EERC Technology… Putting Research into Practice

Renewable Energy

Presentation to the

Energy Development and Transmission Committee

September 16, 2009

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Holy Grail of Energy Production

Zero CO_2, CO_2 Neutral, or Lower CO_2 Signature than Traditional Technologies

Clean

Domestically Produced

Low Water Consumption

Green

"Food Friendly" – Does Not Compete with Food Production – Directly or Indirectly

Needs to Be Low Cost!

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Biomass Feedstock Types

- Agricultural residues
- Wood residues
- Crop oils
- Municipal solid waste (MSW) – refuse-derived fuel (RDF) and acidified biosolids
- Energy crops: grasses and hybrid trees

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Biomass: Availability and Sustainability

Largely dependent on commodity crop prices.

- Need to stay away from commodity crops and good farmland.
- Regional competition for resources make fossil fuels cheaper.

Biomass highly susceptible to climate (and climate change).

- Precipitation
- Pests
- Land rest cycles
- Natural growing season fluctuations

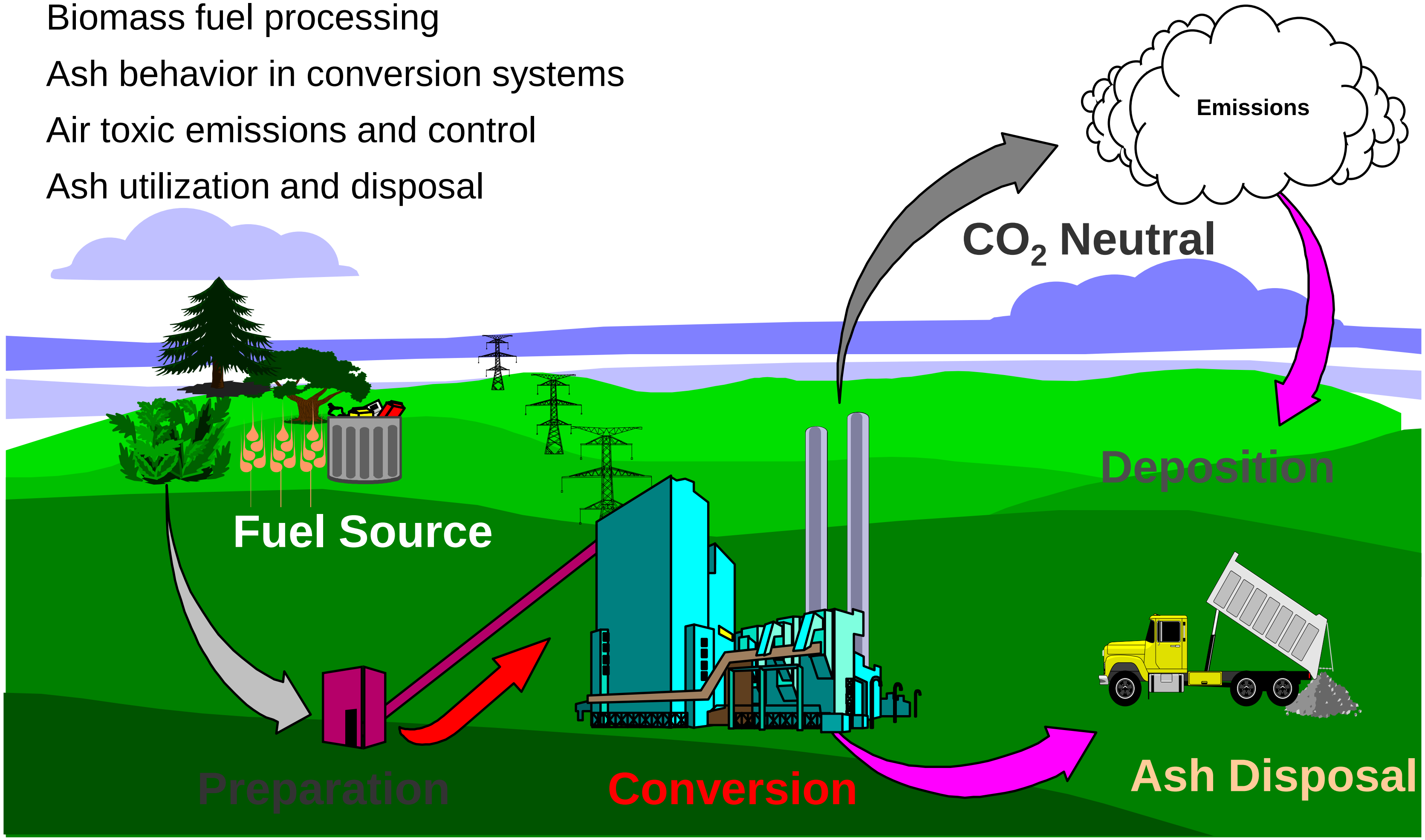
Biomass Power

Biomass Combustion/Cofiring

Biomass Gasification

Considerations for Cofiring at Industrial/Utility Power Plants

- Resource assessment and acquisition
- Biomass fuel processing
- Ash behavior in conversion systems
- Air toxic emissions and control
- Ash utilization and disposal



Incentives for Large Utility Cofiring of Biomass

There are still less than ten current significant cofiring operations in the United States.

- **Few tax incentives, no federal mandates, and weak adherence to Kyoto protocols.**
- **Utilities desire supply guarantees, low financial risk, and bottom-line profits.**

There's been a resurgence in interest in cofiring.

- **A new cap and trade or carbon tax may make biomass cofiring a cheap and easy near-term solution.**
- **Many states now have renewable portfolios for electricity that drive interest in cofiring.**
- **Consumer awareness of global warming is much higher.**

Commercially Viable Gasification Systems for Biomass Waste to Power

Feedstock Preparation

Biomass

Gasification

Syngas

Power and/or Heat Production

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Advantages of Biomass Gasification

Can use any source of biomass

- Agricultural residue
- Wood residues
- Energy crops

Produces clean fuels

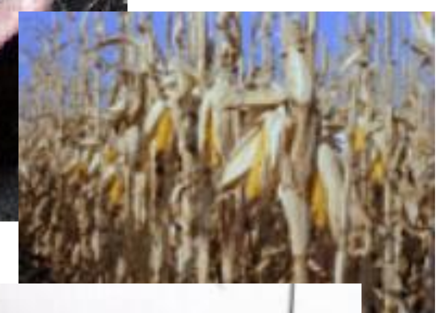
Wide variety of products

- Gasoline, jet fuel, diesel
- Chemicals
- Power

Ease of distribution

Carbon neutral

Willow grown under short rotation intensive culture



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Biomass Gasification Distributed Power Generation

