Possible Impacts of Industrial Biofuels in the US and the World

GUILLAUME LOUYOT, *Wise Monkeys*, onickz aka sc, 2002

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Disclaimer. . .

I receive no money

for biofuels research

Most Important Points

- The astronomic scale of energy consumption from fossil plants and the minute scale of energy production from new plants are fundamentally incompatible
- In engineered crop systems, we continuously apply fossil fuels and nutrients to replenish soil
- All biofuel systems are very inefficient
- Photovoltaic cells seem to be the most energy-efficient alternative to crude oil. . .
- . . . But only if these cells can be mass-produced and equipped with better electricity storage systems

Units in My Presentation...

- The fundamental unit of energy is 1 exa Joule (EJ)

1EJ = 1,000,000,000,000,000,000 J is the amount of metabolized energy in food sufficient to sustain the entire U.S. population for one year @100 J/s-person = 100 W/person continuously

- Currently the U.S. uses 105 EJ/year; one hundred and five times more than we need to live
- If we were to metabolize this amount of energy, we would be 15 m long sperm whales, each weighing 40 tonnes. There are $\sim$1.9 million of sperm whales worldwide and 300 million Americans

Homo Colossus Americanus. . .

1 Statistical American = 1 Sperm Whale

EUGENE ODUM, *Ecological Vignettes*, 1998

Talk Outline

- Claims of plentiful biomass for biofuels:
  - Green land area in US
  - Solar energy sequestration as biomass from agriculture, pastures, forests, and lumber plantations
- Energy efficiencies of large-scale industrial biomass systems:
  - US corn grain and corn stover
  - Brazilian sugarcane
  - Indonesian acacias
- How to pick a winning technology?
- Conclusions

Claims of Plentiful Biomass

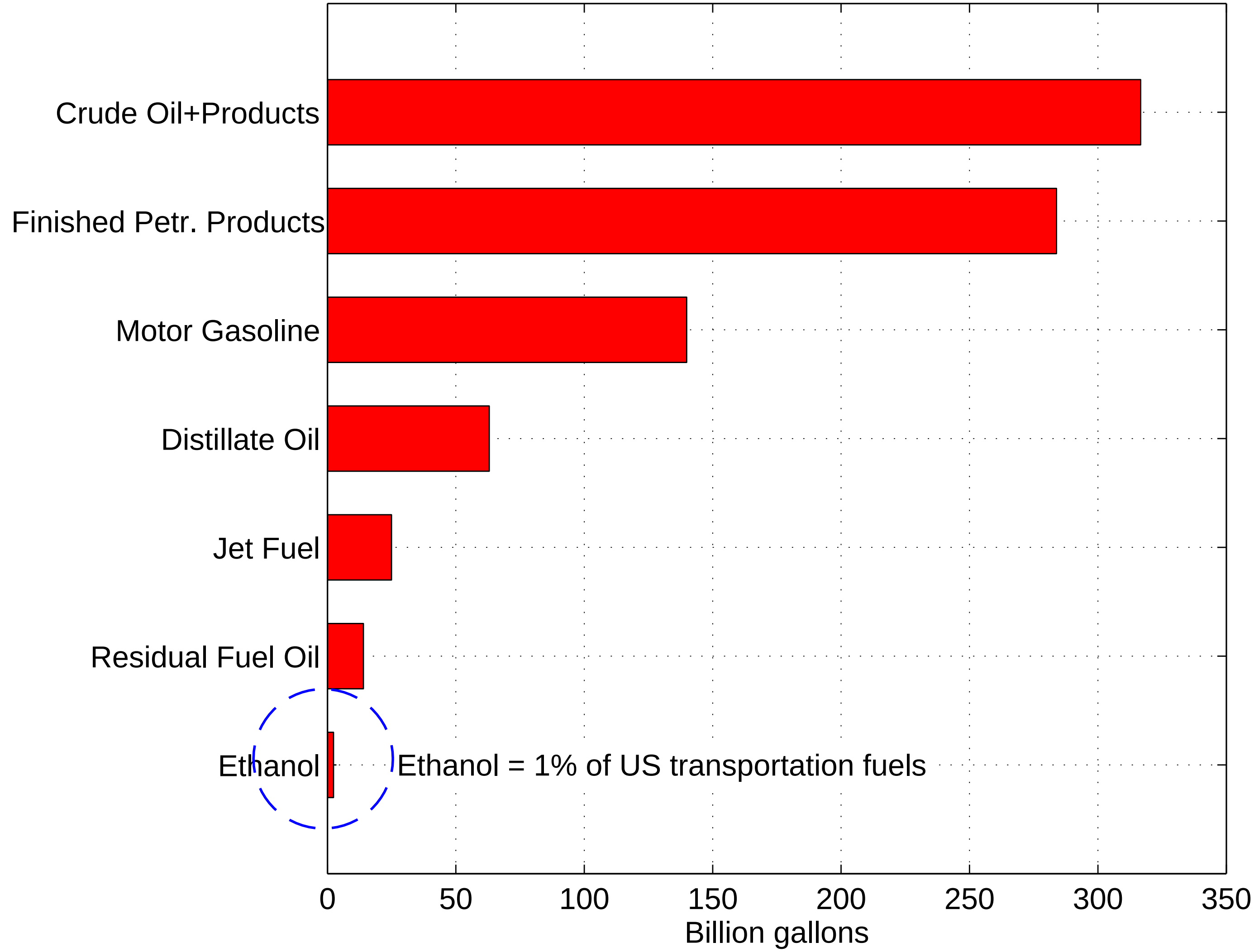
Fuels from Biomass Will Replace Transportation Fuels

- "...An annual biomass supply of more than 1.3 billion dry tons can be accomplished with relatively modest changes in land use and agricultural and forestry practices" *Technical Feasibility of a Billion-Ton Annual Supply US Department of Energy Report*, April 2005
- "Or a 130 billion++ gallons per year!" Vinod Khosla, April 2006 (130 billion gallons of denatured ethanol = 87 billion gallons of gasoline. The US uses 140 billion gallons of gasoline per year)
- "Our goal is replacing 30% of transportation fuels with biofuels by 2030," DOE Secretary Bodman

Do These Claims Make Sense?

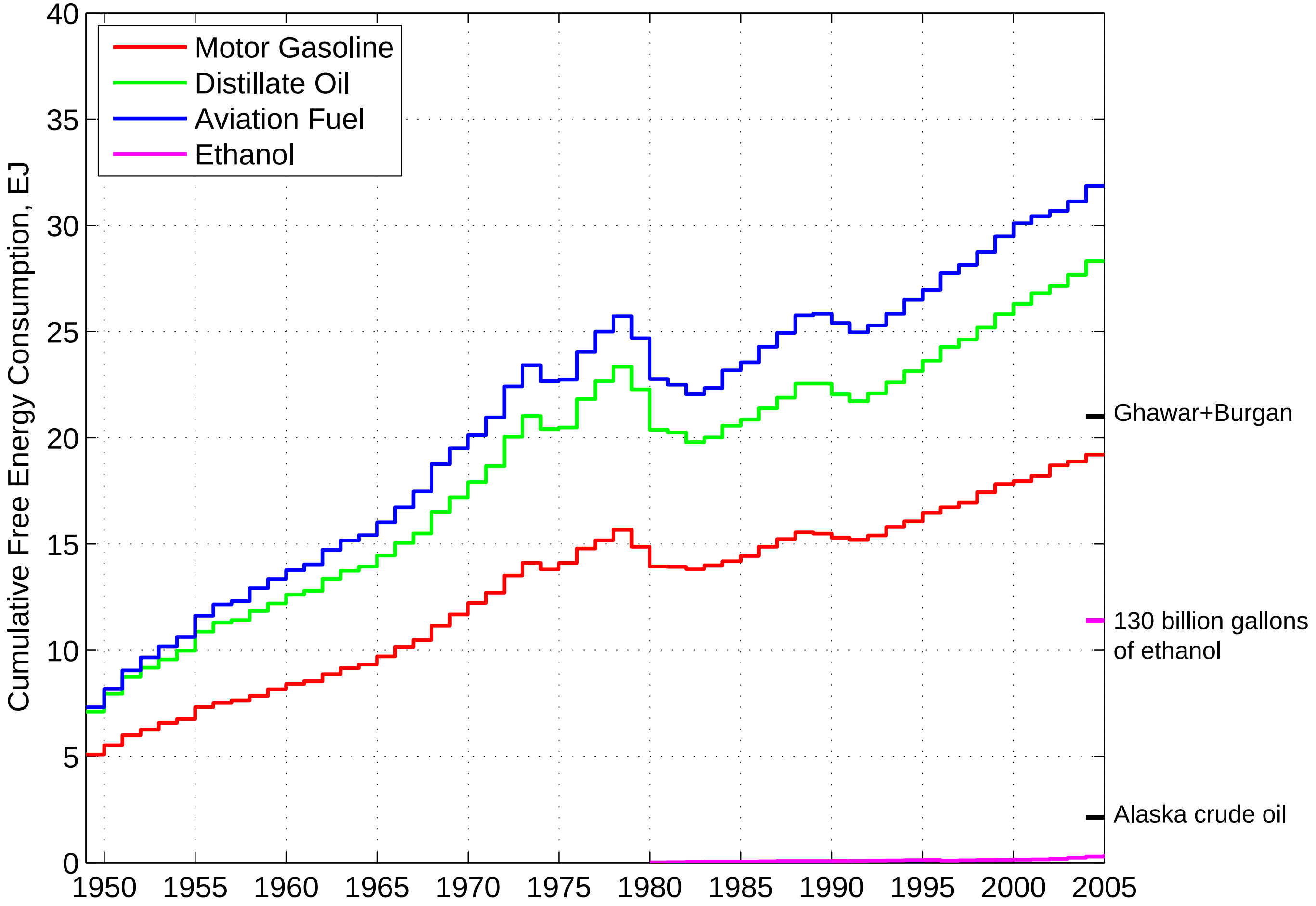
- 130 billion gallons of ethanol is 11.4 EJ per year
- 1.3 billion tons of dry mass is 22 EJ per year, year-after-year, for decades
- Overall conversion efficiency, $11.4/22 = 0.52$ is over 2 times higher than the average energy efficiency of the corn-ethanol cycle
- Current crop production is from best agricultural land in the US, and this efficiency can only go down, not up
- There is not enough clean water
- Industrial cellulosic ethanol technology does not exist, and biomass gasification is in an early pilot stage

