Biofuel Feedstocks and Production

BEE 499/599
Winter, 2015
3 Credit Hours

Bioethanol is one of the important alternatives to fossil fuels. This course will provide an overview of the biofuel feedstocks for production of fuels, feed and industrially valuable chemicals. Issues in feedstock utilization such as suitability, availability, sustainability and economic viability will be addressed. This course will cover the preprocessing, post processing and fermentation technologies in ethanol production in detail. Influence of feedstock composition and process technologies on ethanol and coproducts will be discussed.

Topics Covered

1. Overview of a biobased economy
2. Feedstocks: classification, properties and selection
3. Biochemical technologies for ethanol production
4. Other bioprocessing technologies for fuels and chemicals
5. Systems analysis

Course Schedule and Location

MWF 9.00-9.50 am; 100 HOV

Course Format

Three lectures per week, class tests, exams and a review of Journal articles (Graduate).

Instructors

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Need for Sustainable Biobased Economy

Three important considerations

- Energy resources and their contribution
- Population growth and economy
- Global climate change

World Energy Scenario

Energy sources

- Non Renewable: Petroleum, coal, nuclear
- Renewable: Solar, wind, hydro and biomass

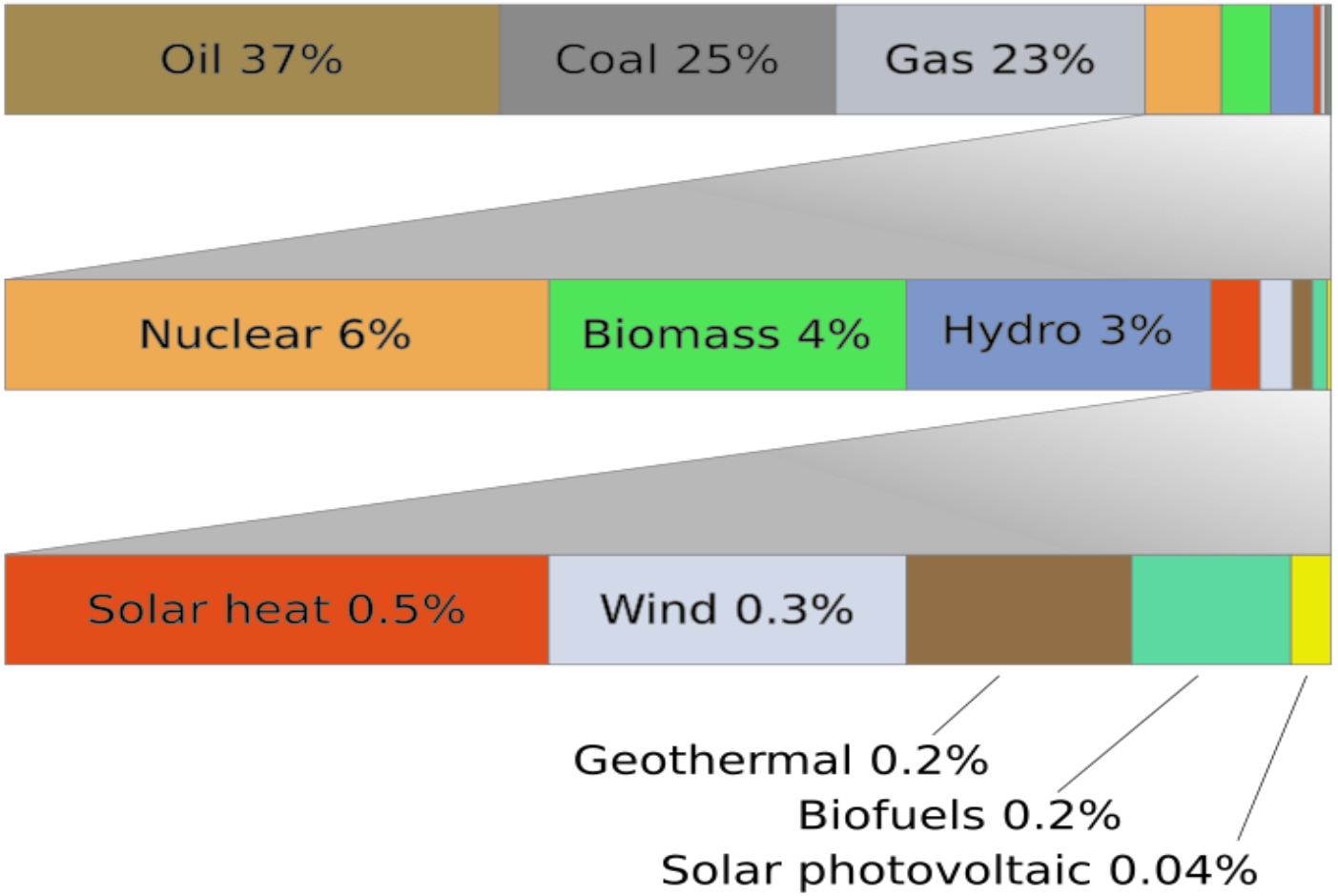
Are all forms of energy the same?

kWhr from coal ≠ kWhr from gasoline ≠ kWhr from electricity

Usability is determined by the following characteristics of energy sources.

- High energy density
- Long shelf life
- Safety
- Quality

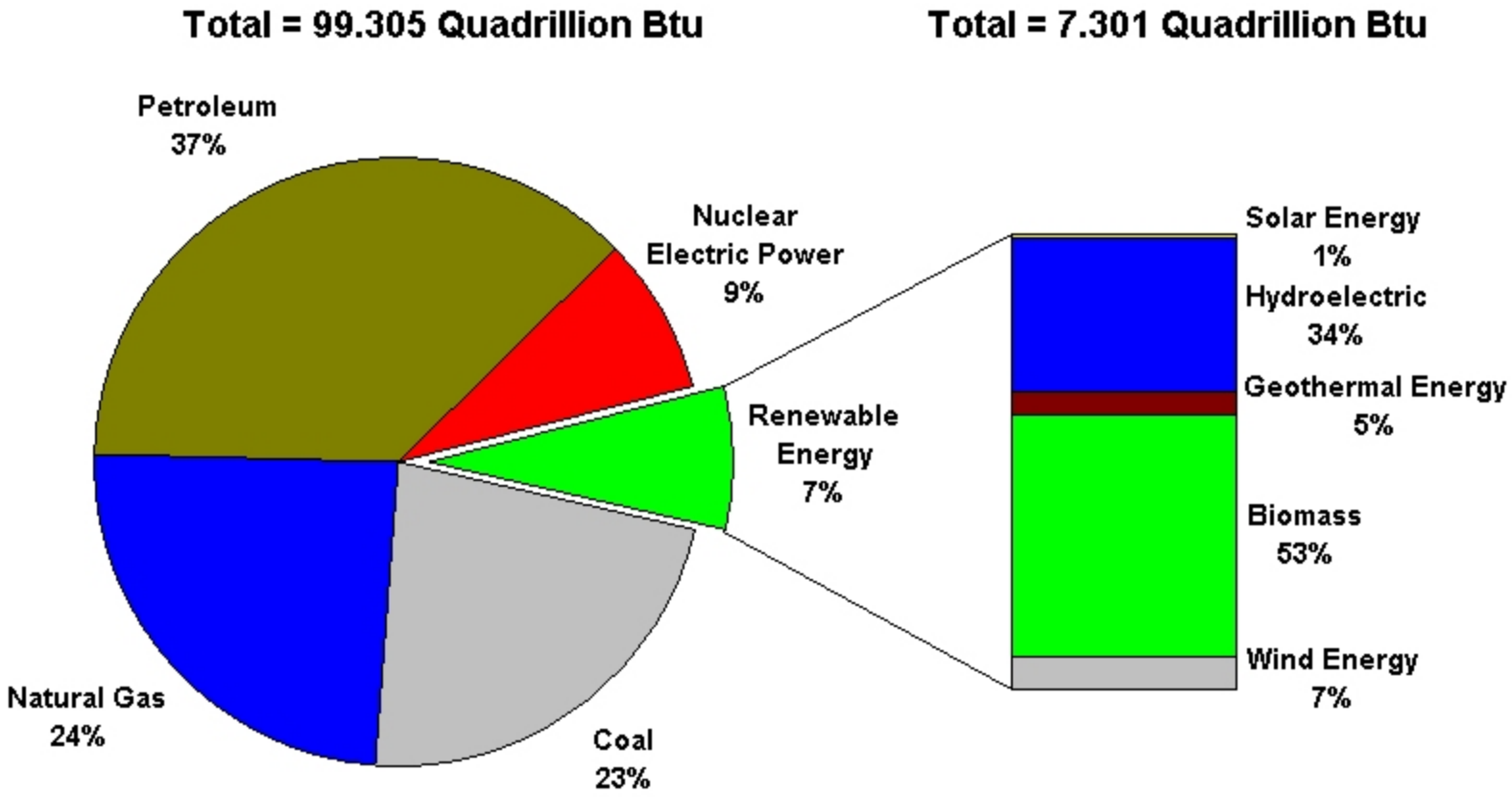
World Energy Scenario



Source: http://en.wikipedia.org/wiki/Image:World_energy_usage_width_chart.svg

Data: Renewables in global energy supply. IEA Report, 2007.

