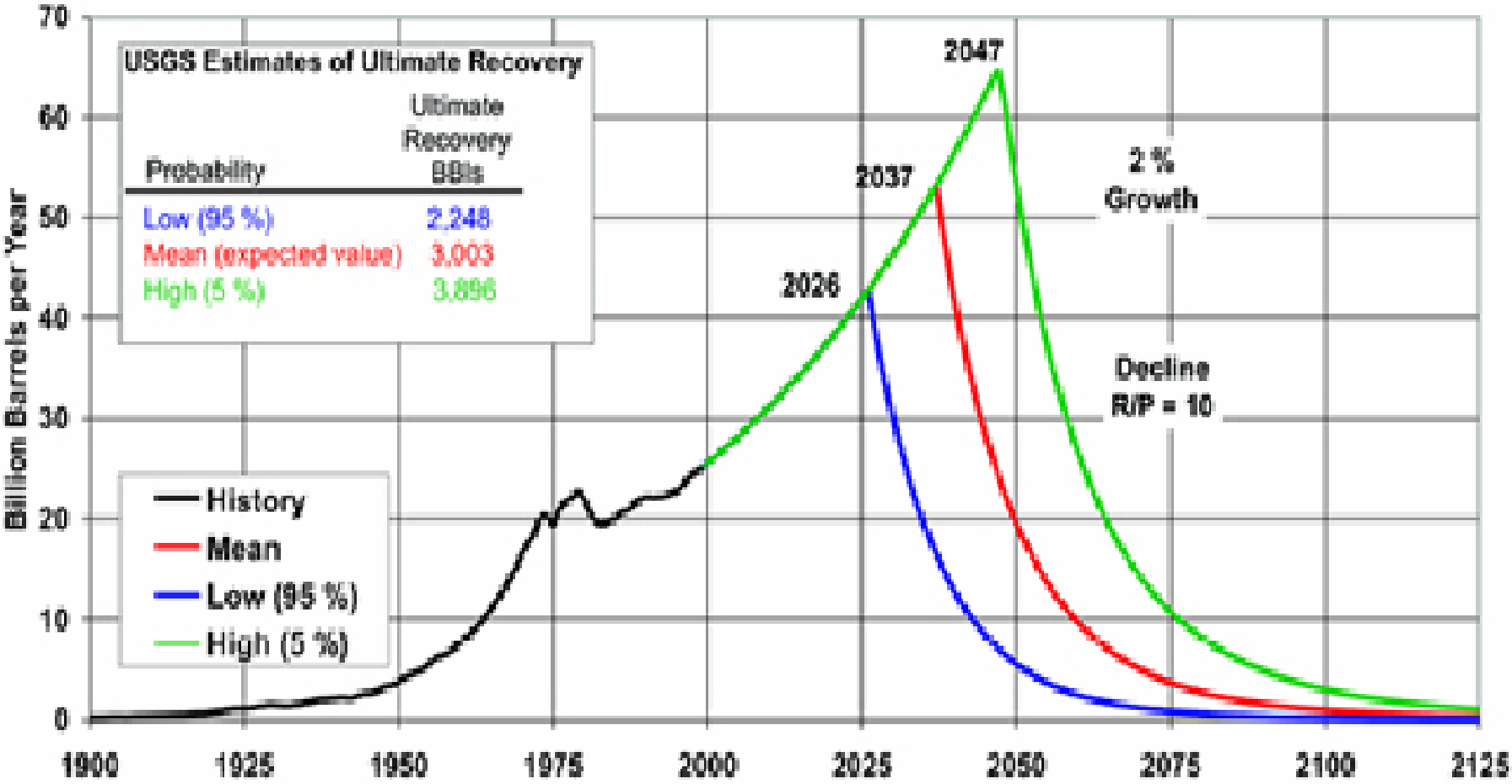
The Case for Bio-Fuels

Lester B. Lave & Michael W. Griffin
Carnegie Mellon University
November 8, 2006

Let’s agree:

