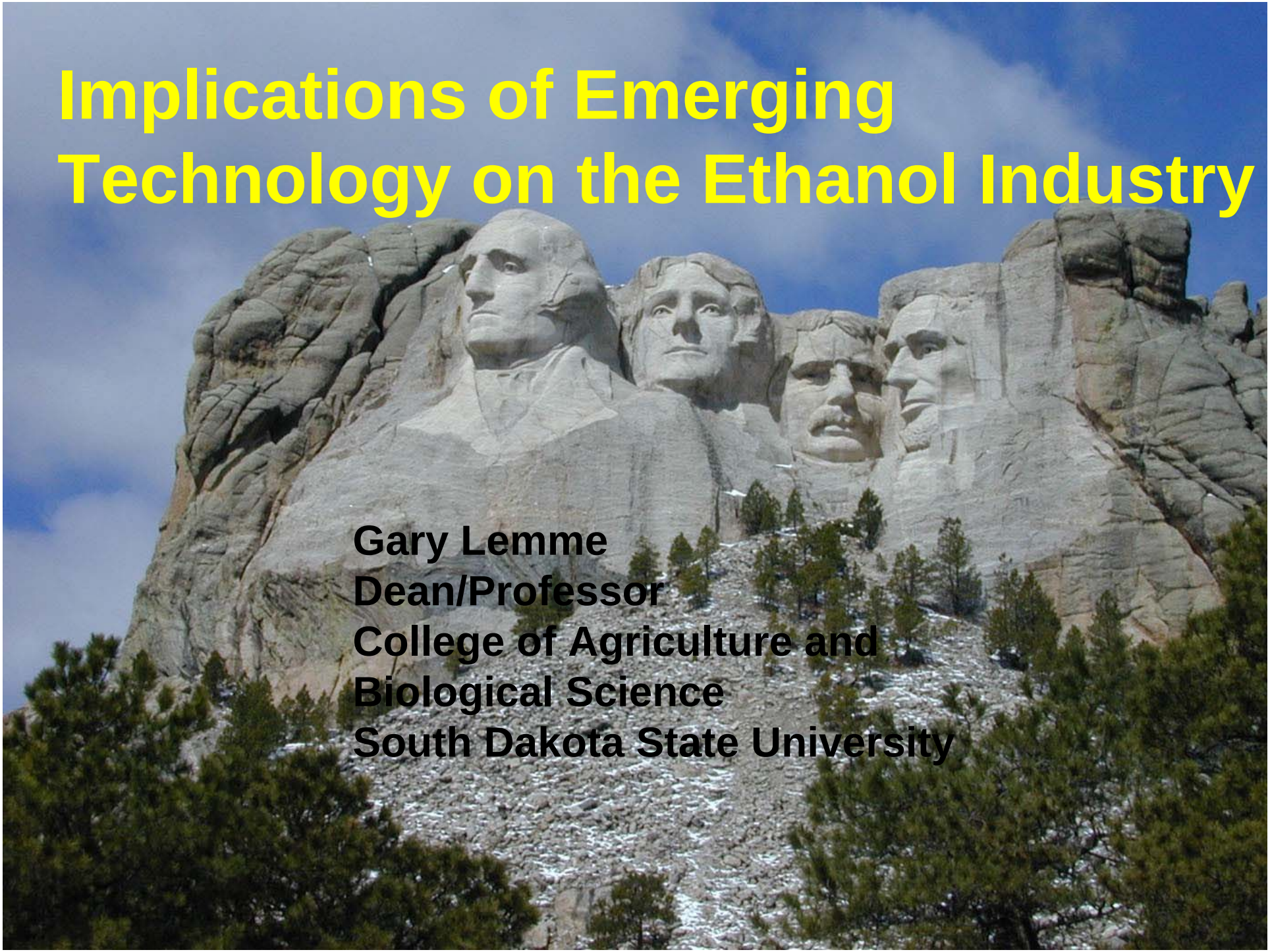
Implications of Emerging Technology on the Ethanol Industry



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Recent Ethanol Industry Expansion