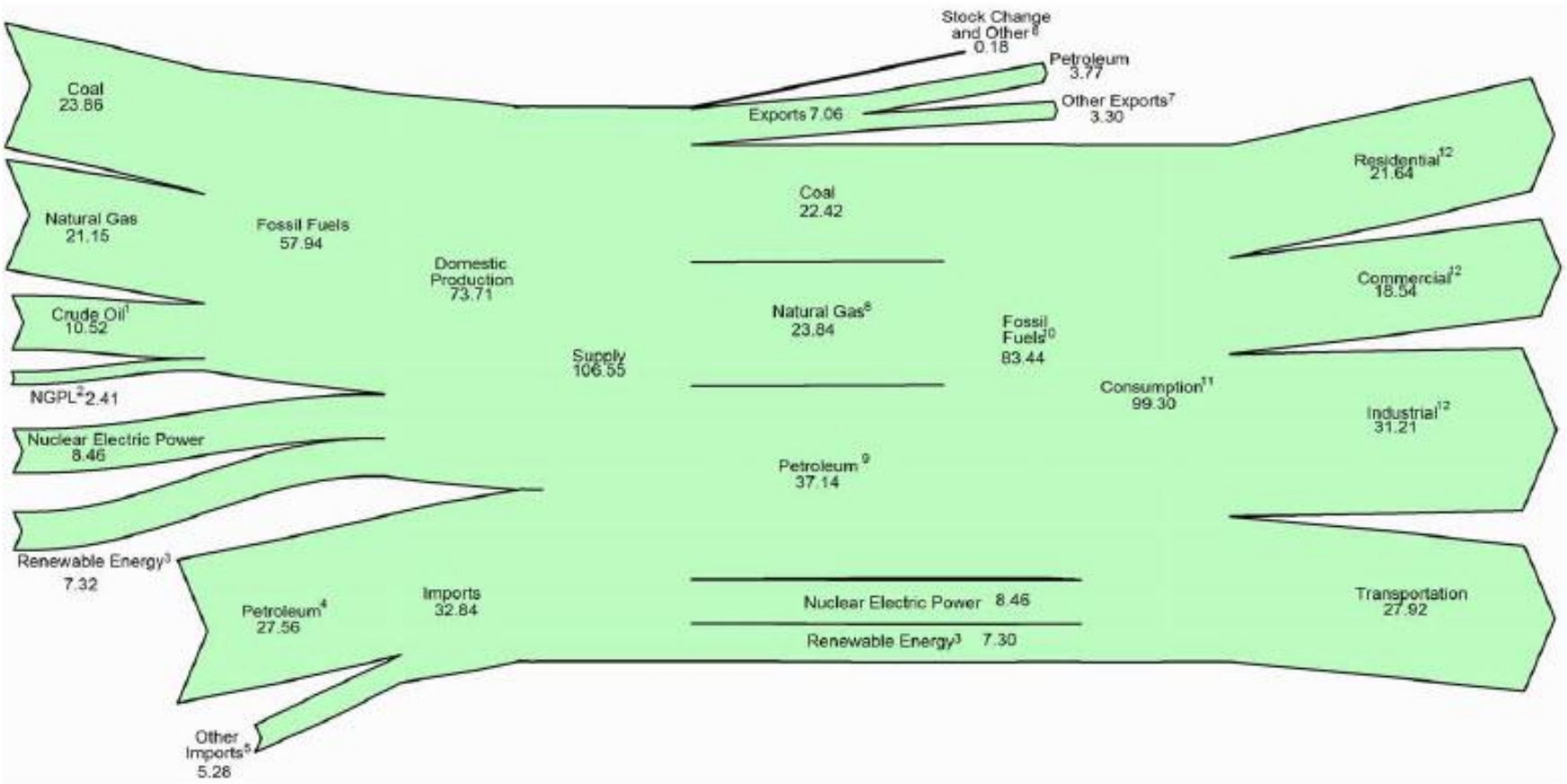
US Energy Scenario



Source: http://www.eia.doe.gov/cneaf/alternate/page/renew_energy_consump/figure1.html

Data: Renewables in global energy supply. IEA Report, 2008.

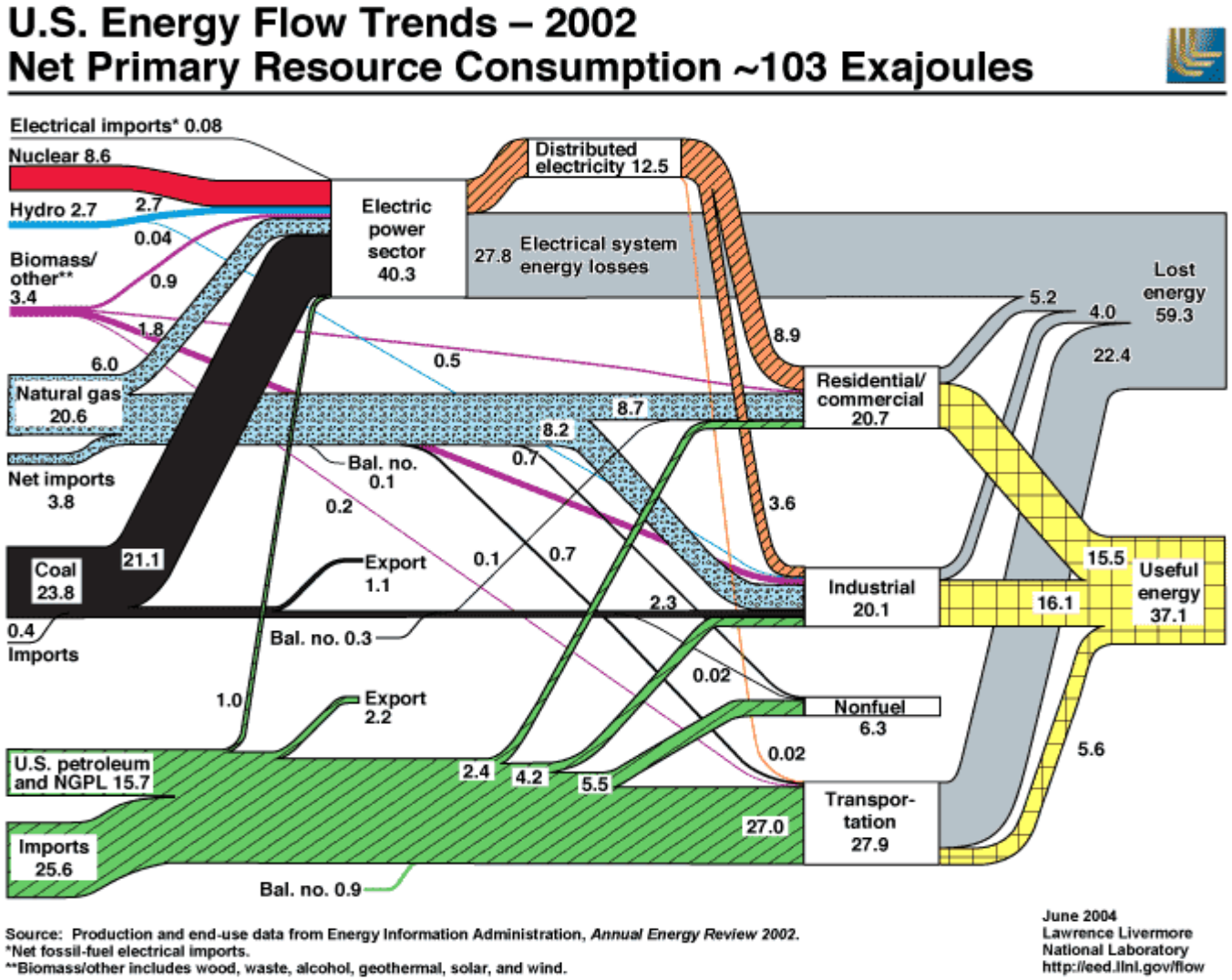
US Energy Flows



Source: EIA

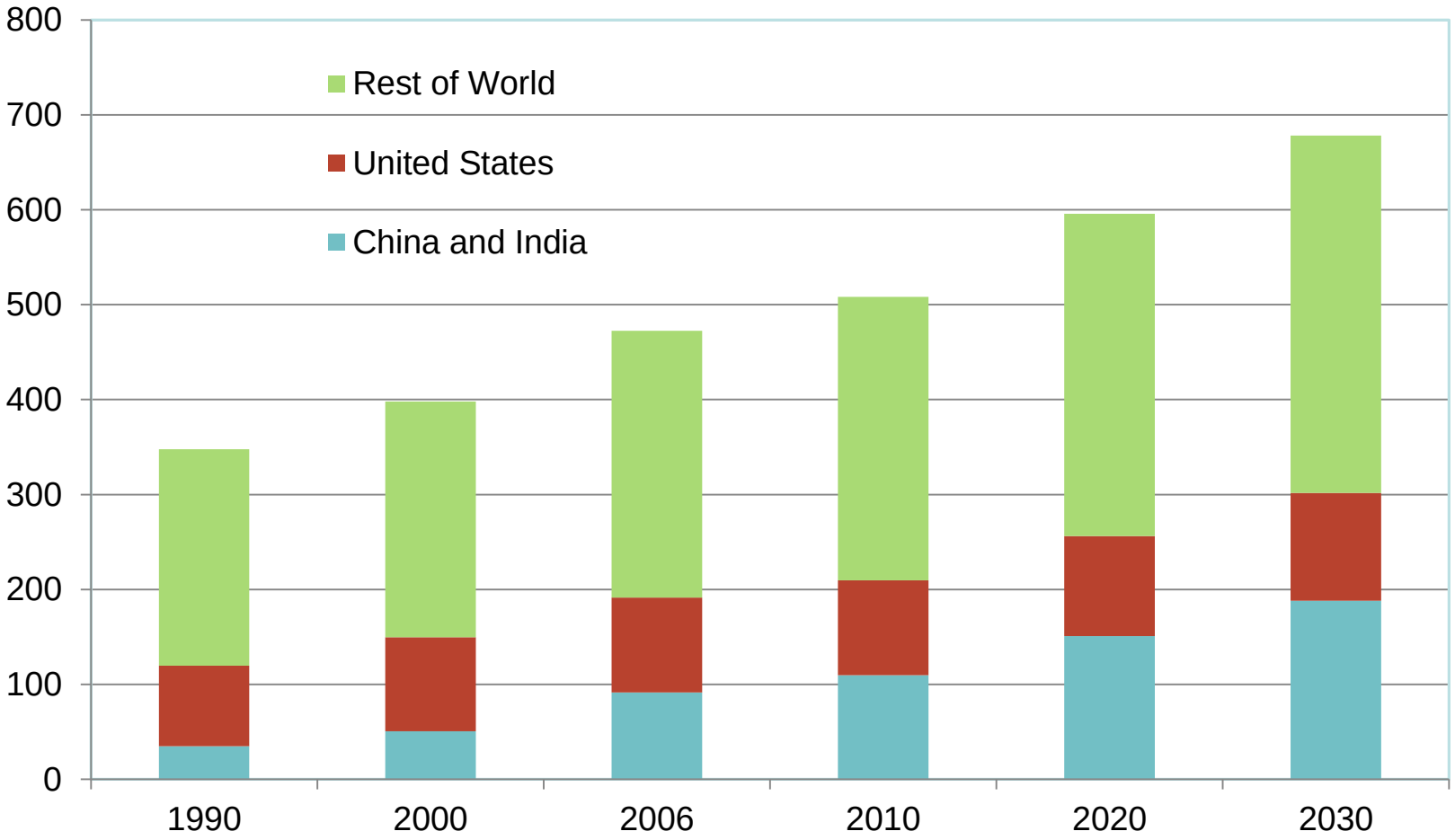
Data: Renewables in global energy supply. IEA Report, 2008.

