The Future Role of Biofuels

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International Farm Managers Association,

Brown Ballroom at Bone Student Center, ISU Campus, 8–9:30

July 24, 2009

Summary of Conclusions...

- We are children of a culture that separates human economy from nature's ecology
- Until we overcome this misconception, we will continue to hallucinate about energy and technology
- Only deep structural changes of agriculture will reverse demise of US farmers
- Biofuels will have an important local role for farming, cooking and bringing local food to the local farmer's markets
- Cellulosic ethanol is a less efficient fuel than corn ethanol
- "N-th generation" biofuels and algae will be similar

This is What We Do. . .

In addition to extracting ancient plants (oil, gas, and coal) from the earth and burning them, we now burn the earth surface in real time:

- Corn, soybeans, sugarcane, wheat, sorghum, rapeseed, beats, potatoes, switchgrass, rice, . . .
- Tropical forests, palm oil, pines, acacias, eucalypts, poplars, . . .
- Wood chips, bagasse, rice straw, corn stover, hay,. . .
- Leftovers of animal carcasses, fish oil, human fat,. . .

Is there anything else left we might burn
to further our lifestyles?

They Spoke So Well For Us. . .

"I perceived it to be possible to arrive at knowledge highly useful in life . . . and thus render ourselves the lords and possessors of Nature."

"I am come in very truth leading you to Nature with all her children to bind her to your service and make her your slave. . . The mechanical inventions of recent years do not merely exert a gentle guidance over Nature's course, they have the power to conquer her and subdue her, to shake her to her foundations."

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RENÉ DESCARTES, 1596-1650, *Discourse on Method* (1637)

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SIR FRANCIS BACON, 1561-1626, *Cogitata et Visa de Interpretatione Naturæ, siva De Scientia Operativa* (1607)

They Also Speak For Us. . .

- Aggressive action to develop advanced biofuels
  . . . could virtually eliminate our demand for gasoline
- Farmers will plant energy crops on a large scale
- Fast-growing, cost-efficient trees such as poplar and eucalyptus, and grasses such as alfalfa and switchgrass, [are] to be harvested as biofuels
- More power plants will burn biomass along with coal to produce electricity

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Natural Resources Defense Council, 2006

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

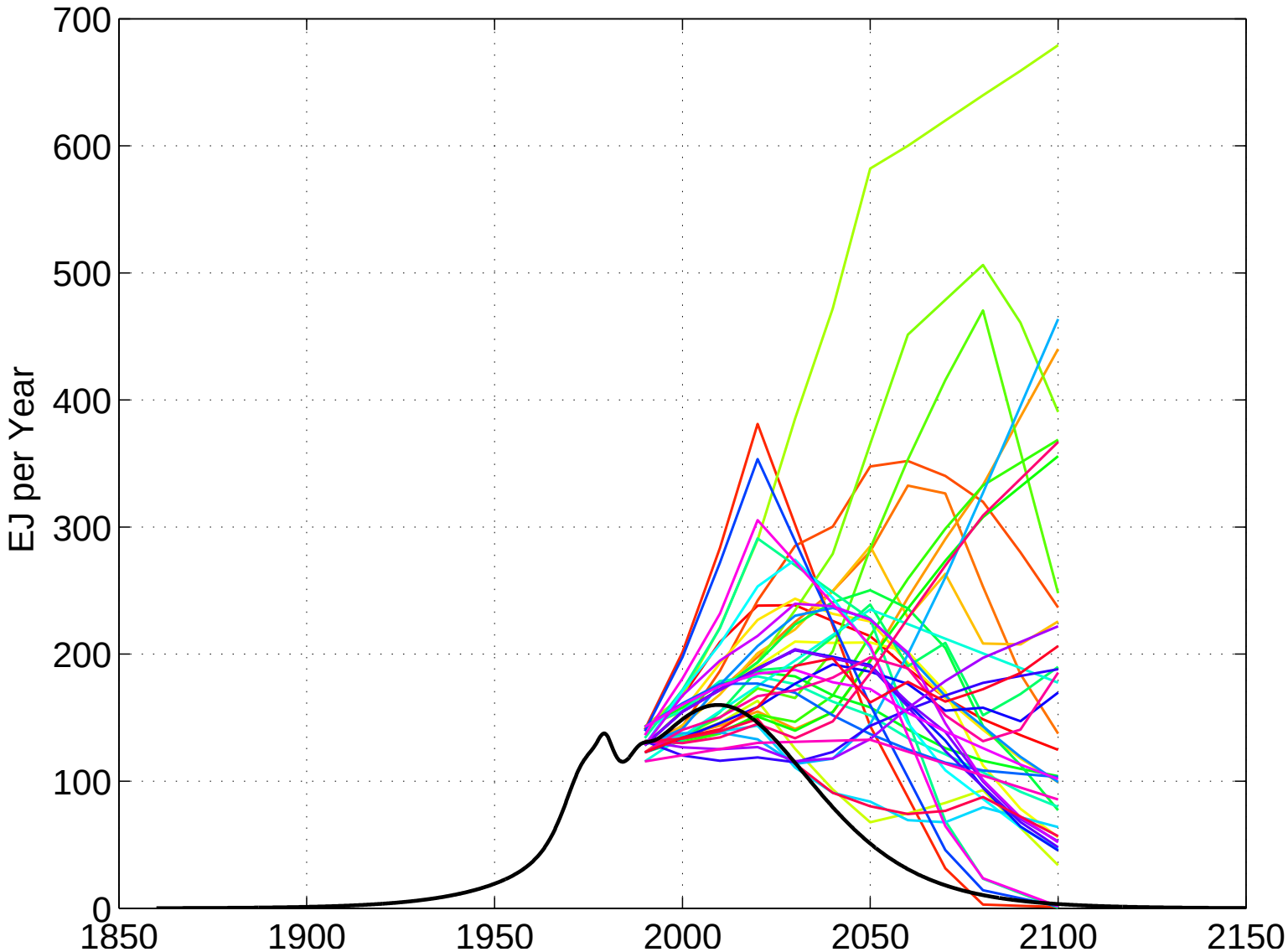
- Currently the U.S. uses 105 EJ/year; one hundred and five times more than we need to live
- If we were to metabolize this amount of energy, we would be 15 m long sperm whales, each weighing 40 tonnes. There are $\sim$300,000 sperm whales worldwide and 1000 times more Americans

Homo Colossus Americanus…

1 Statistical American = 1 Sperm Whale

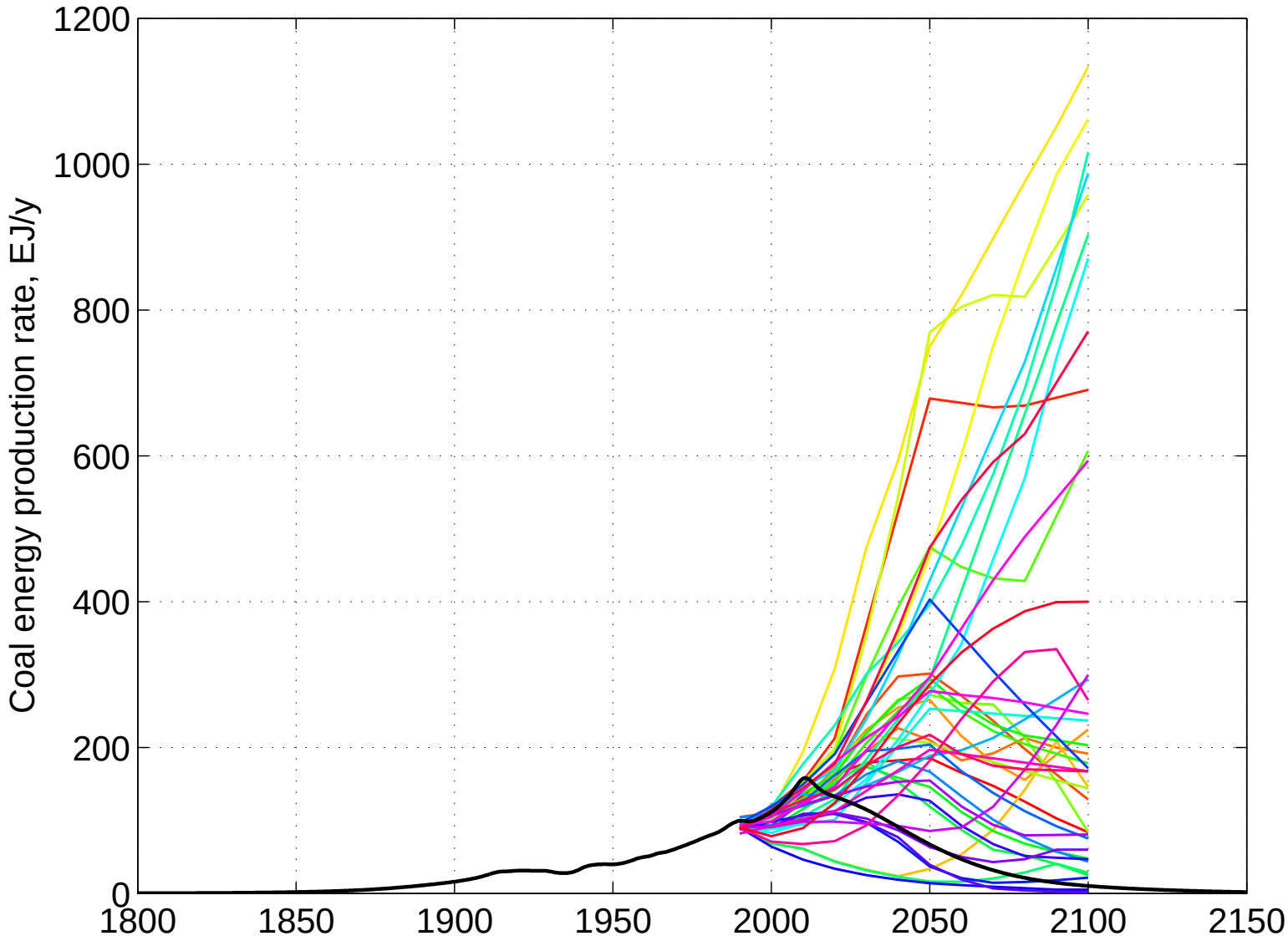
EUGENE ODUM, *Ecological Vignettes*, 1998

