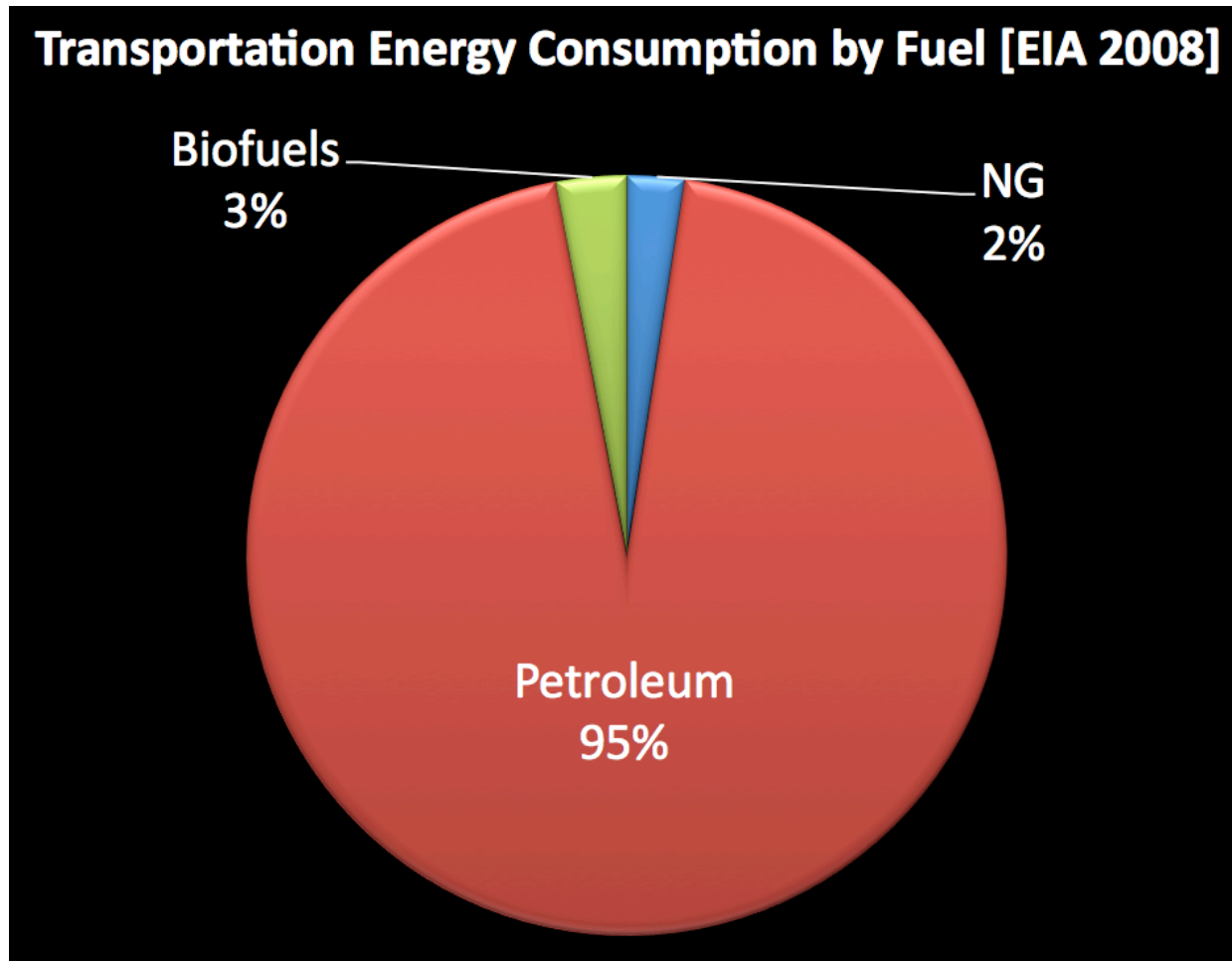




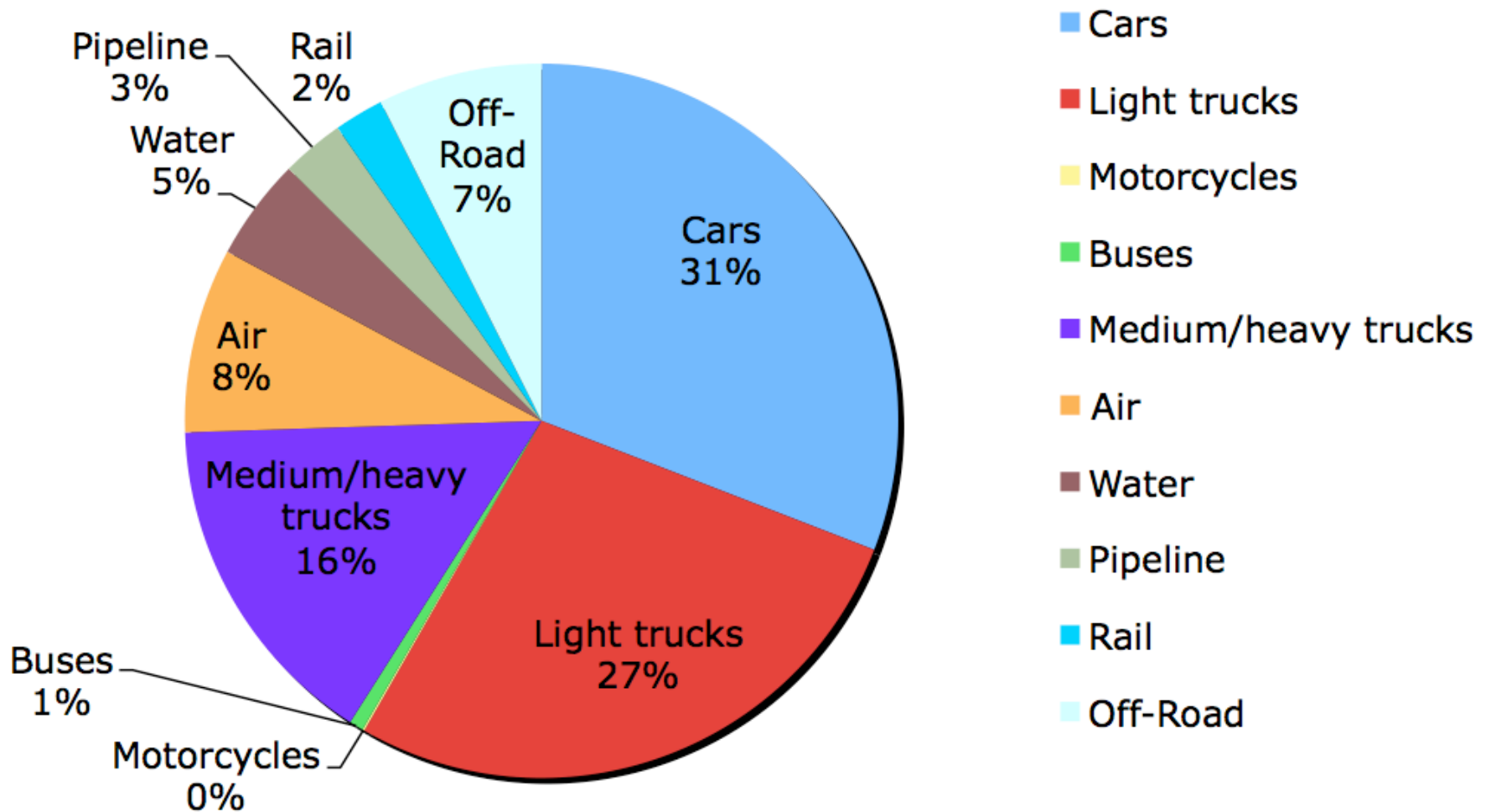
XI. Renewable and Alternative Fuels

Petroleum Is the Dominant Fuel Source for Transportation



Three-Fourths of Transportation Energy Consumption Is From Road/Highway Travel

U.S. Energy Consumption for Transportation by Sector [U.S. DoE, 2005]



Biofuels have several advantages

- **Crop-based biofuels consume CO₂ during photosynthesis**
- **Residue-based biofuels reduce demand for new fuels and bring value to waste products**
- **Domestic sources of biofuels are available**
- **Renewable**
- **Biodegradable**



Biofuels terminology

- **First letter indicates the fuel**
 - **B for Biodiesel (regardless of source)**
 - **E for Ethanol (regardless of source)**
 - **Not clear how to label biobutanol**
- **Second number indicates the percentage**
- **Some standard biofuel blends**
 - **B5 = Diesel blended with 5% biodiesel**
 - **B20 = Diesel blended with 20% biodiesel**
 - **E10 = Gasoline blended with 10% ethanol**
 - **E85 = Gasoline blended with 85% ethanol**