2005 US Consumption



Sources: US DOE EIA, Renewable Fuels Association (2006)

Transportation Fuels in US



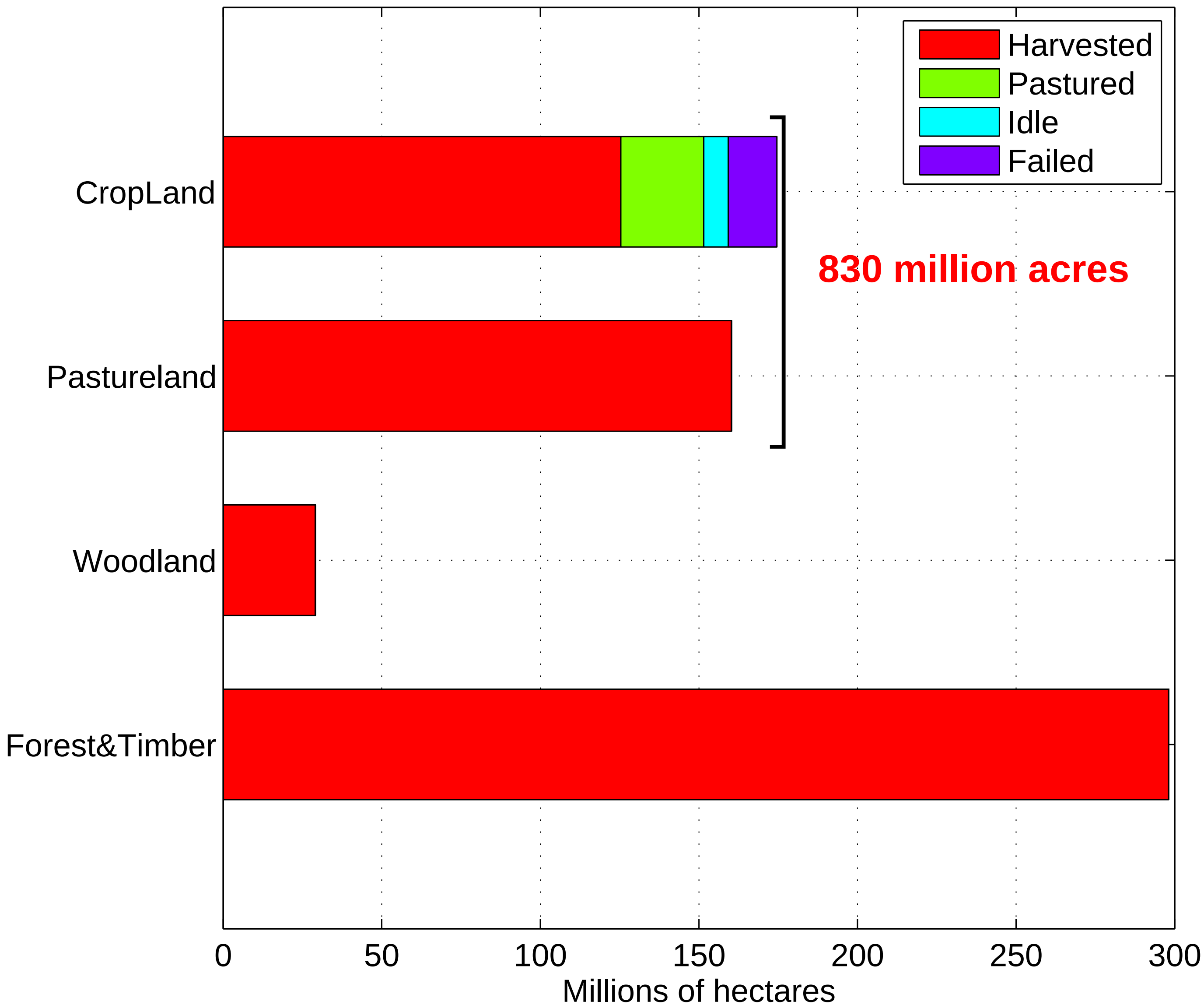
Sources: US DOE EIA, Patzek (2004)

Ghawar and Burgan are the two most productive oilfields on Earth

US Biomass Facts. . .