World Oil and IPCC Predictions



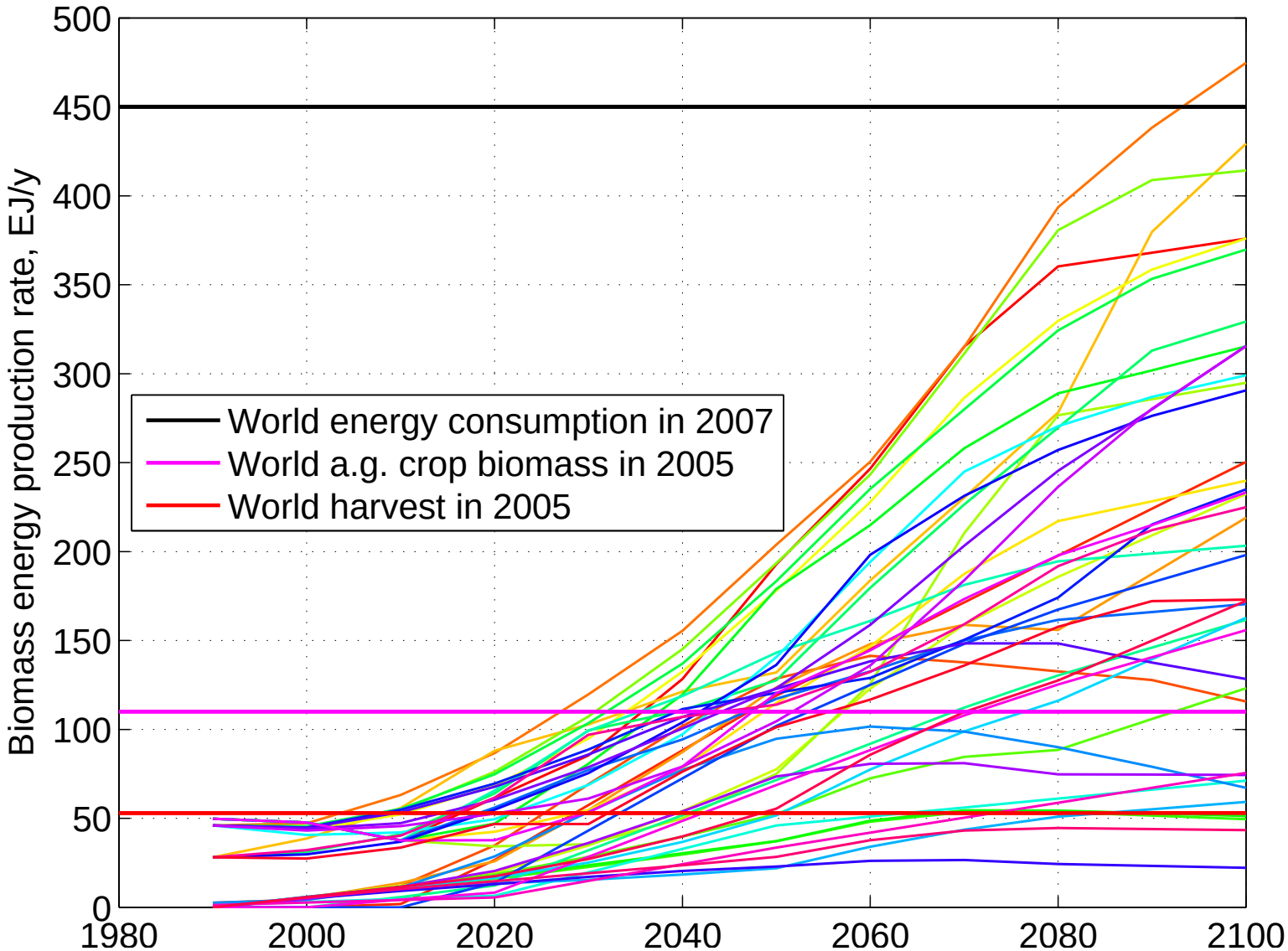
Sources: US DOE EIA, O&GJ (2009), IPCC (SRES Report, 2000)

World Coal and IPCC Predictions



Sources: US DOE EIA, Patzek & Croft (2009), IPCC (SRES Report, 2000)

World Biomass and IPCC Predictions



Sources: FAO, Patzek (2007,2009), IPCC (SRES Report, 2000)

Talk Outline. . .

- The Brief Story of Corn as Fuel
- The Last Act of Global Environment Destruction
- Immediate and Future Alternatives

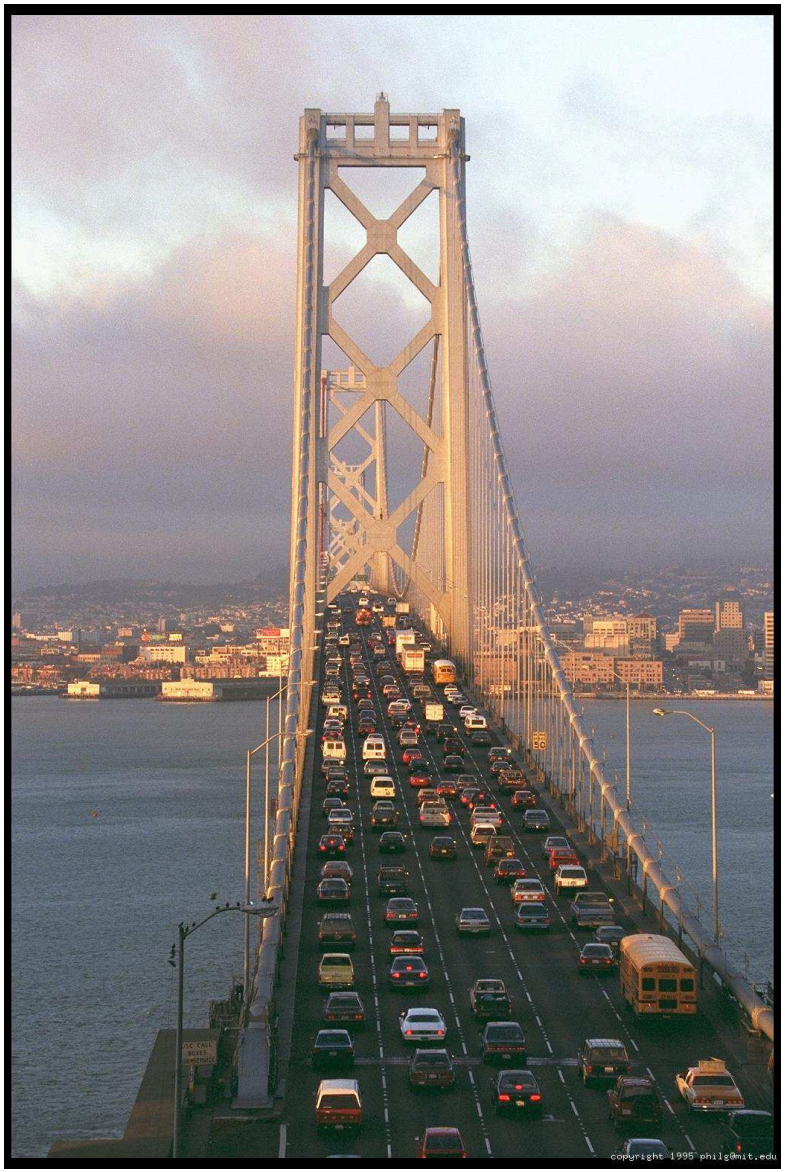
The Story of Corn as Fuel. . .