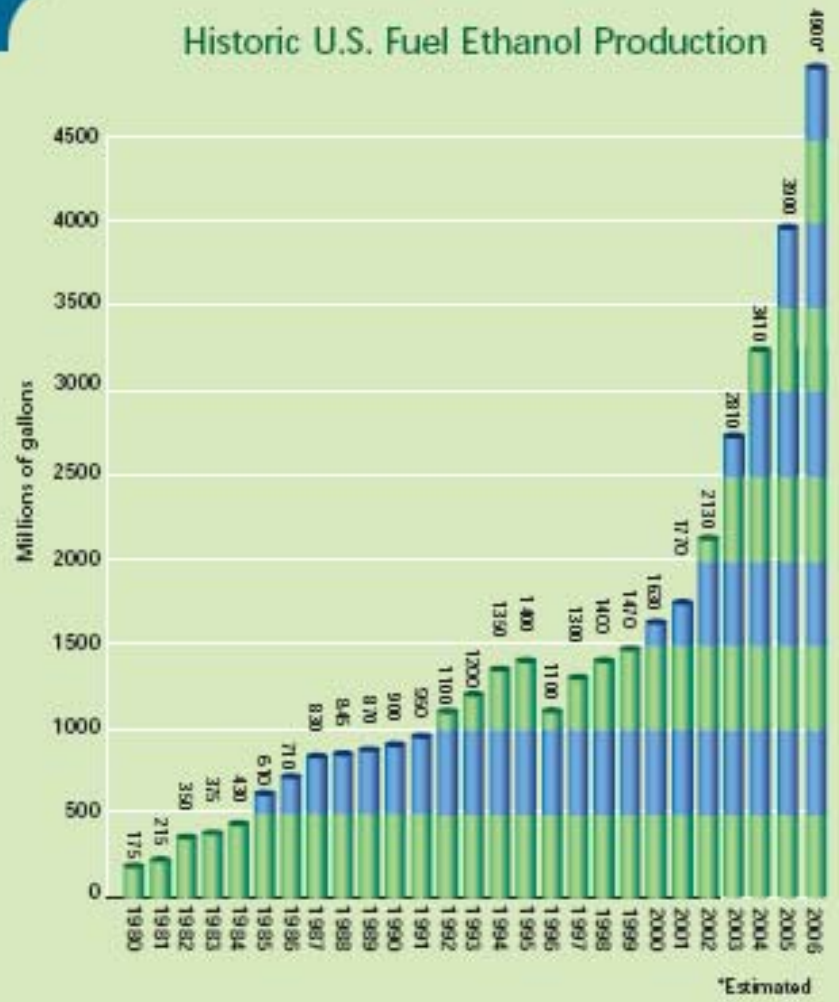
	Jan 2000	Jan 2001	Jan 2002	Jan 2003	Jan 2004	Jan 2005	Jan 2006	Jan 2007
Biorefineries Online	54	56	61	68	72	81	95	110
Capacity (mgy)	1748.7	1921.9	2347.3	2706.8	3100.8	3643.7	4336.4	5493.4

U.S. Ethanol Production Capacity by State

	Online	Under Construction/ Expansion	Total
Iowa	1701.5	1535	3236.5
Nebraska	655.5	965	1620.5
Illinois	831	341	1172
South Dakota	532	378	910
Minnesota	541.6	240.5	782.1
Indiana	102	551	653
Kansas	212.5	295	507.5
Wisconsin	230	272	502
Texas	0	370	370
Ohio	3	330	333
Michigan	155	107	262
North Dakota	83.5	150	233.5
New York	0	164	164
Missouri	155	0	155
Oregon	0	143	143
Colorado	85	40	125
Tennessee	67	38	105
Georgia	0.4	100	100.4
California	68	0	68
Arizona	0	55	55
Washington	0	55	55
Kentucky	35.4	0	35.4
New Mexico	30	0	30
Wyoming	5	0	5
Total	5493.4	6129.5	11,622.9

