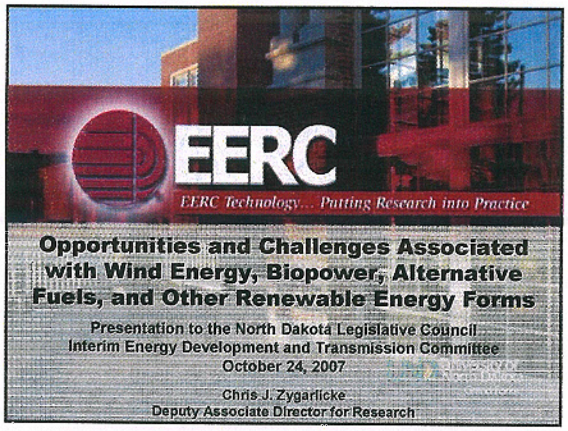

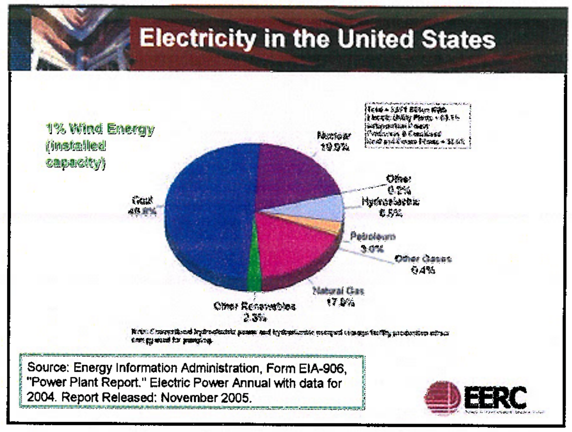

Opportunities and Challenges

- 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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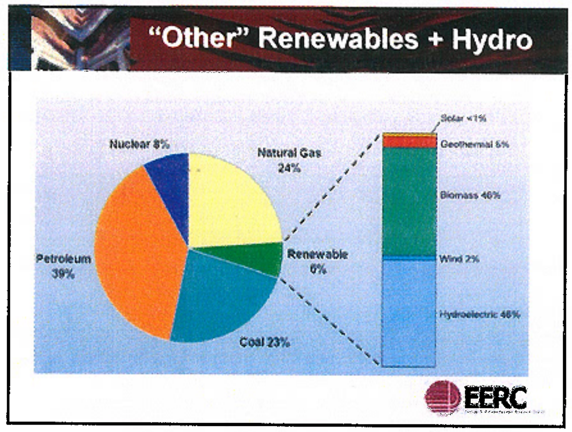
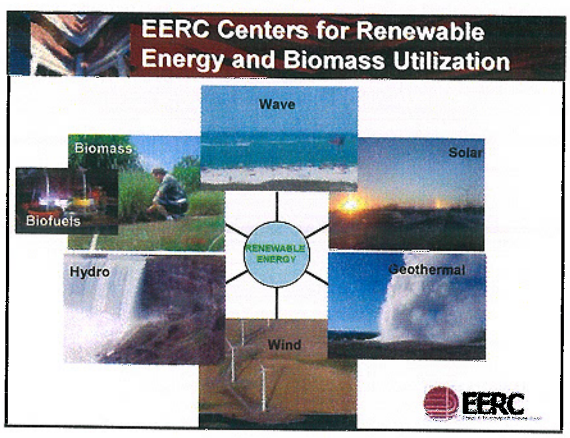
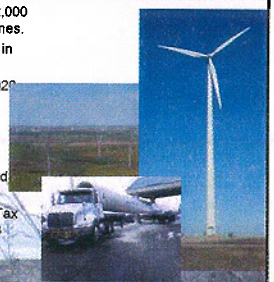
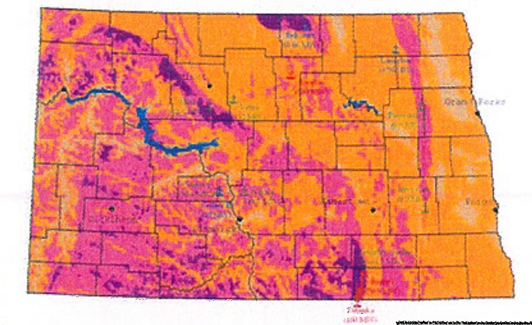




Wind Energy

- 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 (H_2, fertilizer).





North Dakota Wind Energy Development (as of July 2007)

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 (8th)	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.

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Biomass Feedstocks

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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.

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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**

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Biopower – Large Utilities

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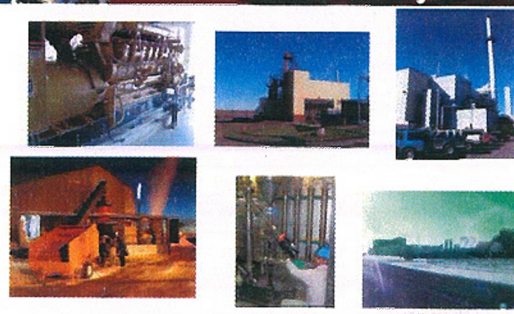
Opportunities for Industrial-Scale or Distributed Systems



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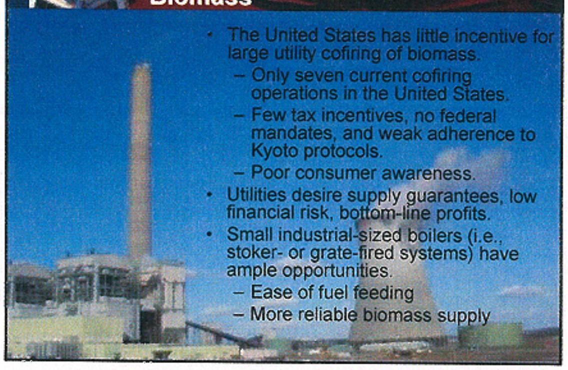
The United States and Biomass



- 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.