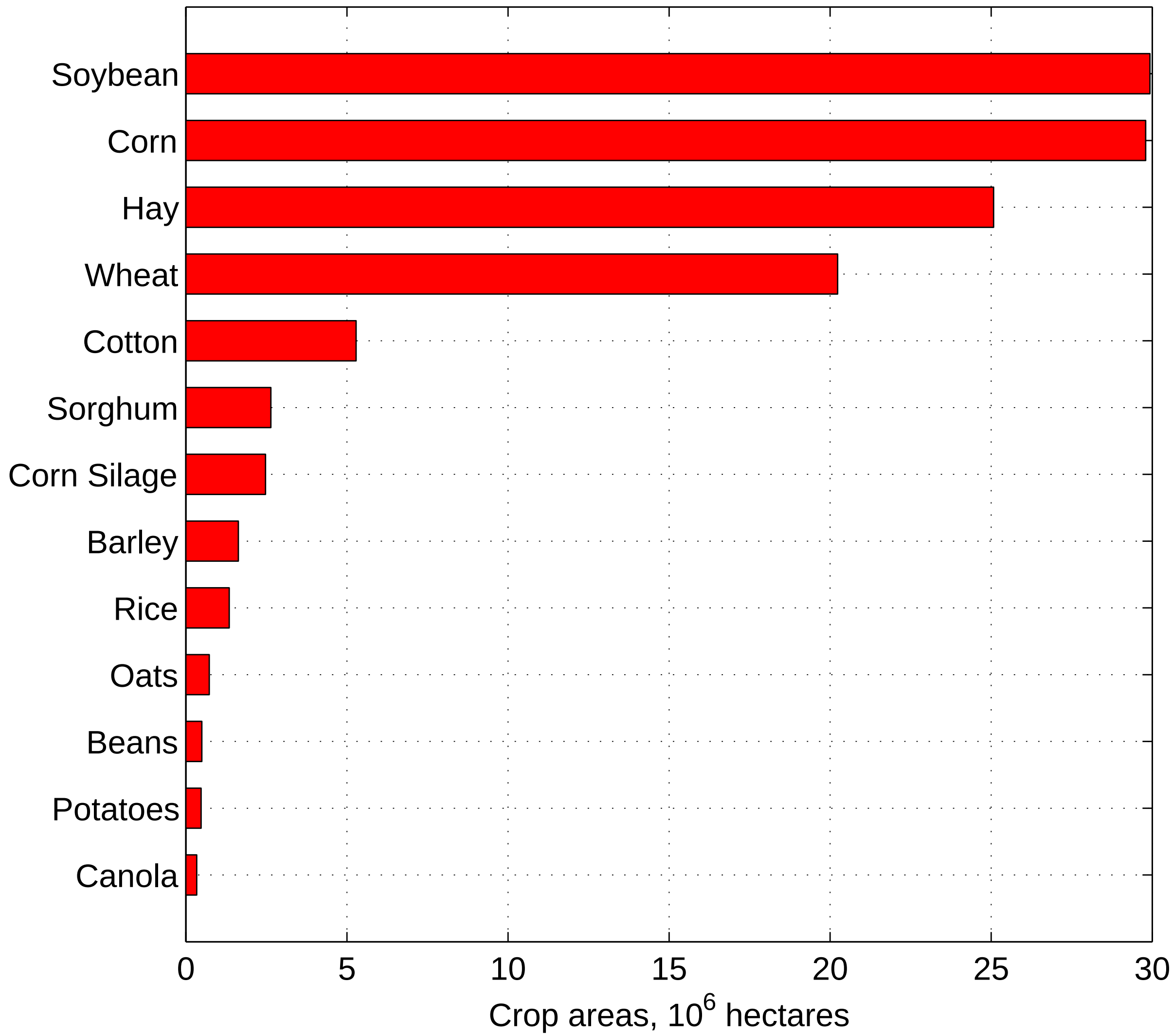
Brief Explanation

Green Land Area in US



72% of land area in US+Alaska+Hawaii. Sources: USDA, US Forest Service

US Agriculture: Crop Areas



Source: USDA NASS, 2004. Total crop area 120 Mha (300 million acres)

Crop→Plant Biomass Conversion

One needs

- Harvest index

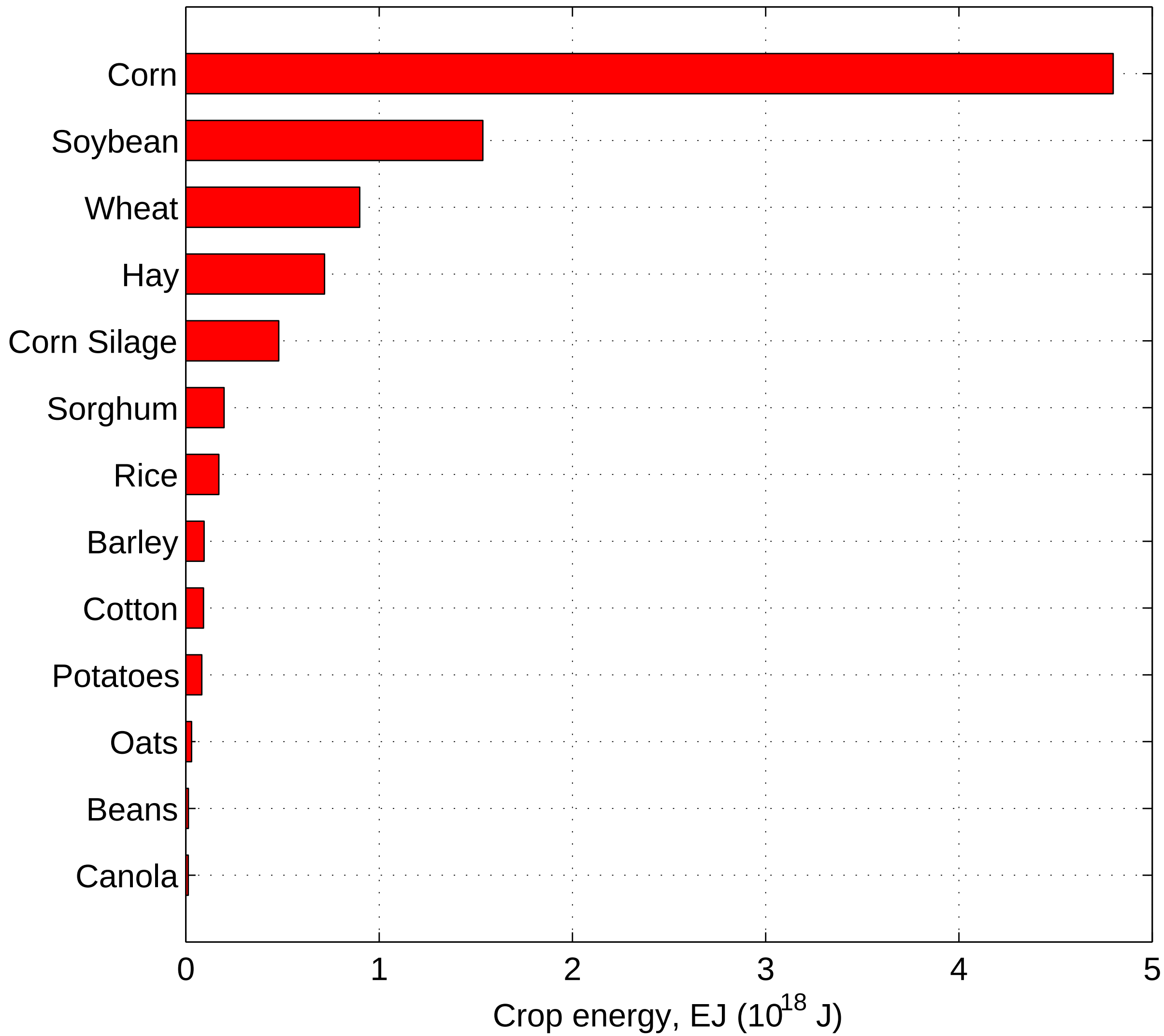
$$\frac{\text{kg harvested seeds}}{\text{kg biomass above ground}}$$

- Root-to-shoot ratio

$$\frac{\text{kg roots at harvest}}{\text{kg biomass above ground}}$$

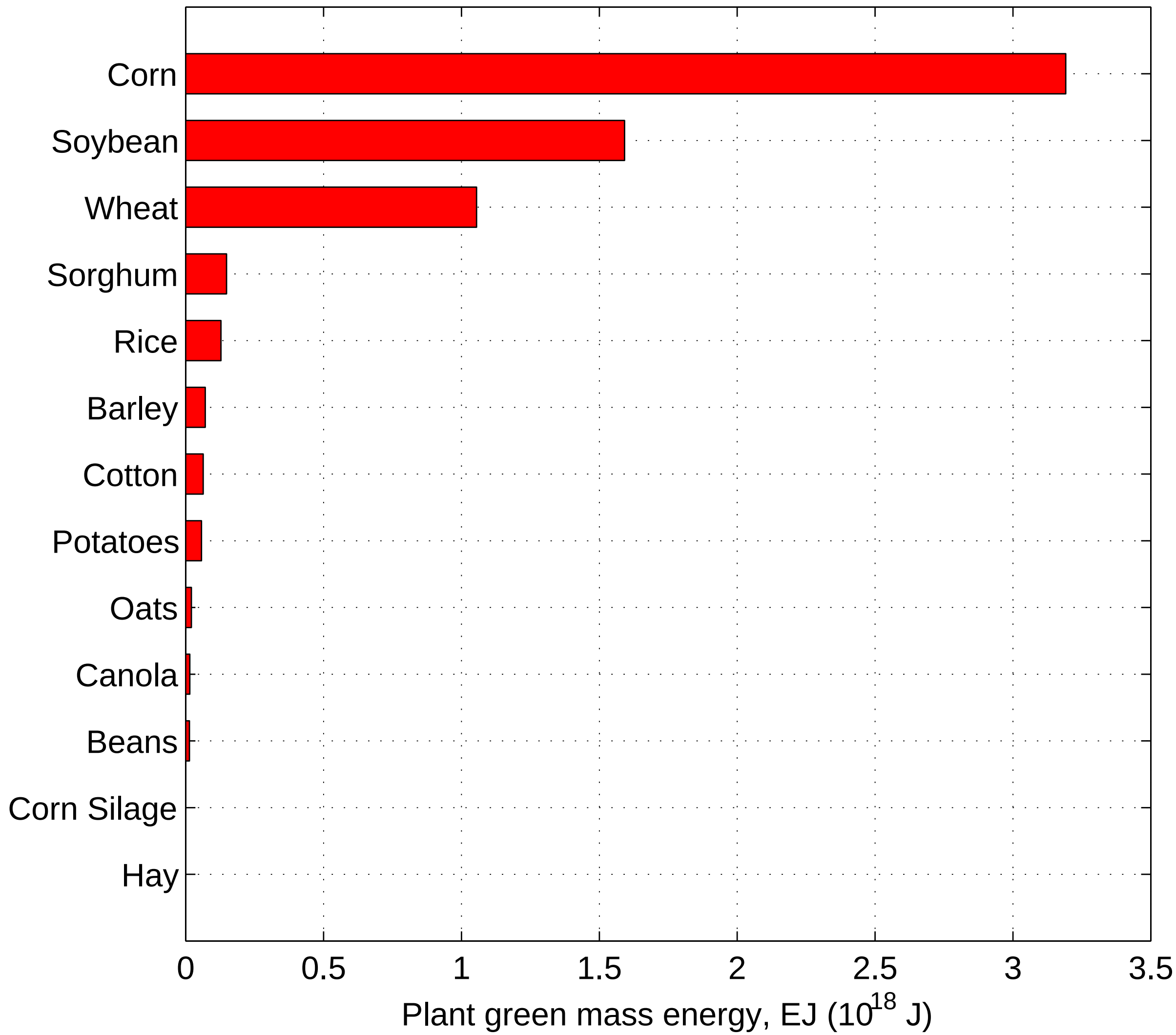
- Moisture contents of crops, above-ground biomass, and roots
- High heating values of plant parts in MJ/kg dry biomass