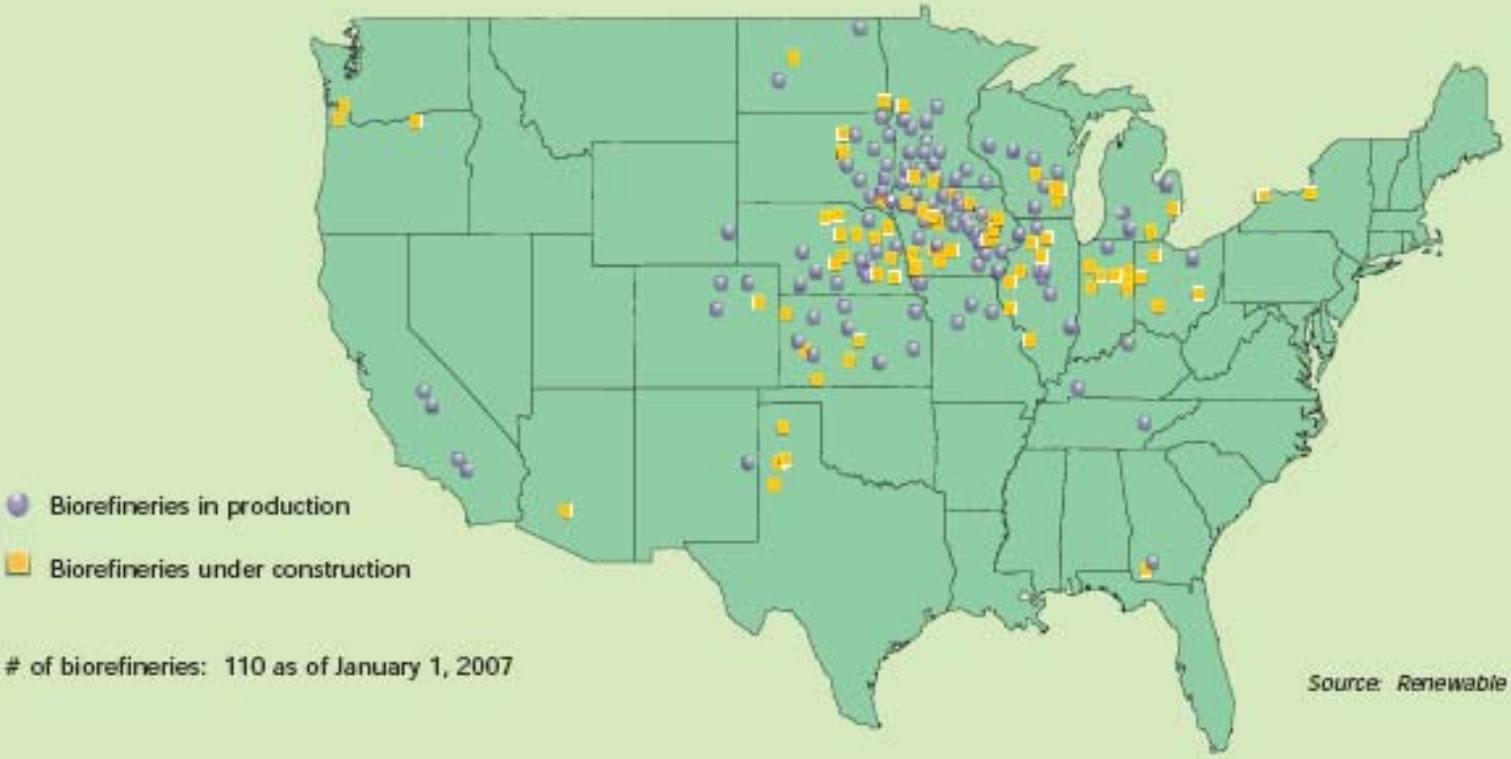
Source: Renewable Fuels Association, January 2007

Historic U.S. Fuel Ethanol Production



Source: U.S. Energy Information Administration / Renewable Fuels Association

U.S. Ethanol Biorefinery Locations



# of biorefineries: 110 as of January 1, 2007

Source: Renewable Fuels Association

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Emerging Ethanol Technology

- **TIME LINE**
  - Current: Corn-based Dry Mill Production
  - Near future (1-3 years): Corn Ethanol with Oil Recovery
  - Intermediate Future (2-4 years): Corn Ethanol with Oil Recovery and Fiber Conversion to Ethanol
  - Distant Future (8-10 years): Biomass Conversion to Ethanol

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Ethanol Industry

- Rural Community Economic Development, 2006
  - $41.1 billion gross output
  - 160,231 jobs
  - $2.7 billion new tax revenue
- Producer ownership/investment
  - Income diversification ($0.60 / gallon dividends)
  - Production integration & partnerships
- National fuel security

