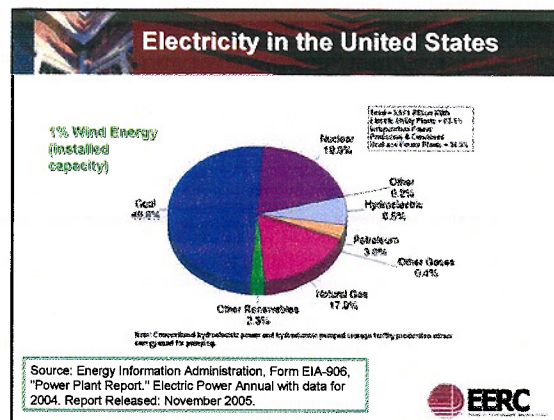


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EERC Technology... Putting Research into Practice

Opportunities and Challenges Associated with Wind Energy, Biopower, Alternative Fuels, and Other Renewable Energy Forms


Presentation to the North Dakota Legislative Council
Interim Energy Development and Transmission Committee
October 24, 2007

Chris J. Zygarlicko
Deputy Associate Director for Research

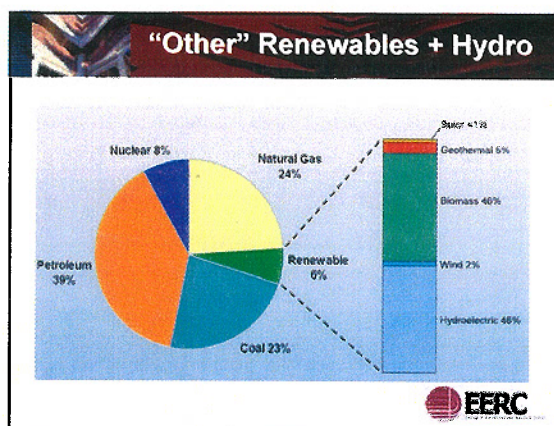


Opportunities and Challenges

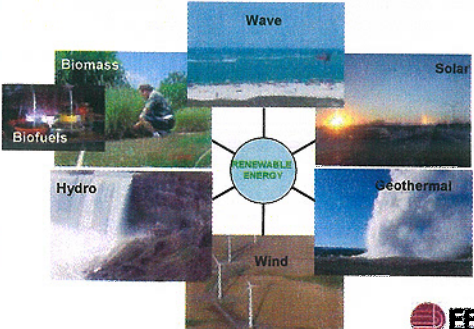
- EERC renewable energy research
- Wind energy
- Biomass feedstocks
- Biopower: large utilities
- Alternative fuels
 - Jet fuel and green diesel
 - Corn ethanol
 - Cellulosic ethanol
- Other renewable energy forms
- Summary of North Dakota renewable energy-alternative fuels



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EERC Centers for Renewable Energy and Biomass Utilization



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Renewables Must Play a Part (electricity and transportation)


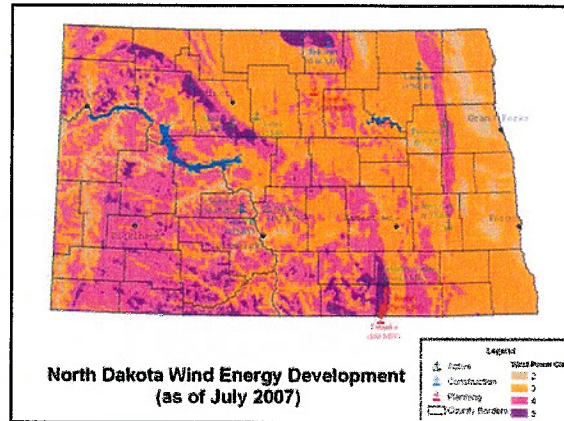


2007 → 2050

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Wind Energy


- Current U.S. installed wind capacity > 12,000 MW, serving ~4 million average U.S. homes.
- Installed capacity is ~ 1% of total energy in the United States.
- Aggressive growth could reach 5% by 2020 but falls short of goals of American Wind Energy Association (AWEA) and others.
 - Need for more steel, construction capacity, cranes, etc.
 - Need for new and expanded baseload capacity
 - Need for assurances on Production Tax Credit of 1.8¢ per kWh beyond 2008
 - Need for transmission
- R&D for storage, transmission, and hybridization or other products from wind (H₂, fertilizer).