US Agriculture: Crop Energy



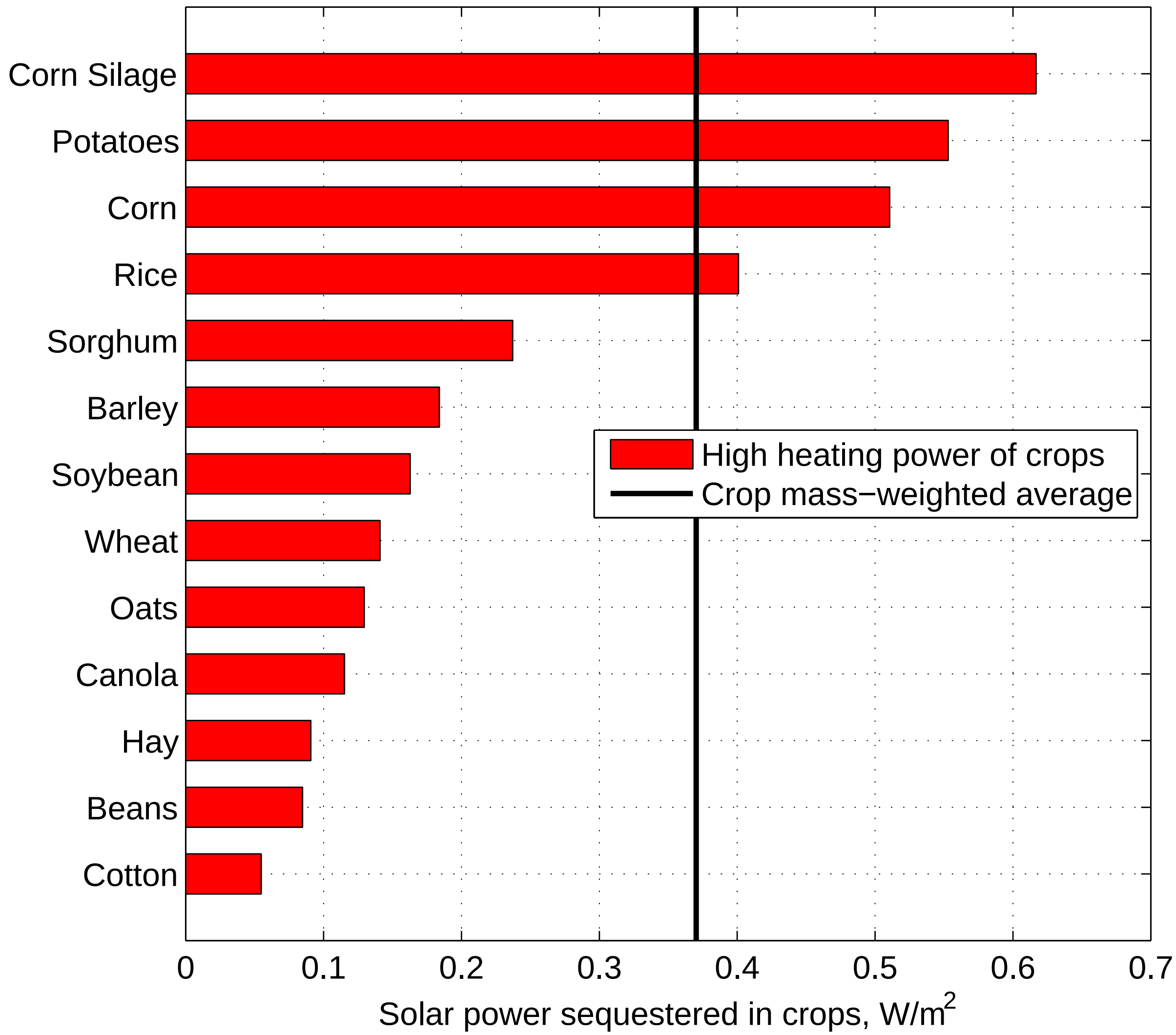
Sources: USDA NASS, Patzek (2006). Total crop energy 9.14 EJ (9 quads)

US Agriculture: Plant Stem Energy



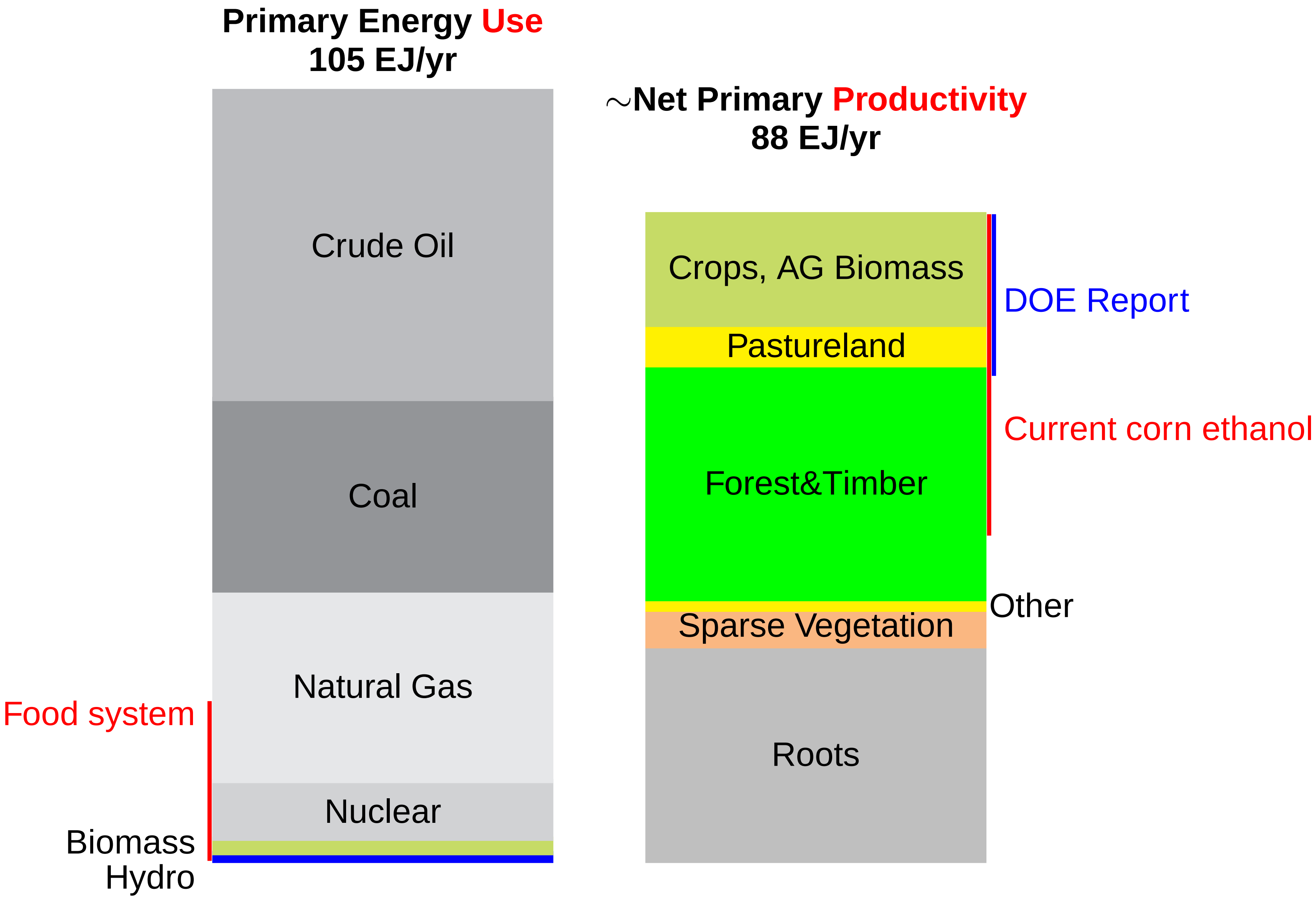
Total energy in above-ground biomass other than seed 6.35 EJ (6 quads)