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Current Dry Mill Technology

1 bushel corn grain =

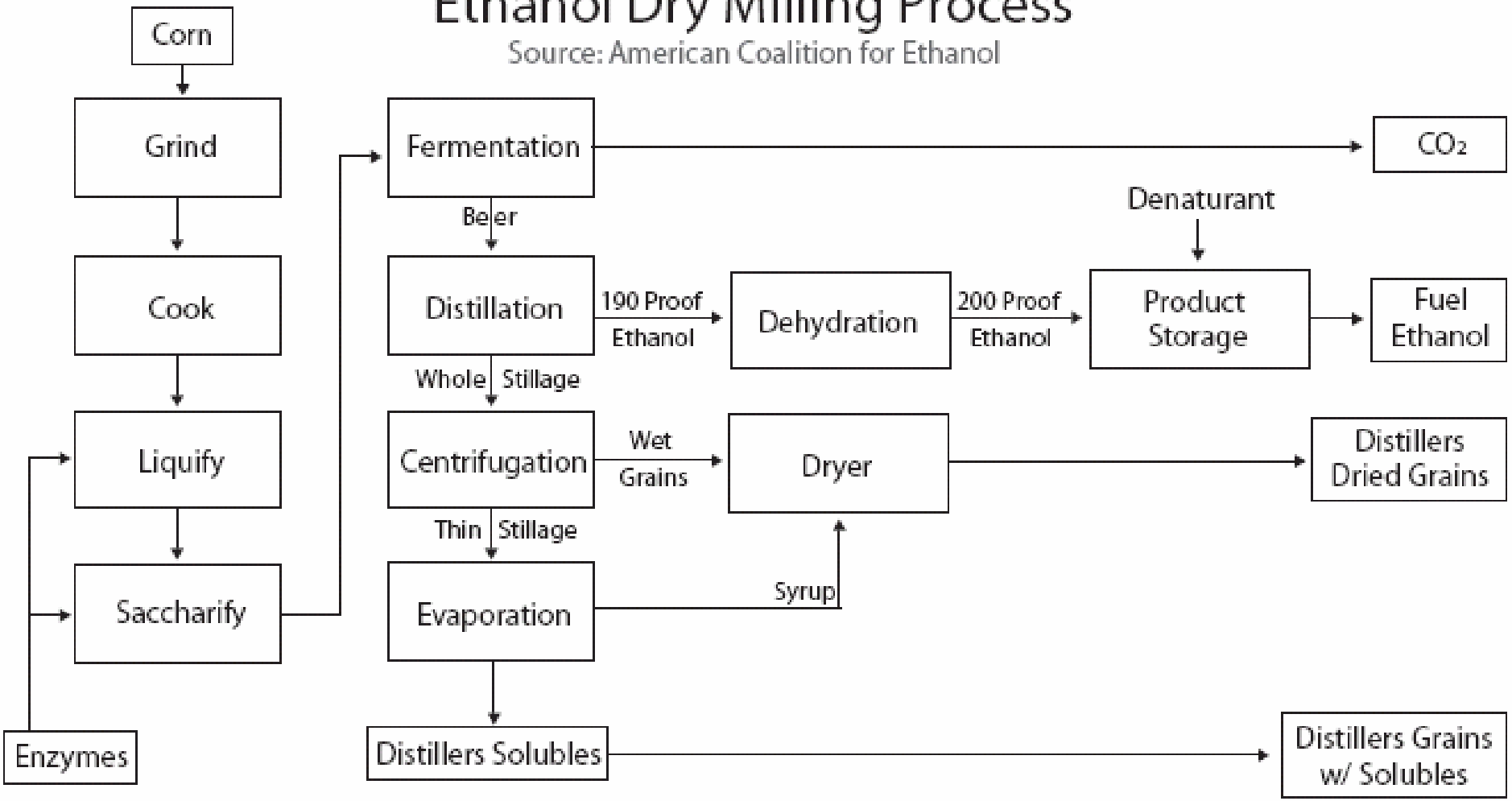
- **2.8 gallons of ethanol**
- **18 pounds dried distillers grains (DDGS)**
- **0 pounds oil**
- **18 pounds carbon dioxide**

Yeast convert sugars to ethanol and CO_2

In equal amounts

Ethanol Dry Milling Process

Source: American Coalition for Ethanol



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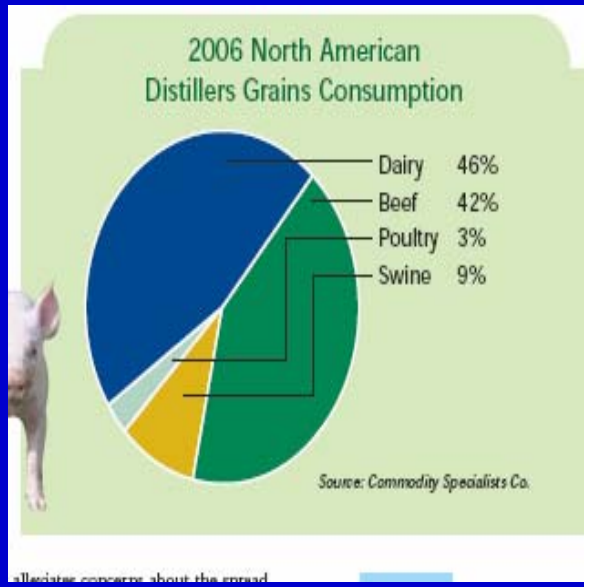
DDGS Feeding Recommendations