Biomass Gasification

Internal Combustion Engine

3 prototype systems constructed

Delivered >20 kW_e onto grid

Eff. ~10%

Gas Turbine

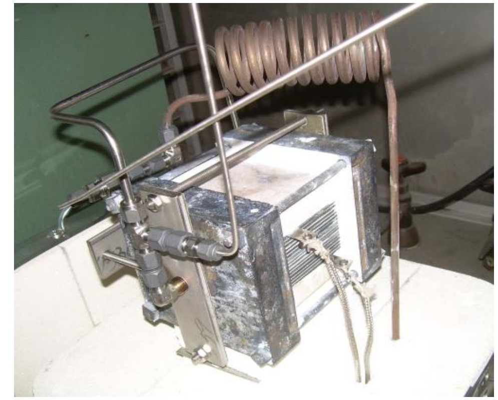
Constructing 30-kW_e system

Skid-mounted design for modular construction

Projected eff. ~20%

Designed to minimize tar issues and operating costs

Solid Oxide Fuel Cells



Demonstrated 100-watt operation from gasifier

8 hours of continuous operation

Plan to demonstrate 1000-watt operation from gasifier

Projected eff. ~35%

SOFC costs very high ~$100/watt

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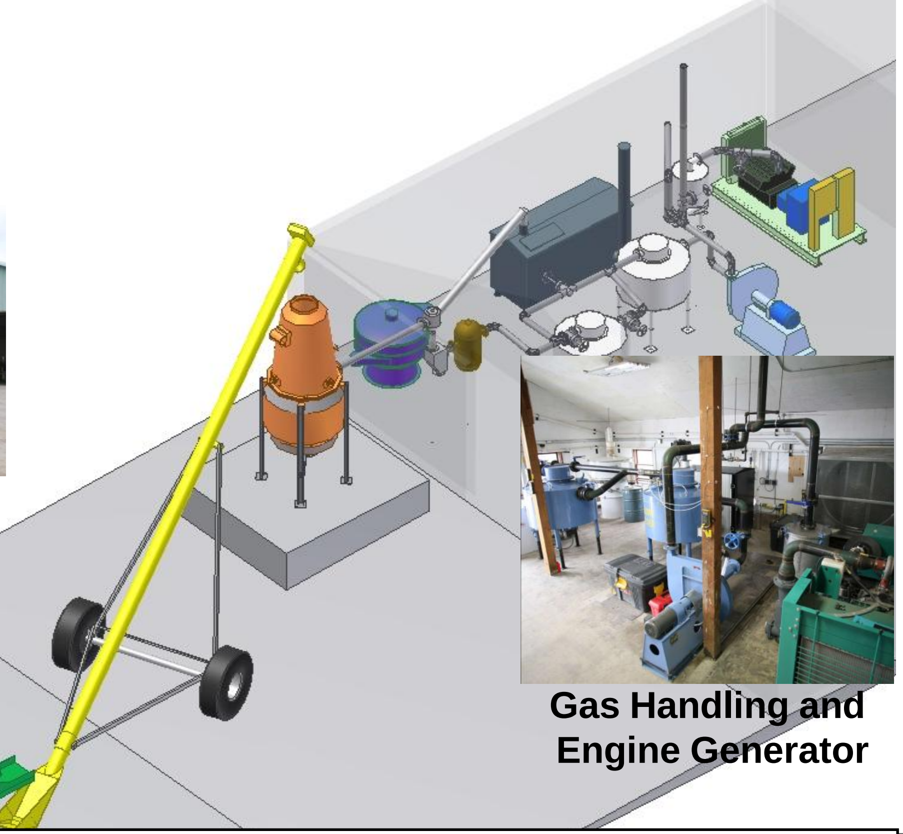
Commercial Demonstration Plant at G F Truss Inc.

50-kWe Wood-Fired Biomass Gasification Power Plant at G F Truss

Feed System and Gasifier



Gas Handling and Engine Generator

**System has run on a variety of biomass feedstocks.
It is currently tested on lignite.**

Other Milestones

Portable gasification demo (2002–2006)

Commercial demonstration (2007–2008)

Second-generation portable gasifier (2008)

Fond du Lac demo (summer 2009)

Northern Excellence demo (end of 2009)

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EERC Technology Spin-Off

Aboriginal Cogeneration Corporation – Biomass to Energy

- Aboriginal Cogeneration Corporation (ACC) is a Native corporation in Winnipeg, Manitoba, Canada, commercializing the EERC's proprietary biomass gasification technology for the production of electricity and heat.
- ACC has two 1-MW biomass gasification systems scheduled for installation in Kamloops, British Columbia, Canada, in 2010 for operation on used railroad ties.
- ACC is currently under contract with the Canadian Pacific Railroad to acquire railroad ties at the Kamloops site.
- Tri-Steel in Grand Forks has been the primary manufacturer of EERC biomass gasification systems to date.

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Biofuels

Long List of "Alternative" Fuels

Indirect coal to liquids
Direct coal to liquids
Indirect gas to liquids
Indirect biomass to liquids
Direct biomass to liquids
Ethanol and cellulosic ethanol
Hydrogen
Biodiesel
Green diesel, jet, and gasoline
Naturally synthesized fuels
Hybrid alternative fuel production
Butanol
Nitroglycerin
Liquid nitrogen
Compressed air …