US Agriculture: Power Flux



Sources: USDA NASS, Patzek (2004). Mean crop power flux 0.37 W/m^2
Each person in US uses 11,250 W of primary energy + Imported goods

Net Production of Biomass in US



Sources: USDA, US Forest Service, Patzek, 2006

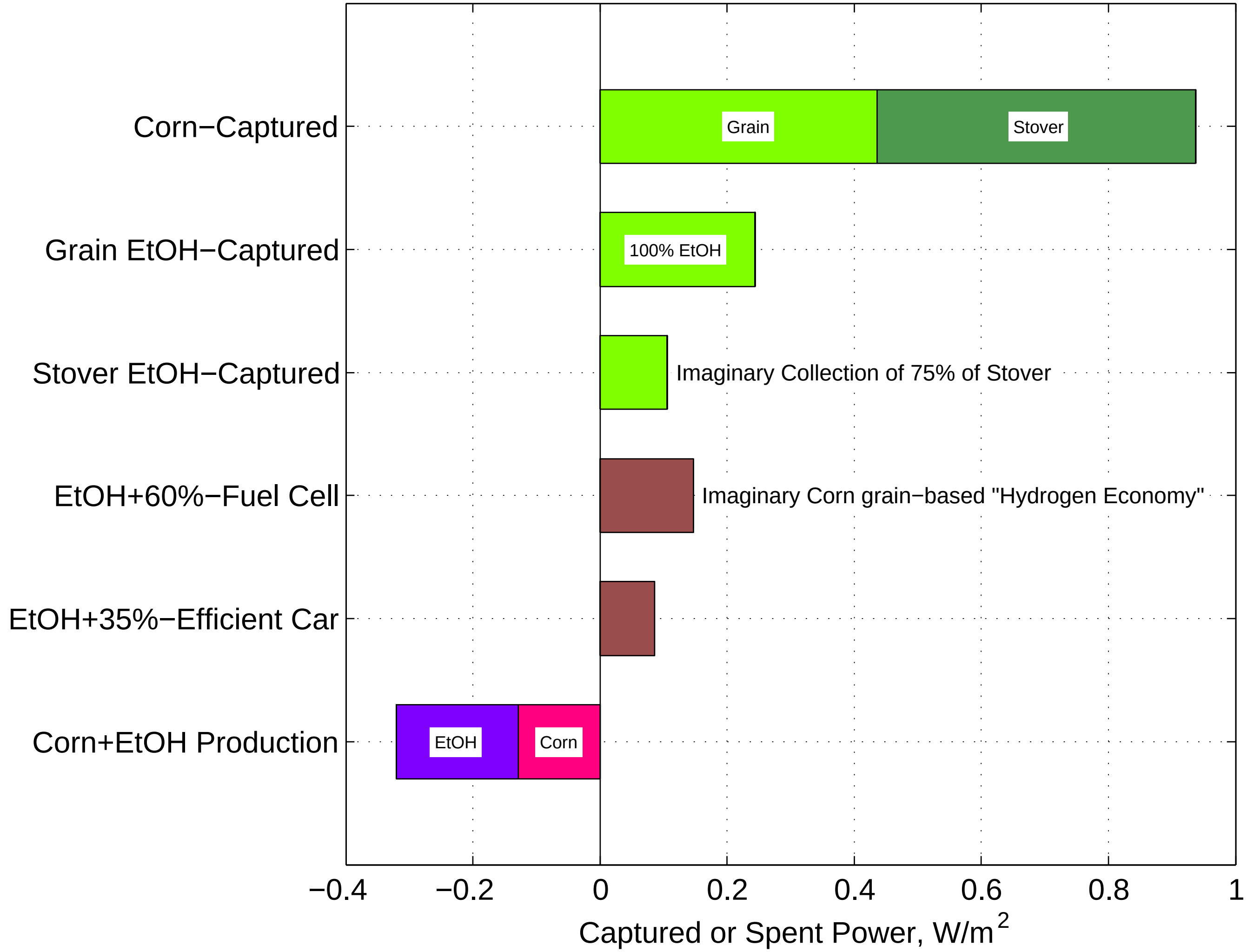
Capturing Solar Power. . .

Major Agricultural Systems

1 Human = 100 W continuously

US Corn. . .

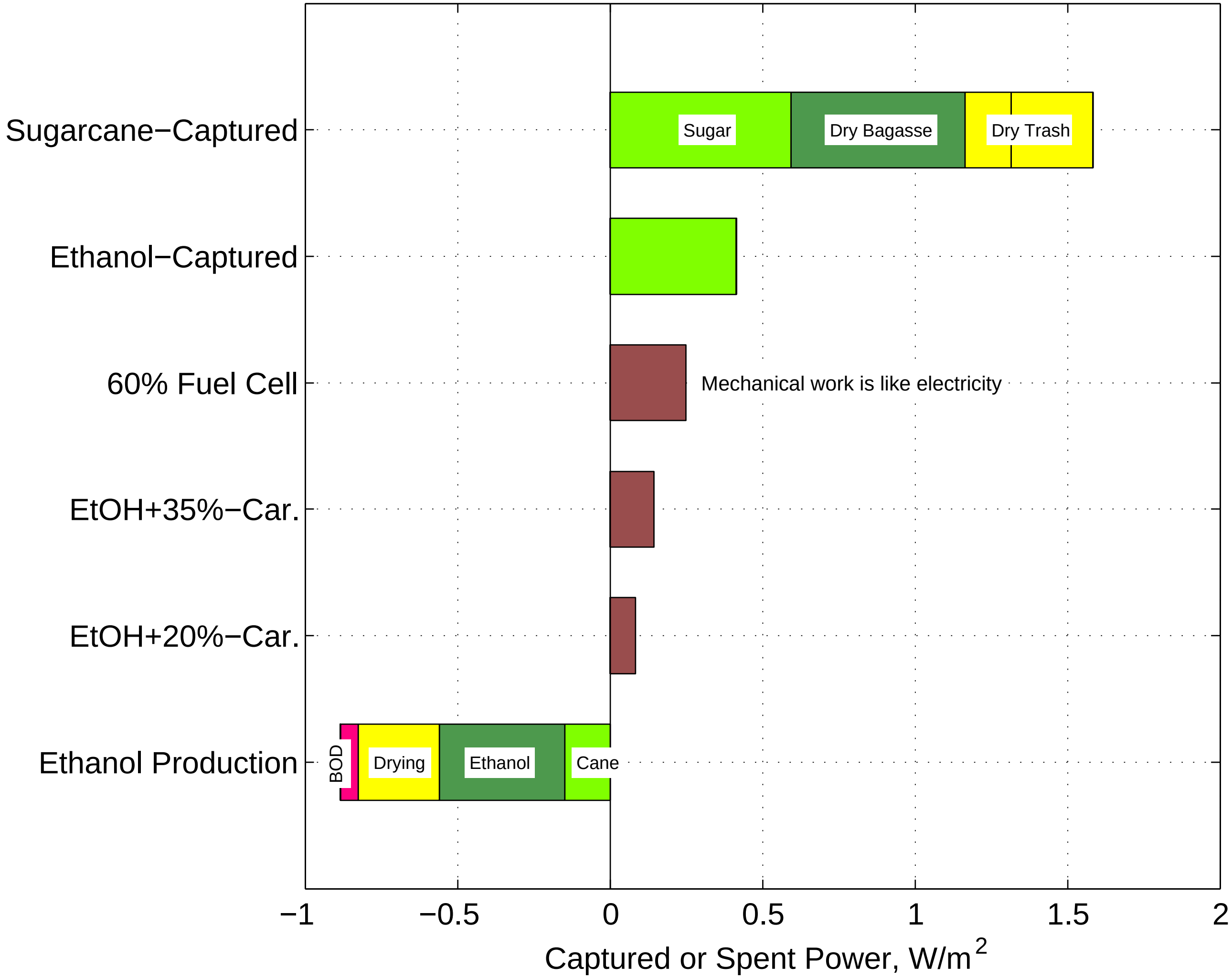
0.25 W/m^2 year-around as grain ethanol, 0.1 W/m^2 as cellulosic ethanol



Source: T. W. PATZEK, *Thermodynamics of the Corn-Ethanol Cycle*, CRPS **23**(6), 2004

Brazilian Sugarcane. . .