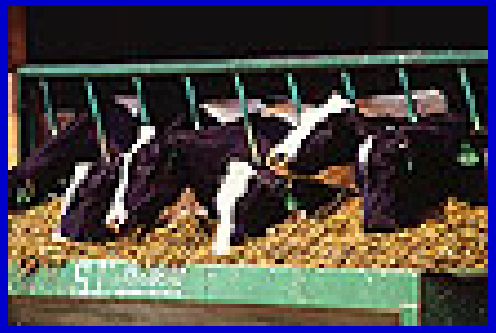
Specie	Lbs. DDGS/HD/Day
Beef Cow	5-7
Beef Steer/Heifer >500 lbs	3-4.5
Calves < 500 lbs	2-3
Dairy Cows	5-10
Dairy Heifers	1-5
Swine nursery	0.1-0.5
Swine Grow-Finish	0.6-1.2
Sows & Boars	0.8-3.2
Sheep Ewe	2
Sheep Lamb	0.5-1.1
Chicken Broilers	0.4
Chicken layers/peak season	0.022
Turkey Hens	0.035



Current South Dakota Usage of DDGS

- Beef = 404,750 T/YR
- Dairy = 201,913 T/YR
- Swine = 305,327 T/YR
- Sheep = 34,050 T/YR
- Poultry = 67,002 T/YR

65% of DDGS produced in SD could be consumed in SD



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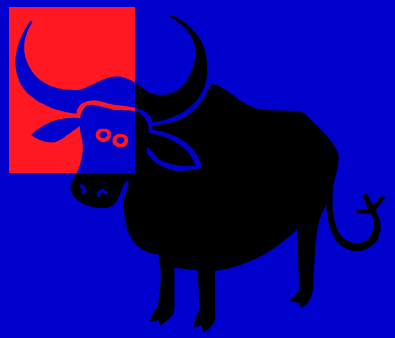
National 2007 DDGS Production

- Situation

5.5 billion gallons per year ethanol produced/2.8 gal/bu=1.9 billion bushels corn consumed*18 lbs DDGS per bushel consumed=$3.5 \times 10^{10}/2000$ lbs/t = 17.65 million tons DDGS

Solution?

or



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Near Future Technology: Corn Ethanol with Oil Recovery

- Process
  - germ recovery (Fractionation of corn prior to fermentation)
  - Co-product oil separation (post-distillation oil capture)
- Impact
  - 1.5 lbs oil/bushel for biodiesel or food uses
  - New DDGS products (range cubes, lick tubs)
  - 4% higher protein DDGS
- Yield/bushel corn
  - 2.8 gallons ethanol
  - 15.5-16.5 lbs DDGS
  - 1.5 lbs oil
  - 18 pounds carbon dioxide

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Intermediate Future Technology:
Corn Ethanol with Oil Recovery and fiber converted to Ethanol

- Process
  - Up stream fractionation with germ recovery (fibers > fermentable sugars using cellulase enzymes & fermented to ethanol)
  - Hydrolyze DDGS with cellulase enzymes yield fermentable sugar for fermentation to ethanol
  - Thermal catalytic conversion to convert DDGS to sugars for ethanol
- Impact
  - 1.5 lbs oil/bushel for biodiesel or food uses
  - DDGS reduced by 2/3
- Yield/bushel corn
  - 3.4-3.6 gallons ethanol
  - 5-6 lbs DDGS
  - 1.5 lbs oil
  - 23-24 pounds carbon dioxide

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“Rumpelstitskin spins gold from straw” ,
Grimm Brother