US Energy Scenario



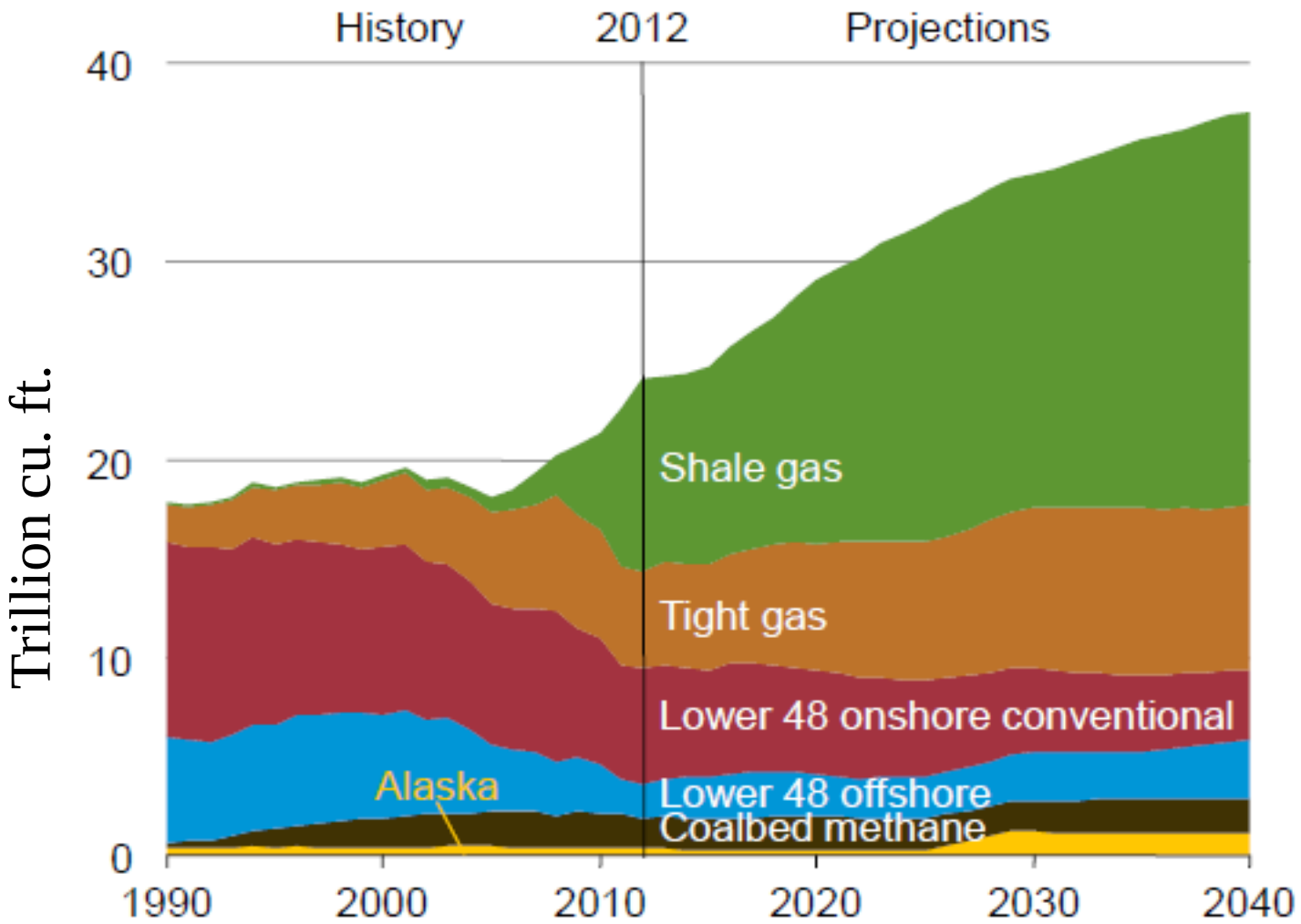
Source: https://eed.llnl.gov/flow/02flow.php

World Energy Use



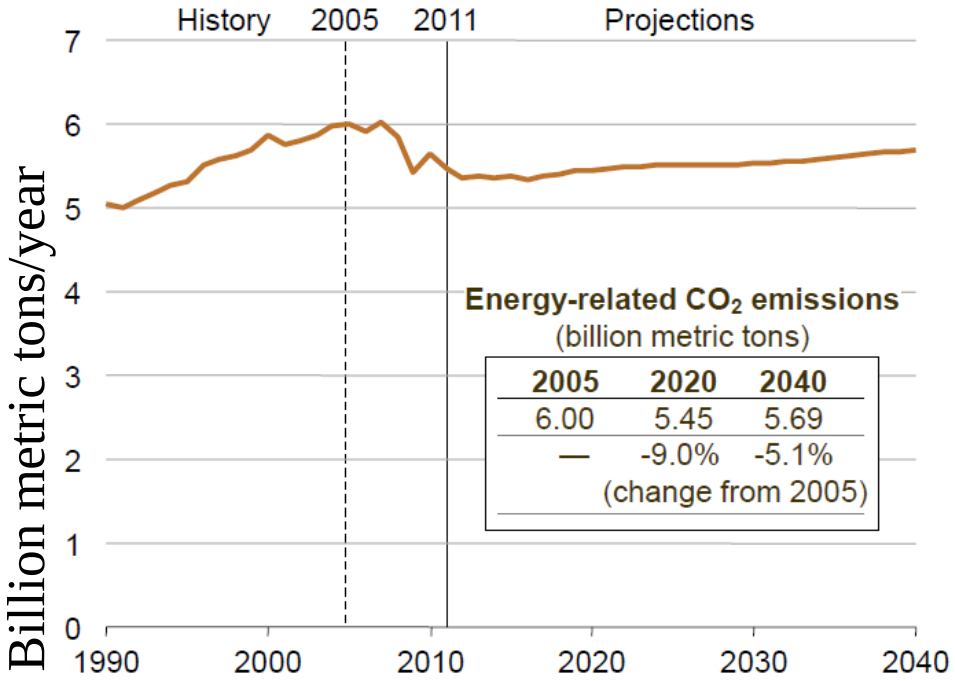
Source: EIA

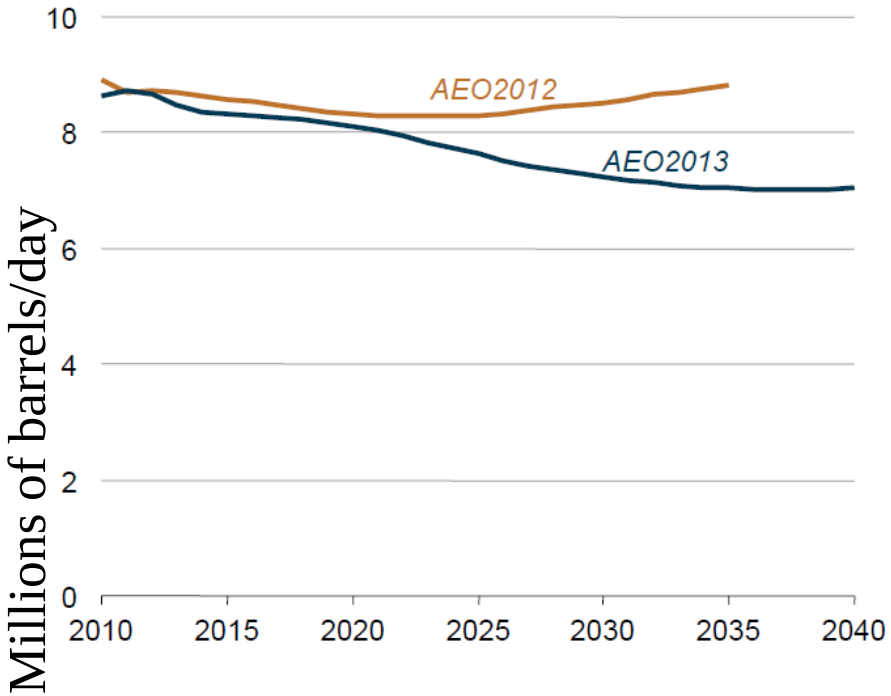
US Natural Gas Production



Source: EIA, 2013 outlook report

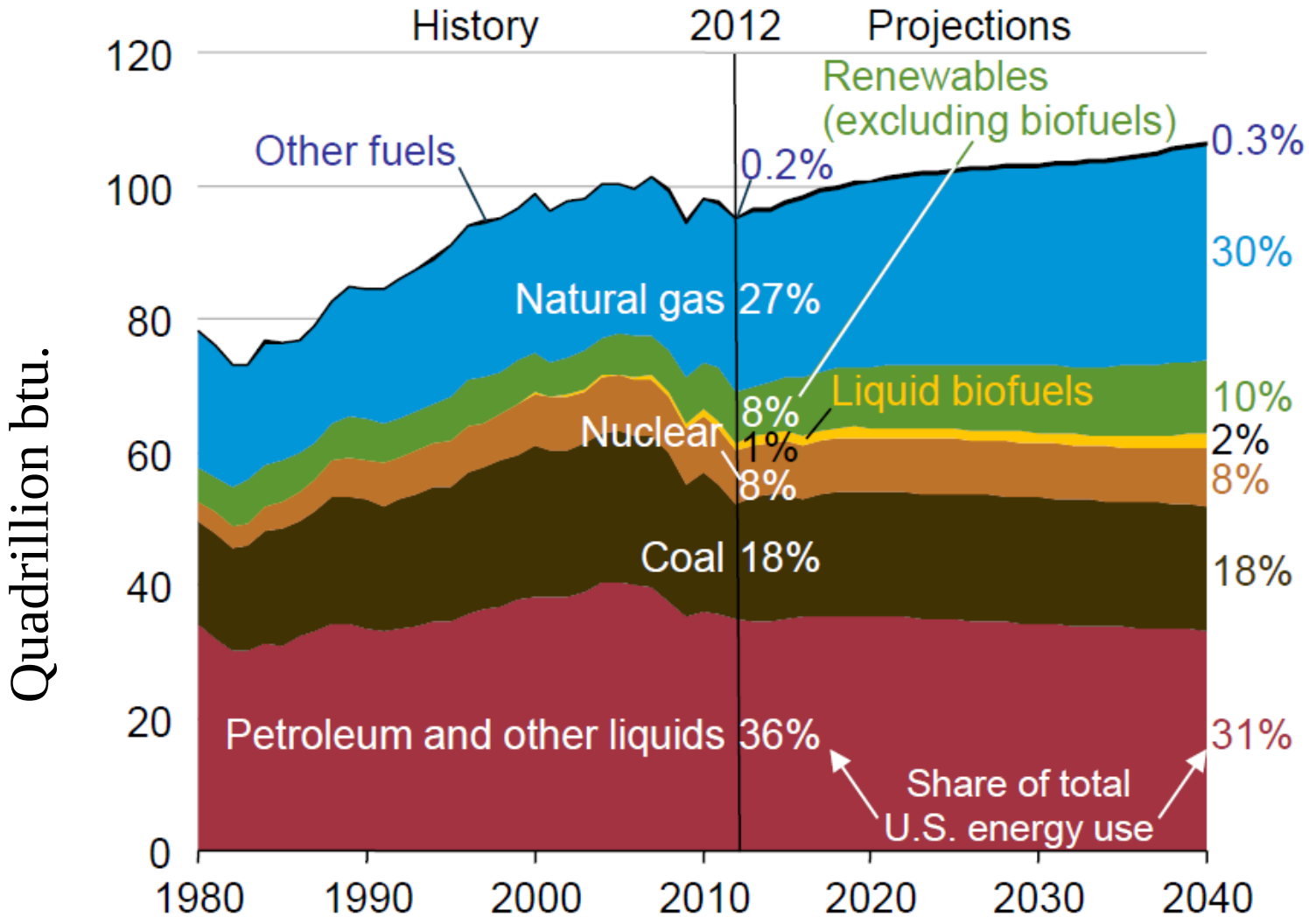
US CO_2 Liquid Fuels consumption and CO2 Emission