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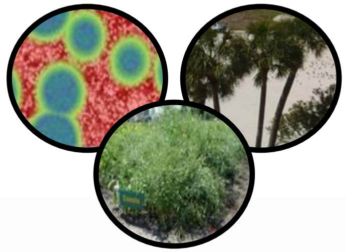
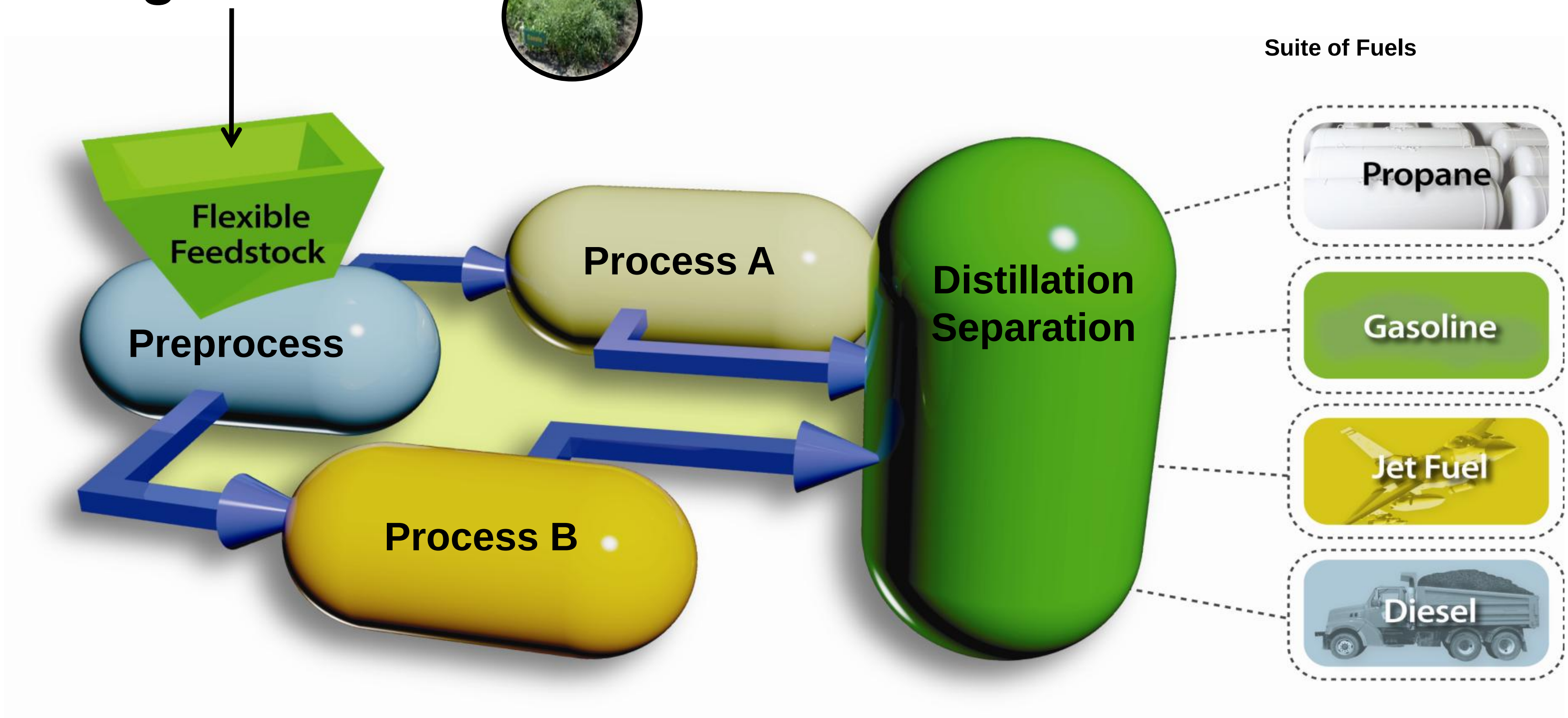
EERC Process Produces Spec-Compliant Fuel from Renewables

Crop Oils
Algae Oils





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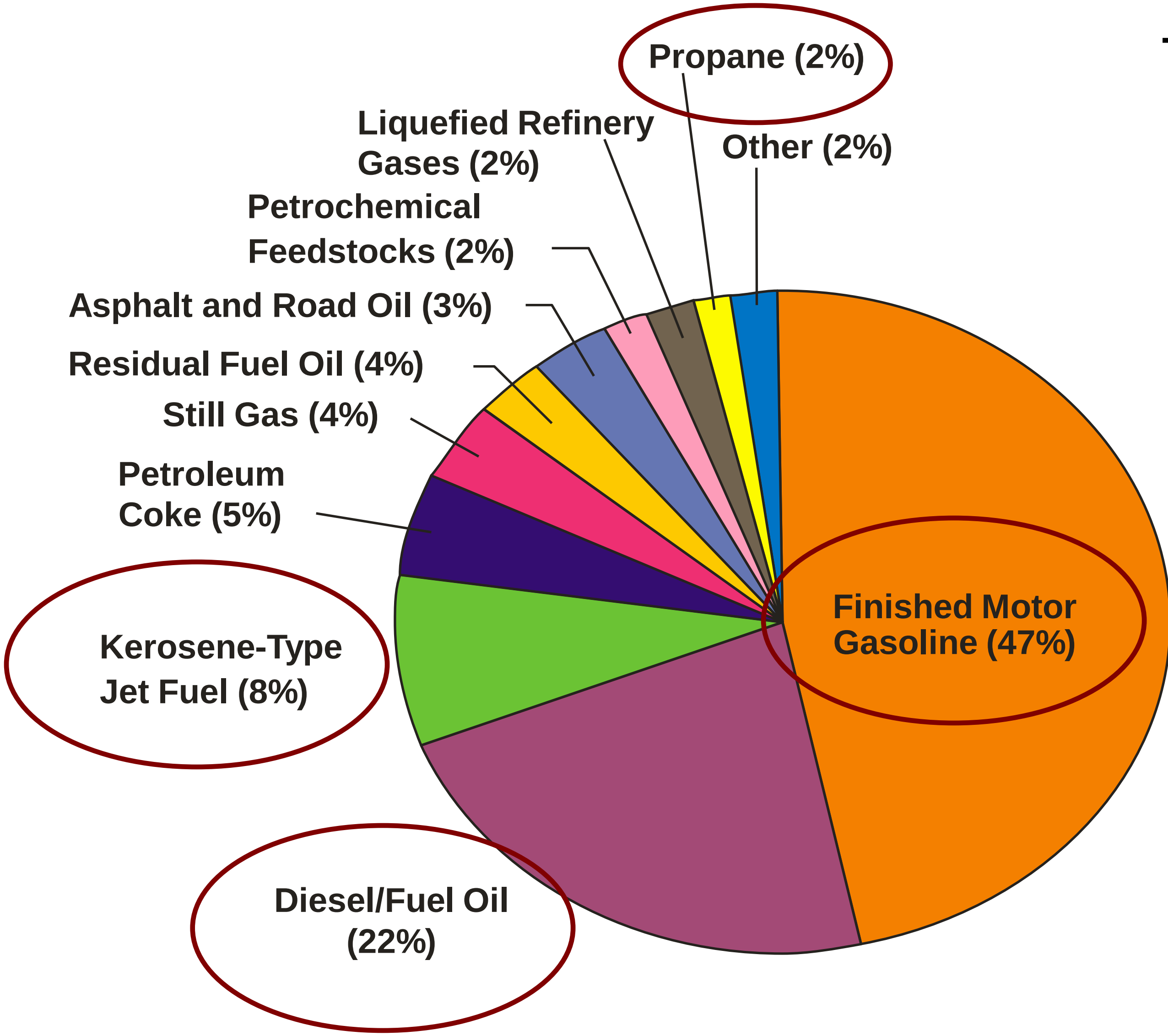
Crude Oil Disposition



The EERC process will produce at least 80% of the suite of products from crude oil.

The primary focus has been on producing 100% renewable jet fuel (JP-8) for the U.S. military (DARPA).

EERC Renewable Fuel – Status

Received $4.7 million from DARPA to produce sufficient quantities of fuel for testing by the U.S. Air Force Research Laboratory

Over 200 liters of fuel to U.S. Air Force

- Qualified as JP-8 based on seven key fuel property screening tests

Submitted bid to Defense Energy Support Center (DESC) to produce 100,000 gallons of JP-8 (jet fuel)

Designing commercial demonstration facility for collocation at Tesoro Mandan

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The Market Needs a Renewable Jet Fuel Solution

New legislative requirements for CO_2 reduction and renewable jet fuel mandate a solution that meets the stringent specifications of U.S. military JP-8 and commercial Jet-A and Jet-A1.