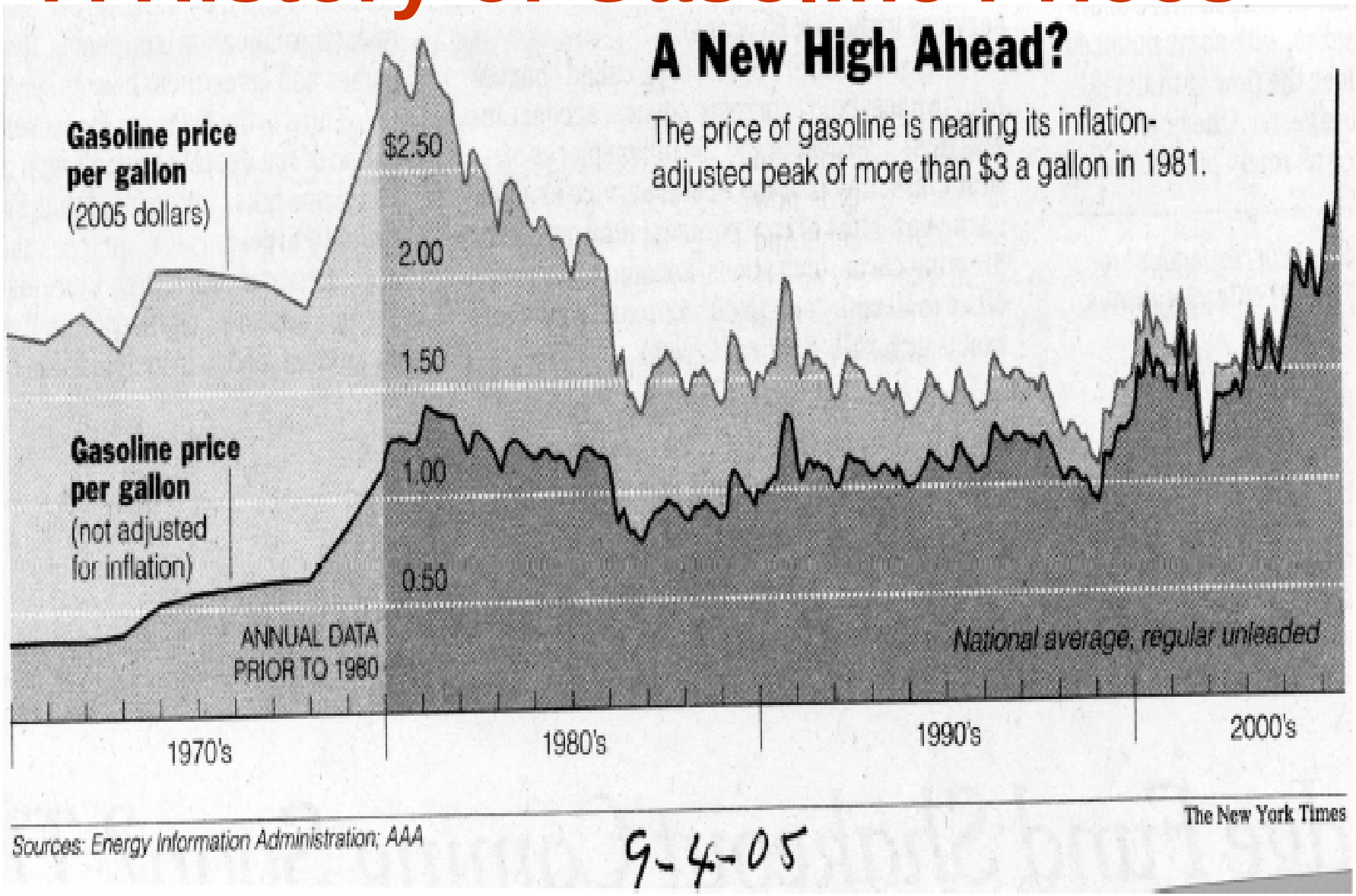
- Oil is a finite resource; We are consuming it faster than it is made!
- At some point oil will be more expensive than other alternatives.
- The largest single user of oil is the transportation sector so gasoline is a very important target.
- Price is volatile & likely to get more volatile
- There are many reasons to use less oil

Figure 2. Annual Production Scenarios with 2 Percent Growth Rates and Different Resource Levels (Decline R/P=10)



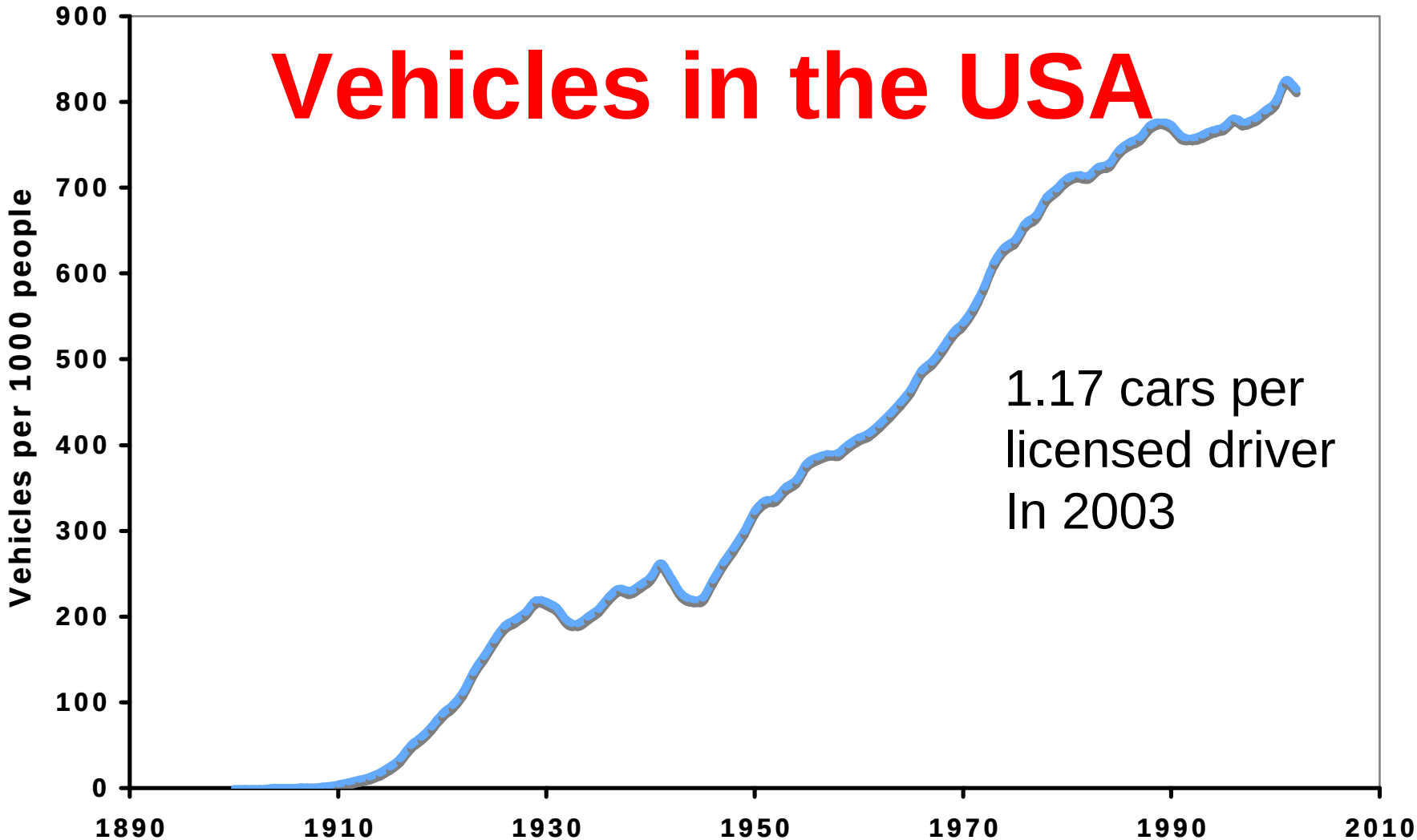
Source: Energy Information Administration
Note: U.S. volumes were added to the USGS foreign volumes to obtain world totals.