Brief Explanation

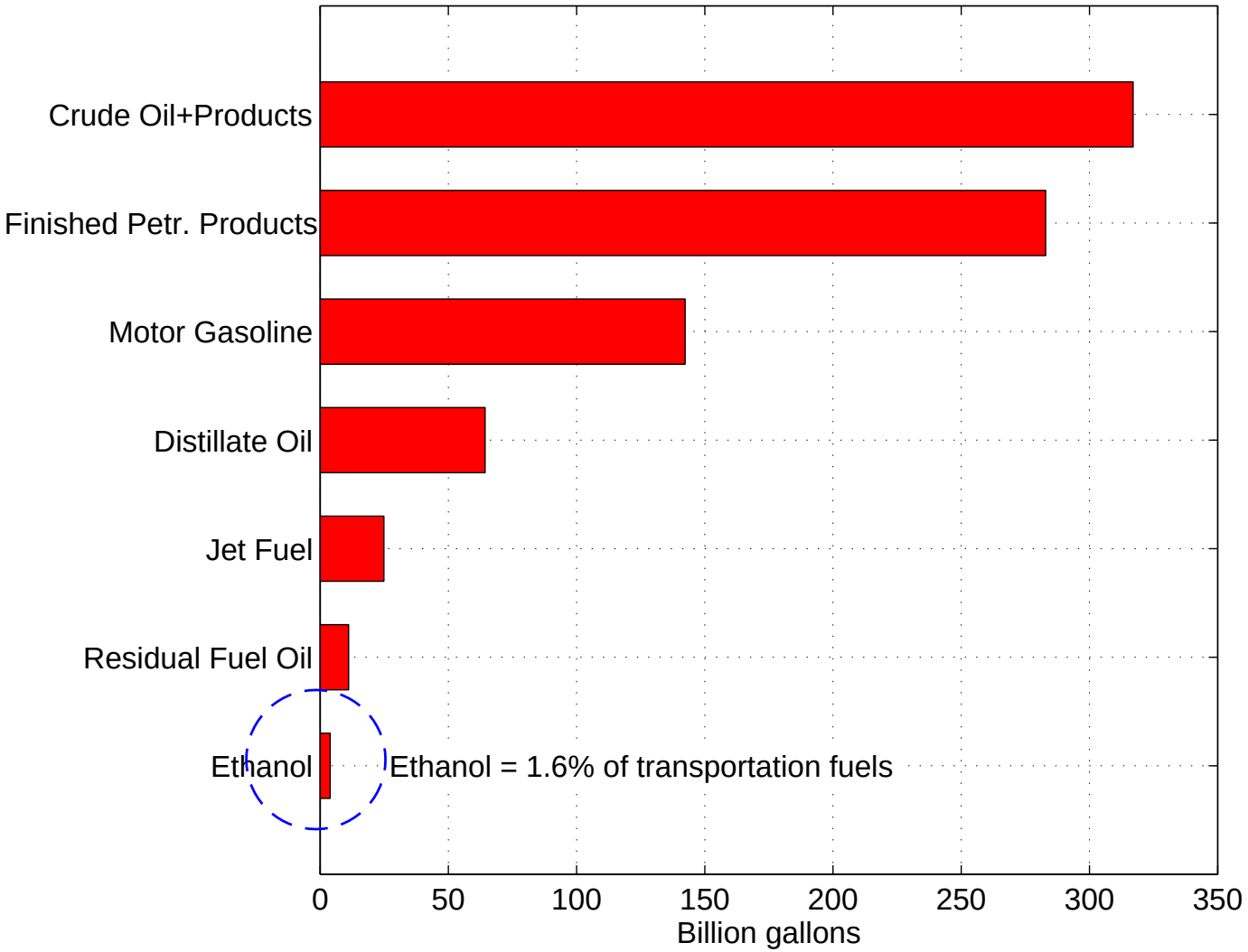
Overview

Industrial agrofuels have been introduced by several nations because of

- Energy “security” (US)
- “Abatement” of Greenhouse Gas (GHG) emissions (All)
- “Sustainable” transportation systems (currently meaningless)
- Helping the “farmers” (open-ended subsidies in rich countries)

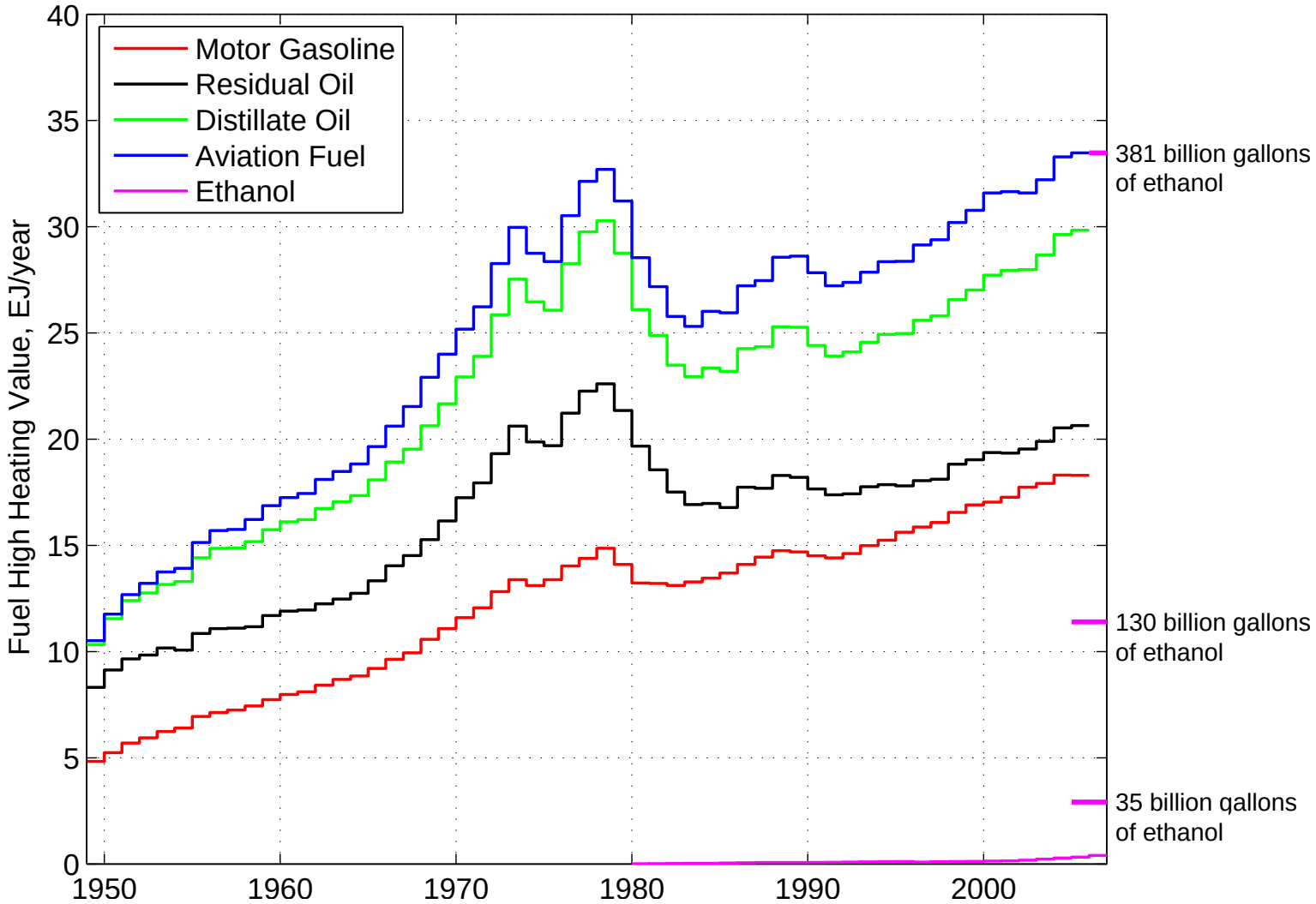


2007 US Consumption



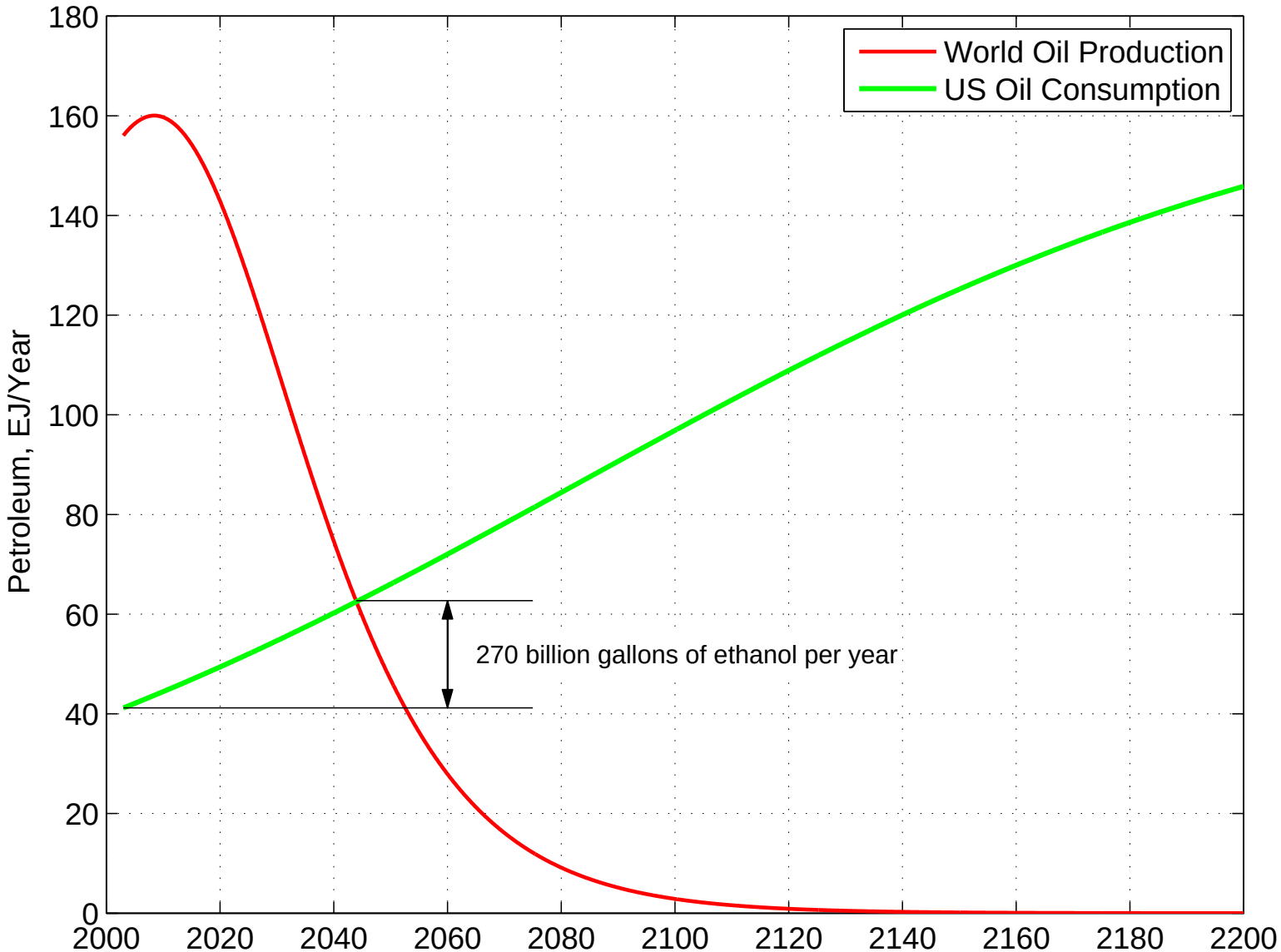
Sources: US DOE EIA, Renewable Fuels Association (2008)

