bag
- GC results:

Component	Mol %	Det. Limit	Weight %
Helium		0.1%	
Hydrogen	**38.1%**	0.1%	**4.17%**
Carbon Dioxide	**1.70%**	0.03%	**4.05%**
Oxygen/Argon	**1.66%**	0.03%	**2.92%**
Nitrogen	**8.84%**	0.03%	**13.4%**
Carbon Monoxide	**49.5%**	0.03%	**75.3%**
Methane	**0.129%**	0.002%	**0.112%**
Ethane	**0.006%**	0.002%	**0.011%**
Ethene	**0.006%**	0.002%	**0.009%**
Ethyne		0.002%	
Propane		0.002%	
Propene	**0.003%**	0.002%	**0.006%**
Propadiene		0.002%	
Propyne		0.002%	
i-Butane		0.002%	
n-Butane		0.002%	
1-Butene		0.002%	
i-Butene		0.002%	
trans-2-Butene		0.002%	
cis-2-Butene		0.002%	
1,3-Butadiene		0.002%	
i-Pentane		0.002%	
n-Pentane		0.002%	
neo-Pentane		0.002%	
Pentenes		0.002%	
Hexane Plus	**0.002%**	0.002%	**0.010%**
Hydrogen Sulfide		0.10%	
Carbonyl Sulfide	**N.A.**	0.000005%	**N.A.**
Total	**100.0%**		**100.0%**

Pyrolysis Ash Composition

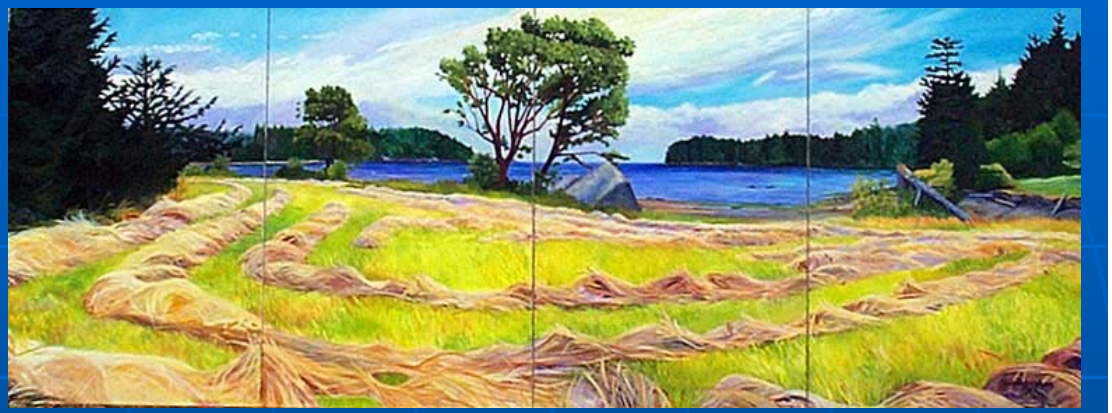




Design Hurdles

- Low Bulk Density of Corn Stover
  - 5 lb/ft^3 ---- 10 lb/ft^3
  - Particle size ---- large & fibrous
- Post harvesting processing
- Large storage requirements
- High bridging potential

Collecting Biomass



- Traditional
  - Windrow
  - Bale
  - Store, stack, or stay
- Future
  - Gather biomass from gleaner discharge
    - Material is relatively dry
    - Has little or no soil/sand
    - Collect at same rate (volume) as grains
    - Leaves plenty of organic material for humus

Baling

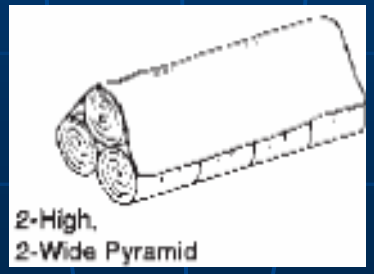
- Old-fashioned 2- and 3-string bales (man-handleable) are phasing out.
  - Used mostly for horses nowadays.

- Round bales (5’ or 6’ diameter)
  - Low bulk density

- Square bales (4’x4’x8’)
  - Higher bulk density
  - About 800-1000 lbs

Storing Biomass

- Sausages – density too low
- Silo – too expensive for biomass
- 5-sided shed – good if available
- Wrapped bales – good choice!
- Stacked & covered
  - Retrieve as-needed
  - Dry matter loss due to microbial action



Transporting Biomass

- Design focus is on-farm operations
- Grain farmers not set up to collect stover
  - “Custom farmers” are one solution
  - They bring equipment to you, process on-site.
- Animal farmers will generally have all needed equipment.
- On-farm operations avoids transport requirements for large-scale lignocellulosic biomass operations.
  - Low bulk density
  - Susceptible to weather
  - Fuel use harms overall system efficiency

Summary

- Novel gasification process promises high efficiency for economical farm-scale operation.
- Energy can be used immediately, or converted to storable/tradeable nitrogen fertilizer.

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Thank You