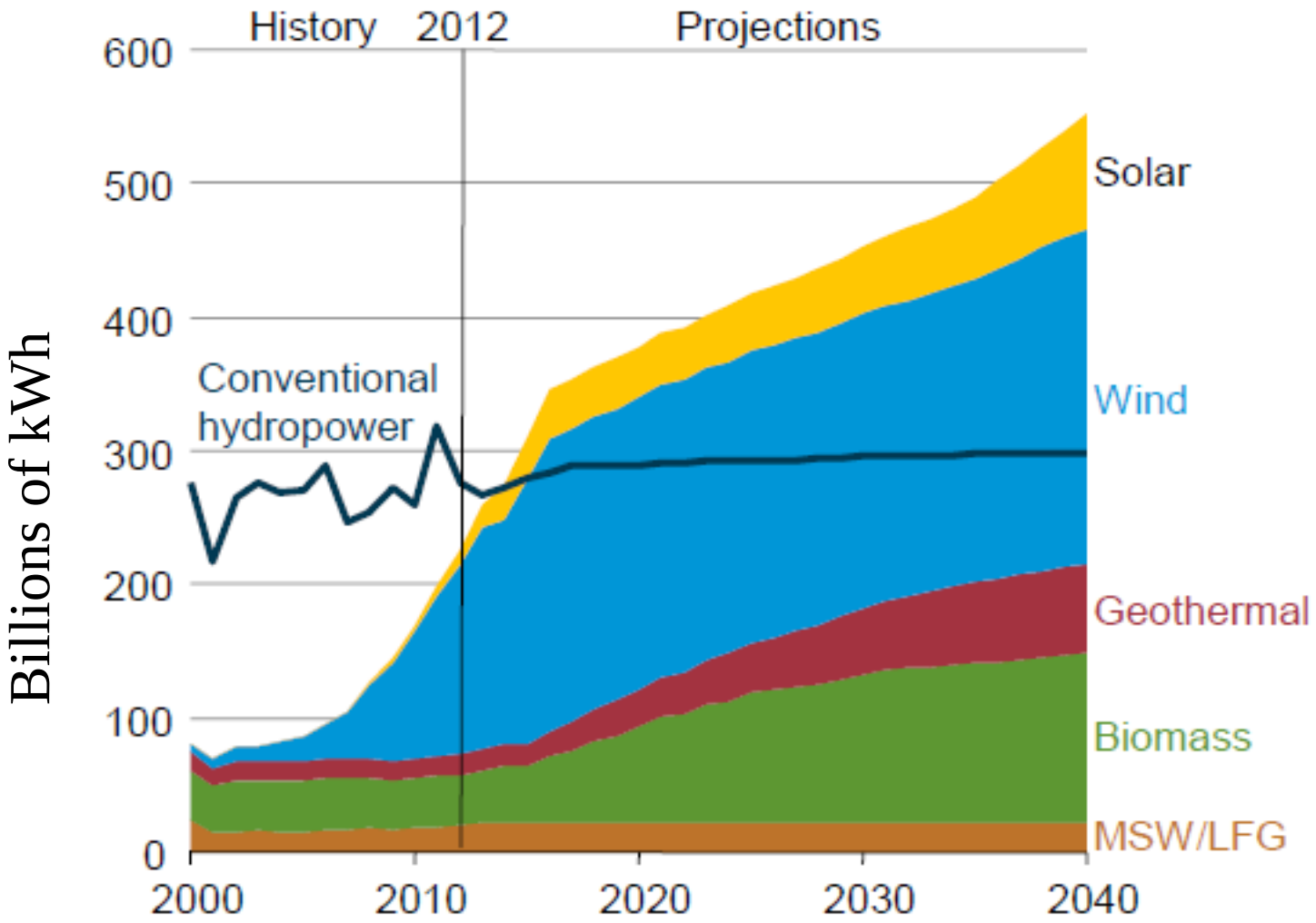
Source: EIA, 2013 outlook report

US Primary Energy Consumption by Fuel



Source: EIA, 2014 outlook report

Renewable Electricity Generation



Source: EIA

Need for Sustainable Biobased Economy

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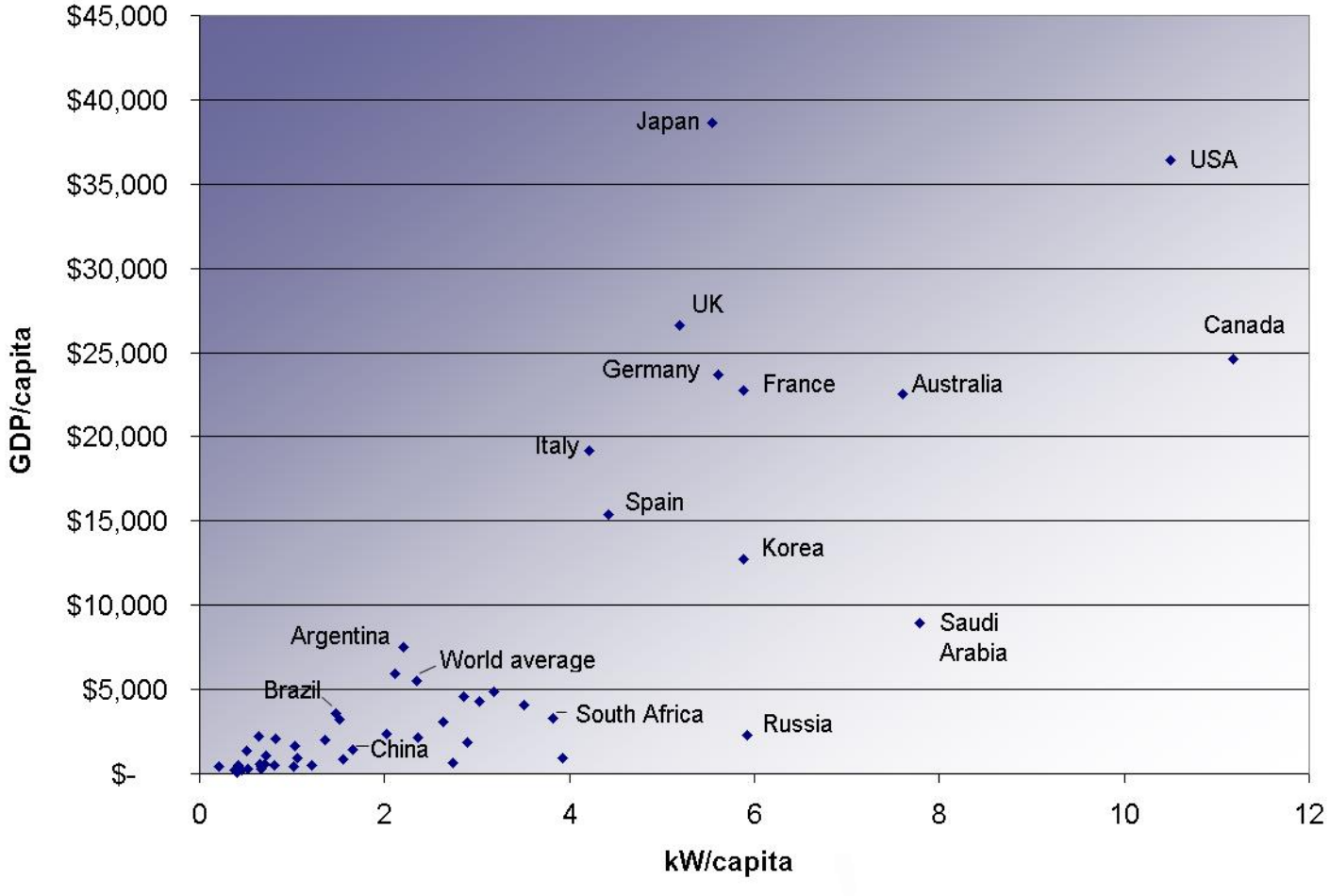
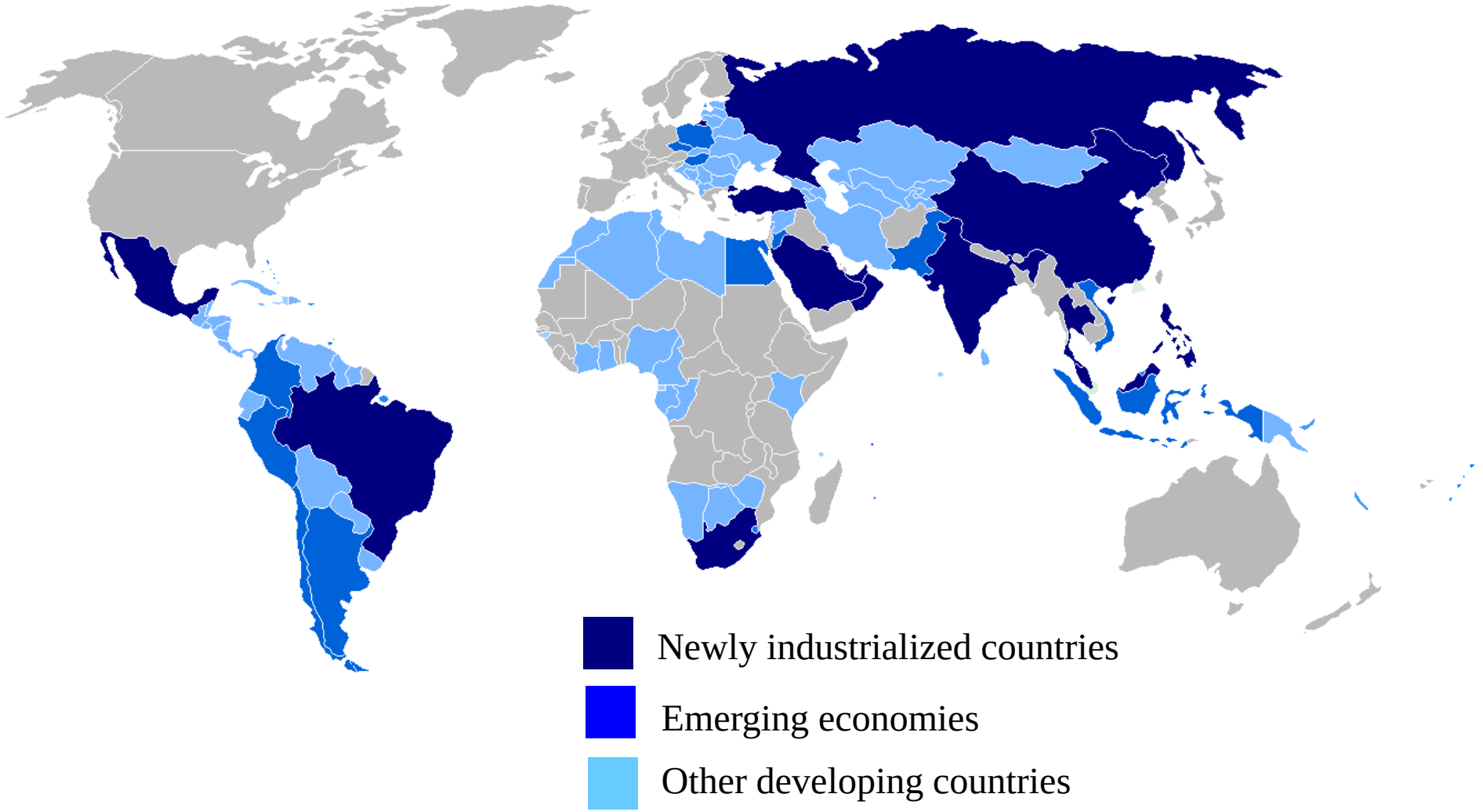
Energy Consumption and Economy