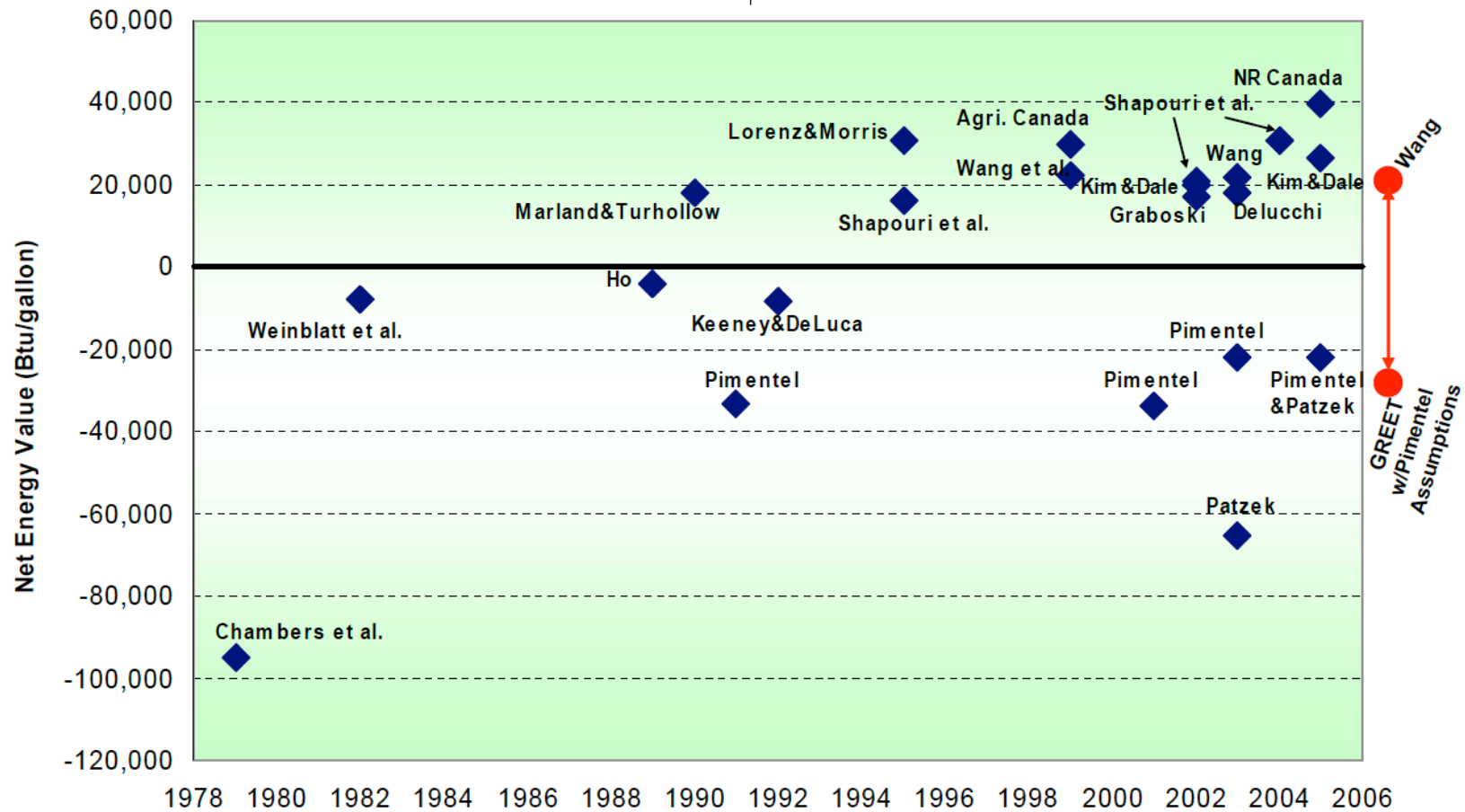


There are several different sources of ethanol

- **Starches**: corn, etc.
 - least amount of energy return per unit mass
 - process into sugars, then ferment to alcohol
- **Sugars**: sugar cane, sugar beets, etc.
 - more energy output per unit mass than corn
 - ferment directly to alcohol
- **Cellulosic materials**: corn stover, wood chips, switchgrass,...
 - grows without irrigation, tillage, topsoil erosion
 - not everyone agrees with these claims
 - requires enzymes to break down lignin



Not All Studies Show Positive Energy Balance for Corn-Based Ethanol



Energy balance here is defined as Btu content a gallon of ethanol minus fossil energy used to produce a gallon of ethanol

Energy required to produce ethanol includes energy required to make fertilizer, energy required to run farm equipment, energy required to perform irrigation, and other energy demands; most recent studies show positive energy balance

Source: Wang, Argonne National Lab. *Updated Energy and Greenhouse Gas Emissions Results of Fuel Ethanol*, 2005.



Corn-Based Ethanol is not Problem-Free

- **Consumes fossil fuels: fertilizers, pesticides, heat for fermentation, diesel-powered trucks and farm equipment**
- **Consumes water:**
 - **6 gal H₂O/gal EtOh (processing), 600-1500 gal H₂O/gal (growing)**