US Energy Security: Nothing



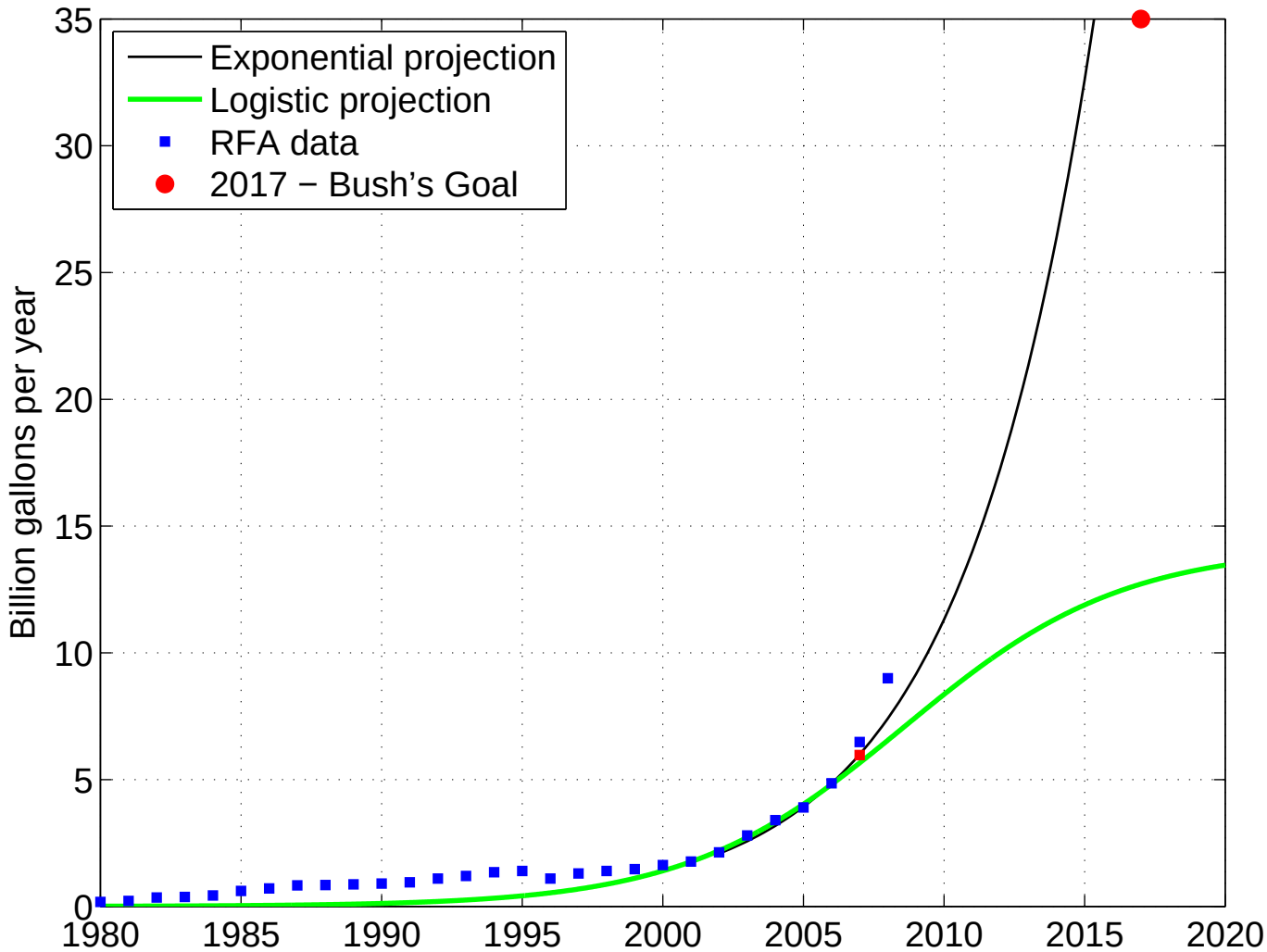
Sources: US DOE EIA, Patzek (2004)

US Petroleum Use Projection in BAU



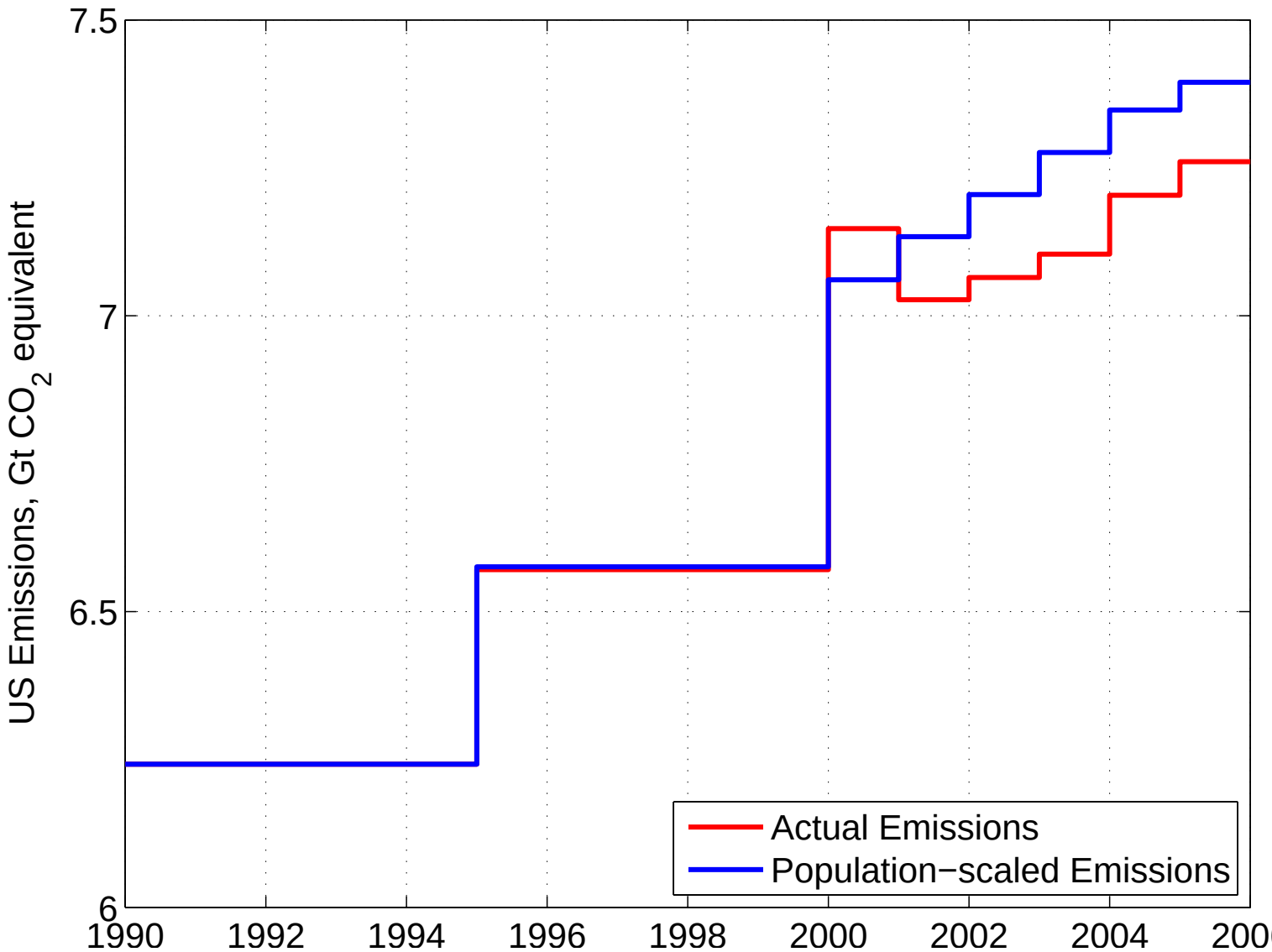
Sources: US DOE EIA, Patzek OECD (2007)

US Ethanol Production



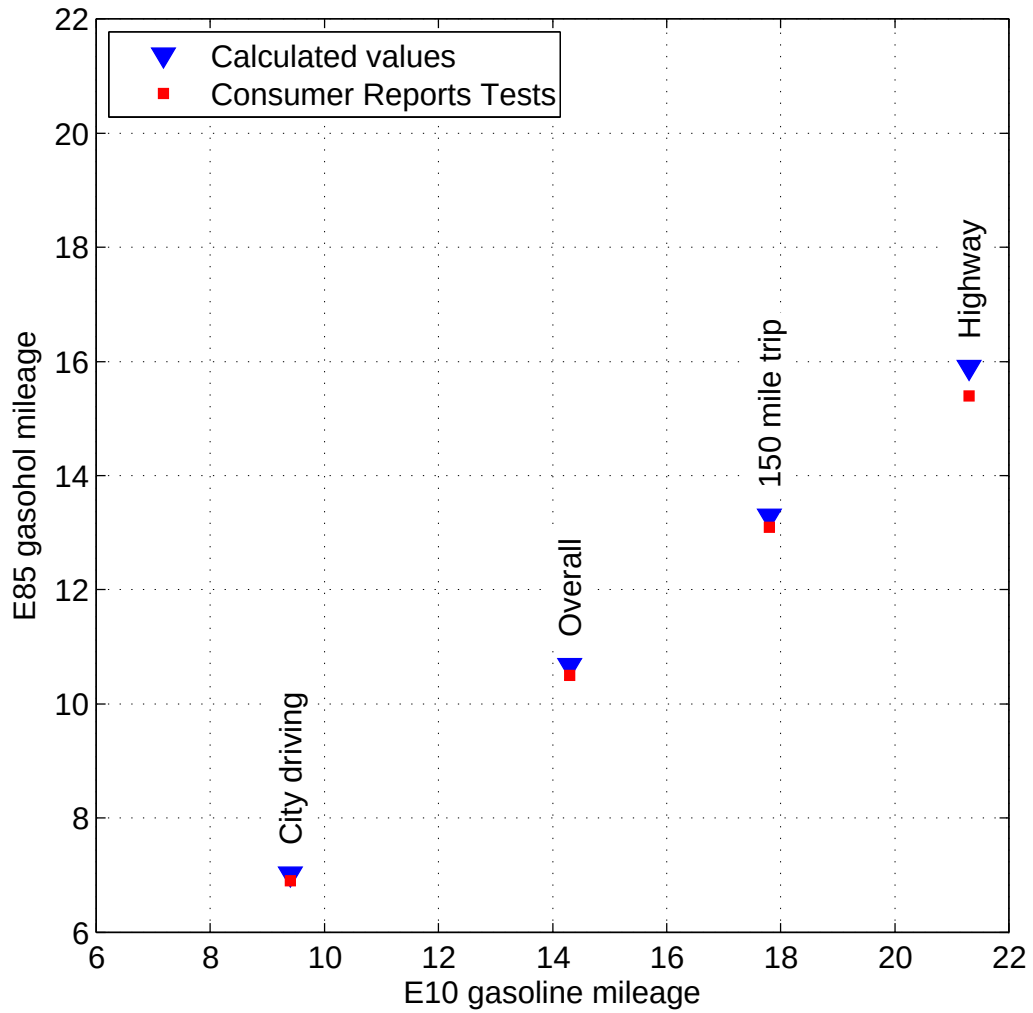
Sources: US DOE EIA, RFA, Patzek OECD (2007), Current rate of growth 21 %/y, production doubles each 4 years