Energy is the real currency of economies.



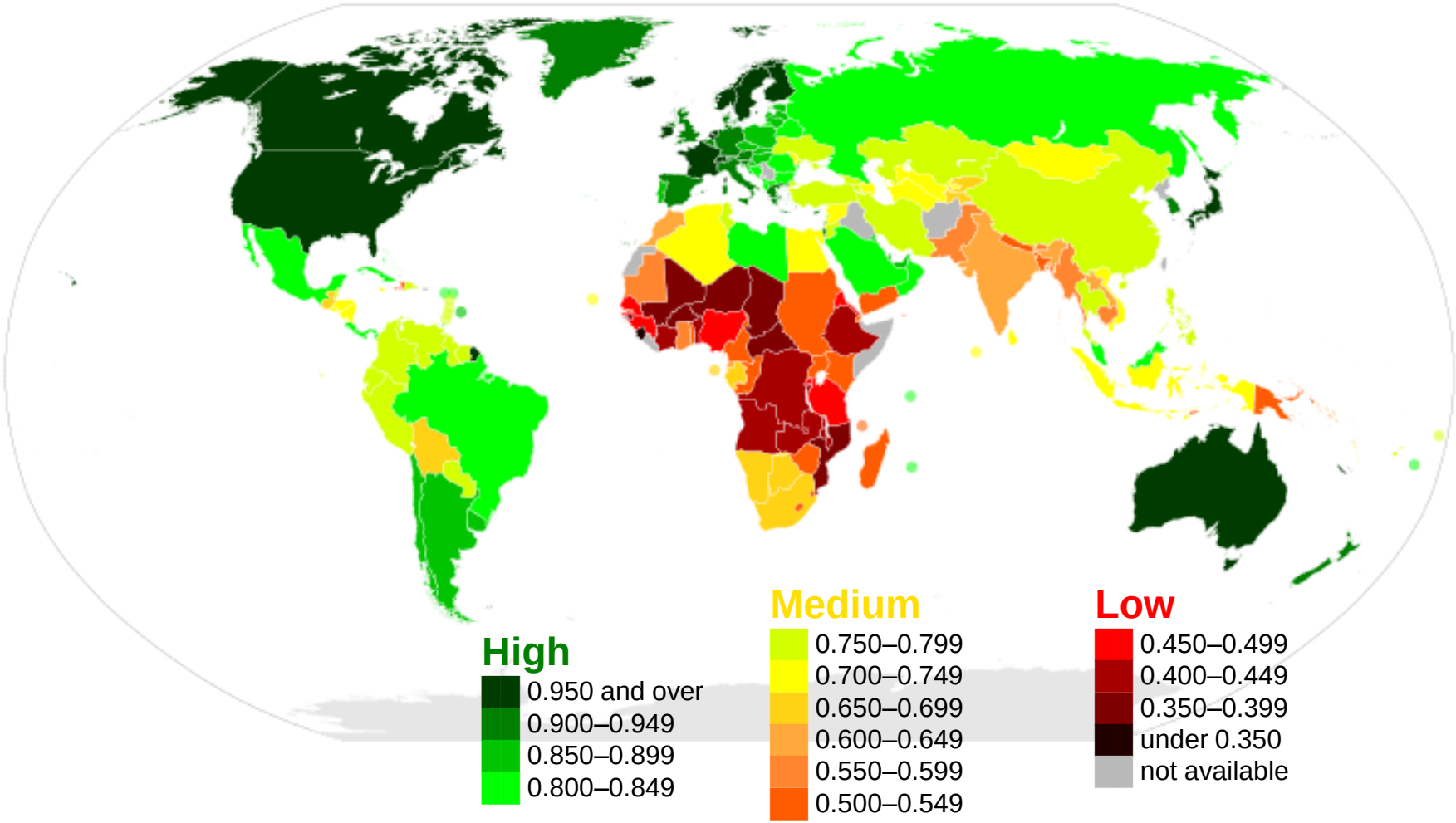
Source: Frank van Mierlo , http://en.wikipedia.org/wiki/Image:Energy_consumption_versus_GDP.png

World emerging economies



Source: http://en.wikipedia.org/wiki/Image:World_population.PNG

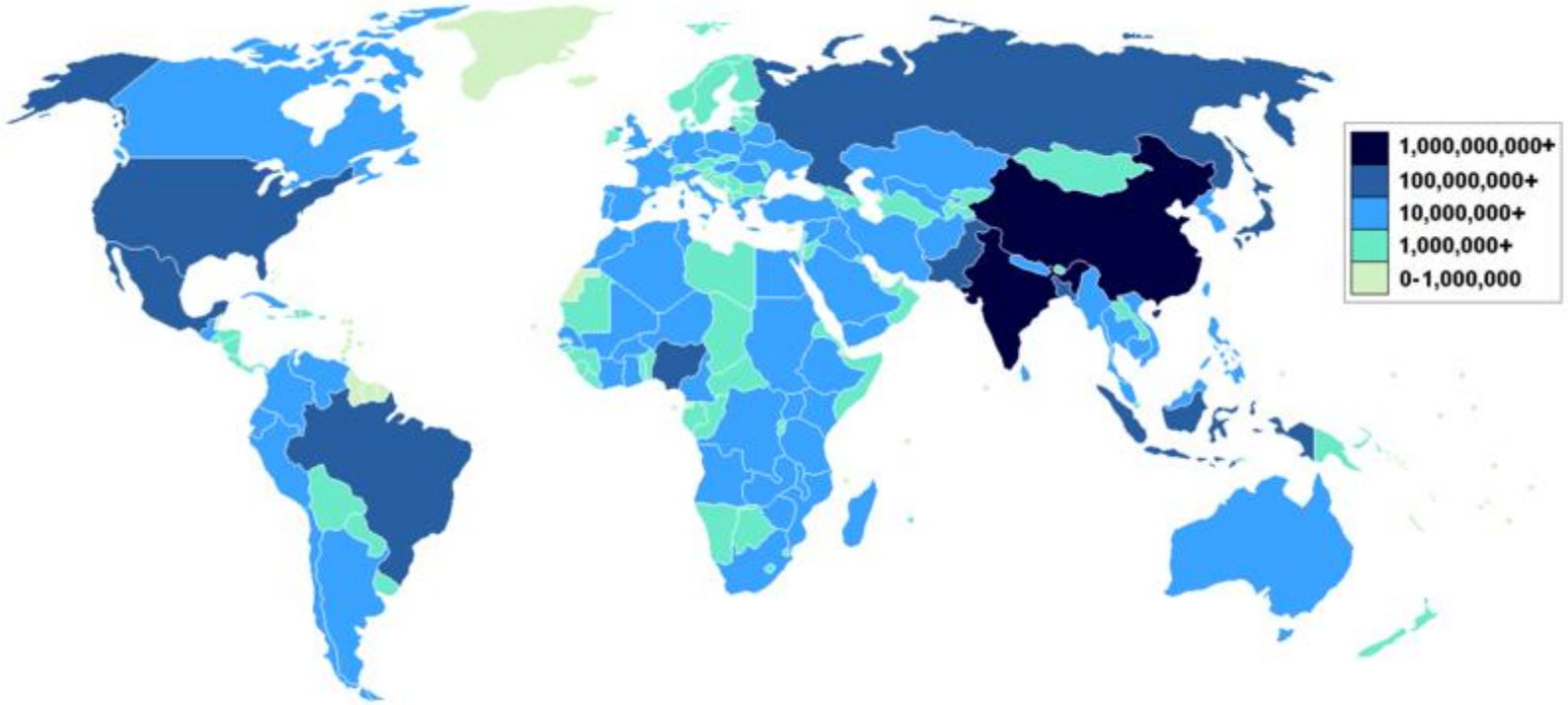
World human development index



Source: http://en.wikipedia.org/wiki/Image:UN_Human_Development_Report_2007_%282%29.svg

Data: Human Development Report, 2007.