- **Expedited topsoil erosion**
- **Negatively impacts the nitrogen cycle**
 - **growing dead zone in the Gulf of Mexico**
- **Ethanol has lower energy content than gasoline by ~30%**
- **Ethanol corrodes pipelines, so it must be trucked (w/Diesel)**
- **Corn cannot be piped, so it must be trucked (with Diesel)**



Biodiesel Can Be Made From a Variety of Feedstocks

- **Soybean oil: most common source in the U.S.**
- **Canola (Rapeseed) oil: most common source in EU**
- **Palm oil: World production exceeds soybean oil and concentrated in Far East (Main producers: Malaysia and Indonesia)**
- **Coconut oil: High concentration of saturated fatty acids**
- **Beef lard: obtained from cows, restaurant grease, etc.**
- **Algae: highly productive, but experimental**



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Biodiesel Productivity Varies for Different Feedstocks

Feedstock	Production [gallons/acre]
Algae	500-20,000
Palm Oil	625
Canola/Rapeseed	125
Castor	113
Sunflower	90
Jatropha	75
Soybeans	63
Cottonseed	38



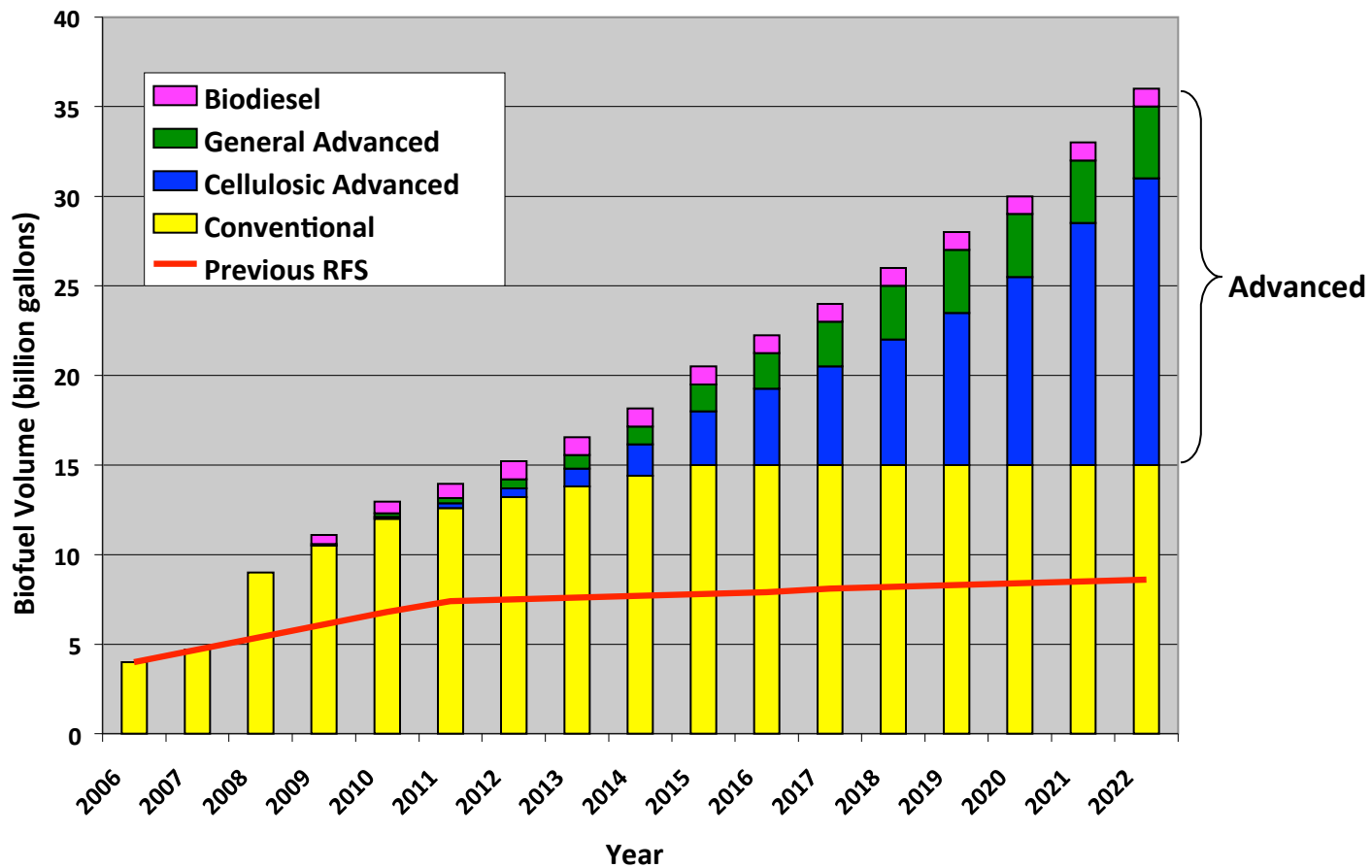
Sources: 1) "Grow Your Own," *Science Observer, American Scientist*, Volume 94, September-October, 2006. 2) National Renewable Energy Lab, U.S. Department of Energy, 1998. 3) NREL, Algal Biomass Summit 2007