US GHG Abatement: Nothing



We have done **nothing** about GHG emissions. Sources: U. S. EPA, US Census Bureau

Mileage = Fuel Energy Content



Under the CAFE formula a 2007 Tahoe truck would receive a CAFE rating of 21 mpg, but a 2007 Tahoe truck with an FFV engine would be rated at 35 mpg. Sources: Consumer Reports, Oct 2006; Patzek (2006)

Driving on Pure Corn Ethanol

Assumptions:

- Chevy Tahoe, 9 mpg, 10,000 miles/year: 1,111 gal ethanol/year
- 2.5 gallons of pure ethanol/bushel (no denaturant)
- Fossil energy output:input = 1.25

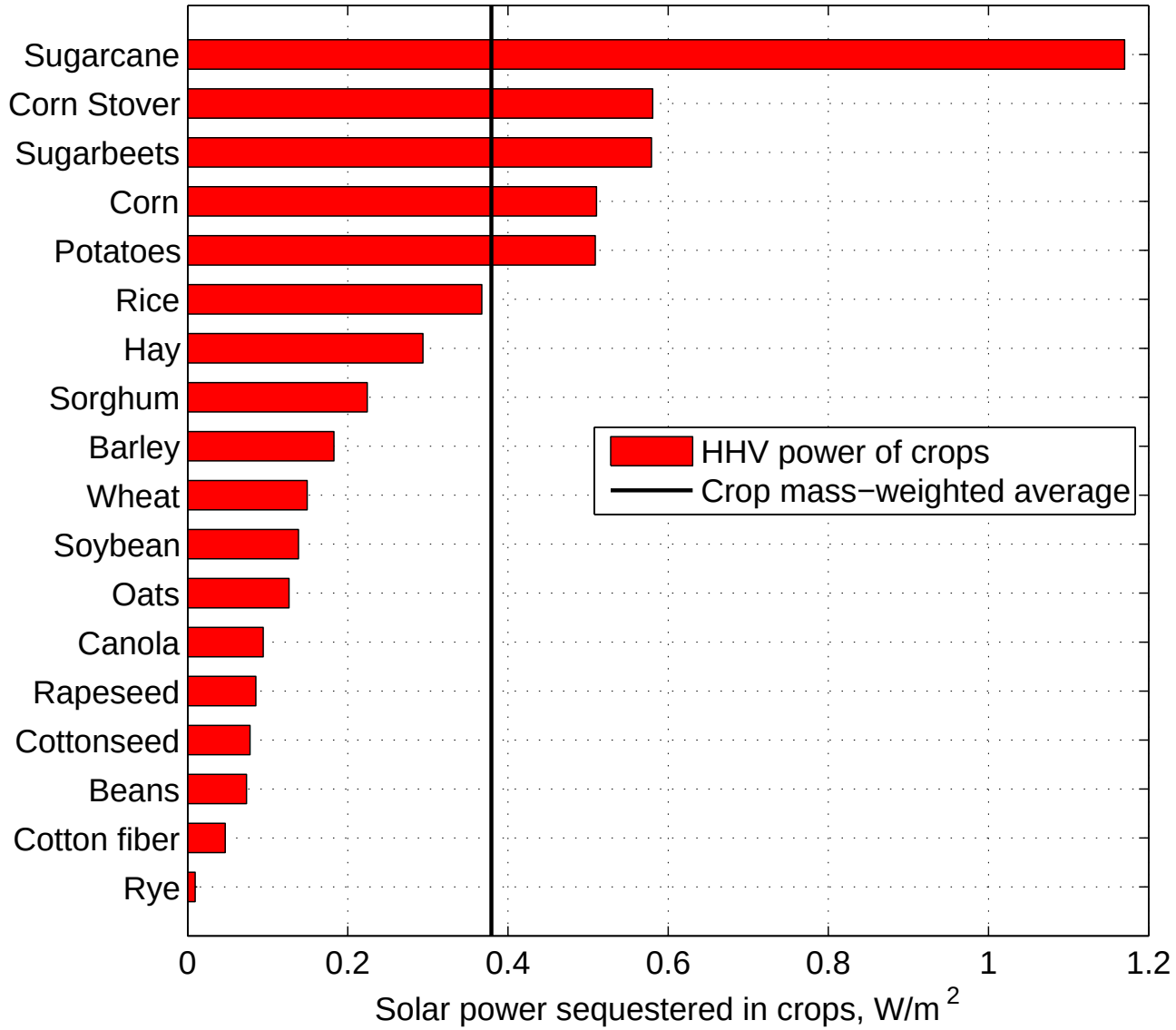
Results:

- Burn corn sufficient to feed 67 people to drive and 54 people to produce the ethanol fuel
- All Americans driving of corn ethanol = food for 36 billion people on 6 Earths
- Emit up to 50 % more GHGs than from gasoline

100 people

E7 Lecture, 4 Leconte, UC Berkeley, CA, April 2, 2008

Little Thermodynamics. . .



Continuous thermal power from the largest US crops. The mass-averaged power is 0.38 $\mathrm{W\,m^{-2}}$, 0.2% of average US insolation. Sources: USDA NASS

A Little More Thermodynamics

Let's compare apples with apples:

- On average, corn grain sequesters 0.5 W/m^2 of thermal power or $0.35 \times 0.5 = 0.17$ W$_e$/m^2 of electric power.
- A very inefficient solar photovoltaic cell sequesters 20 W$_e$/m^2 on average.
- Therefore, if corn were burned to produce electricity, PV cells would be $20/0.17 \approx 100$ times more efficient.
- If ethanol is produced from corn and burned to power a car, one gets $0.27 \times 0.5 \times 0.20 = 0.027$ W$_m$/m^2, $\sim$700 times less than PV cells.

Corn ethanol is somewhat inefficient as a car fuel

The Fundamental Incompatibility...

- The rate at which we use fossil energy, makes replacing it by biomass impossible
- Colonizing all available land on the earth will be insufficient
- If we really want to switch to solar cells, biofuels, wind, etc., we will have to shrink our energy use by a factor of 10
- US will have to look and act more like China or India

Indefensible Assumptions

- Fossil fuels we use to produce anything are the only relevant limiting factor
- All other factors are limitless and irrelevant:
  - The Earth provides us with an infinite and instantaneous supply of pure air, fertile soil and clean water full of nutrients
  - She can regenerate all soil we destroy, and purify all water and air we pollute
  - Forever, she can feed 7–12 billion people, 1 billion cows, and all other non-human *living* consumers of plant and animal matter, . . .
  - . . . and – now – 1 billion cars and trucks (620 million produced since 1961)

A Defensible Proposition

- Every large ecosystem on Earth must approach a steady state characterized by zero net ecosystem productivity (NEP)
- When humans are not a natural part of an ecosystem, large-scale biomass harvesting by humans leads to an eventual breakdown of that ecosystem
- Remedial actions (waste cleanup, erosion management, and applications of nutrients) are necessary to slow down – but never stop – the ecosystem deterioration
- All these actions require massive inputs of fossil energy and are unsustainable

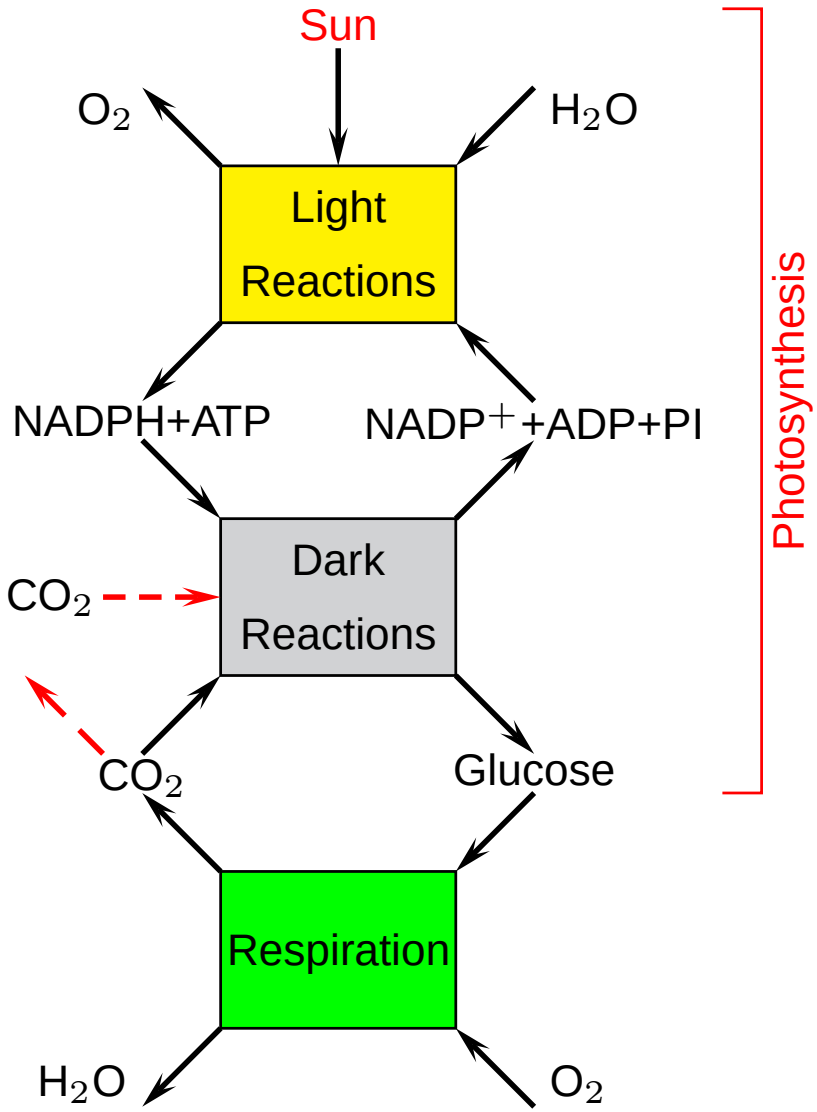
Background Terminology...