A History of Gasoline Prices

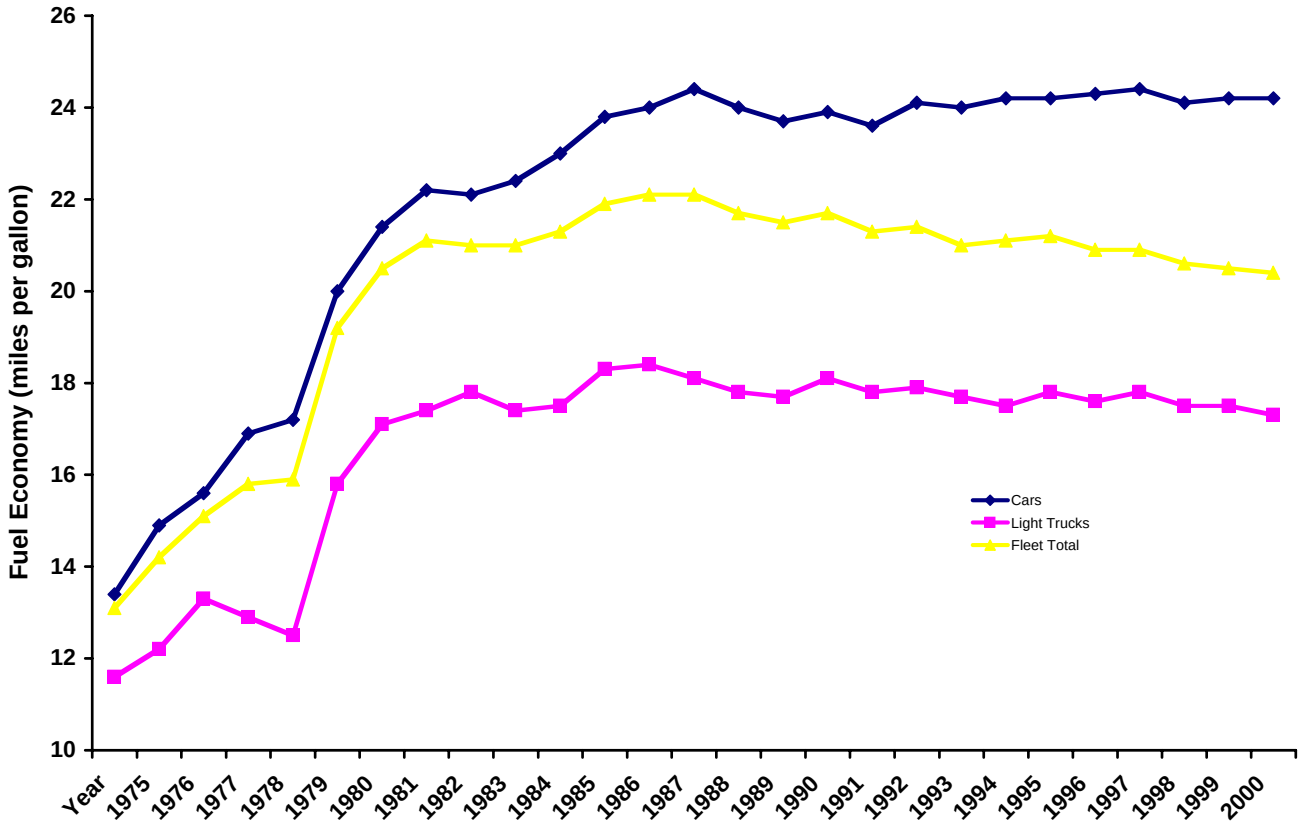


Gasoline: Federal Policy is Bankrupt

- We don't plan, we just muddle through!
- Relieving short-term pressures got us here
- High gas lead some politicians to want to suspend gas taxes or send a rebate check – but never admit policy failures
- Blame oil companies, MBTE, air pollution controls, OPEC, closing ANWR, etc. to exploration – just distract us from reality