- In July 2008, the European Union decided to regulate aviation emissions under its carbon emission-trading scheme. It is estimated to cost the industry an additional 7 billion euros over the next decade.
- The U.S. Air Force aims to acquire 50% (325 million gallons) of its continental U.S. fuel from a nonpetroleum source by 2016.

Today's biofuels are not an alternative.

- Ethanol and biodiesel have limitations that leave sectors of the marketplace, namely, aviation, with no renewable fuel alternatives.
- In addition, existing biofuels have cold-flow, storage, and thermal stability issues that preclude their use in aviation applications.

EERC Renewable JP-8 vs. Petroleum JP-8

EERC renewable JP-8 meets key specifications – testing conducted by Wright–Patterson Air Force Base Air Force Research Laboratory.

Specification Test	EERC JP-8	JP-8 Avg	JP-8 Spec.
Aromatics, vol%	19.8	17.9	≤25.0
Olefins, vol%	1.9	0.8	≤5.0?
Specific Gravity	0.805	0.803	0.775–0.840
Flash Point, C	49	49	≥38
Freeze Point, C	−52	−51.5	≤−47
Heat of Combustion, MJ/kg	42.9	43.2	≥42.8

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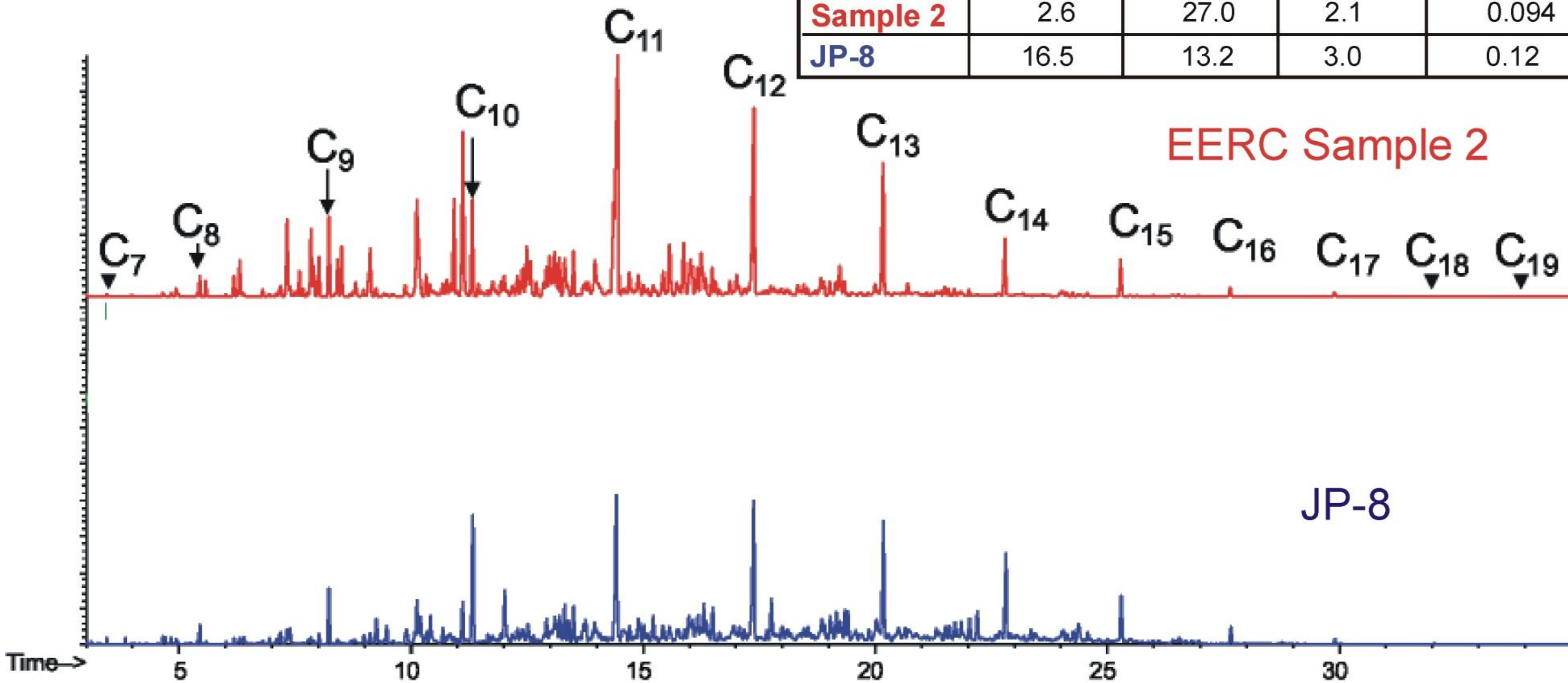
Composition Comparison – EERC JP-8 vs. Petroleum JP-8

Looks like petroleum JP8 – just a new, renewable source.

EERC TA31442.CDR

Weight % n-Paraffins				
	C_7–C_9	C_{10}–C_{13}	C_{14}–C_{16}	C_{17}–C_{19}
Sample 2	2.6	27.0	2.1	0.094
JP-8	16.5	13.2	3.0	0.12



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EERC Jet Fuel Tested in Rocket Launch

Fuel provided excellent performance

Ignition was excellent and categorized as a “Hard Start”

Very clean burn until oxygen out

Injector plates cleaner than for Jet-A

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1 Launch Injector Plates

POST FLIGHT INJECTOR BIOFUEL

POST FLIGHT INJECTOR JET A

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Liquefaction of Coal and Biomass

Feedstock

Biomass

Coal

Liquefaction Process

Indirect Liquefaction

Gasification → Syngas Production → Fischer–Tropsch Synthesis

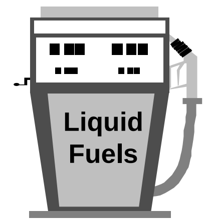
Direct Liquefaction

Direct hydrothermal processes that break down the carbon matrix

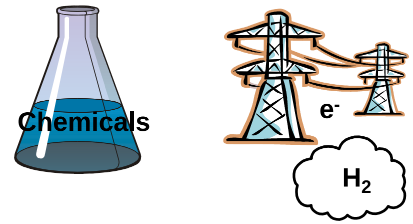
Mild Gasification or Pyrolysis

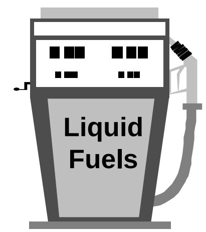
Chemical decomposition of organic materials by heating in the absence of oxygen

Production



Produces high-quality fuels and other valuable by-products





Efficient conversion process with primary products are fuels.