Ecosystems are characterized by:

- Gross Primary Production (*GPP*) = amount of CO_2 converted by plant photosynthesis to biomass
- Respiration = biomass plants, R_a, and animals, R_h, consume to live
- Net Primary Production, *NPP*

  $NPP = GPP - R_a$
- Net Ecosystem Production

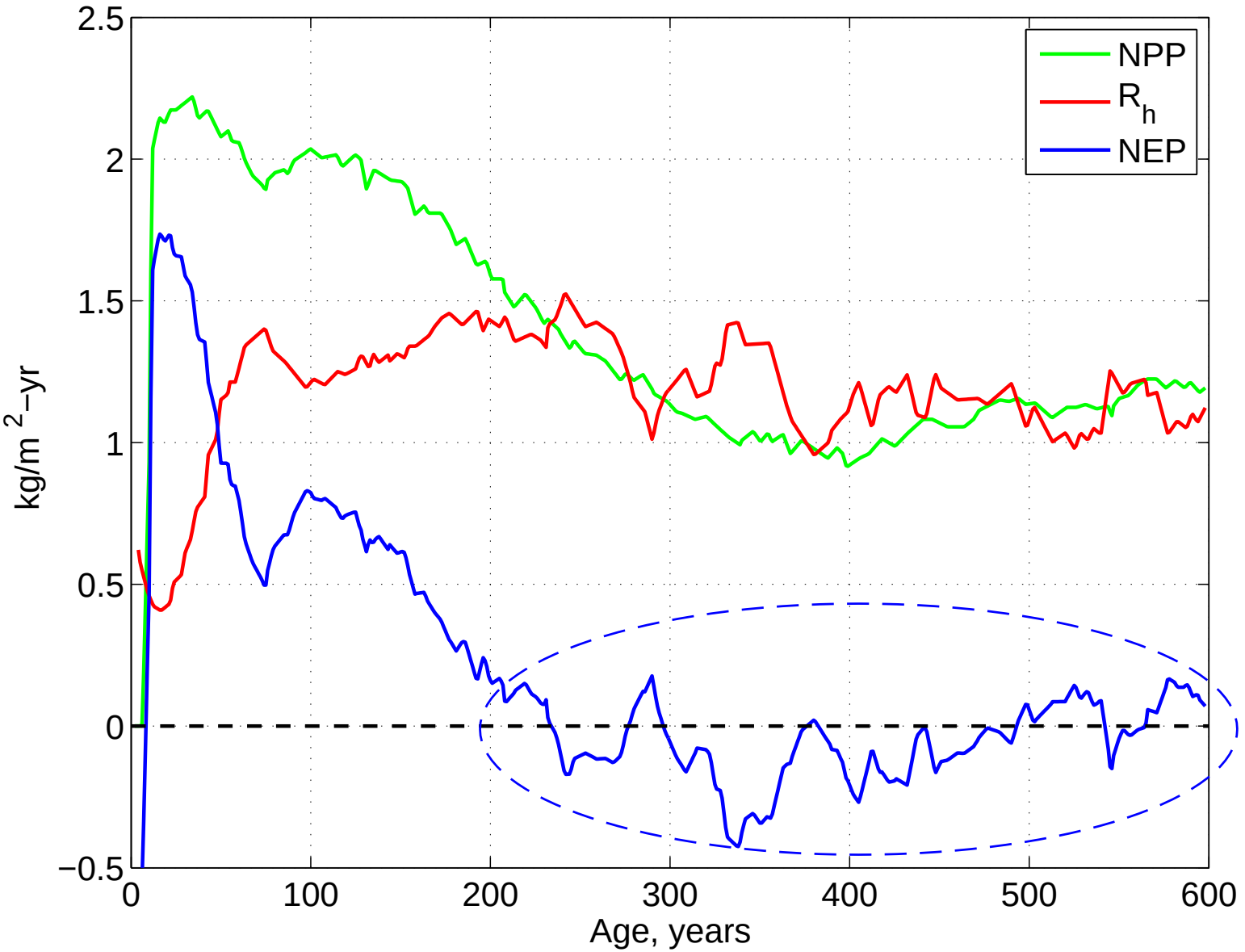
  $NEP = NPP - R_h - R_{\text{other}}$
- In natural ecosystems, $NEP \approx 0$
- Dry biomass$\times$HHV = Energy



Facts about Ecosystem Productivity

- Autotrophic respiration = $\sim$1/2 of photosynthesis (GPP)
- Heterotrophic respiration consumes up to 95% of the remainder
- On average, net ecosystem productivity (NEP) oscillates around zero
- Agricultural ecosystems must be heavily subsidized with ancient plant matter and minerals