Vehicles in the USA
Vehicles per 1000 people
900
800
700
600
500
400
300
200
100
0
1890
1910
1930
1950
1970
1990
2010
1.17 cars per
licensed driver
In 2003

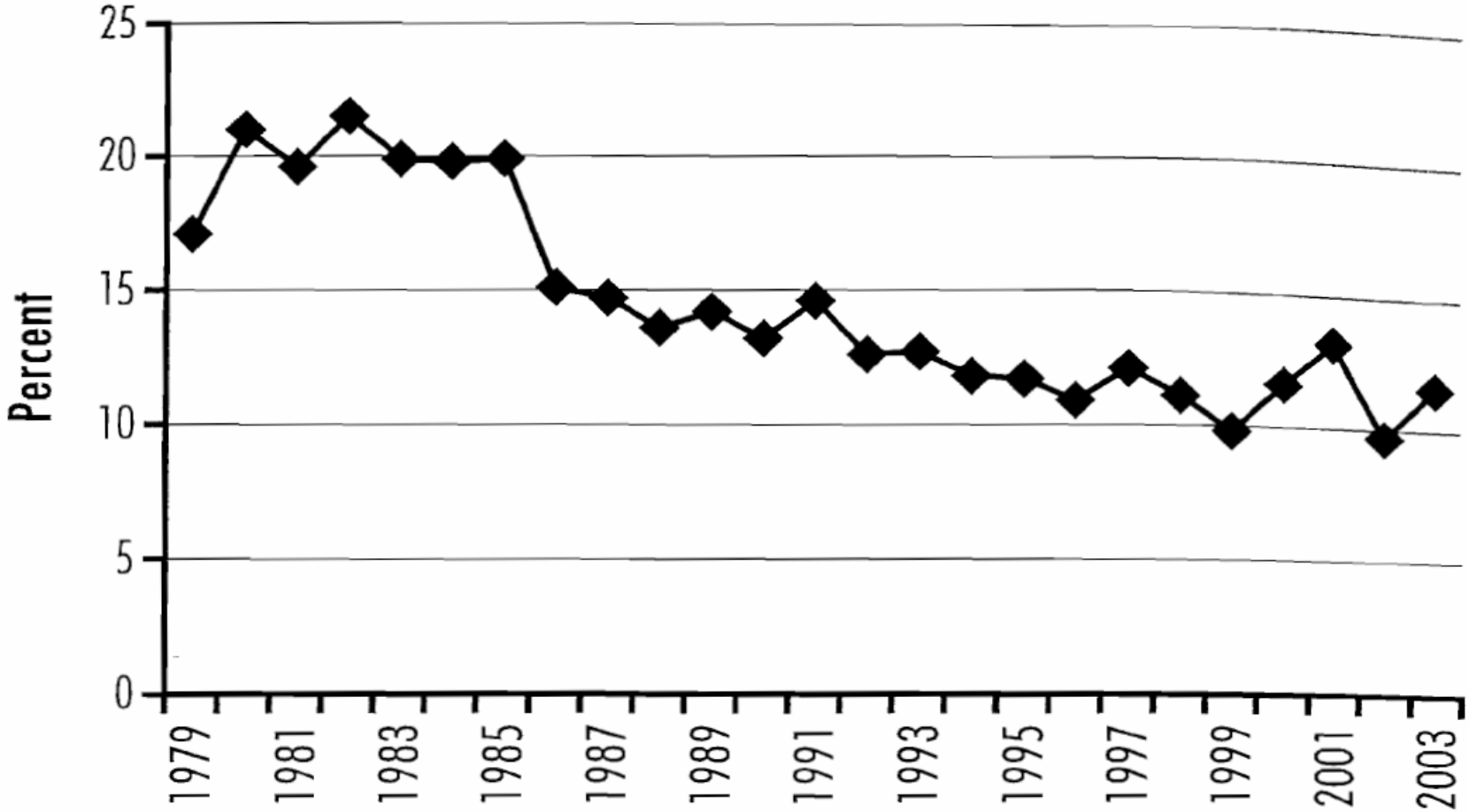
New Vehicle Fuel Economy, 1975-2001



Burgeoning World Demand

- The world loves cars: Chinese & Indian demand growing
- US largest oil importer – 58% of our use
- We are dependent on unfriendly nations - US foreign policy focused on oil supply: High prices could ruin US economy
- Fuel is 10-20% of the cost of owning a vehicle – If you worry about gas prices, don’t buy a Hummer!

Gas & Oil as a Percent of Auto Operation Cost



Source: *Transportation Energy Data Book*, 24th ed., Oak Ridge National Laboratory, Oak Ridge, Tennessee, 2004.