Liquids produced represent complex mixtures that are difficult to separate and upgrade.

Tremendous opportunity to increase North Dakota energy exports without adding transmission capacity. Includes advanced tactical fuels for the military, fuels for energy markets, and specialty chemicals.

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Liquefaction of Coal and Biomass

Indirect liquefaction is currently the only commercially available technology for producing liquid fuels from coal or biomass, cost-effective at approximately $40–$50/barrel.

The process is similar to the existing Great Plains Synfuels facility except instead of producing a synthetic natural gas, the facility would produce a liquid fuel via Fischer–Tropsch synthesis.

Future coal gasification systems could be built to produce three energy sources: electricity, liquid fuel, and hydrogen.

There are no commercial plants in the United States; however, Sasol has been doing this for many years in South Africa, and other countries are currently building facilities.

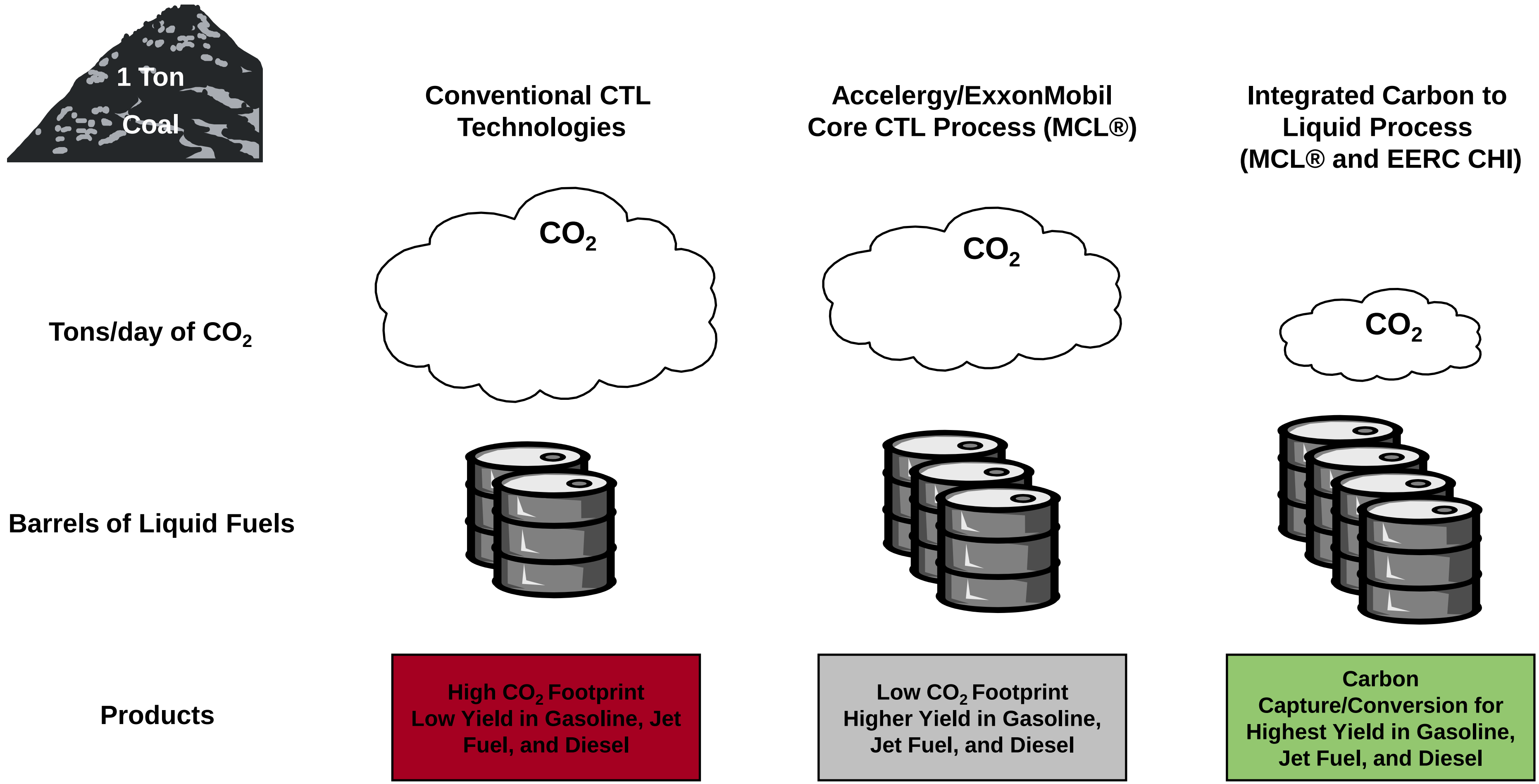
The EERC partners with Accelergy Corporation addressing challenges in direct CTL and establishing a program for the conversion of North Dakota lignite.

Note: Accelergy is an Emerging Leader in Advanced Direct CTL Processing with licensed MCL® (Microcatalytic Coal Liquefaction) technology from Exxon Mobil.

EERC Technology Spin-Off
Accelergy – Renewable Fuel

- Accelergy is an alternative fuel company with a broad suite of strategic partners and technologies for producing liquid fuels from coal and biomass.
- Combining the ExxonMobil coal-to-liquid technology with the EERC's renewable fuel technology to produce domestic, drop-in-compatible jet fuel (Jet-A, JP-8), diesel, and gasoline with a low CO_2 footprint.
- The Accelergy scale-up coal-to-liquid demonstration facility will be located at the EERC.
- A commercial demonstration design of the EERC renewable fuel production technology is currently being conducted for future placement at the Tesoro Mandan facility.

Integrated Carbon-to-Liquid Process Offers High Yield and Low Carbon Footprint



(1) MCL® - Microcatalytic Coal Liquefaction
(2) CHI – Catalytic Hydrodeoxygenation and Isomerization