World population



Source: http://en.wikipedia.org/wiki/Image:World_population.PNG

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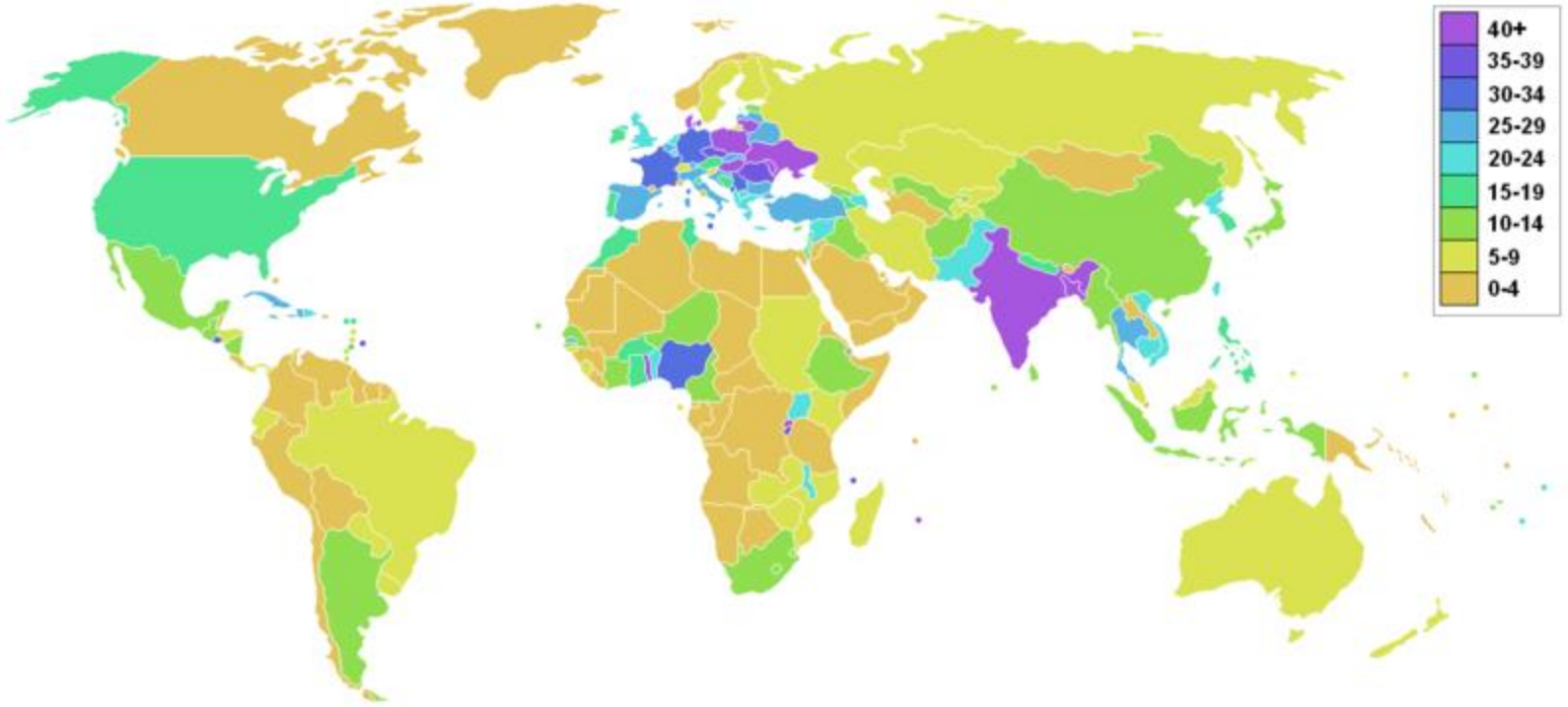
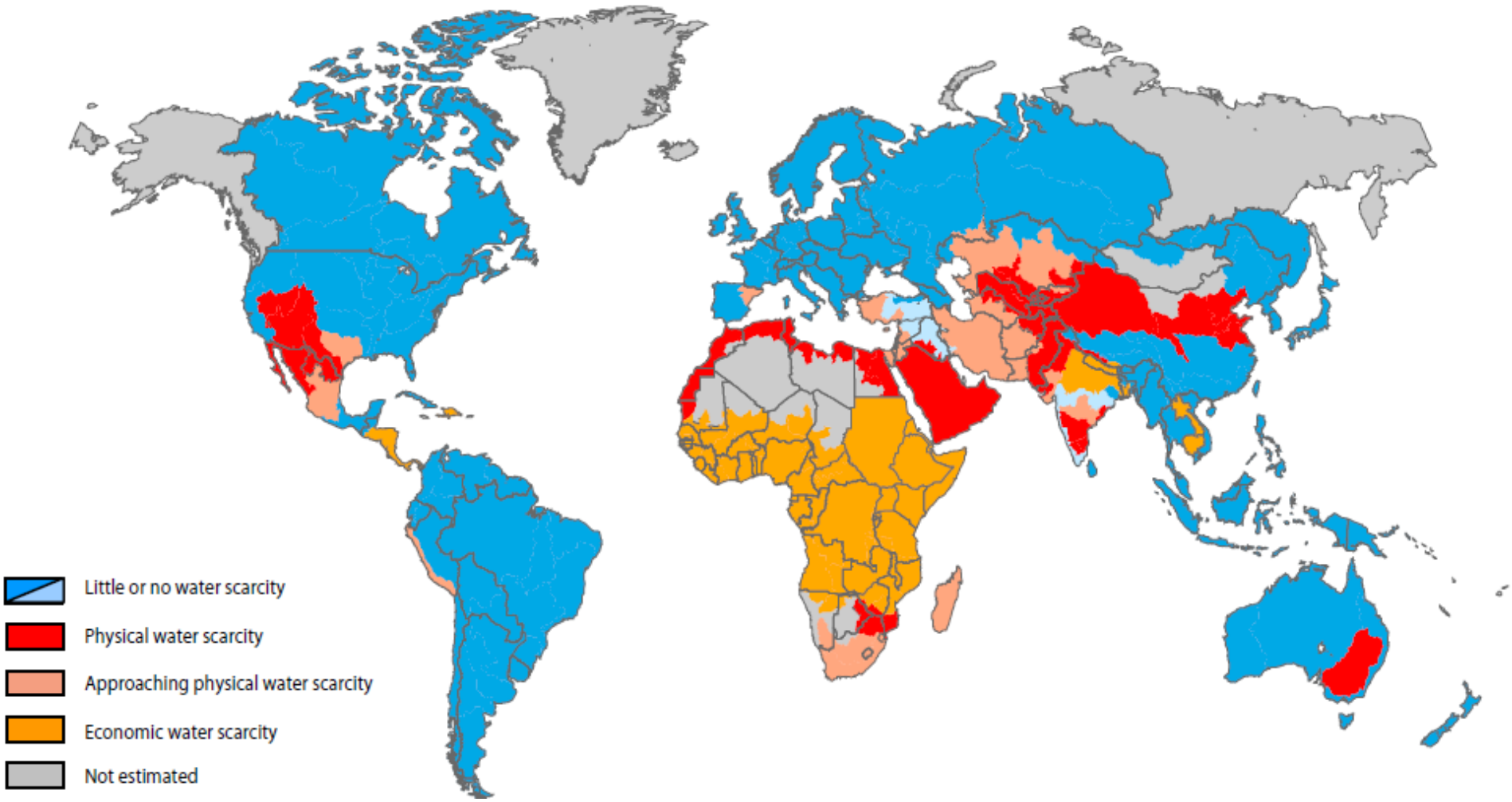
Arable land in world



Source: http://en.wikipedia.org/wiki/Image:Arable_land_percent_world.png

Data: CIA Factobook

Resources: World Water Stress



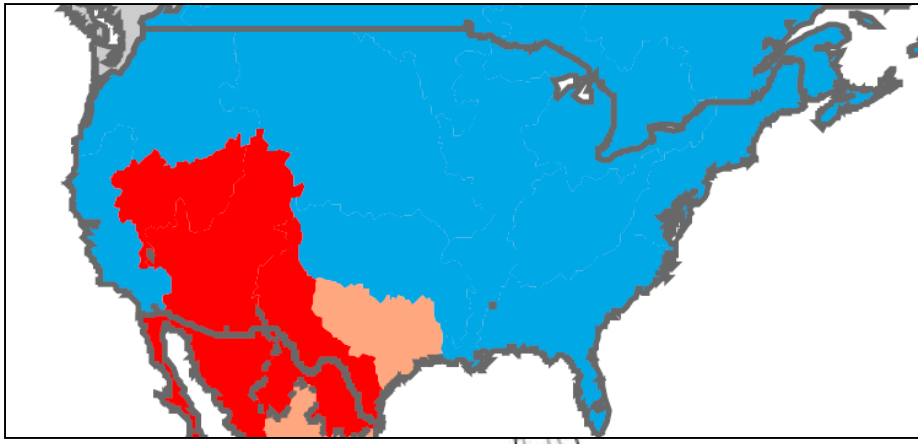
Physical water scarcity
Red: >75% river flows already in use
Light Red: >60% river flows already used

Orange: Economic Water scarcity, <25% used due to economic reasons.
Blue: Water resources available.<25% is withdrawn for human purposes.