The Case for Ethanol

- Cheaper than gasoline

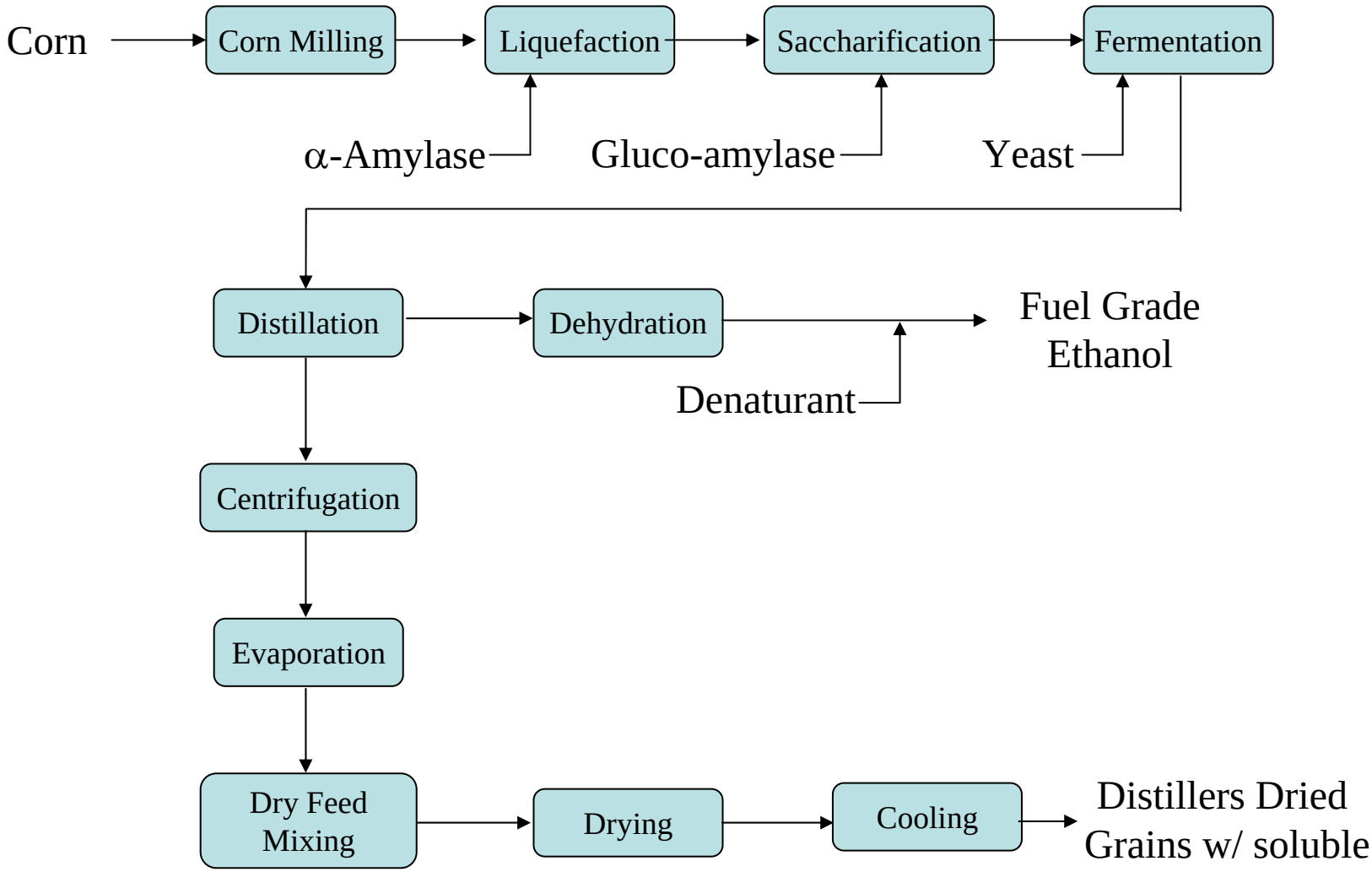
  -Production: $1.10 ($1.65) vs. $2
- Monopsony power ($150/bbl oil)
- Don’t subsidize terrorists
- Good for farmers & rural America-sensible agriculture policy
- Sustainable: No net CO_2 emissions
- Improves soil, water quality, etc.

Biomass: The Case Against

- Biomass expensive: Eth subsidy 51¢/gal.
- We don't have enough land to make more than a trivial contribution to US energy
- Pimental: Ethanol produces no net energy
- Large-scale biomass will ruin the ecology
- Why commit to an expensive biomass program when cheap, non polluting energy will come from innovation? Stake our future on hydrogen and cold fusion! 2020? 2030?

Corn Ethanol

Dry Milling Simplified Process



Corn or Switchgrass?

- The export market for corn is disappearing
- Stop soil loss & pesticide & fertilizer runoff
- Switchgrass improves soil quality
- Potentially greater profit from farming switchgrass – no subsidies
- Return much of Great Plains to prairie grass
- Annual harvest (mowing hay)
- Let herds of bison & elk roam
- More diverse, natural ecology

Cellulosic Sources

- Bioethanol defined as being derived from cellulose/hemicellulose
- Types of energy crops:
  - Hybrid Poplars & other trees
  - Switchgrass & other grasses
- Agricultural Wastes
  - Corn Stover, Wheat Stover