Net Ecosystem Productivity $\rightarrow$ 0

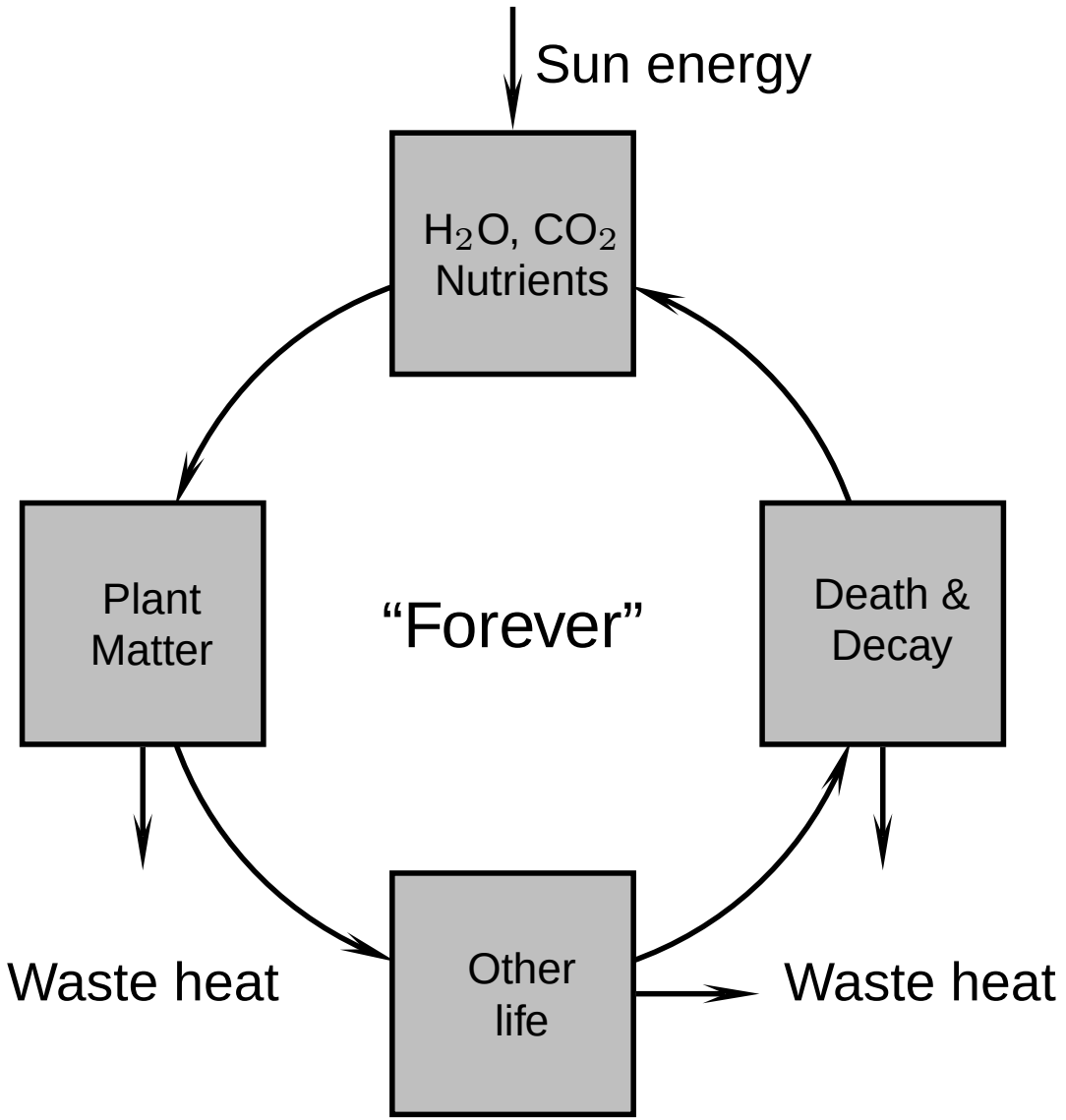


Source: SONGA & WOODCOCK (2003), simulation of H. J. Andrews Experimental Forest

Mass Stays on Earth, Heat Leaves

Source: Image Science & Analysis Laboratory, Johnson Space Center

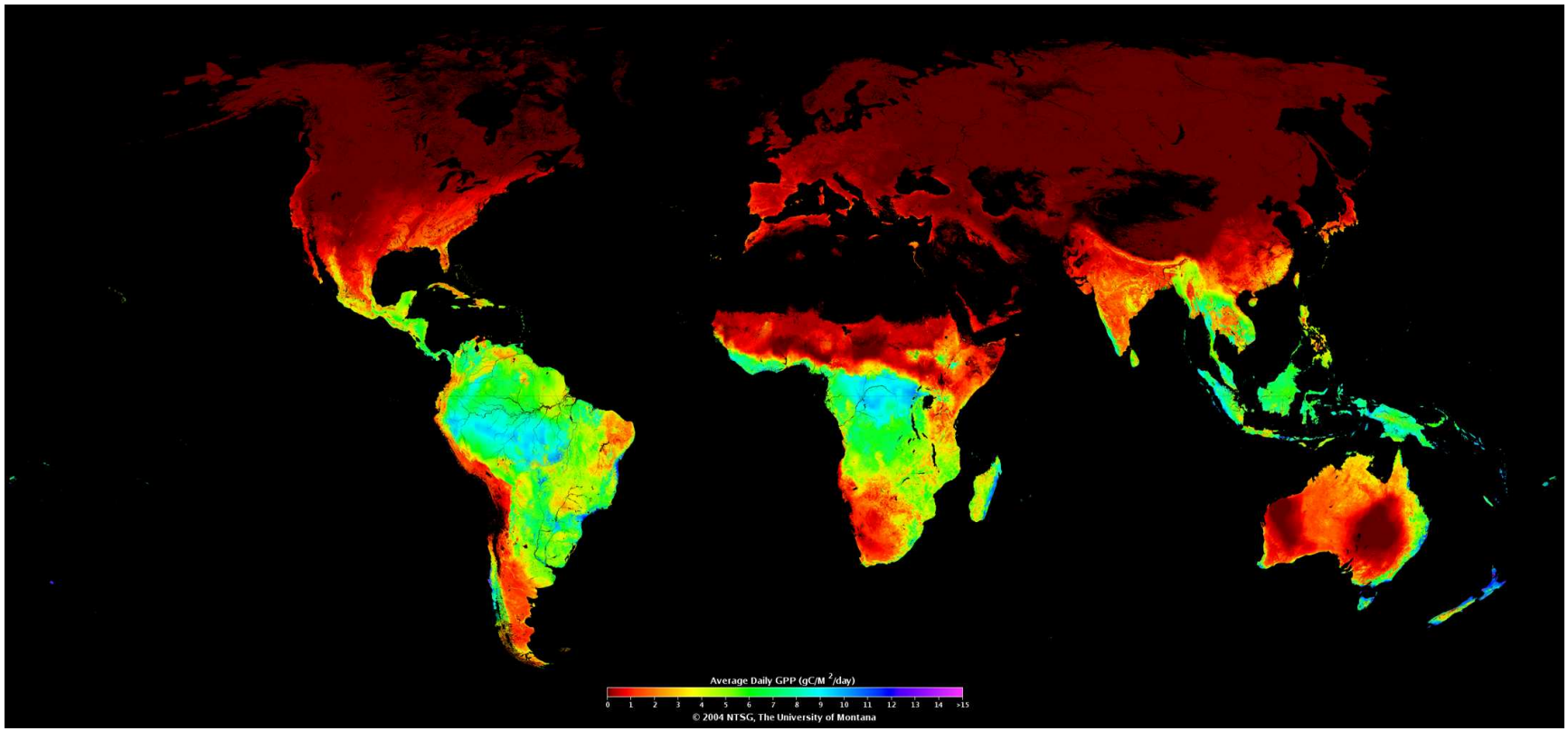
Ecological Cycles = No Waste!



Almost All Mass is Recycled. . .

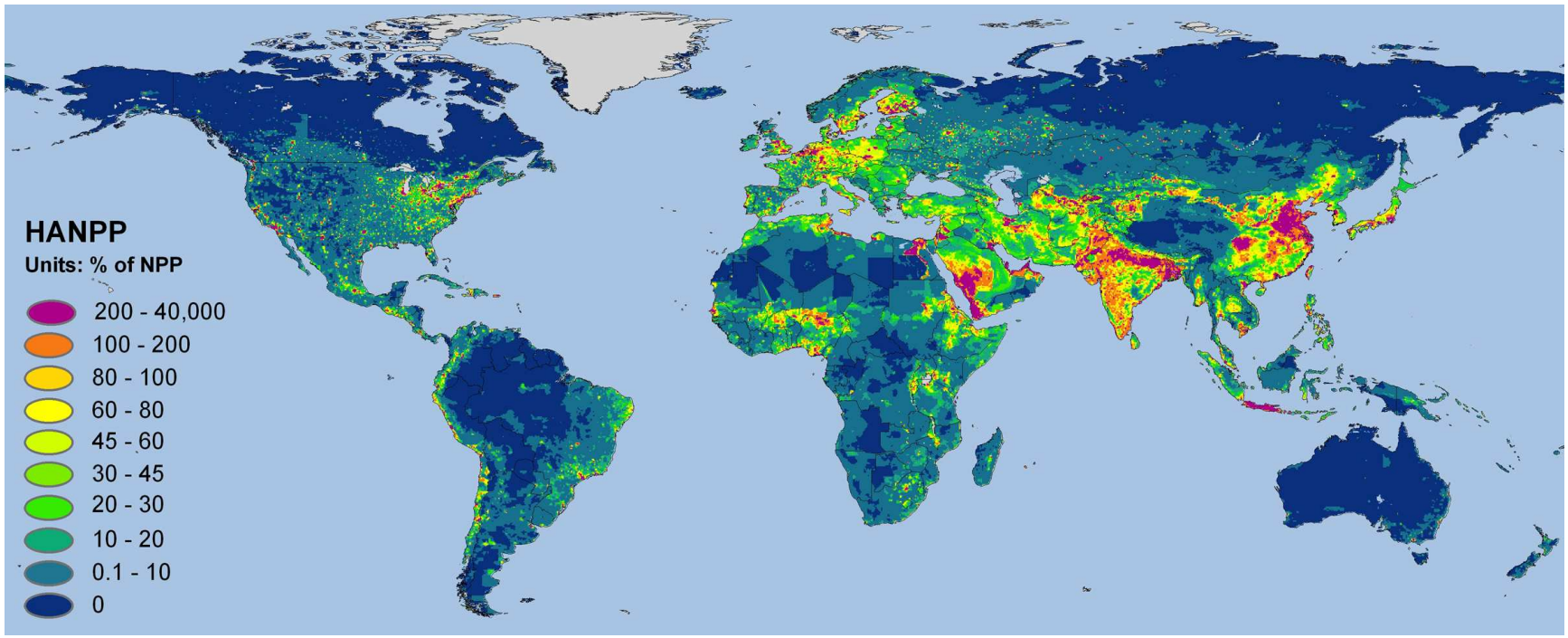
The recycling goes mostly above the ground

Global GPP and NPP are Known



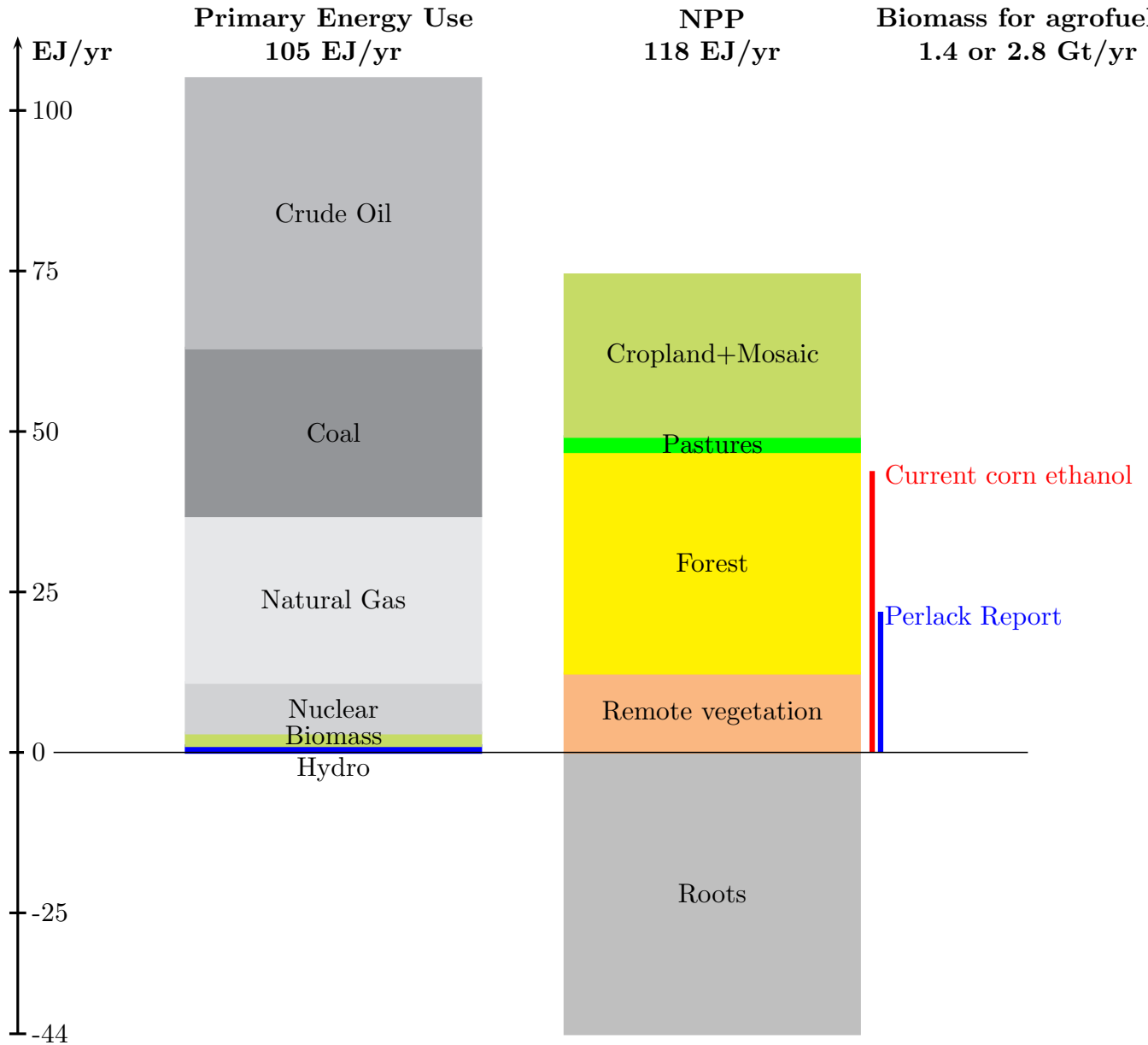
NASA produces a regular global estimate of gross primary productivity (GPP) and annual net primary productivity (NPP) of the entire terrestrial earth surface at 1-km spatial resolution, 150 million cells, each having GPP and NPP computed individually (MOD17A2/A3 User's Guide)
Image from Numerical Terradynamic Simulation Group, Missoula, Montana. Date: 12/27 – 12/31/2003