Cellulosic Ethanol

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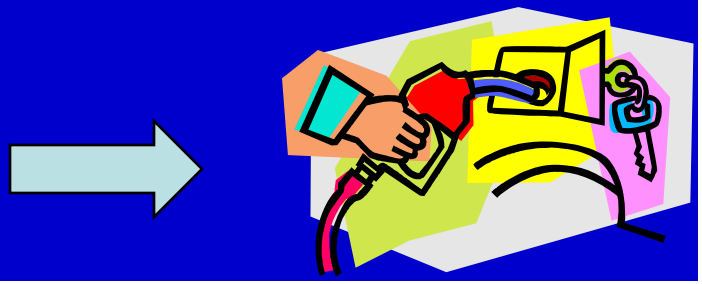
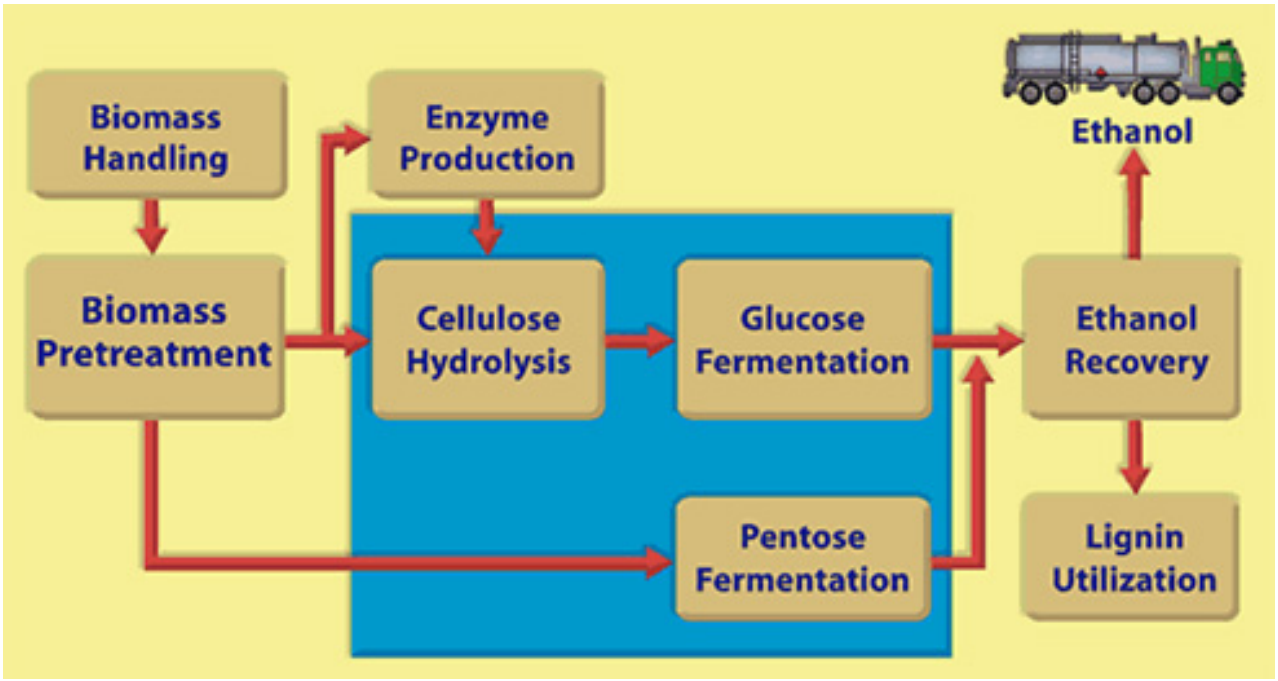
Distant Future (8-10 years): Biomass Conversion to Ethanol

- Process
  - Biomass feedstocks (1/3 cellulose, 1/3 hemicellulose, 1/3 lignin)
  - Developing Technology
    - (>80% cellulose & hemicellulose conversion required)
    - Biological conversion processes to sugars to ethanol
    - thermal kinetic conversion processes to sugars to ethanol
- Impact
  - No DDGS or feed materials
  - No oil produced
- Yield/ton Biomass
  - 90-100 gallons of ethanol
  - 600-650 lbs lignin (burned as boiler fuel)
  - 620-680 lbs CO_2