Wind Resource in the United States

Wind Resource Rank*	Wind Energy Potential, MW	Installed Capacity at the End of 2006, MW	Planned (Near-Term) or Under Construction Capacity, MW
1. North Dakota	138,400	179 (8 th)	208
2. Texas	136,000	2768	1013
3. Kansas	121,900	364	0
4. South Dakota	117,200	44	200
5. Montana	116,000	146	500
6. Nebraska	99,100	73	0
7. Wyoming	85,000	288	201
8. Oklahoma	82,763	535	60
9. Minnesota	75,000	895	100
10. Iowa	62,900	837	222
17. California	6770	2361	565

* Wind resource rank from AWEA.




Biomass Feedstocks





Opportunity for Expansion of North Dakota Wind Energy

- Increased electrical transmission capacity
- Improvements in technologies and economics
- Use wind energy to make products other than electricity
 - Hydrogen for vehicles, fertilizer, specialty chemicals, etc.
- State policies that create a more positive environment for wind energy development.
 - Minnesota and Iowa are regional examples.
- Federal policies that create a more positive environment for wind energy development.
 - The proposed federal renewable portfolio standard is one example.




Diversity of Biomass Types

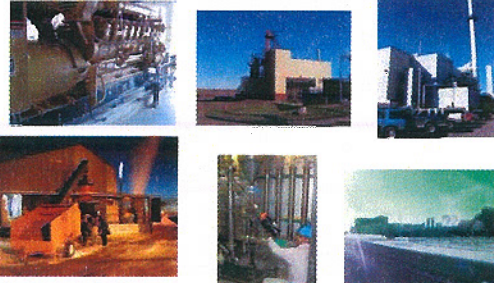
- **Diversity** of biomass and coal inorganic content may lead to unpredictable conversion performance.
- **Wastes and residues**
 - **Wood** – forest or tree trimmings, sawdust, demolition wood, crates, and railroad ties
 - **Lignin** – from ethanol processing of wood, ag residues, and municipal solid waste (MSW)
 - **Ag** – Wheat straw, rice straw, alfalfa stems, potato and beet residue, and corn stover
 - **Animal** – poultry litter and manures (cows and hogs)
 - **MSW** – refuse-derived fuel (RDF) and acidified biosolids
- **Agricultural energy crops**

Biopower – Large Utilities

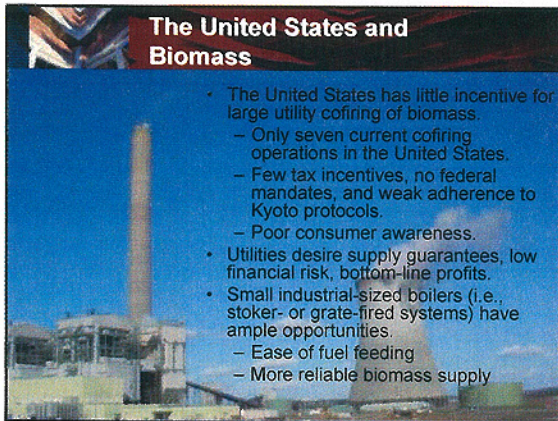


Opportunities for Industrial-Scale or Distributed Systems



The United States and Biomass

- The United States has little incentive for large utility cofiring of biomass.
 - Only seven current cofiring operations in the United States.
 - Few tax incentives, no federal mandates, and weak adherence to Kyoto protocols.
 - Poor consumer awareness.
- Utilities desire supply guarantees, low financial risk, bottom-line profits.
- Small industrial-sized boilers (i.e., stoker- or grate-fired systems) have ample opportunities.
 - Ease of fuel feeding
 - More reliable biomass supply



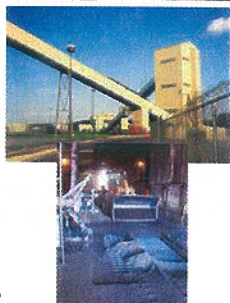
Collocation of Ethanol Plants at Power Stations

- Capital investment is shared and better utilized.
- Lower production costs for both the ethanol plant and the power plant.
- For a 50-million-gallon/year biomass ethanol facility:
 - Ethanol plant residues are primarily lignin.
 - Lignin could provide 10%–15% of the coal in a 500-MW pulverized coal (pc)-fired coal boiler.
- Combustion behavior will be impacted.