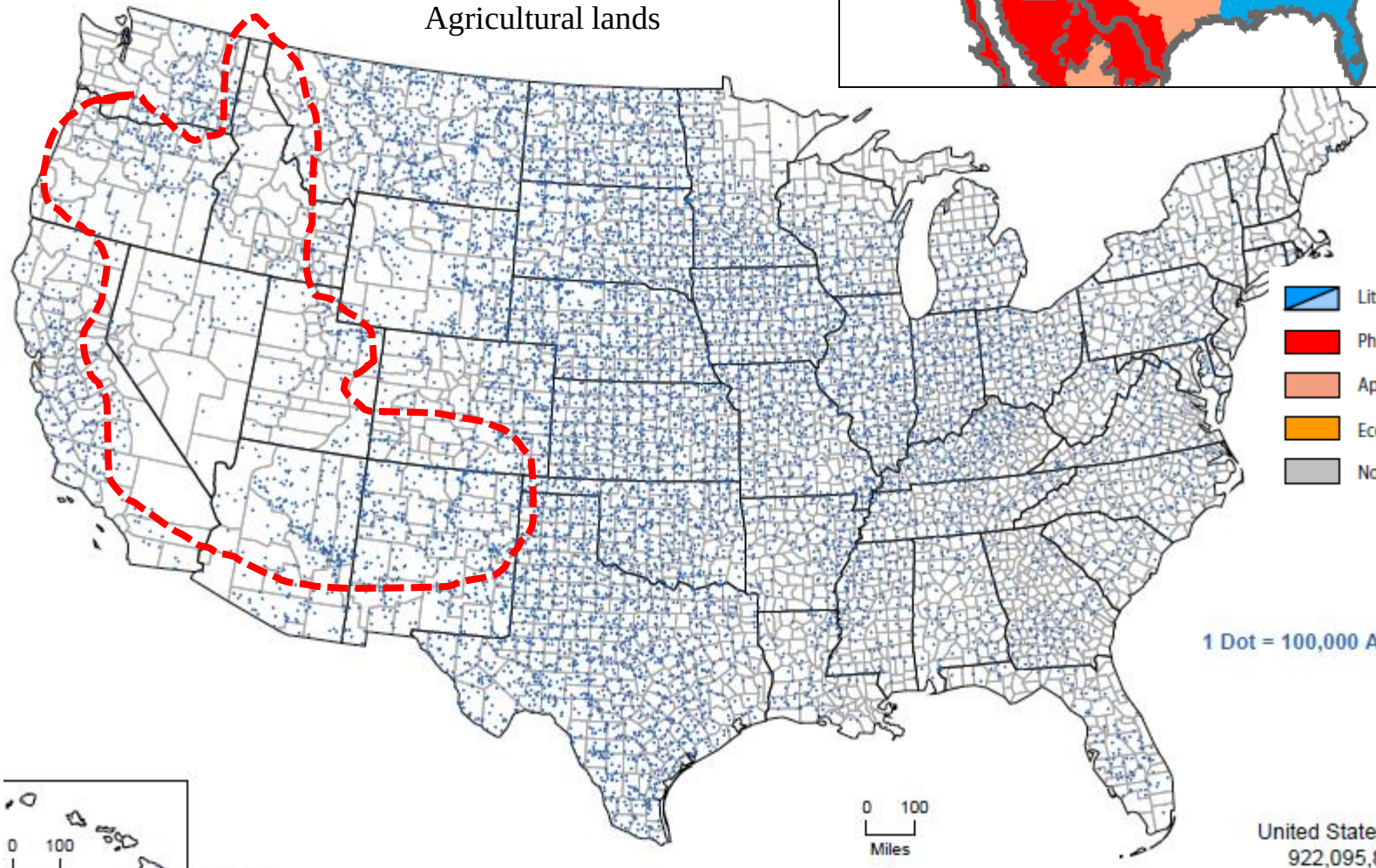
Ref: .Comprehensive Assessment of Water Management in Agriculture, International Water Management Institute, 2006.

Resources: World Water Stress

Water stress map



Agricultural lands



EROEI and EROWI for Different Fuels

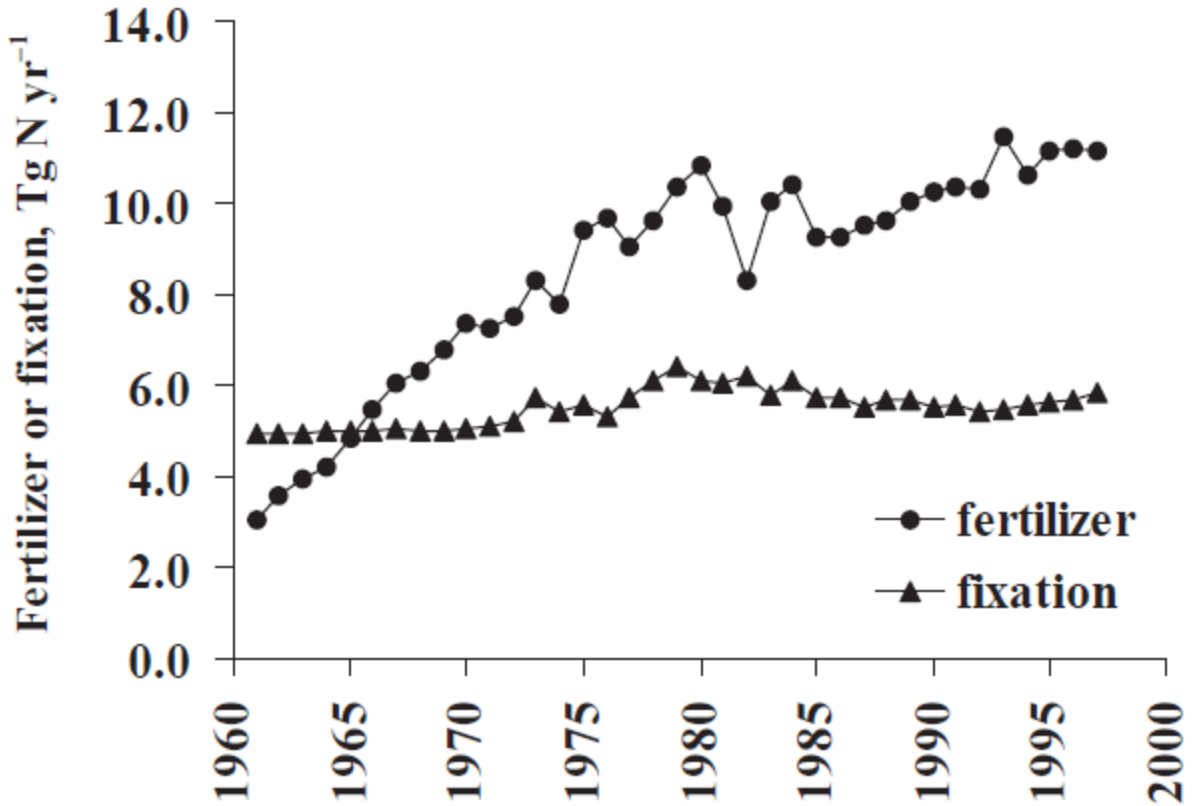
	Water usage (L/MJ)	EROWI (MJ/L)	EROEI (MJ/MJ)	Net EROWI
Nuclear Electric	1.162(0.145)	0.861(1.517)	10	0.775 (1.137)
Coal Electric	0.560(0.488)	1.786 (2.049)	-	-
Conv. Diesel	0.0035	285.3	5.01	228.4
Biodiesel				
Rapeseed	100-175	0.010-0.0057	2.33	0.0057-0.0033
Algae (Ponds)	20.142*	0.004965	3.33	0.03475
Ethanol				
Sugarcane	38-156	0.026-0.0065	8.3	0.023-0.0057
Corn	73-346	0.014-0.0029	1.38	0.0039-0.00081
Lignocellulosic Crops				
Ethanol	11-171	0.091-0.0058	4.55	0.0071-0.0045
Hydrogen	15-129	0.067-0.0078	4.67	0.053-0.0062
Electricity	13-195	0.077-0.0051	5.0	0.062-0.0041

*20142 L/ 4 days ~25 people (201 L/person-day)

Data from: Mulder et al. 2010. AmBio. 39:30-39. and Sander Murthy. 2010. IJLCA.15:704-714

Resources: Nutrients

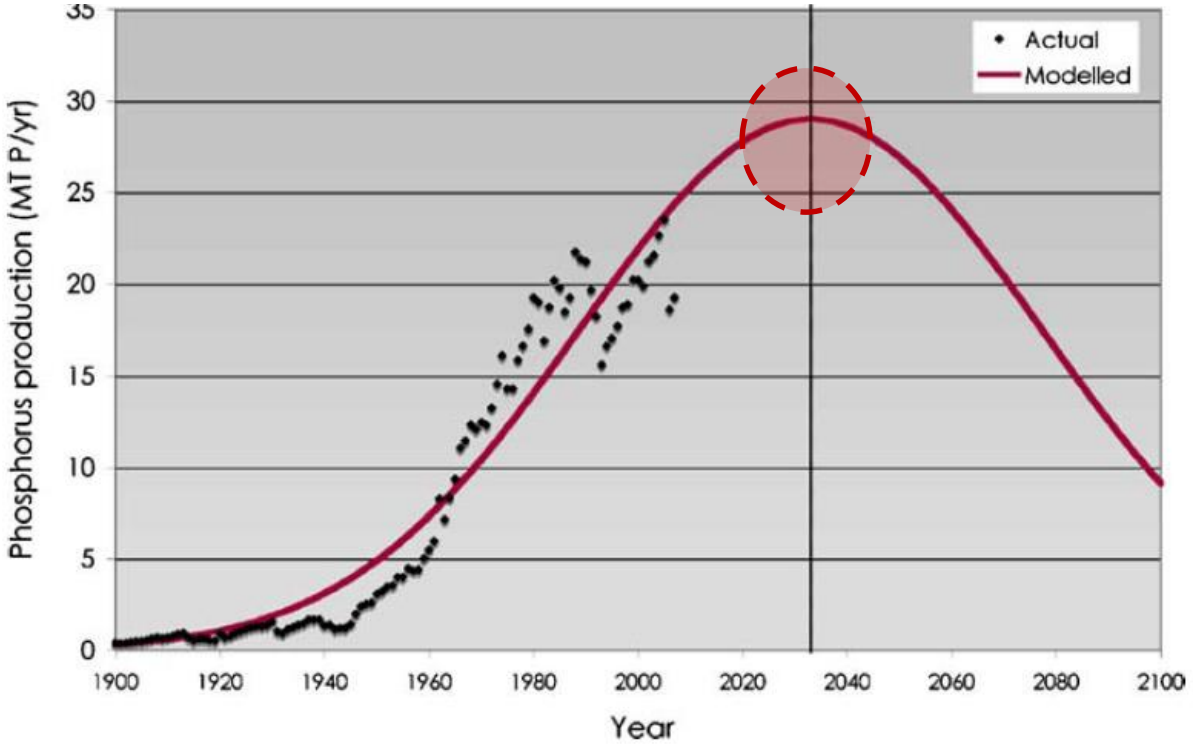
- Nitrogen supply and use.



Ref: .Howarth et al. 2002

Resources: Nutrients

Peak phosphorous?



Ref: .Cordell et al. 2009. Global Env. Change. 19:292-305.