THE PRODUCTION OF ETHANOL FROM CELLULOSIC BIOMASS



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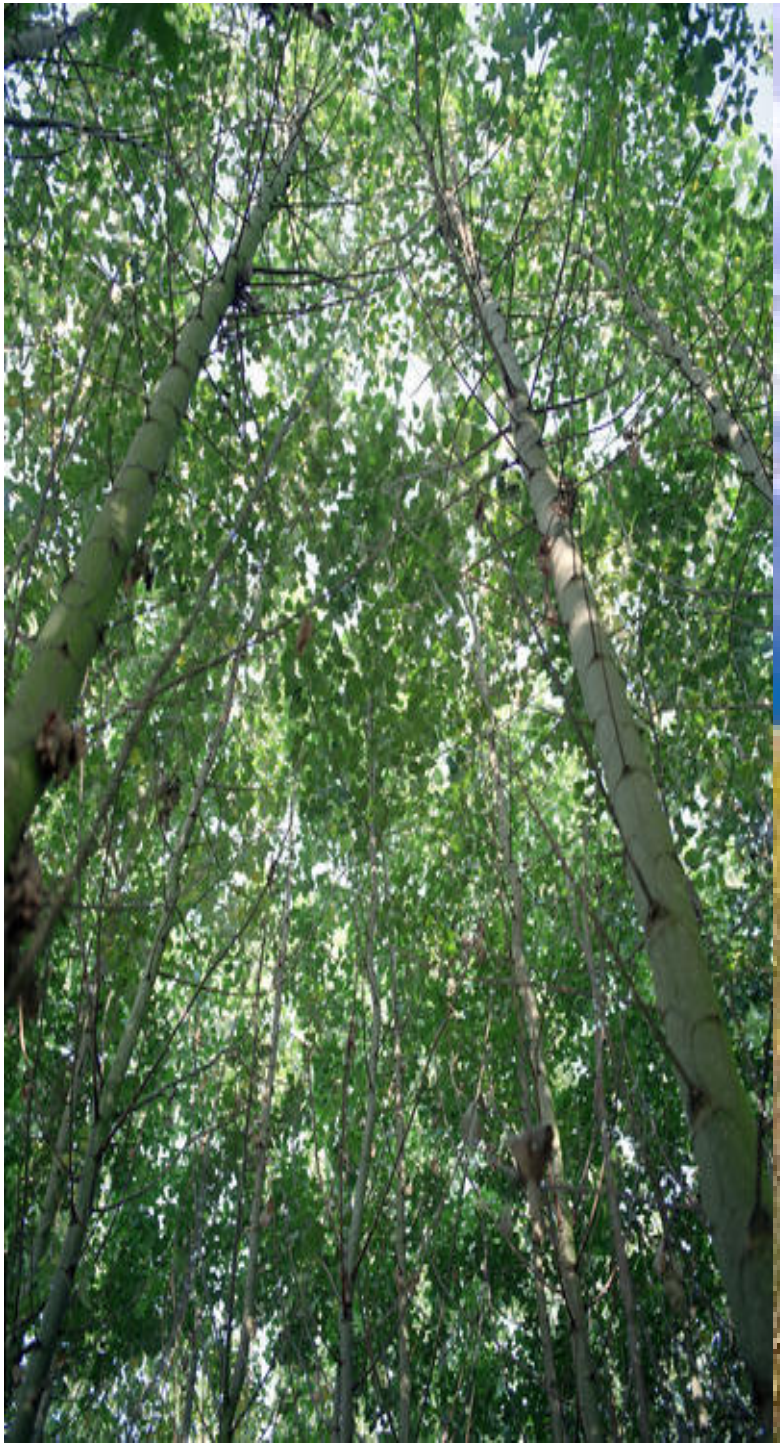
Growing America's: Biorenewable Energy

Ag residues

Corn stover (4 tons/acre/year)

Small grain straw (1 ton/acre/year)