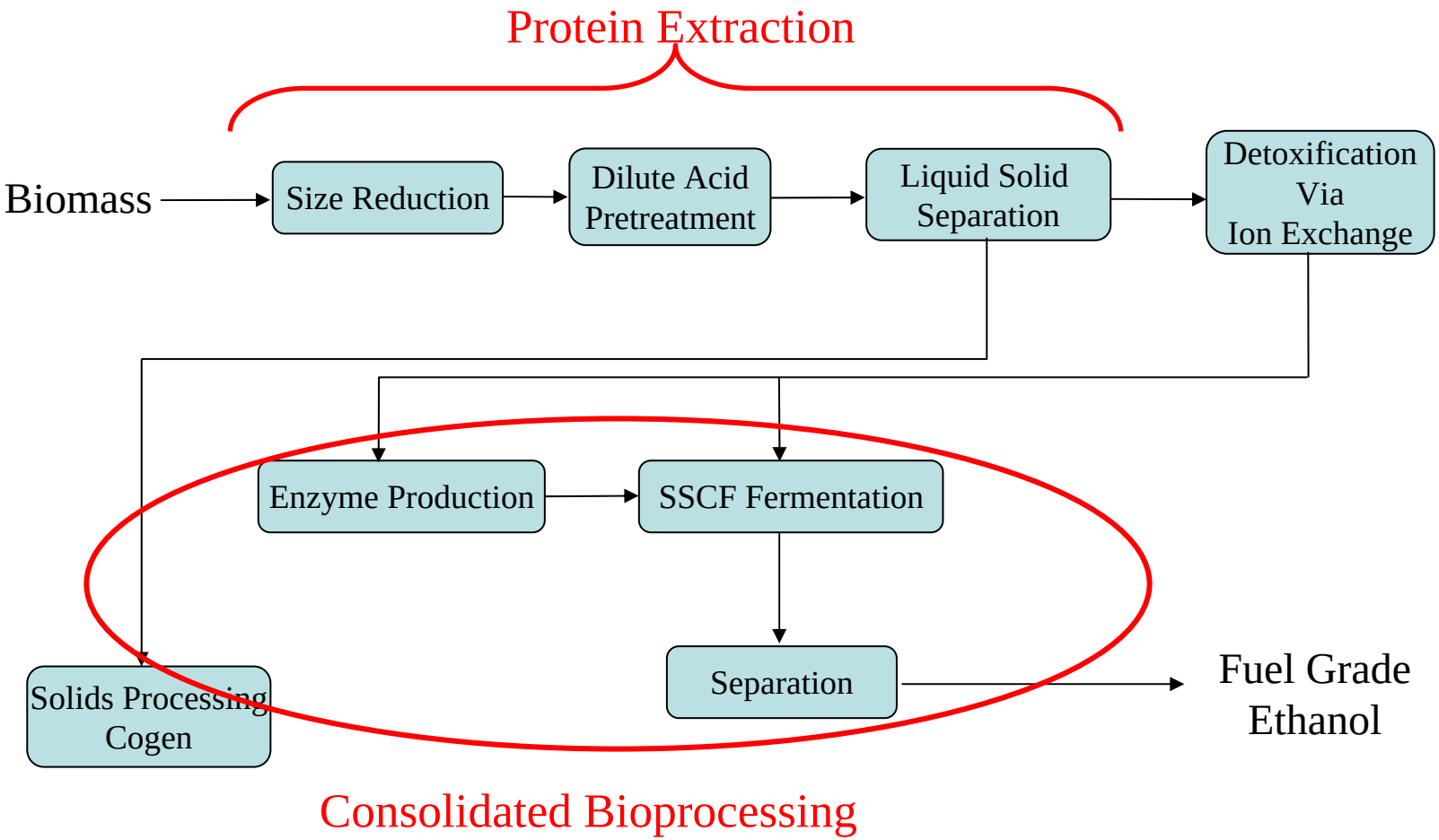
Focus on Switchgrass

- Selected based on results of screening trials in the Northeast, Southeast, Midwest, & Great Plains (Wright 1995).
- Produced:
  - –without irrigation
  - –perennial basis
  - –with nitrogen & phosphorous fertilizer requirements that were typically one-fourth to one-half those for corn production (Downing et al. 1995).

Switchgrass

Switchgrass Stand

Simplified Bioethanol Process



Key to the analysis is yields

- Switchgrass Yields
  - Avg yields 4.8 to 5.3 tons/acre
  - Max yields reached 8.8 to 11.9 tons/acre
  - Theoretical yields to 20 tons/acre
- Ethanol Yields
  - 80 to 90 gallons/ton
  - 100 to 115 gallons/ton
  - 120 gallons/ton (theoretical)

Land requirements needed to meet ethanol-gasoline blend levels[1]

Fuel[2]	Cellulosic Eth Required (billion gallons)	Land Required (million acres)	
		@ 5 tons/acre	@ 10 tons/acre
E5	2	4	2
E10	8	16	8
E20	25	50	25
E85	146	291	146
E100	186	372	186

1 – Base year is 2001, gasoline consumption was 129.7 billion gallons of which 1.5 billion gallons was ethanol

2 – HHV for gasoline (125,000 Btu/gal) and ethanol (84,100 Btu/gal) were used for the calculations

Land Use in the Contiguous 48 States

	Acreage (Million Acres)	Proportion of Total Area (%)
Grassland Pasture & Range	589	31
Forest	559	30
Cropland Total	460	24
Currently Planted	350	18
Special Use	194	10
Other Use	92	5

Possible availability for biomass: cropland 110, some pasture & forest

Current Ethanol Production Costs

	Dry Mill	Wet Mill	Cellulosic @$25/ton
Net Feedstock Costs	0.45	0.37	0.37
Other Operating Costs	0.34	0.31	0.25
Annualized Capital Costs	0.26	0.22	0.54
Total Costs: $/gal	$1.05	$0.90	$1.16