EPRI-DOE Cofiring Studies in Large Coal-Fired Utilities

- Biomass transportation is still primary concern.
 - Cost for transport
 - Logistics
 - Availability
 - Sustainability of quantity and quality
- Use of traditional coal transport and delivery systems can impact boiler performance.
- In some cases, may reduce NO_x emissions.
- Reduced emissions of fossil CO₂, sulfur, and metals.



Alternative Fuels: Jet Fuel, Green Diesel, Ethanol (corn and cellulosic)



Alternative Liquid Fuels from Coal and Biomass

Alternative Feedstocks

Alternative Fuels

Suite of nonpetroleum alternative fuels being commercialized, demonstrated, or laboratory-tested from coal, oil sands, oil shale, biomass residues, and energy crops:

- Ethanol – conventional corn/cereal grain fermentation
- Ethanol – cellulose conversion using fermentation or catalytic thermochemical
- Biodiesel – conventional methyl esterification
- Green diesel – Fischer-Tropsch (FT) conversion of gasification syngas
- Jet fuel (JP-8) – catalytic thermochemical conversion of crop oils

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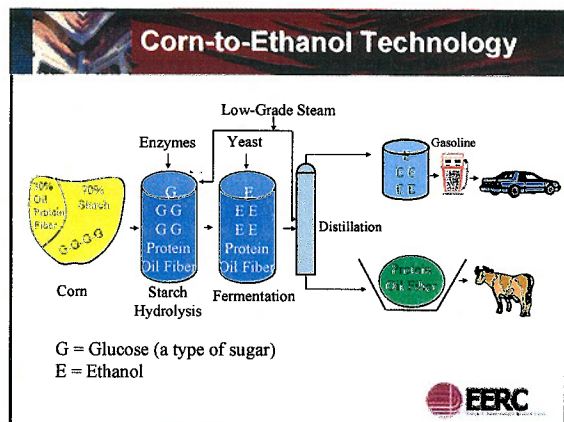
Corn Ethanol

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Biojet Fuels or Green Diesel

- Biojet fuels
 - Utilize crop oils such as soybean, canola, or next-generation crop oil feedstocks.
 - Catalytic cracking to produce a fuel with improved cold-flow performance and storage stability.
 - Optimization of continuous process for fuel with carbon chain length similar to that of JP-8 (drop-in compatible).
- Green diesel
 - Biomass conversion to syngas products (CO , CO_2 , H_2 , CH_4)
 - FT reactions to distillate

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Challenges and Opportunities for Jet Fuels, Green Diesel, and Biodiesel

- All are superior in emissions, lubricity, and CO_2 abatement, and all alleviate petroleum feedstock pressure.
- Jet fuel and green diesel
 - Biobased jet fuels are in laboratory stage of development.
 - FT diesel (coal-gas) diesel produced by Sasol in South Africa; biomass FT diesel being developed.
- Traditional biodiesel
 - Surging world and U.S. market
 - Poor public perception
 - Higher vehicle costs
 - Competing with food vegetable oils (coconut, palm, soybean, canola)
 - Limited cropland availability
 - Needs glycerol by-product uses

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Ethanol Opportunity

- 2000 tons/day of feedstock sold by farmers for one plant.
- Local businesses to store and transport.
- Production of 70 million gallons of ethanol plus higher-value products (chemicals, nutraceuticals, etc.).
- \$150–\$350 million in capital and construction costs.
- 20–50 highly skilled and well paid workers, scientists, and managers.
- Sales of \$100–\$250 million per year.
- Property and sales taxes paid to the local community.