Ethanol Production Has Been Actively Encouraged

- **Energy Policy Act of 2005 (EPACT 2005)**
 - required 7.5 billion gallons of renewable fuels by 2012
- **Energy Independence and Security Act of 2007 (EISA 2007)**
 - **Requires 36 billion gallons of biofuels by 2022**
 - **Up to 15 billion gallons per year from corn**
 - **21 billion gallons must be derived from non-cornstarch products**



Renewable Fuel Standard (Energy Independence and Security Act of 2007)



Source: National Geographic, Nov 2008

VANISHING FORESTS

Logging on Borneo kicked into high gear in the 1970s, and for decades the island provided much of the world's tropical hardwoods. About half its forest cover remains. The less accessible central highlands have received the most protection; lowland forest loss remains a threat as more concessions are granted for lucrative plantations of oil palms and other commercial trees, which conservationists point out could be planted on unforested land. Even degraded and fragmented forests can sustain some wildlife, but a plantation's one-crop habitat is inhospitable terrain.

BORNEO LAND COVER AS OF 2005

- Deforested between 2002-2005
- Degraded lowland forest and regrowth
- Palm oil and tree plantations, heavily fragmented forest, agriculture, bare soil, and aquaculture
- Remaining forest cover
- National park and selected forest reserve
- Inland water

TATTERED DEFENSES

Satellite images of Gunung Palung National Park reveal how logging stripped the bordering lands and invaded the park. New park management has stemmed the damage.

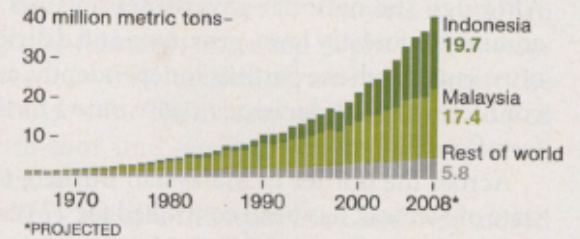


Biodiesel Is a Leading Cause of Deforestation in Malaysia

The Impact of Oil Palms

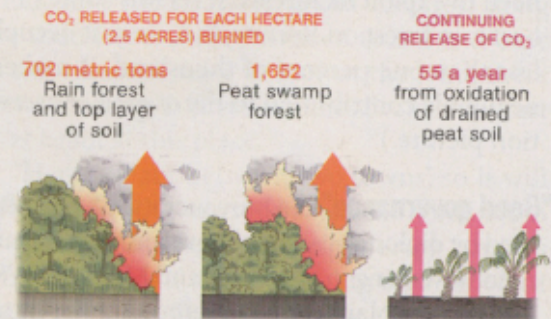
PRODUCTION

Indonesia and Malaysia dominate the global palm oil market, with much of it produced on Borneo. Extracted from the fruit of the oil palm, the oil is used in foods, cosmetics, detergents, and biofuel.



CO₂ EMISSIONS

Among the consequences of clearing forest to create farmland: Indonesia trails only China and the U.S. in CO₂ emissions. Cultivating the island's organically rich peat soil also releases massive amounts of carbon.

