

# Biofuel Feedstocks and Production

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

# 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

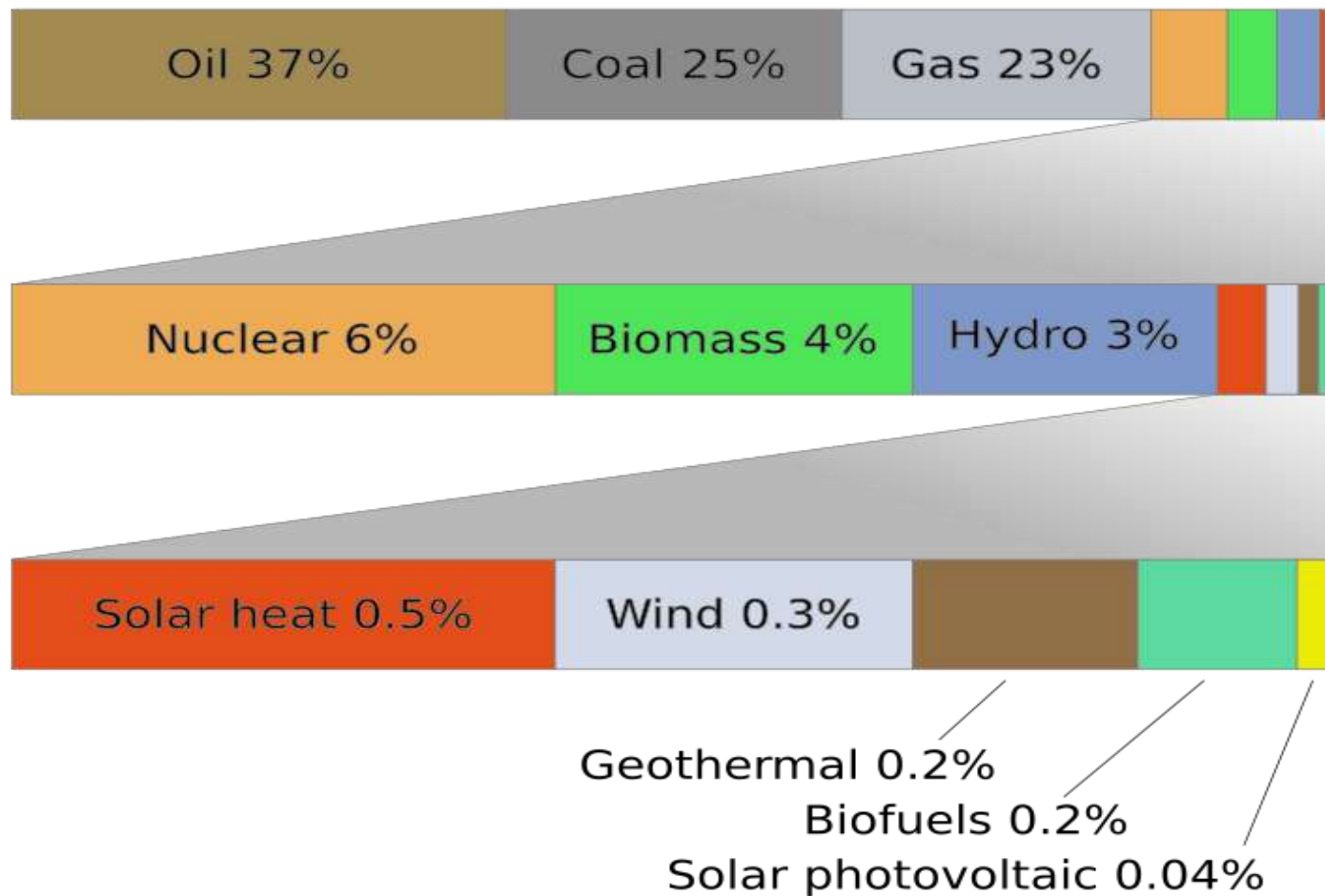
Are all forms of energy the same?

kWhr from coal  $\neq$  kWhr from gasoline  $\neq$  kWhr from electricity

Usability is determined by the following characteristics of energy sources.