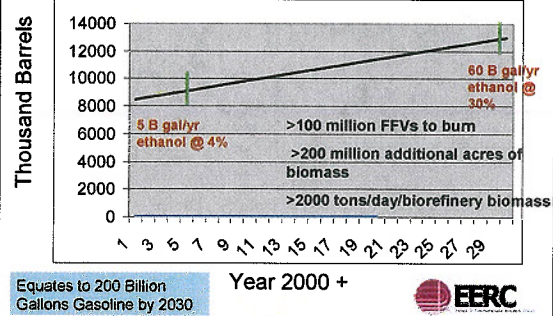
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Cellulosic Ethanol and Integrated Biorefinery



A Lot of Corn, Land, and Cars

EIA Estimated Gasoline Consumption

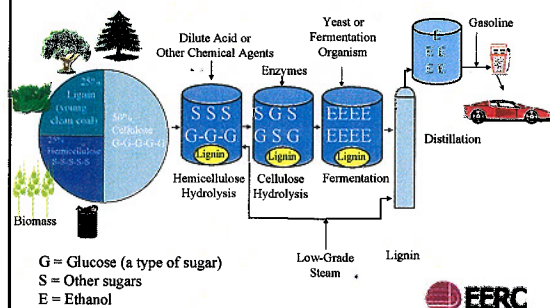


Biomass-to-Ethanol Technology

- Uses nonedible feedstocks
 - Switchgrass, straw, corn stover, wood residue, MSW
- Emerging technologies
 - Thermo – heat and catalysts to gasify (very little O_2) or pyrolyze (some O_2) biomass to a syngas or bio-oil; subsequent conversion of syngas or bio-oil to ethanol, butanol, methanol, FT liquids, or other high-value chemicals.
 - Fermentation using pretreatment of dilute or concentrated acid hydrolysis or various enzymatic and physical (i.e., steam) pretreatments.



Nonthermal Biomass-to-Ethanol Technology Requires Pretreatment

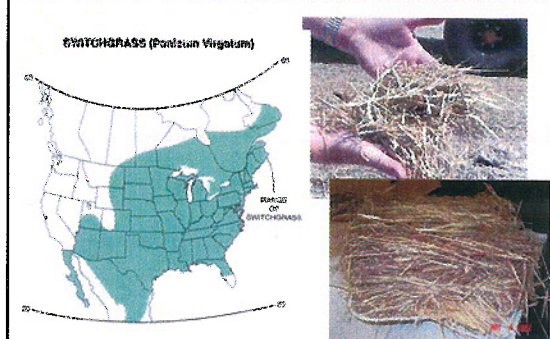


Cost Comparison of Biofuels on Btu Basis

	Corn Ethanol	Wood-Based Ethanol	Canola Biodiesel	Gasoline
Energy in Fuel (Btu/gal)	76,300	76,300	118,000	120,000
Cost (including subsidies) per Btu of Energy in Fuel (\$/million Btu)	36.60	41.10	24.20	15.00
Cost per gallon (\$)	1.50–1.75	2.50–4.00	2.25–3.50	0.50–1.00



Switchgrass



Ethanol Challenges

Corn Ethanol

- Oversupply
- Not enough E85-compatible cars
- Not enough stations and pumps
- Competition for food

Cellulosic Ethanol

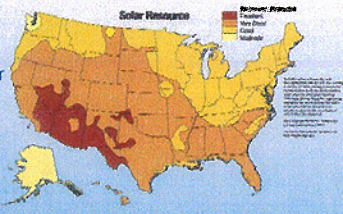
- Still being proven
- Capital equipment expensive
- Overwhelming amount of residues, energy crops, and land space needed



Solar

DOE Solar Program goals

- Photovoltaics: 6¢/kWh by 2020
- Concentrating solar power/troughs: 5¢/kWh by 2012



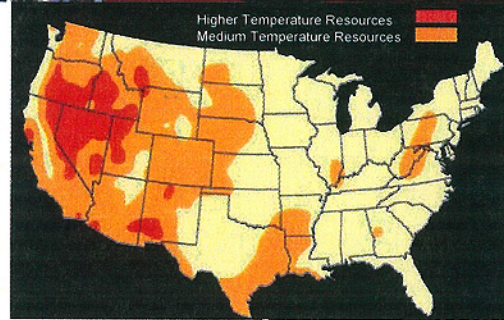
U.S. Ethanol Production

Rank	State	Ethanol Production Capacity (Million Gallons Per Year)
1	Iowa	3,431.5
2	Nebraska	1,460.5
3	Illinois	1,212.0
4	Minnesota	1,104.1
5	South Dakota	910.0
6	Indiana	808.0
7	Kansas	507.5
8	Wisconsin	498.0
9	Ohio	387.0
10	Texas	385.0
11	Michigan	262.0
12	North Dakota	233.5
	United States Total	12,578.3