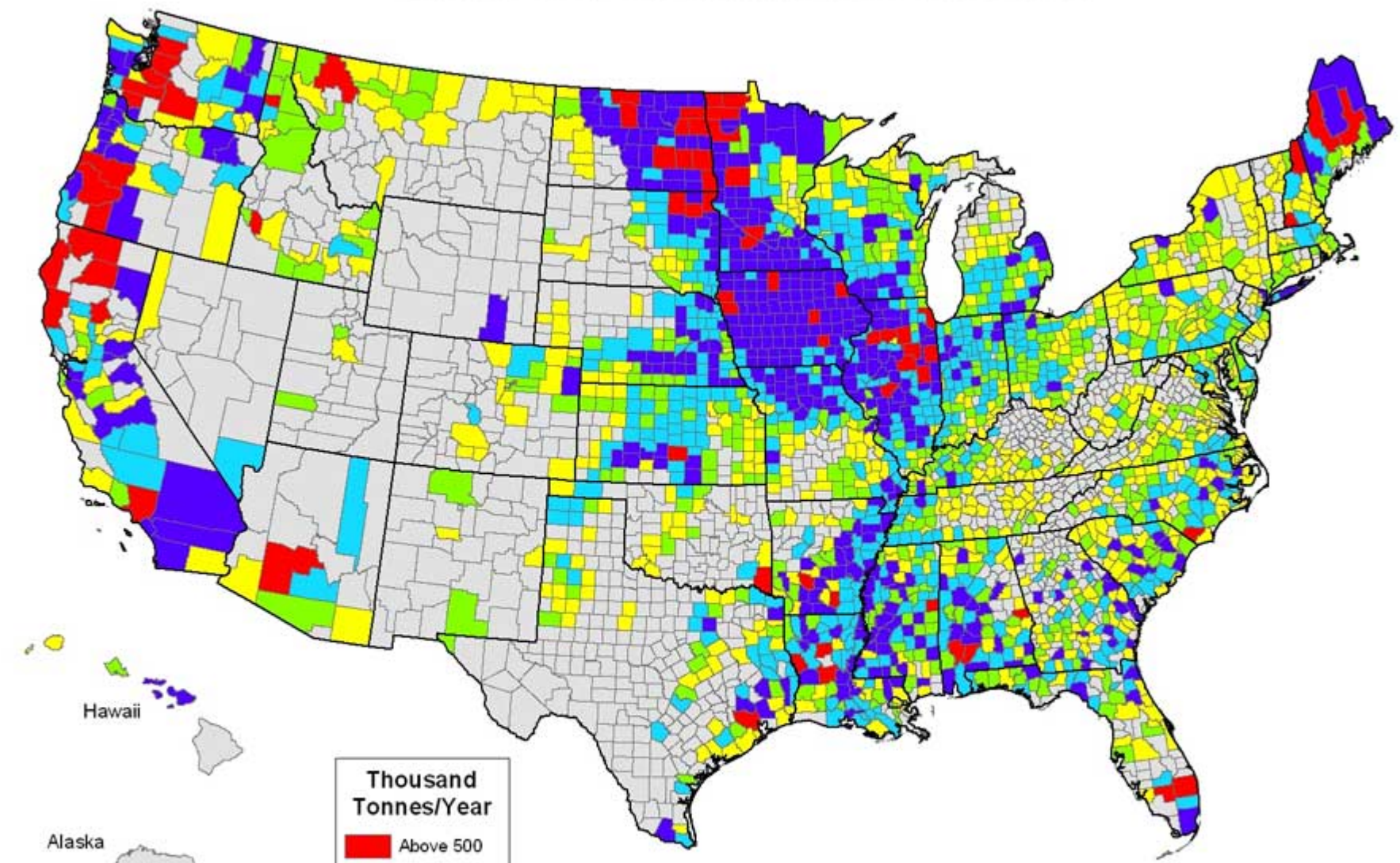


Bioenergy Field

Energy Crops

- Perennial crops
- Grass crops (5 - 20 tons/year)
- Woody crops (10 tons/year)
- 1,000 gallons ethanol/acre

Biomass Resources Available in the United States



This study estimates the technical biomass resources currently available in the United States by county. It includes the following feedstock categories:

- Agricultural residues (crops and animal manure);
- Wood residues (forest, primary mill, secondary mill, and urban wood);
- Municipal discards (methane emissions from landfills and domestic wastewater treatment);
- Dedicated energy crops (on Conservation Reserve Program and Abandoned Mine Lands).

NREL

September 2005

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Challenges to Biomass Energy

- Developing a stable & sustainable feedstock supply
- Feedstock infrastructure
- Conversion efficiency hurdles
- Cost-competitiveness


Impacts Public Policy
on Technology and
Industry

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Public Policy Issues facing Biorenewable Energy Industry

1. Effective & timely permitting processes
2. Infrastructure investment:
   roads, rails, water, capital
3. Environmental and transportation regulations/mandates on producers and consumers
4. Intergenerational farm transfer
5. Economic competitiveness
6. Workforce development:
   education system,
   vitality of communities

Adapting technology to grow rural America


Stewardship of natural resources while growing the economy (field to fuel tank to family analyses)

Emerging Ethanol Technology

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    - Corn Ethanol with 1.5 lbs/bu Oil Recovery
  - Intermediate Future (2-4 years):
    - Corn Ethanol with 1.5 lbs/bu Oil Recovery and Fiber Conversion to 0.8 gal/bu Ethanol
    - 2/3 reduction in DDGS
  - Distant Future (8-10 years):
    - Biomass Conversion to 110 gal/t Ethanol
    - No DDGS; No oil

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How much ethanol can SD produce from corn stover? (2004 data)

- 4.15 million acres corn @ 130 bu/a
- 539.5 million bu corn = 15.1 million tons corn & 15.1 million tons stover (1:1 mass ratio)
- 45% stover removal (sustains tilth) = 6.8 million tons
- 680 million gallons ethanol/year produced (100 gal ethanol/ton stover)
- Plus {1.51 billion gallons ethanol from grain} (2.8 gal/bu grain)