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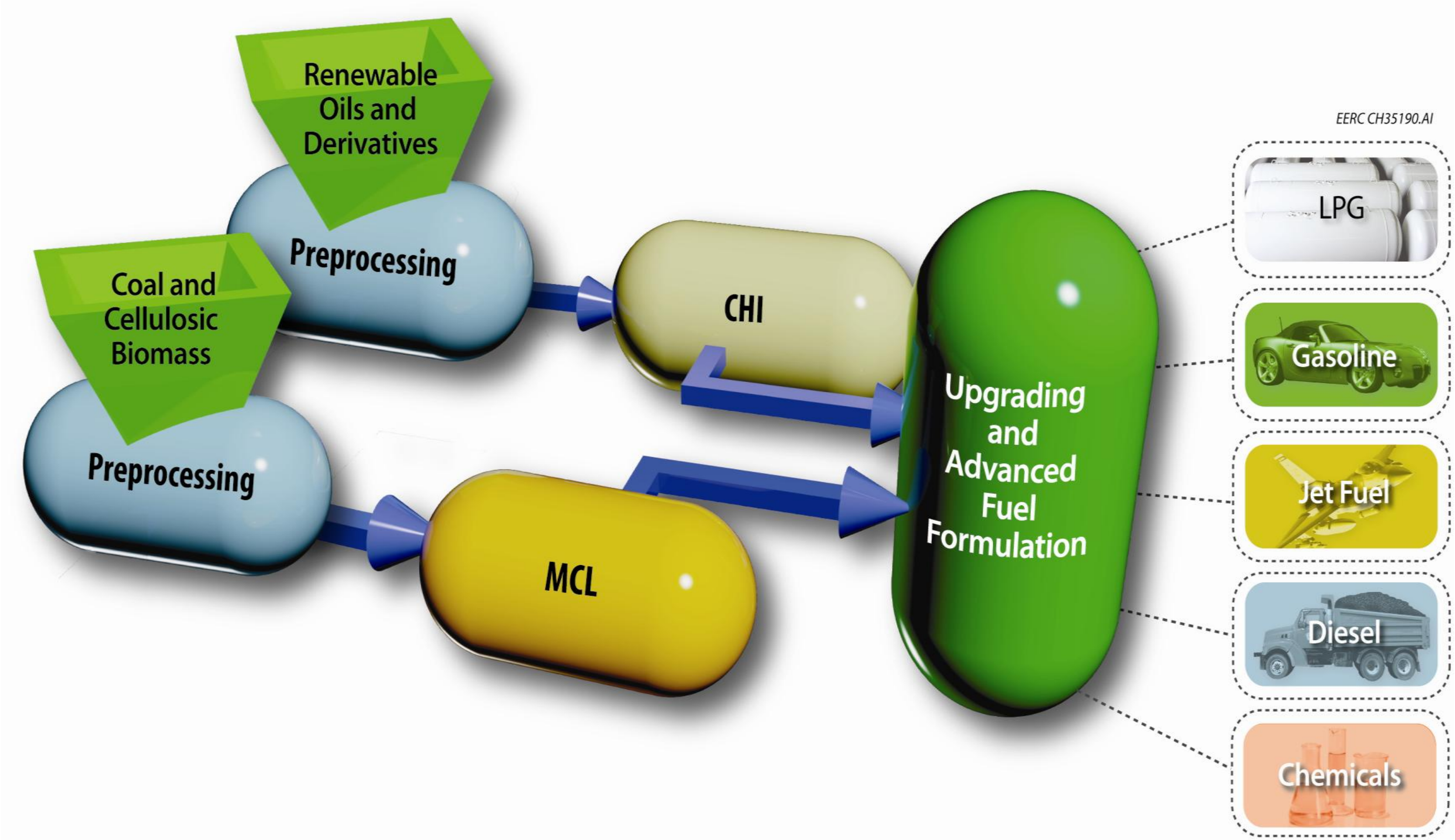
Substantial Synergies for Producing Advanced Fuels by Combining Coal with Biomass



(1) MCL® - Microcatalytic Coal Liquefaction
(2) CHI – Catalytic Hydrodeoxygenation and Isomerization

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Renewable Hydrogen

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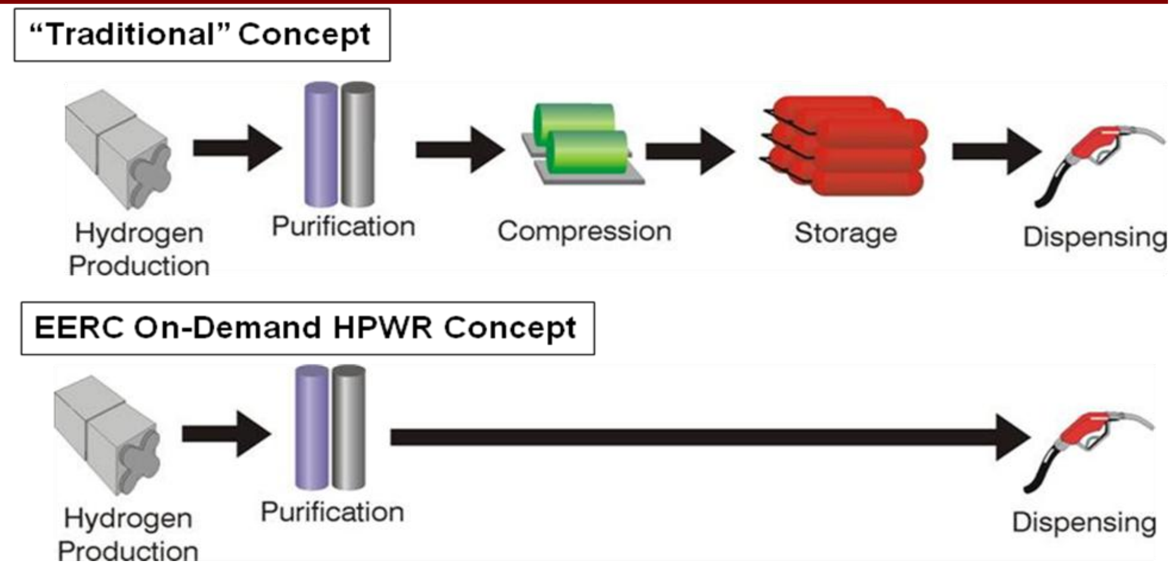
EERC On-Demand Fueling Station

- Hydrogen produced via high-pressure water reforming
- Minimizes need for extensive infrastructure for compression and storage.
- Utilizes existing distribution network for liquid fuels (ethanol, biodiesel, diesel, JP-8).



- Able to be integrated into existing liquid fuel fueling stations with minimal impact.
- Ready for first commercial demonstration in 2010.