Ethanol required to meet blend levels. with various fuel economies[1] -10[9] gal

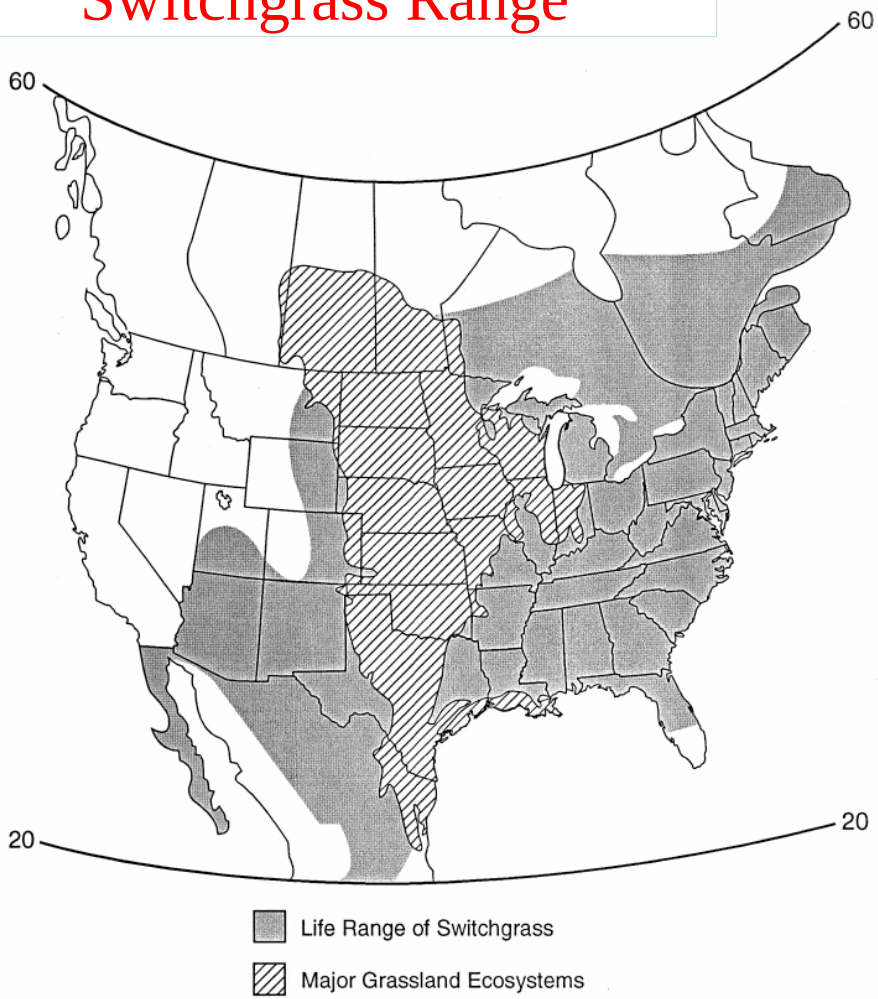
Fuel[2]	Light duty fleet fuel economy increase			
	10%[3]	25%	50%	100%
E5	6[5]	5	4	3
E10	12	11	9	7
E20	27	24	20	15
E85	138	122	101	76
E100	174	153	128	96

1 – Base year is 2001, gasoline consumption was 129.7 billion gallons of which 1.5 billion gallons was ethanol

2 – HHV for gasoline (125,000 Btu/gal) and ethanol (84,100 Btu/gal) were used for the calculations (DOE, 2004)

3 – Base fleet mpg is 20.2 mpg; at 10%, 22 mpg; at 25%, 25 mpg; at 50%, 30 mpg, at 100%, 40 mpg. (DOT, 2004)