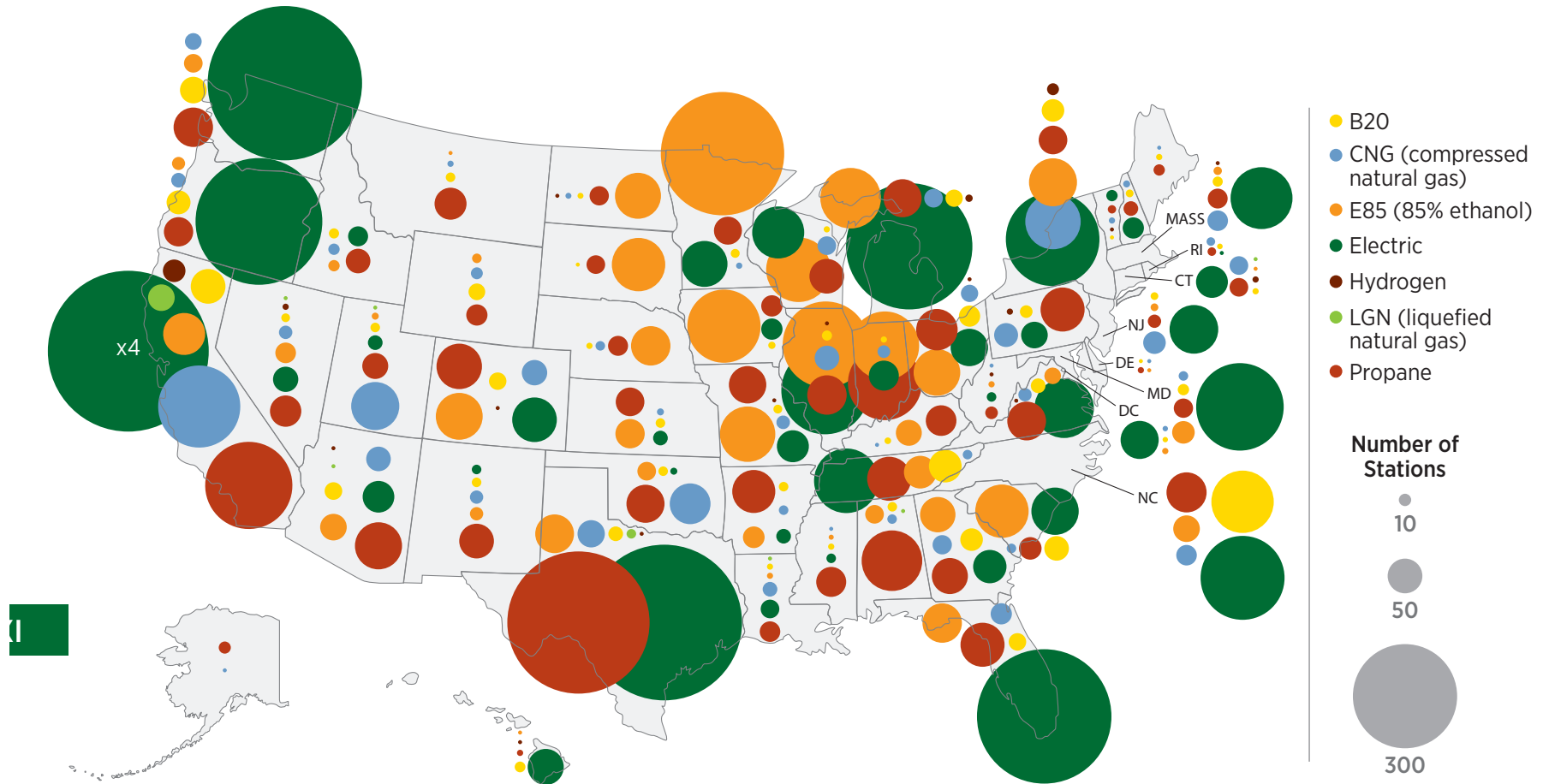


24.4 Annual CO₂ emissions for average U.S. household

Renewable and Alternative Fuels

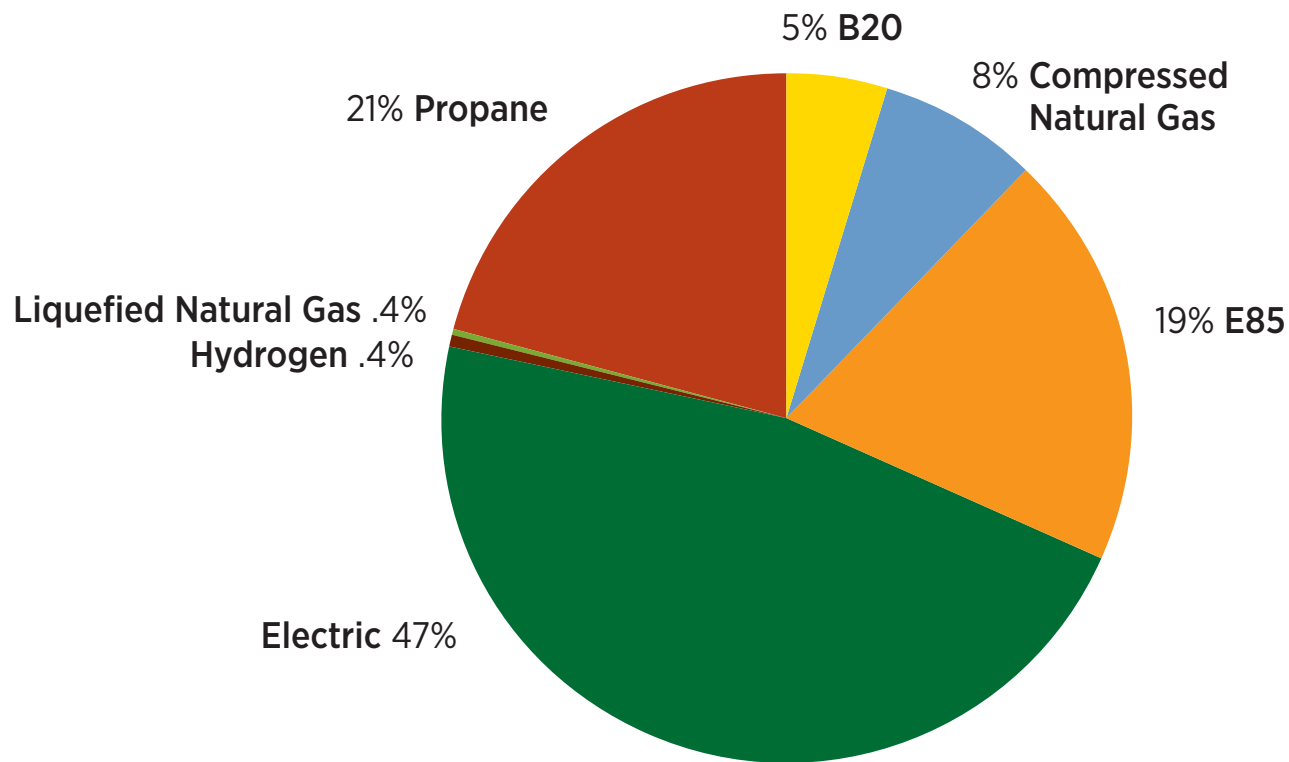
- Corn ethanol production in contrast to Brazil's ethanol, which is produced from sugar cane, continues to expand rapidly in the United States. **Between 2000 and 2011, production increased more than 8 times.**
- U.S. ethanol production **grew nearly 5% in 2011** over 2010 to reach almost **14,000 million gallons** per year.
- In 2011, the United States* produced 62.2% of the world's ethanol, followed by Brazil at 24.9%, the European Union at 5.4%, China at 2.5%, and Canada at 2.1%.
- In 2011, the number of electric vehicle charging stations expanded by a factor of 9 to 6,033.