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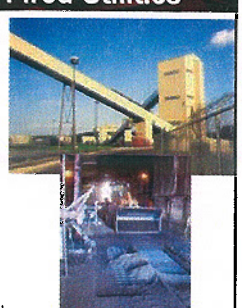
EPRI–DOE Cofiring Studies in Large Coal-Fired Utilities

- 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 CO_2, sulfur, and metals.



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

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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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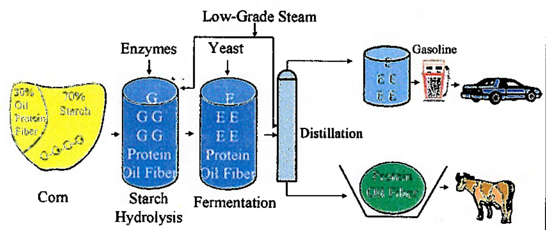
Corn-to-Ethanol Technology



G = Glucose (a type of sugar)
E = Ethanol

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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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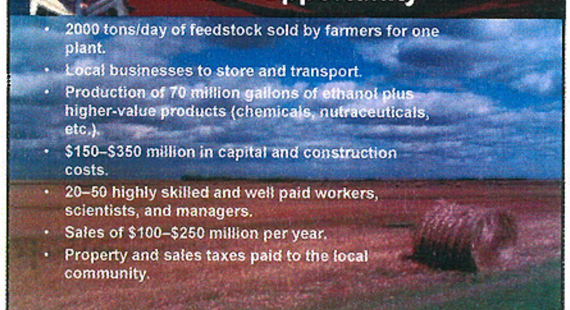
Ethanol Opportunity



- 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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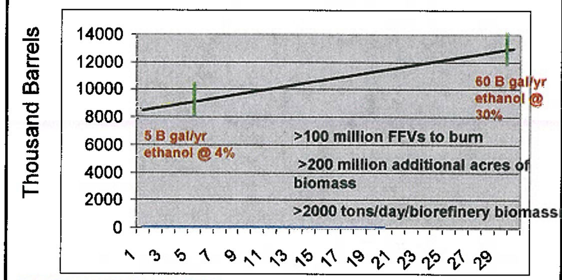
Cellulosic Ethanol and Integrated Biorefinery

A Lot of Corn, Land, and Cars

EIA Estimated Gasoline Consumption



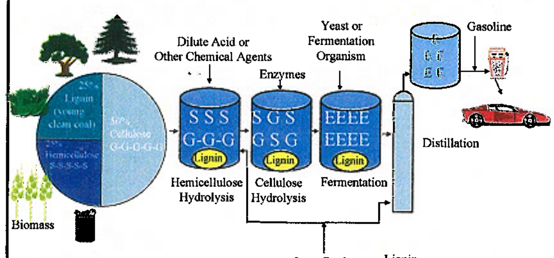
Year 2000 +

Equates to 200 Billion Gallons Gasoline by 2030

Biomass-to-Ethanol Technology

- Uses nonedible feedstocks
  - **Switchgrass, straw, corn stover, wood residue, MSW**
- Emerging technologies
  1. 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.
  2. 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

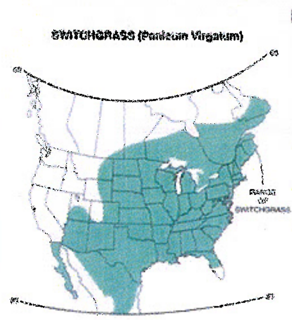


G = Glucose (a type of sugar)
S = Other sugars
E = Ethanol

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

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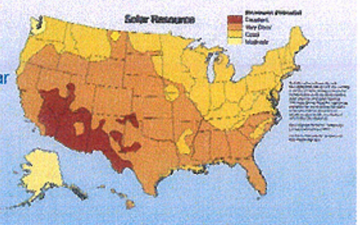
Solar

DOE Solar Program goals
- Photovoltaics: 6¢/kWh by 2020
- Concentrating solar power/troughs: 5¢/KWh by 2012



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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

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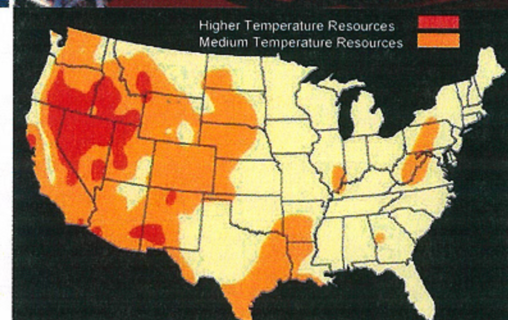
U.S. Geothermal Potential



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Other Renewable Energy Forms

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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.

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Hydrogen Vehicles: Future and Now

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Renewable Hydrogen

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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.

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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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