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Wind-to-Hydrogen (W2H2) Project

- Wind-to-hydrogen demonstration in Minot, North Dakota
- Twin 1.3-MW wind turbines
- Hydrogenics Corporation electrolysis unit and filling station
- Internal combustion multifuel vehicles

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Department of Energy United States of America

Hydrogenics Corporation

Basin Electric Power Cooperative
A Touchstone Energy® Cooperative

Verendrye Electric Cooperative

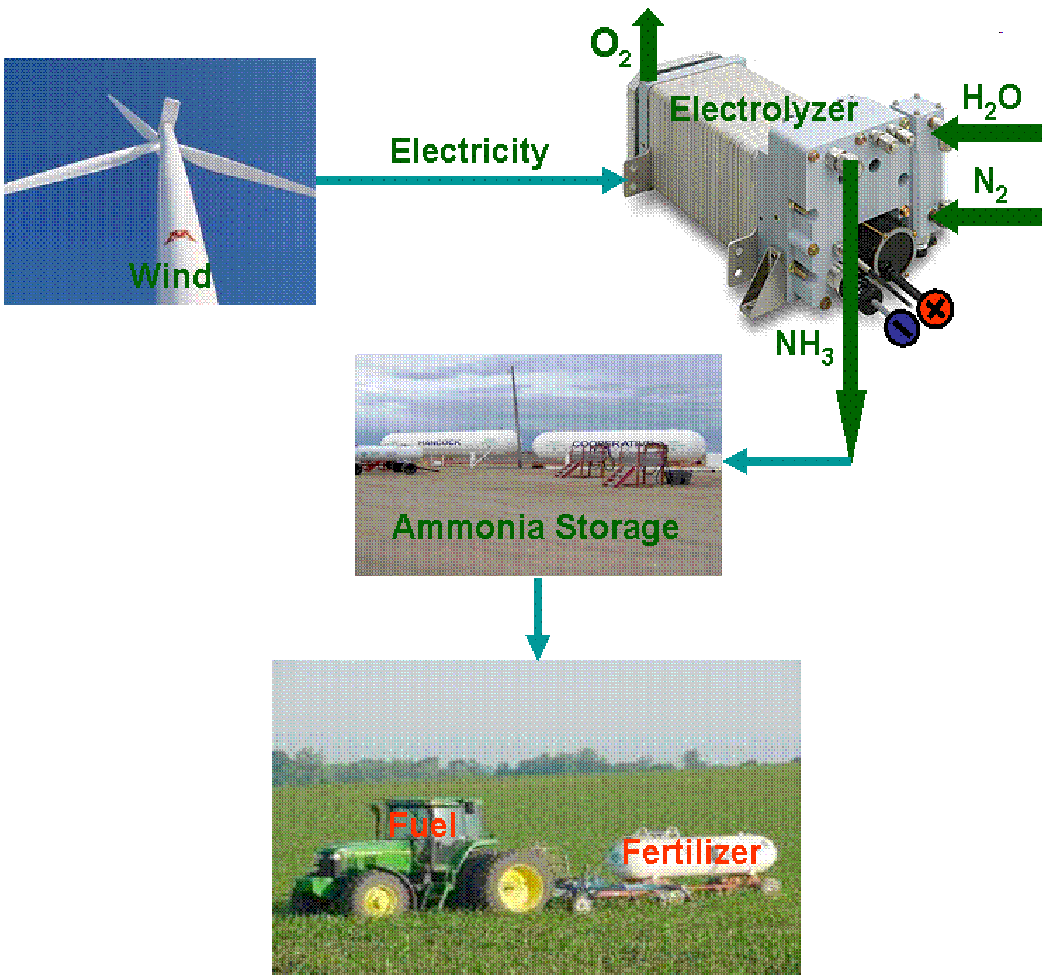
National Rural Electric Cooperative Association

NDSU North Dakota State University
North Centra Extension Center

Central Power Electric Cooperative, Inc.
Your Touchstone Energy® Partner

Renewable Fertilizer

Water-Based Renewable Electrolytic Ammonia Process Advantages



Use wind energy to replace high-cost natural gas for domestic fertilizer production.

Renewable ammonia also usable as fuel for zero-carbon direct ammonia fuel cell for transportation and other applications.

Derive value from wind without need for transmission capacity expansion.

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Per-Ton Water-Based Ammonia Production Cost Projection – 150 lb/day Capacity

Electricity Price	$0.03/kWh[1]	$0.04/kWh	$0.05/kWh
Cost of Electricity[2]	$264	$352	$440
Cost of water	$10	$10	$10
Capital Cost	$21	$21	$21
O&M Cost	$20	$20	$20
Cost of N_2	$18	$18	$18
Total Cost	$333	$421	$509

[1] ***Kilowatt hour.***

[2] ***Electricity consumption of 8800 kWh/ton anhydrous ammonia.***

Low-cost electricity and/or reducing electricity consumption is critical to reducing ammonia production cost.

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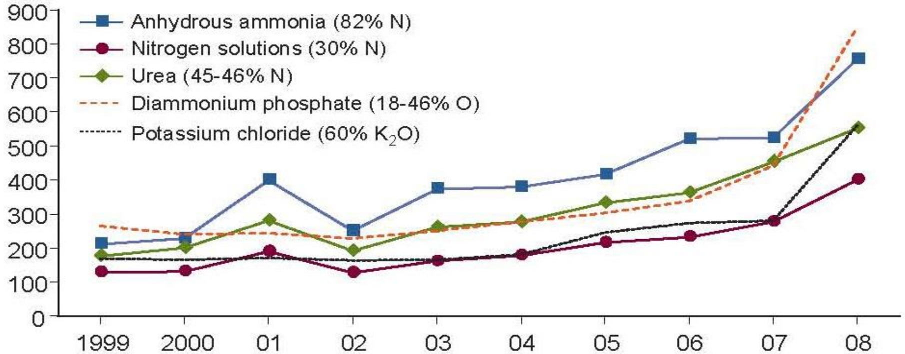
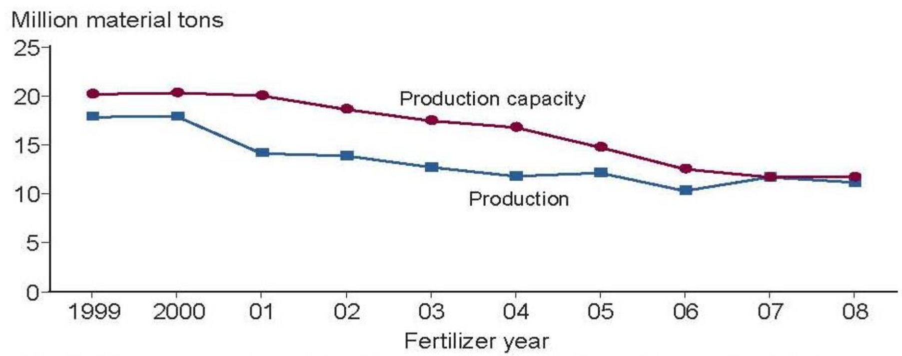
Historic Fertilizer Prices and Production

Historic April prices of major fertilizers used in the United States



Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service, *Agricultural Prices, 1999-2008*.

U.S. ammonia production and production capacity



Note: Fertilizer year runs from July of the preceding year to June of the year indicated in the chart.

Source: USDA, Economic Research Service using capacity data from International Center for Soil Fertility and Agricultural Development and production data from U.S. Department of Commerce.