Sources: Renewable Fuels Association, Washington, DC; Nebraska Energy Office, Lincoln, NE; July 2007



U.S. Geothermal Potential



Other Renewable Energy Forms



Geothermal Potential



- Deep well technology improvements
 - Extends potential across the United States
- Innovations in distributed systems
 - Great potential as transmission grid is revamped
- Western ND may have similar deep well resources

Boise, Idaho, area homes, government buildings, and businesses pump 700 million gallons of water, annually; with 60 percent reinjection; using wells at 1000–3000 feet deep.



Hydroelectric Opportunities and Challenges


- Wind-hydro firming could be a more effectively demonstrated.
- Costs may soon be viable.
- Some new opportunities possible in Manitoba.
- Capacity for new hydro very limited in the United States.
- River or waterway hydrologic or environmental issues barricade the process.
- More innovation needed in hybridization.

Hydrogen Vehicles: Future and Now





Renewable Hydrogen



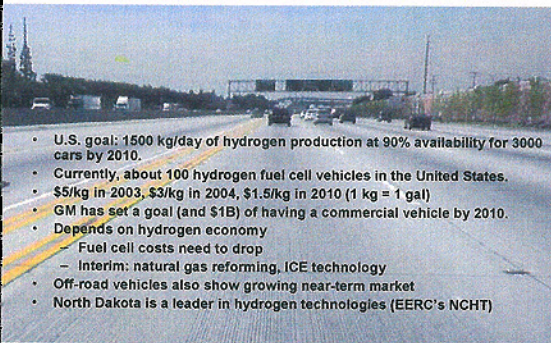
ND Renewable Energy Markets to Watch

Markets

- Transportation fuel
 - World demand will outpace sporadic growth in production capacity, leading to increasing price instability.
 - Alternative fuels from coal or biomass are competitive with oil at about \$40–\$45/bbl.
 - Ethanol and biodiesel plants can grow as demand is established (two to three plants each over next several years).
 - Cellulosic ethanol waiting for six DOE test facilities and several small commercial test efforts by 2010.
- Electricity
 - 2%–3% annual growth in demand in the region outpaces national average.
 - Coal will gain at the expense of high-priced natural gas.
 - 50% growth in ND wind energy production is possible with adequate development of transmission and integration with coal and hydro.

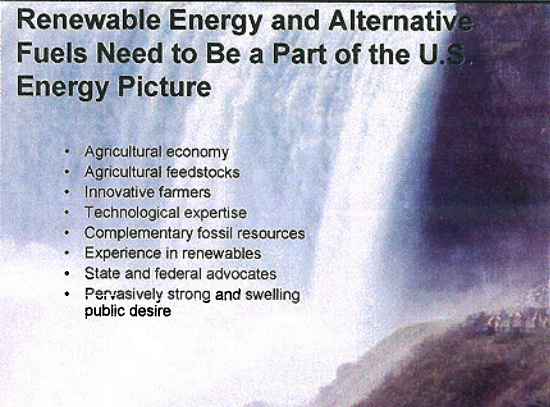


Renewable Hydrogen – U.S. Activity



- U.S. goal: 1500 kg/day of hydrogen production at 90% availability for 3000 cars by 2010.
- Currently, about 100 hydrogen fuel cell vehicles in the United States.
- \$5/kg in 2003, \$3/kg in 2004, \$1.5/kg in 2010 (1 kg = 1 gal)
- GM has set a goal (and \$1B) of having a commercial vehicle by 2010.
- Depends on hydrogen economy
 - Fuel cell costs need to drop
 - Interim: natural gas reforming, ICE technology
- Off-road vehicles also show growing near-term market
- North Dakota is a leader in hydrogen technologies (EERC's NCHT)

Renewable Energy and Alternative Fuels Need to Be a Part of the U.S. Energy Picture



- Agricultural economy
- Agricultural feedstocks
- Innovative farmers
- Technological expertise
- Complementary fossil resources
- Experience in renewables
- State and federal advocates
- Pervasively strong and swelling public desire



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