Switchgrass Range

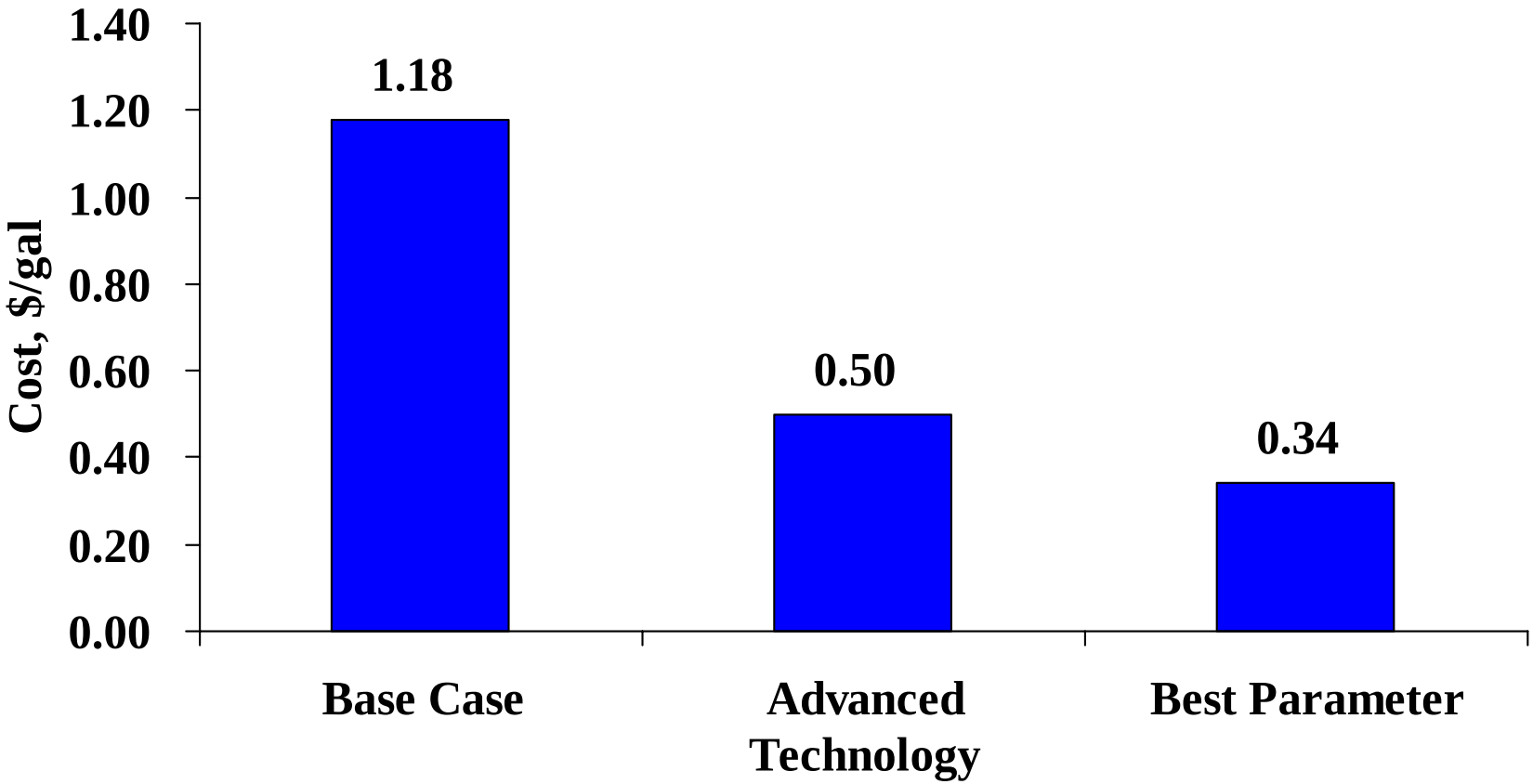


McLaughlin and Walsh 1998

Wood Chips

- Trees can provide cellulose
- Cellulose from trees is estimated to be somewhat more expensive than from switchgrass
- Commercial forests (paper) in NE, SE, NW
- Much of this land is no longer competitive in producing pulp logs
- Potentially large supply from trees

Projected Bioethanol Costs



Other Biomass Fuels

- Ferment sugars to butinol: Advantages in shipping and blending – Cost?
- Gasify biomass: Lower efficiency but can produce any desired fuel – Cost?

Biodiesel:

- Used fry oil to biodiesel: Great idea!
- Soy, Corn or canola oil: OK if excess oil
- Technically feasible, economically bankrupt
- Palm oil and jatropha may be attractive

Environmental Impact

- Food vs. energy vs. other uses
- Soil quality
- Water quality
- Chemical inputs
- Biodiversity
  - Monoculture
  - Suitability for wildlife habitat
  - Landscape effects
  - Stability

National Security Issues

Why are we sending $300 billion per year to Iran, Venezuela, Libya, Saudi Arabia, etc.?

Lenin: "The capitalists are so hungry for profits that they will sell us the rope to hang them with." …and they will send us the money to buy the rope!

Acknowledgments

We thank the U.S. Environmental Protection Agency, U.S. National Science Foundation, Canadian National Science & Engineering Research Council, Texaco, Sloan Foundation, W. Alton Jones Foundation, & General Motors (U.S.,Canada) for support

Questions?

Renewable Resources

- At best US Sites, electricity is generated 1/3 of the time: Need 3 times the wind capacity even with free storage
- At best US sites, PV generates electricity 22% of the time – need 5 times capacity
- Or we can modify demand to take power only when it is available – Regulate our activities by the sun and wind?

Can U.S. Reduce CO_2 80%?

- U.S. the Saudi Arabia of coal
- The world has lots of fossil fuels – we will run out of atmosphere first
- Produce electricity with nuclear, renewables coal with carbon capture & storage
- What powers the transportation fleet?

Renewable Options

- Wind, photovoltaic (PV) (solar cells), solar thermal, dams, tides, waves, geothermal, biomass (energy crops)
- Wind cheapest in good locations, but not dependable and supply limited: Local climate effects & global climate effects
- PV is the largest resource, but expensive – sun may not shine when you need power
- Efficient, cheap energy storage critical

Renewable Resources

- At best US Sites, electricity is generated 1/3 of the time: Need 3 times the wind capacity even with free storage
- At best US sites, PV generates electricity 22% of the time – need 5 times capacity
- Or we can modify demand to take power only when it is available – Regulate our activities by the sun and wind?

Other Renewables

- In addition to wind and photovoltaic cell, there are river dams, tides, waves, geothermal, & biomass
- All, except solar, have limited capacity – they can contribute, but not satisfy our demand
- All have adverse environmental effects

Energy for Transportation

- Cars, trucks, aircraft, ships, trains major energy users & CO_2 emitters
- No way to capture CO_2 – don't produce it!
- Biofuels is the short-term answer
- Hydrogen economy?: Energy source?: H_2 is an energy carrier, like electricity
- H_2 difficult to transport & store – dangerous
- H_2 unlikely to be commercial for 20-30 yrs
- H_2 advantage: Water (H_2O) is only emission

Importance of Life Cycle Analysis

- Carnegie Mellon Green Design Institute: www.gdi.ce.cmu.edu
- Input-Output Life Cycle Assessment: www.eiolca.net.
- Book: *Environmental Life Cycle Assessment of Goods & Services: An Input-Output Approach*, 2006.
- Available at Resources for Future or Amazon