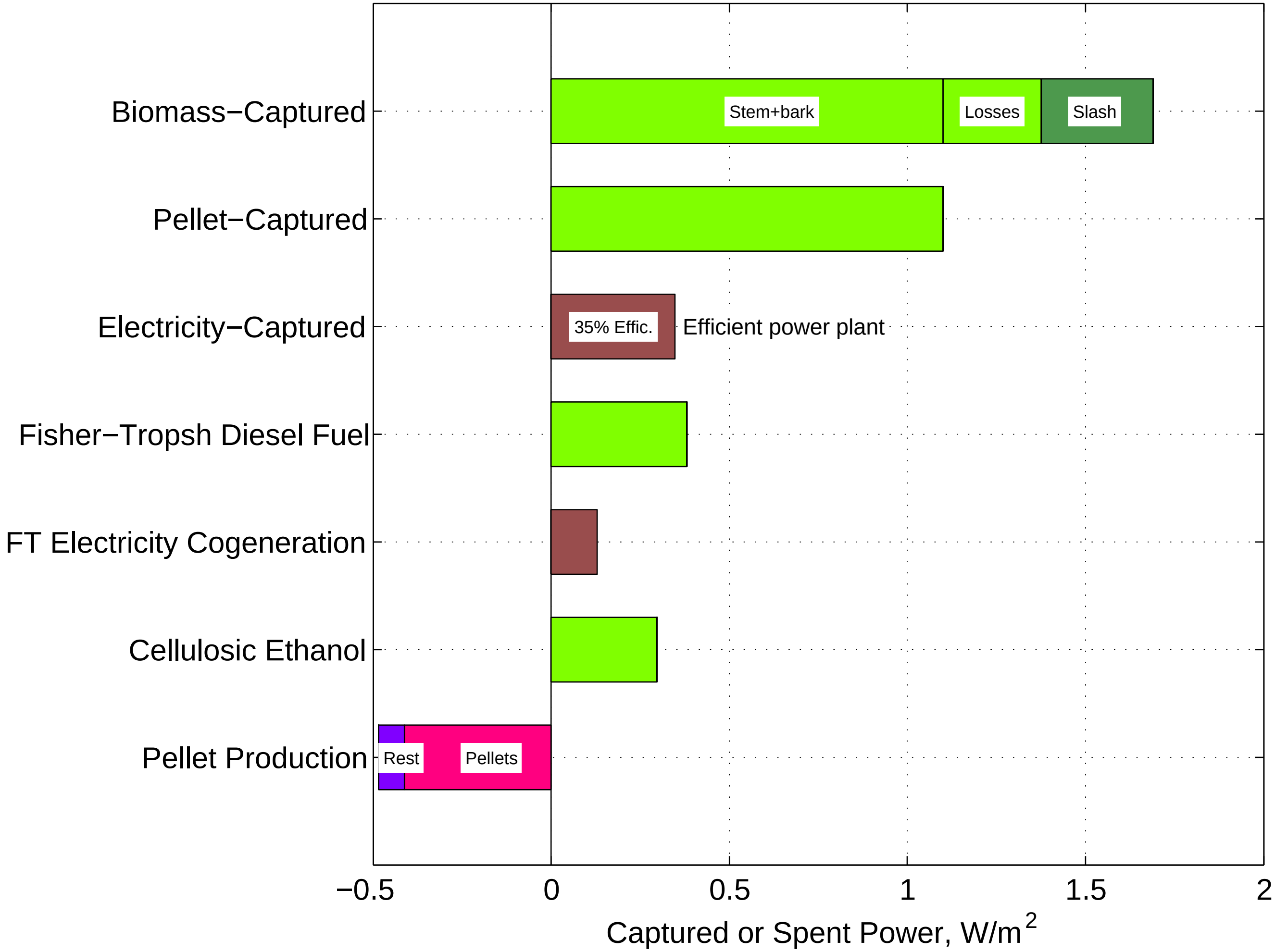
0.40 W/m^2 year-around as sugarcane ethanol



Source: T. W. PATZEK & D. PIMENTEL, CRPS **24**(5-6), 2005

Indonesian Acacias. . .

0.38 W/m^2 year-around as diesel fuel, 0.11 W/m^2 as cellulosic ethanol



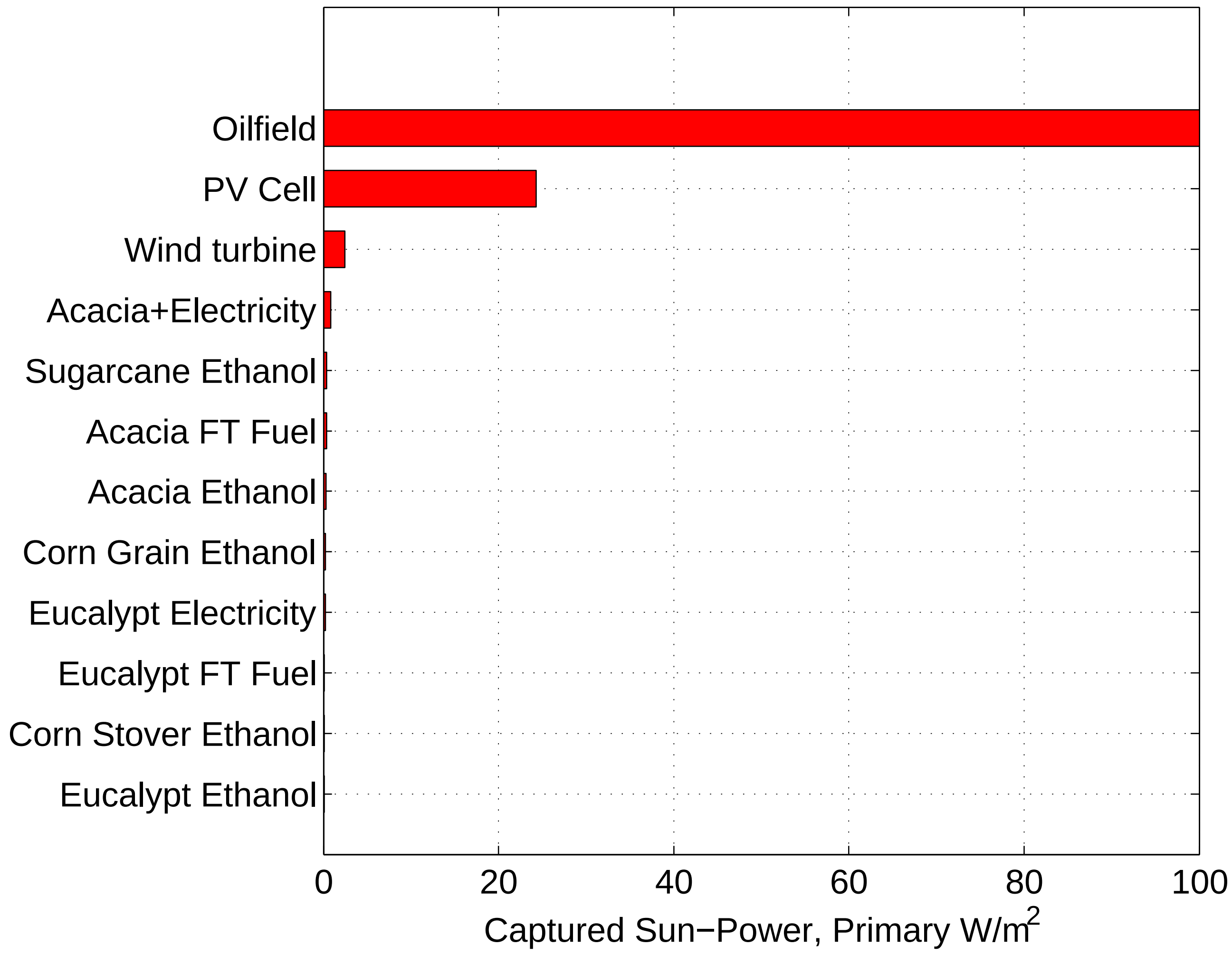
Source: T. W. PATZEK & D. PIMENTEL, CRPS **24**(5-6), 2005

Capture of Solar Power. . .

Brief Explanation

Primary Power From the Sun. . .