We Already Grab Most of NPP



Source: The Visible Earth, NASA images, 06-25-2004

130 Billion Gallons of Ethanol



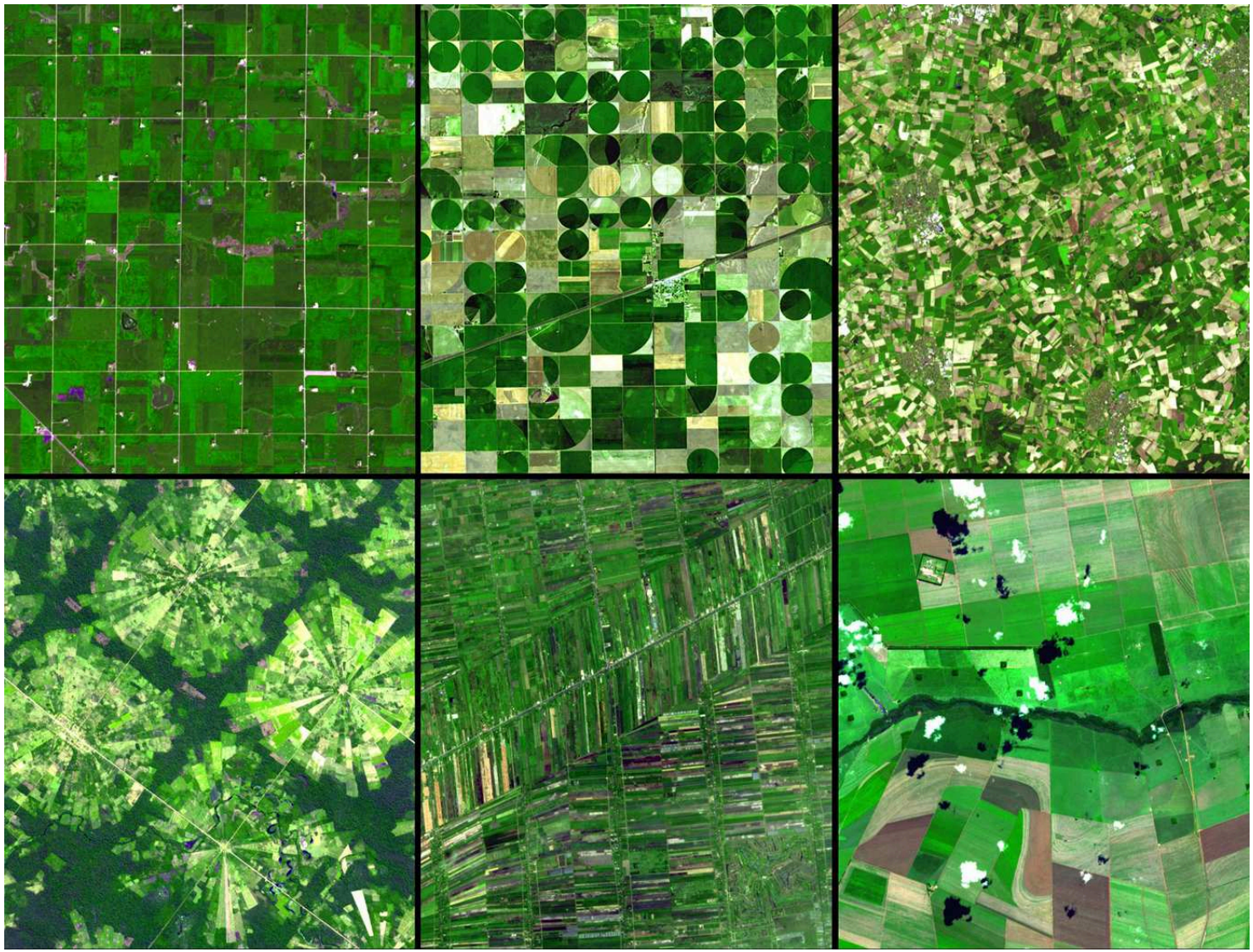
Sources: NASA MODIS; NTSG Missoula, Montana; Patzek OECD, 2007

Old and New Agriculture

Old Agriculture = Many People, Small Energy Inputs, Small Harvests, No Pollution
New Agriculture = Few People, Huge Energy Inputs, Large Harvests, High Pollution

Old Agriculture = Diverse, almost sustainable ecosystems powered by the sun
New Agriculture = Unsustainable deserts paved with single plants running on fossil fuels

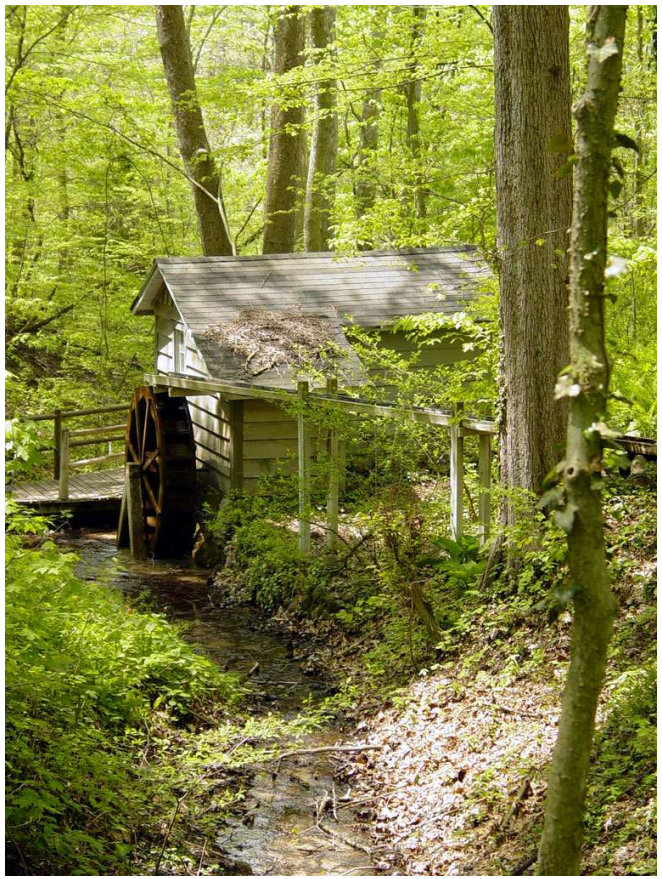
Field Development Patterns



Each ASTER sub-image covers an area of 10.5 x 12 km.

Courtesy of NASA/GSFC/METI/ERSDAC/JAROS and U.S./Japan ASTER Science Team

Old and New Machines



Old Machines = Small and Few, Powered by Animals, Water or Wind, No Pollution

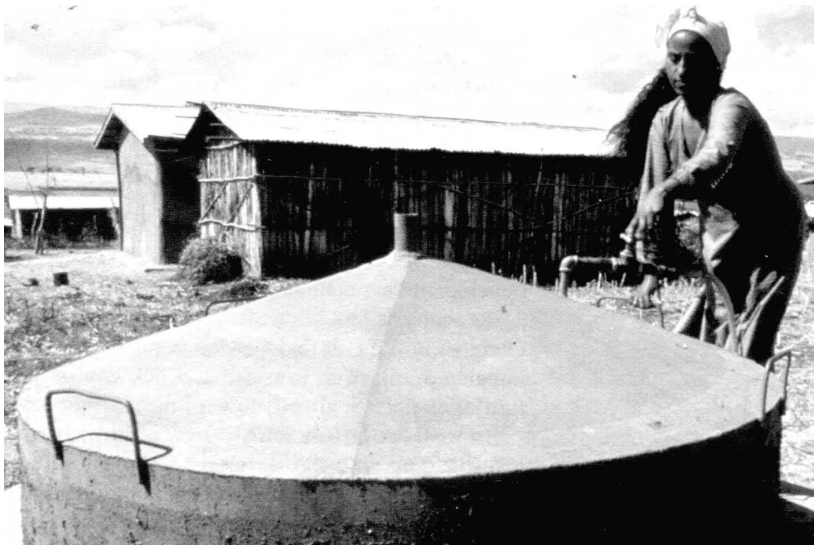
New Machines = Gigantic and Many, Powered by Fossil Fuels, High Pollution

Developing and Developed Countries

Developing = Huge Poor Farming Populations, Low Agricultural Productivity
Developed = Tiny Farming Populations, High Agricultural Productivity

Agricultural workers in China = 40% of population can barely feed China
Agricultural workers in US = 0.17% of population can feed US, China, and Bangladesh

Developing and Developed Countries



Developing = Tiny Chemical Waste Fluxes, Low Environmental Impact, Sustainable
Developed = Large Chemical Waste Fluxes, High Environmental Impact, Unsustainable

CO_2 emissions in Kenya = 0.2 tonnes/person
CO_2 emissions in US = 20.2 tonnes/person