Renewable and Alternative Fueling Stations by State

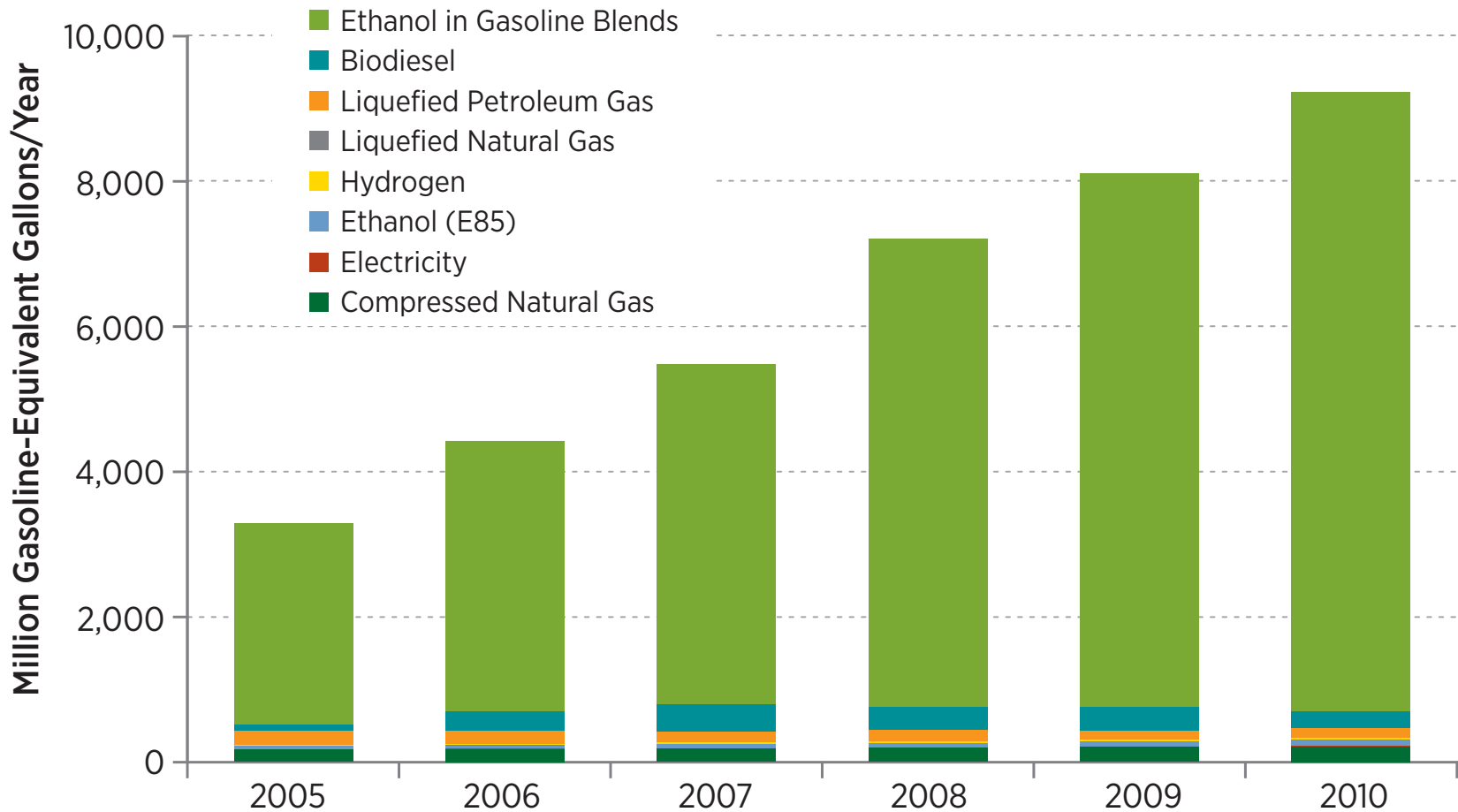


Renewable and Alternative Fueling Stations

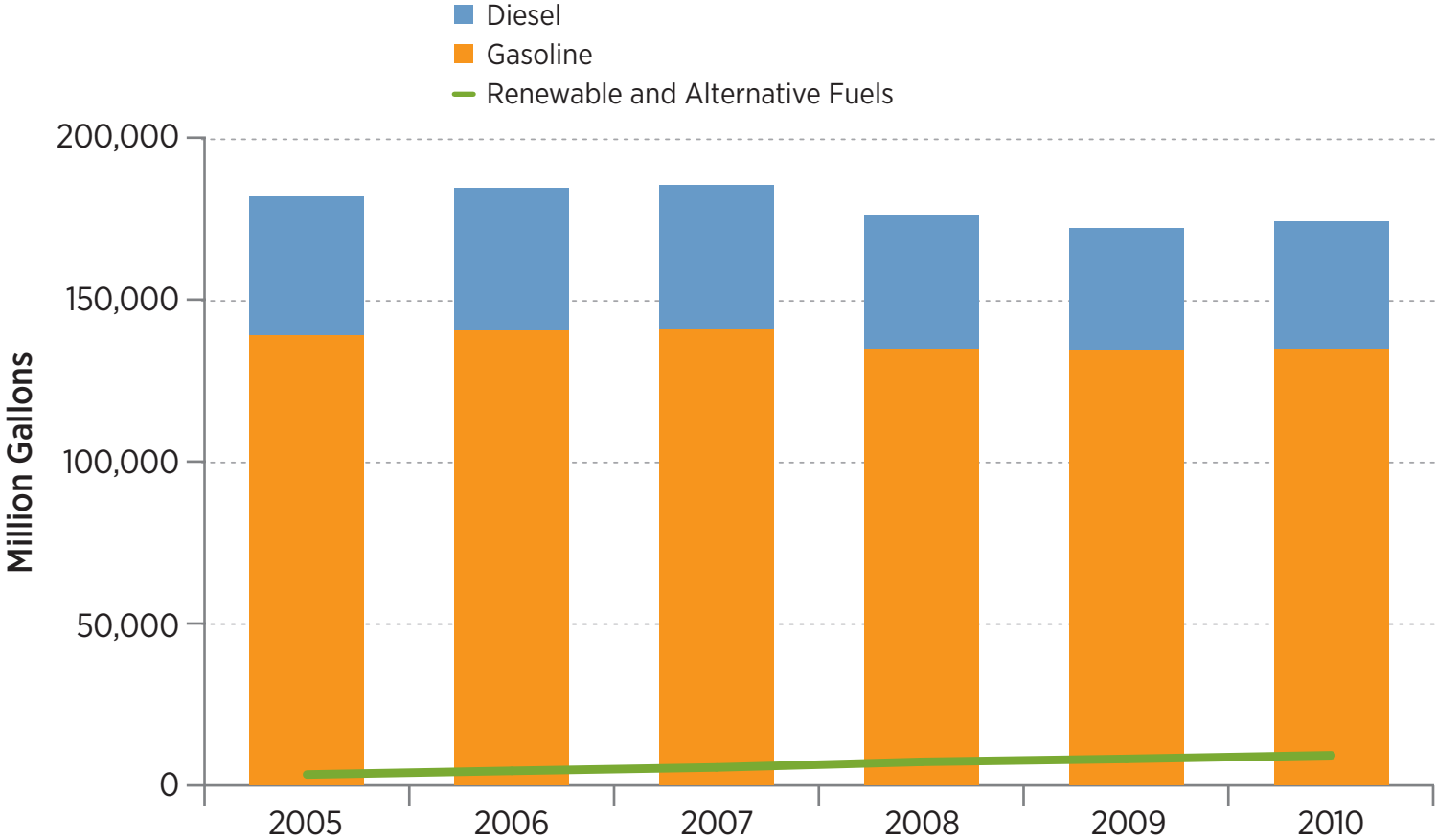
12,927 Alternative Fueling Stations in the United States