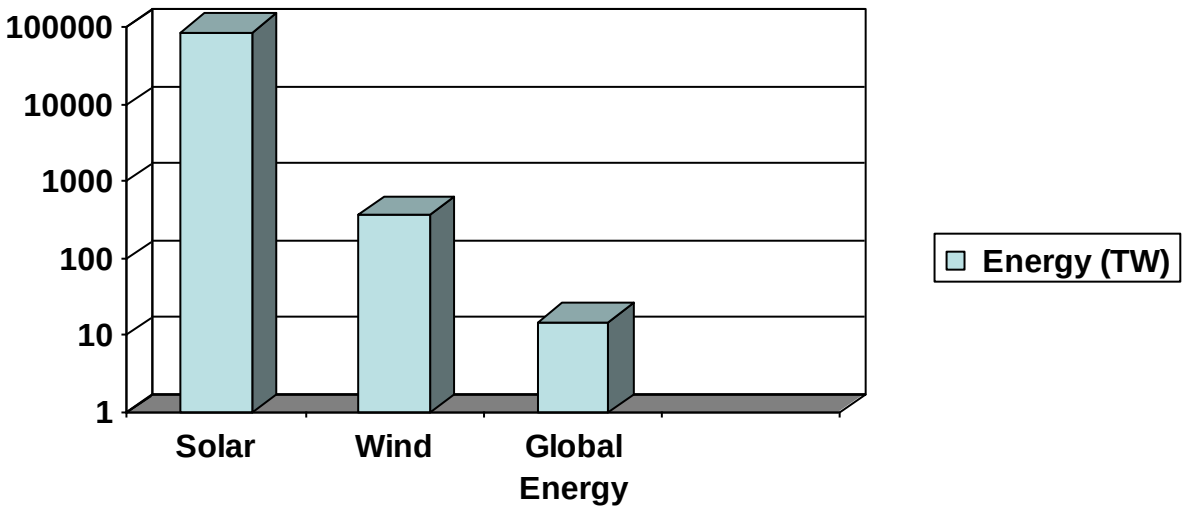
Impact of Global Climate Change on Agriculture

Impact of global climate change on agriculture

- Unpredictable rainfall
- Loss of forest cover and biodiversity
- Increase in pests and diseases
- Loss of fertile lands due to rising ocean levels
- Change in the direction of ocean currents
- Ocean acidification

Source: http://www.fao.org/NEWS/FACTFILE/FF9721-E.HTM

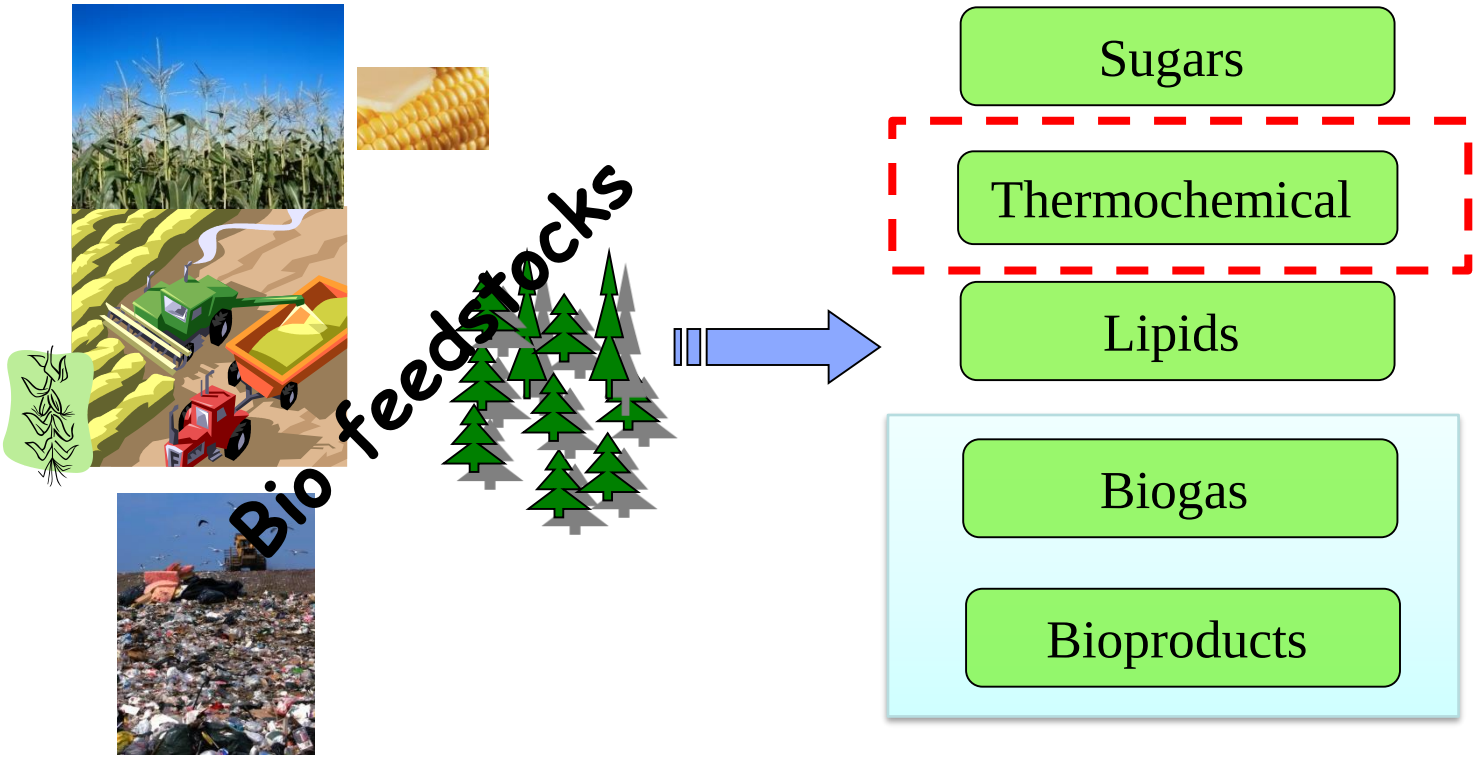
Renewable Energy Availability



Source: Tester, Jefferson W.; et al. (2005). *Sustainable Energy: Choosing Among Options*. The MIT Press. ISBN 0-262-20153-4.

Technologies for Conversion of Bio-feedstock

Technologies for conversion of biomass can be divided into five platforms (Biomass Program, DOE Classification)



Consolidated Bio processing (CBP)

- Increase biomass yield per acre
- Improve biomass characteristics

Size reduction

Pretreatment

- Exploit biological catalysts
- Reduce severity and wastes
- Raise sugar yields

- Eliminate separation
- Combine enzyme production, hydrolysis, and fermentation into one reactor
- Integrate total process

Direct conversion of cellulose and hemicellulosic sugars

Product recovery

Ethanol

Residue processing

Coproducts

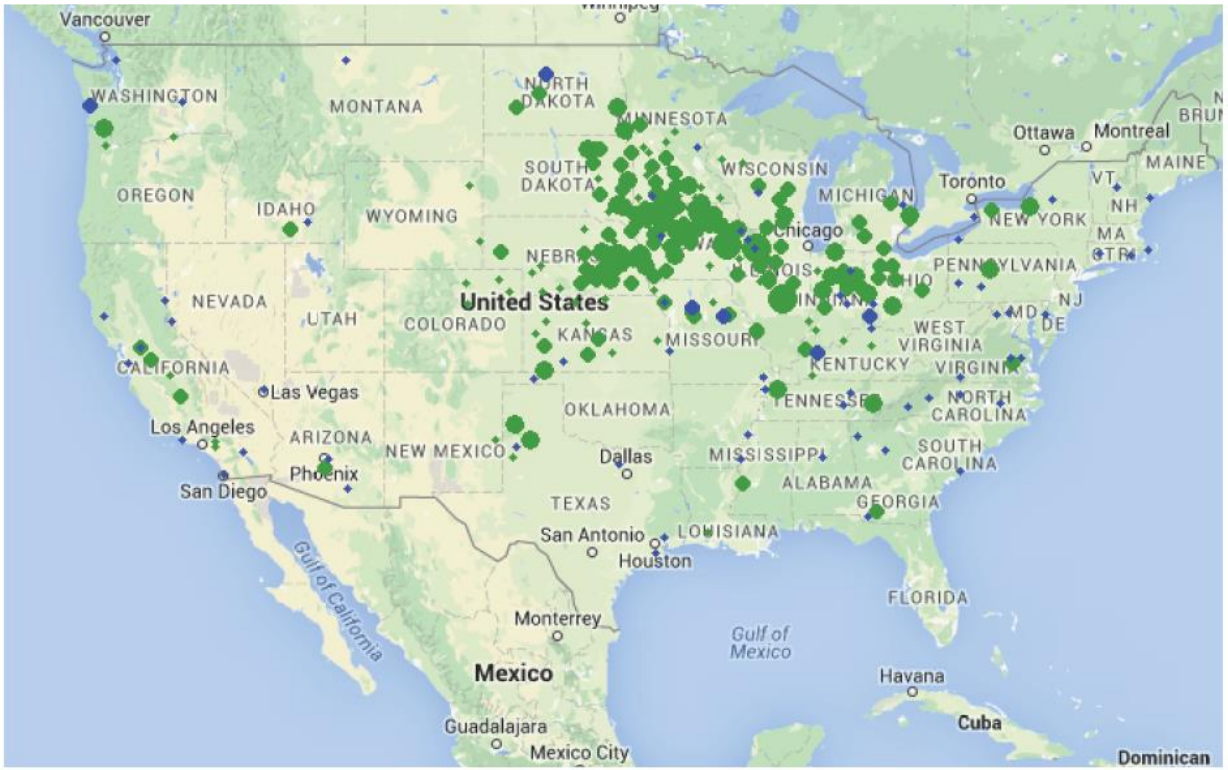
Advantages:

- Cost reduction
- Higher Efficiency

Challenges:

- Microorganisms

Biofuel plants in the U.S.



Bioenergy Plants - Biofuels Plants - Biodiesel Plants (mgal/yr)

- Less Than 50
- Between 50 and 100
- Between 100 and 150
- Between 150 and 200
- Greater Than 200

Bioenergy Plants - Biofuels Plants - Ethanol Plants (producing) (mgal/yr)

- Less Than 50
- Between 50 and 100
- Between 100 and 150
- Between 150 and 200
- Greater than 200

Thank you

Renewables: Just Fuels?

- Nitrogenous fertilizers
- Production of polymers (polylactic acid and zein)
- Fuels and chemicals from cattle manure
- Alternate uses for lignin: production of value added products, use for heating
- Nutraceuticals

Thank you