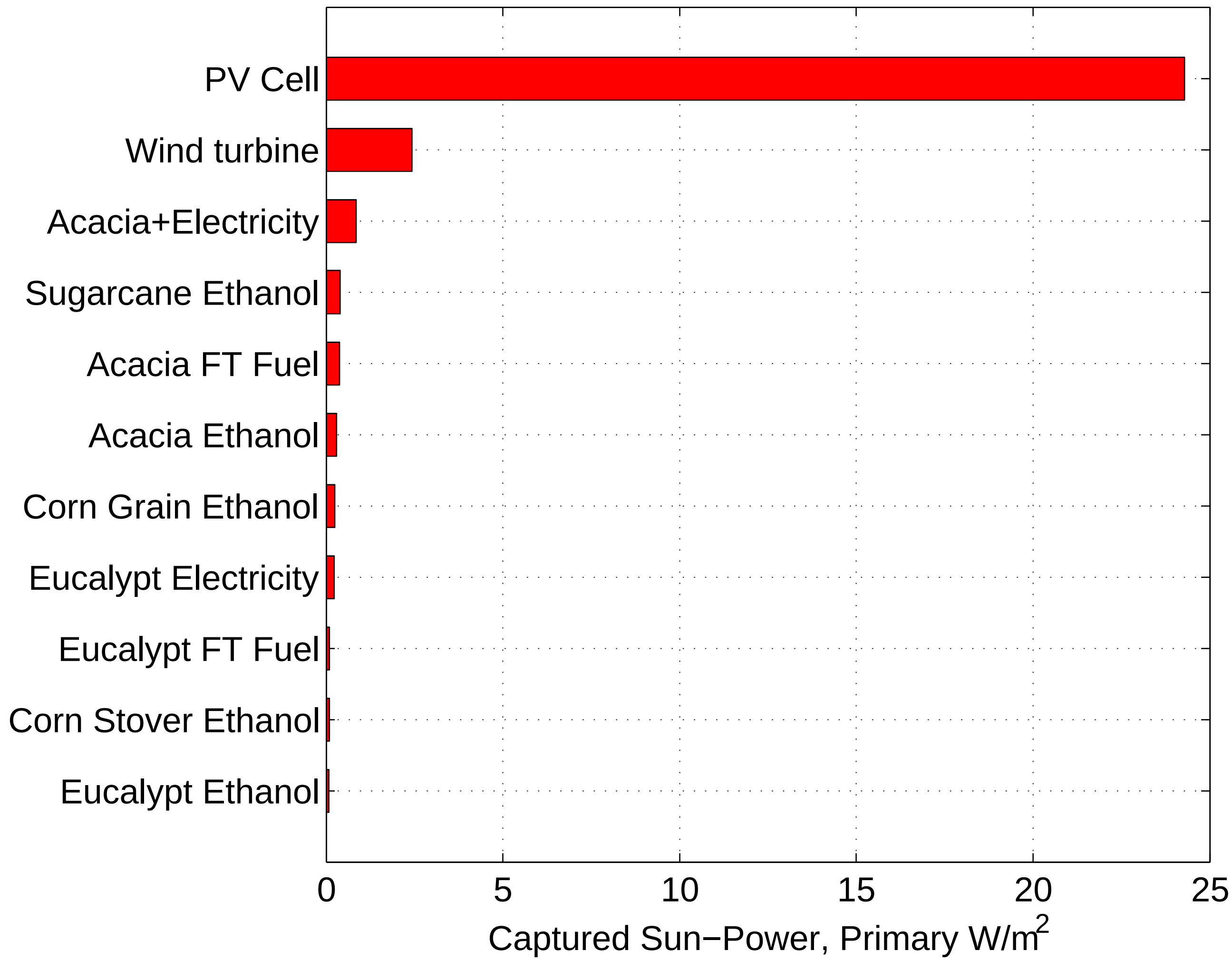
Oil field will be depleted in 30-100 years



Source: T. W. PATZEK & D. PIMENTEL, CRPS **23**(6), 2004, **24**(5-6), 2005

Exclude Oil. . .

Solar cells are up 400 times more efficient than biofuels

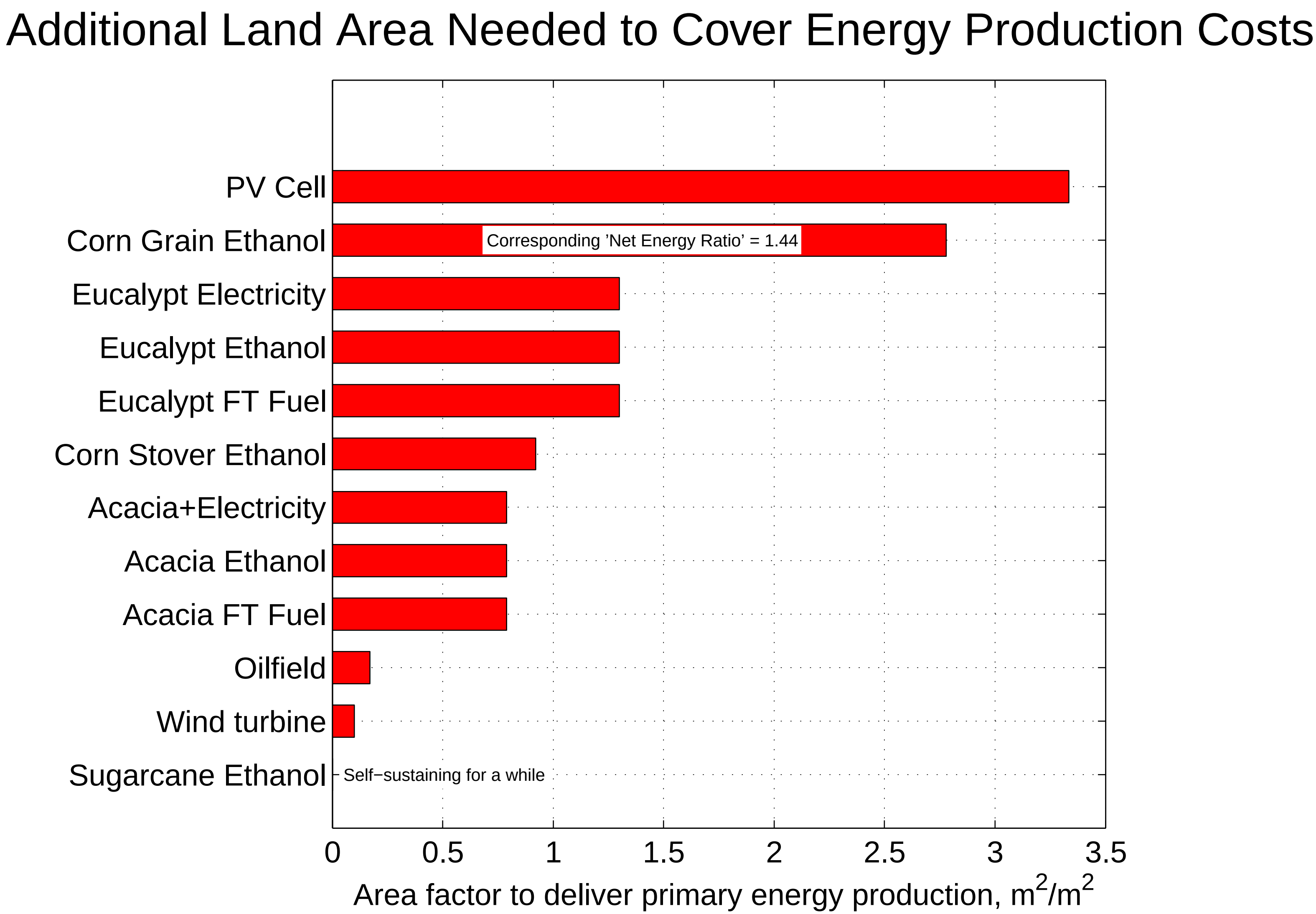


Source: T. W. PATZEK & D. PIMENTEL, CRPS **23**(6), 2004, **24**(5-6), 2005

Land Area to Drive a Car. . .

- Assume driving 15,000 miles/year @40 mpg in a Toyota Prius hybrid
- Alternatively, drive an all-electric car that is 2.5 times more efficient than the Prius
- Account for average energy costs of producing gasoline from crude oil (17%) and biofuels from biomass as in the slides above
- Assume energy costs of manufacturing and deploying PV panels and wind turbines, 33% and 10% of their 30-year production

Extra Area to Deliver Energy. . .