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Algae

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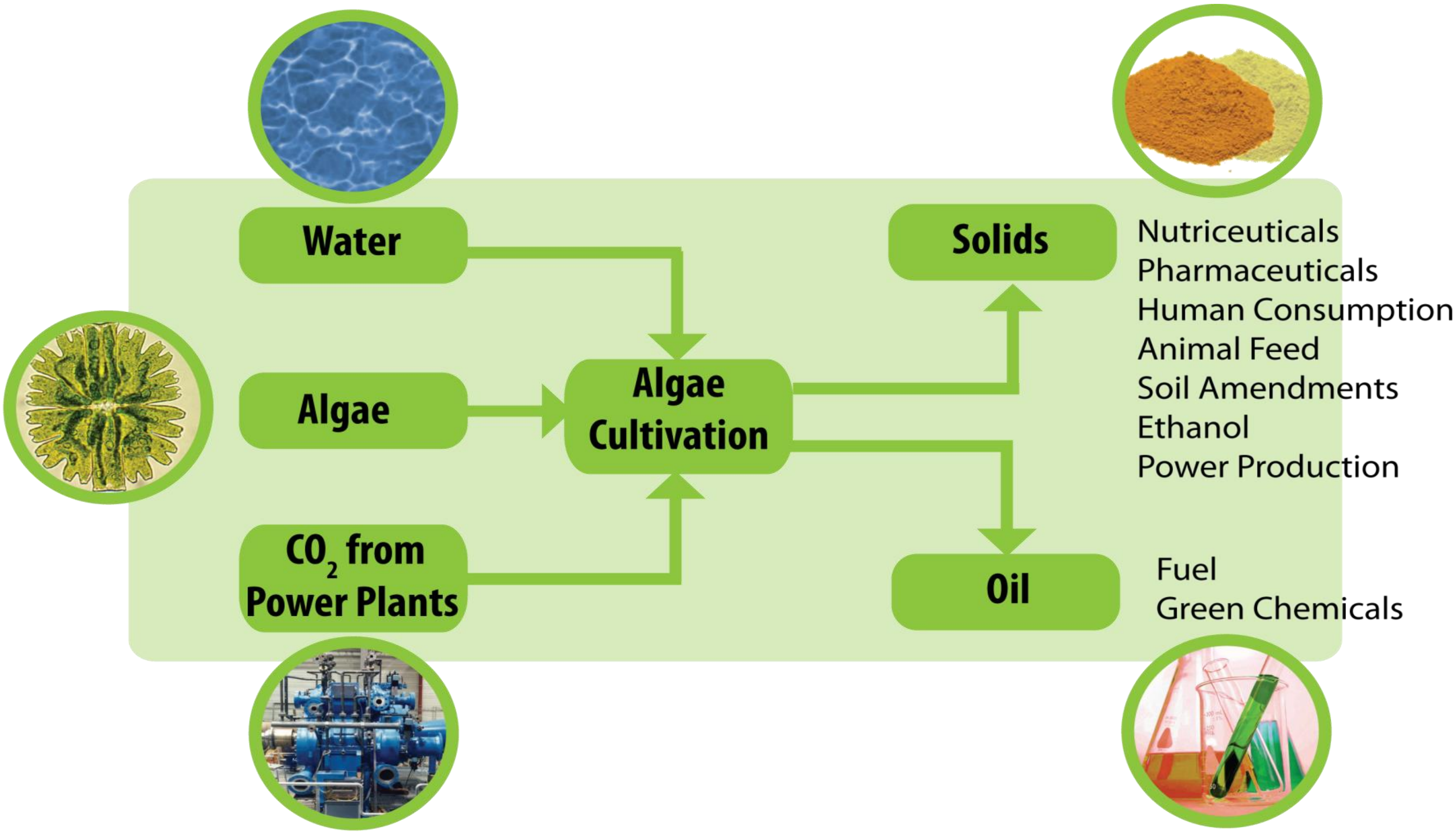
Algae – Part of the Answer for U.S. Energy Security



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Why Use Algae for Biofuels?

Greenhouse gas reduction

- Renewable feedstock

Does not compete with food

Does not compete with high-value agricultural land

Higher-energy-density oil with more potential fuel products

Stimulates rural economies

Provides energy security

Technology being developed

Unwanted algae in bay off of Qingdao, on an east China coast

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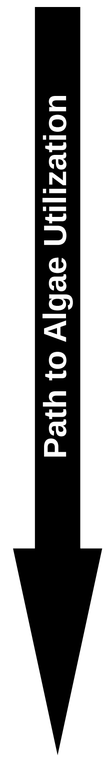
Projected Oil Production Yields

Feedstock	Gallons of Oil per Acre per Year
Soybean	48
Sunflower	102
Rapeseed	127
Castor Bean	151
Jatropha	200
Kukui	237
Coconut	287
Palm Oil	635
Microalgae	5000–15,000



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Water Consumption for Algae Growth

Water consumption varies significantly with each system type.

- Closed-loop(less) vs. open-loop design (more)
- Pond (more) vs. reactor design (less)

Able to utilize brackish water.

Use gray water from power production, CO_2 cleanup, coalbed methane production, …

HR BioPetroleum

PetroSun

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Power Plant CO_2 for Algae Cultivation

Few companies currently using power plant CO_2.

Variations in coal and operational performance can alter algae performance significantly.

Key – How to produce a consistent, high-quality CO_2 feedstock.

Seambiotic

GREENFUEL
TECHNOLOGIES CORPORATION

Algae becomes a flue gas-scrubbing system (removing CO_2 and NO_x).

Potential for carbon credits.

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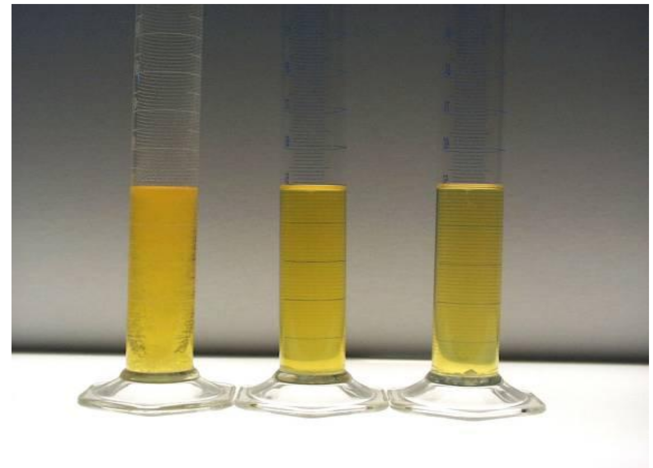
Producing Fuel from Algae Oil

- The EERC has produced 100% renewable JP-8 (jet fuel) from multiple crop oils – no expected differences with algae oil.
- Currently partnered with two DARPA awardees to convert algae oil to JP-8.
- In discussions with multiple algae producers to conduct fuel production tests.



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Algae-Derived JP-8 Sample

Submitted JP-8 sample to Air Force Research Laboratory on June 17, 2009.

Preliminary results:

- Flash point = 56 C
- Freeze point = –51.8 C
- Density = 0.7846
- Aromatics = 19.72%

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