Consumption of Renewable and Alternative Fuel in the United States (2005–2010)

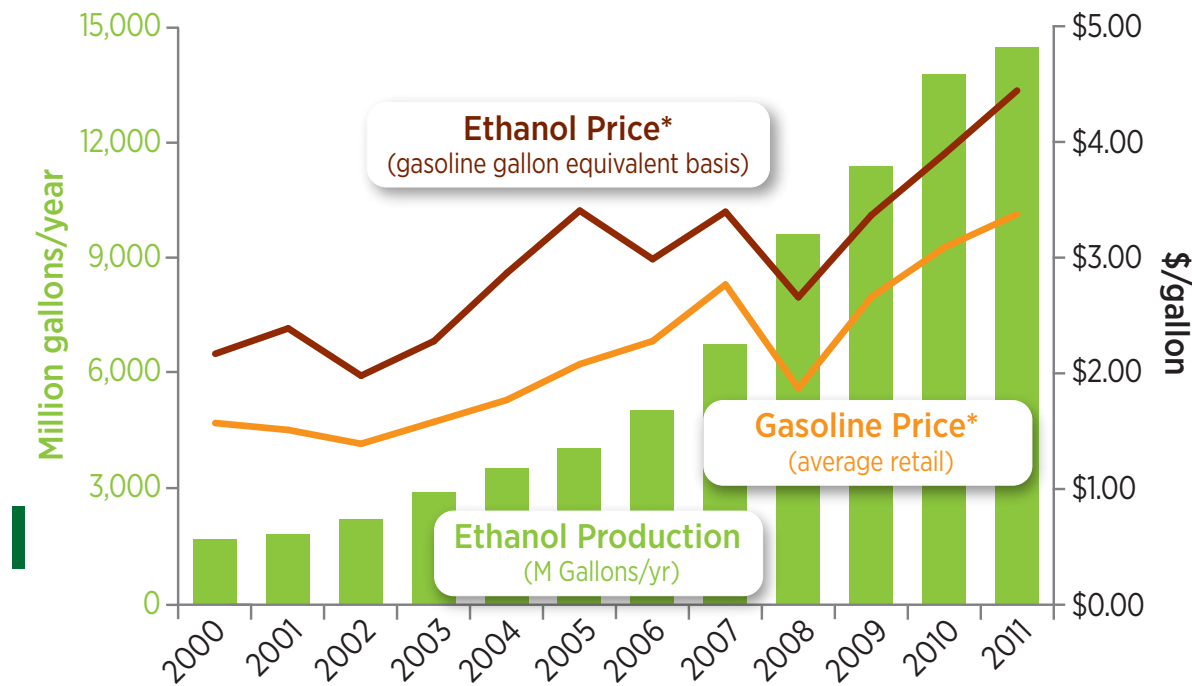


Consumption of Traditional Fuel in the United States (2005-2010)