Source: T. W. Patzek & D. Pimentel, CRPS **23**(6), 2004, **24**(5-6), 2005

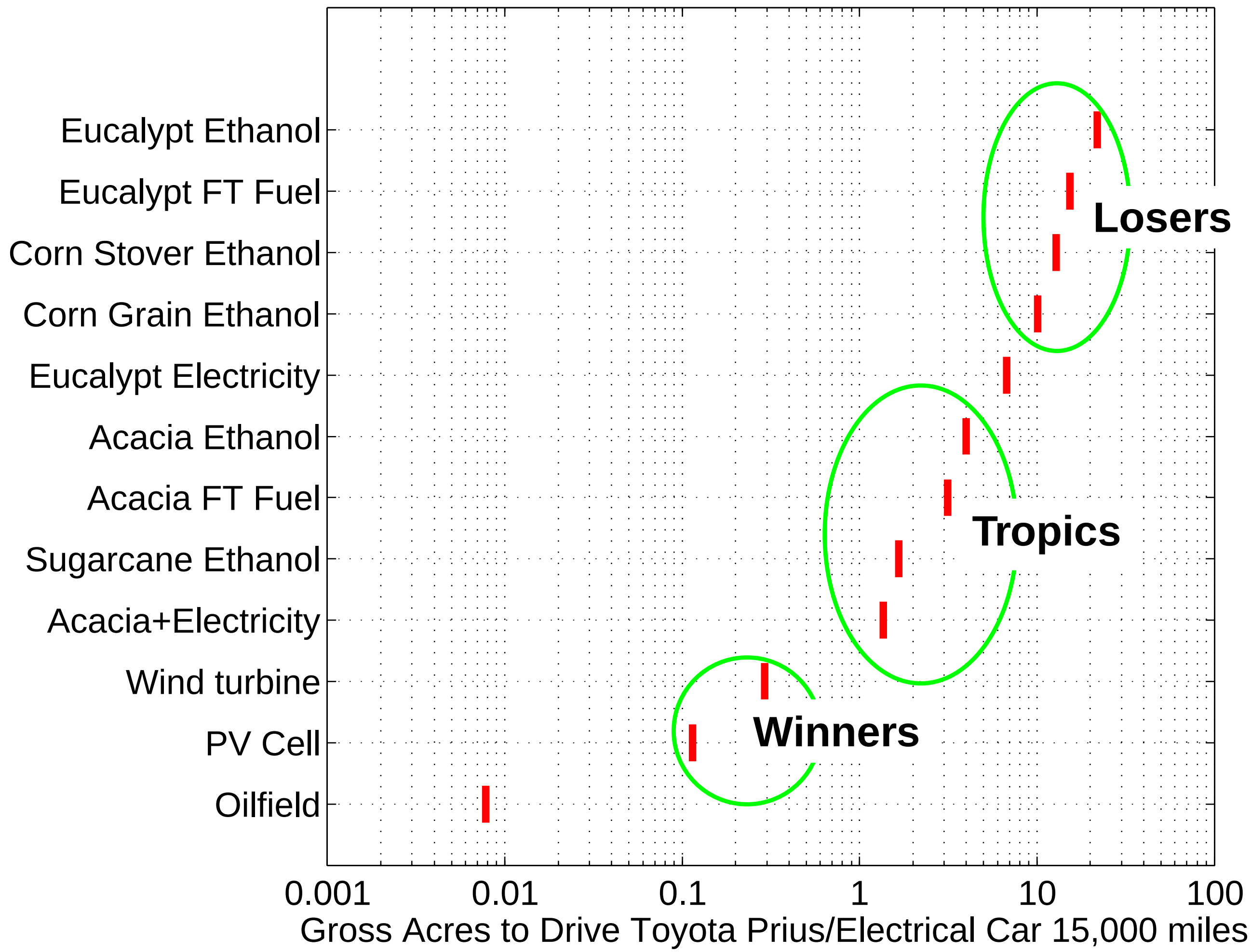
Areas Relative to Oilfield. . .

Oil field area to drive the Prius is 330 square feet (30 m^2)

Technology	Net Ratio	Gross Ratio
Oilfield	1	1
PV Cell	4	15
Wind turbine	40	37
Acacia+Electricity	114	174
Sugarcane Ethanol	250	214
Acacia FT Fuel	263	403
Acacia Ethanol	333	510
Eucalypt Electricity	400	869
Corn Grain Ethanol	442	1292
Corn Stover Ethanol	1000	1641
Eucalypt FT Fuel	1000	1966
Eucalypt Ethanol	1429	2808

Gross Acres to Drive a Car. . .

Solar cells and 85%-efficient electrical car are clear winners



Source: T. W. PATZEK & D. PIMENTEL, CRPS **23**(6), 2004, **24**(5-6), 2005

Conclusions

Thirty million hectares (75 million acres) covered with:

Corn = 7 million Priuses from grain + 6 million Priuses from stover – for a while

Sugarcane = 44 million Priuses – for a while

Solar cells = 646 million electric cars

Wind turbines = 254 million electric cars

We need to invest is solar cell and electricity storage technologies, *not* in biofuels

Conclusions

Biomass myths need to be confronted and banished:

Perpetuummobilomania: Take from the Earth forever, put nothing back

Hyperyieldamia: High yields in tiny plots $\longrightarrow$ Higher yields $\times$ Enormous areas

Hyperareaomania: Plow up entire landscape, regardless

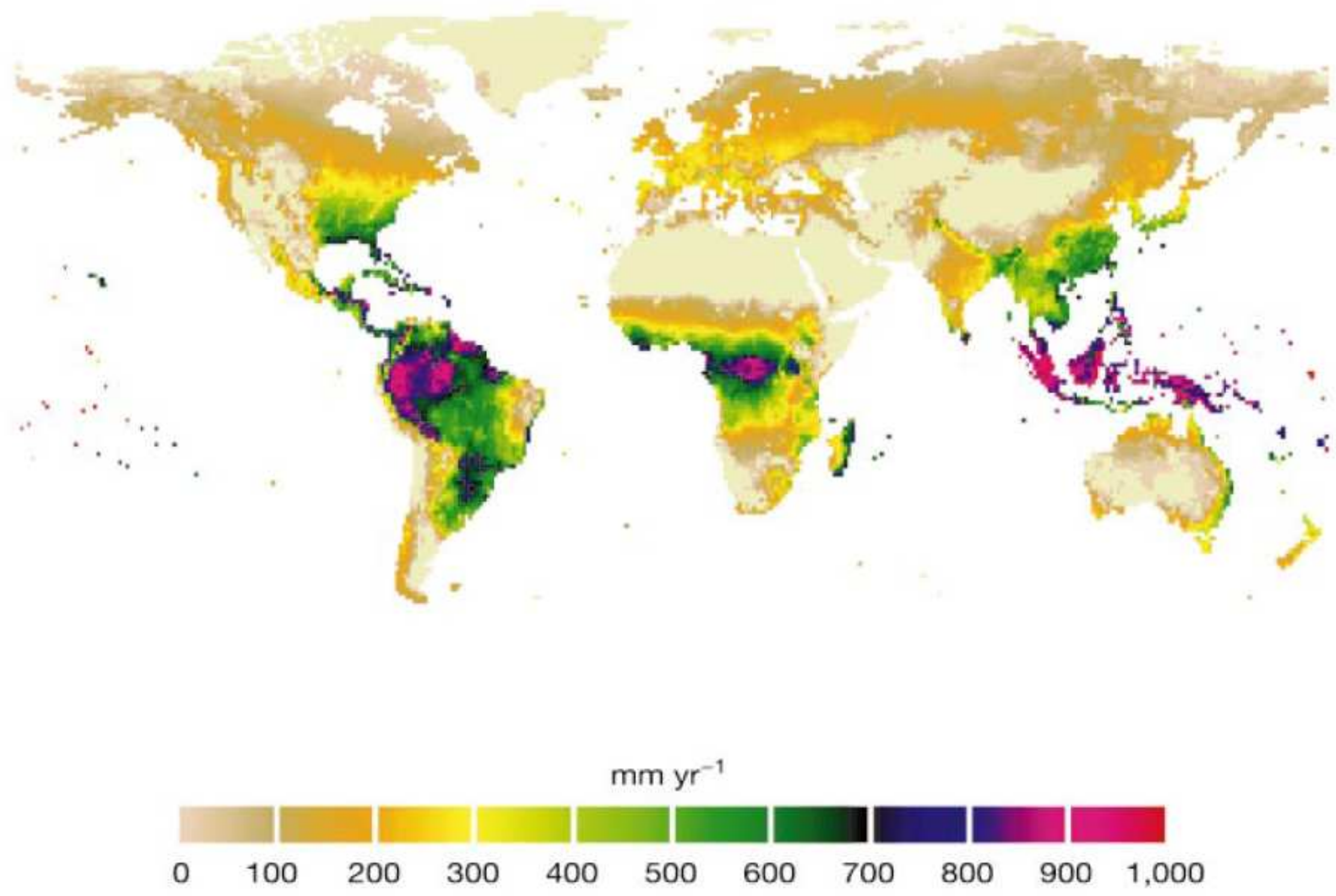
Leibnitz Syndrome: All gets better and better, *ad infinitum*

Chronoverlookemia: Assume instant technology availability

Technopsychosis: See miraculous technologies when none exist

Industrial Biofuels = Earth's Death

Water pumped through plant leaves = biomass



Logically, we must destroy most tropical forests