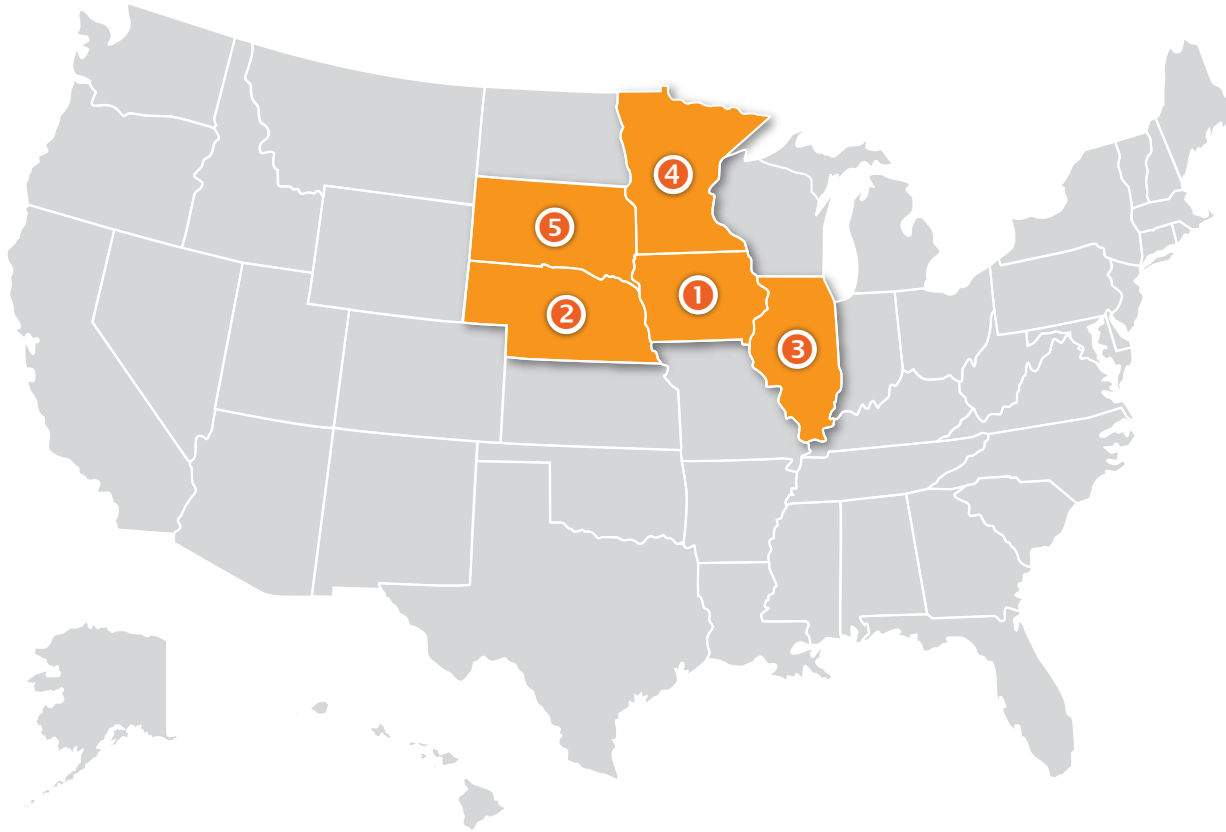
U.S. Corn Ethanol Production and Price Trends

In 2010, there were **1,424,878 ethanol (E85) fueled vehicles** on the road in the United States



	Gasoline Price (Average Retail, \$/gallon)	Ethanol Price (gasoline gallon equivalent basis, \$/gallon)	Ethanol Production (million Gallons/year)
2000	\$1.56	\$2.16	1,630
2001	\$1.50	\$2.38	1,770
2002	\$1.38	\$1.97	2,130
2003	\$1.54	\$2.27	2,810
2004	\$1.76	\$2.86	3,410
2005	\$2.07	\$3.40	3,905
2006	\$2.27	\$2.98	4,855
2007	\$2.76	\$3.39	6,485
2008	\$1.86	\$2.56	9,235
2009	\$2.65	\$3.36	10,938
2010	\$3.08	\$3.89	13,231
2011	\$3.37	\$4.44	13,900

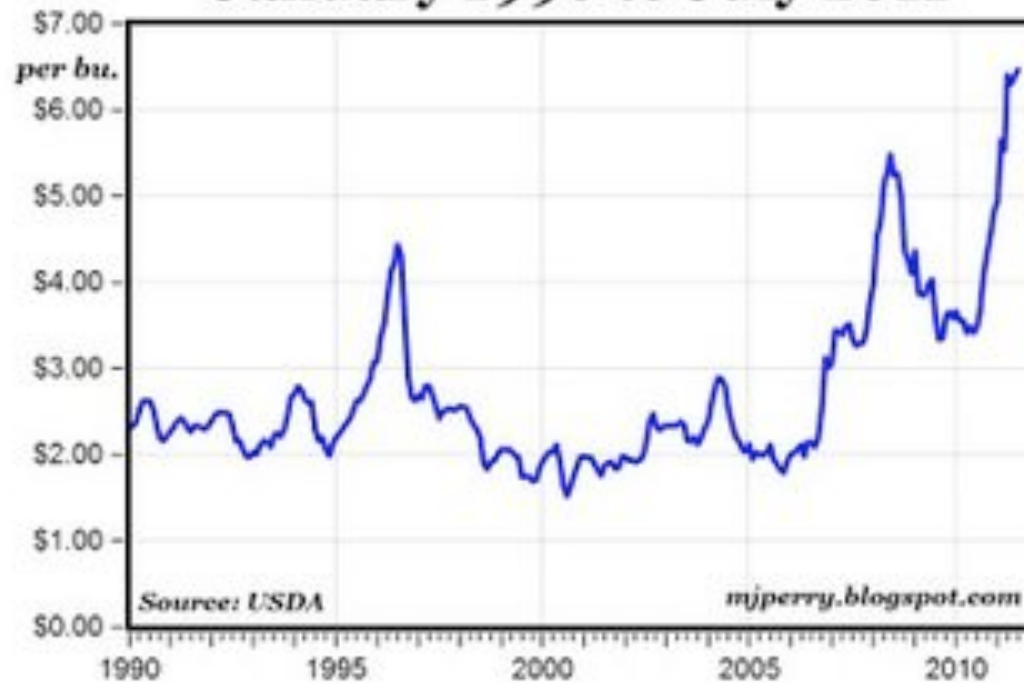
U.S. Corn Ethanol Production Capacity



Top Five States for
U.S. Ethanol (operating)
Production Capacity in 2011
(millions of gallons/year)

1 Iowa.....	3,625
2 Nebraska.....	1,973
3 Illinois	1,486
4 Minnesota	1,129
5 South Dakota	1,009

U.S. Corn: Avg. Price to Farmers January 1990 to July 2011



Federal subsidies for corn ethanol installed in 1970's,
removed in 2011

Towards a lighter carbon footprint for corn ethanol