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

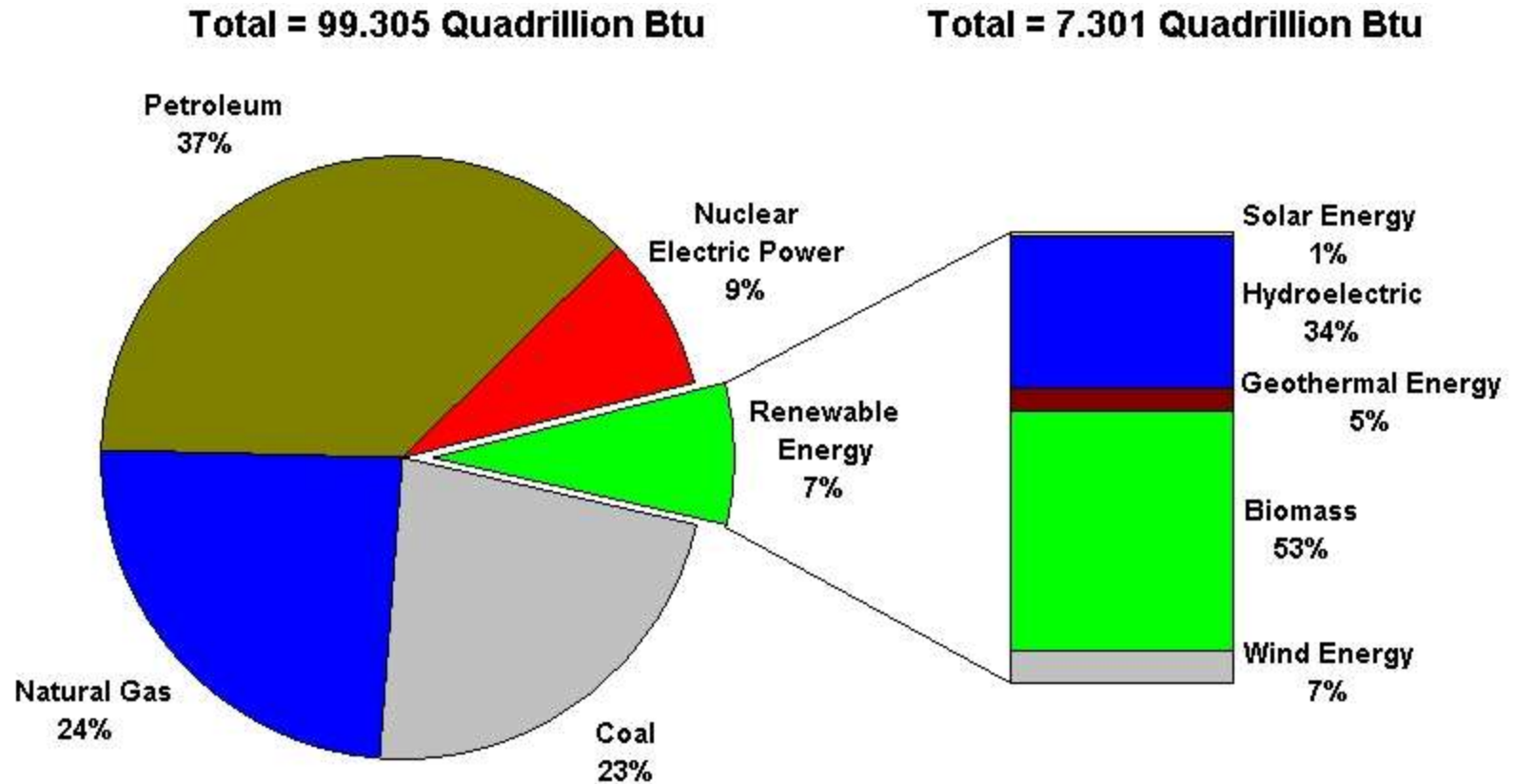
# World Energy Scenario



Source: [http://en.wikipedia.org/wiki/Image:World\\_energy\\_usage\\_width\\_chart.svg](http://en.wikipedia.org/wiki/Image:World_energy_usage_width_chart.svg)

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

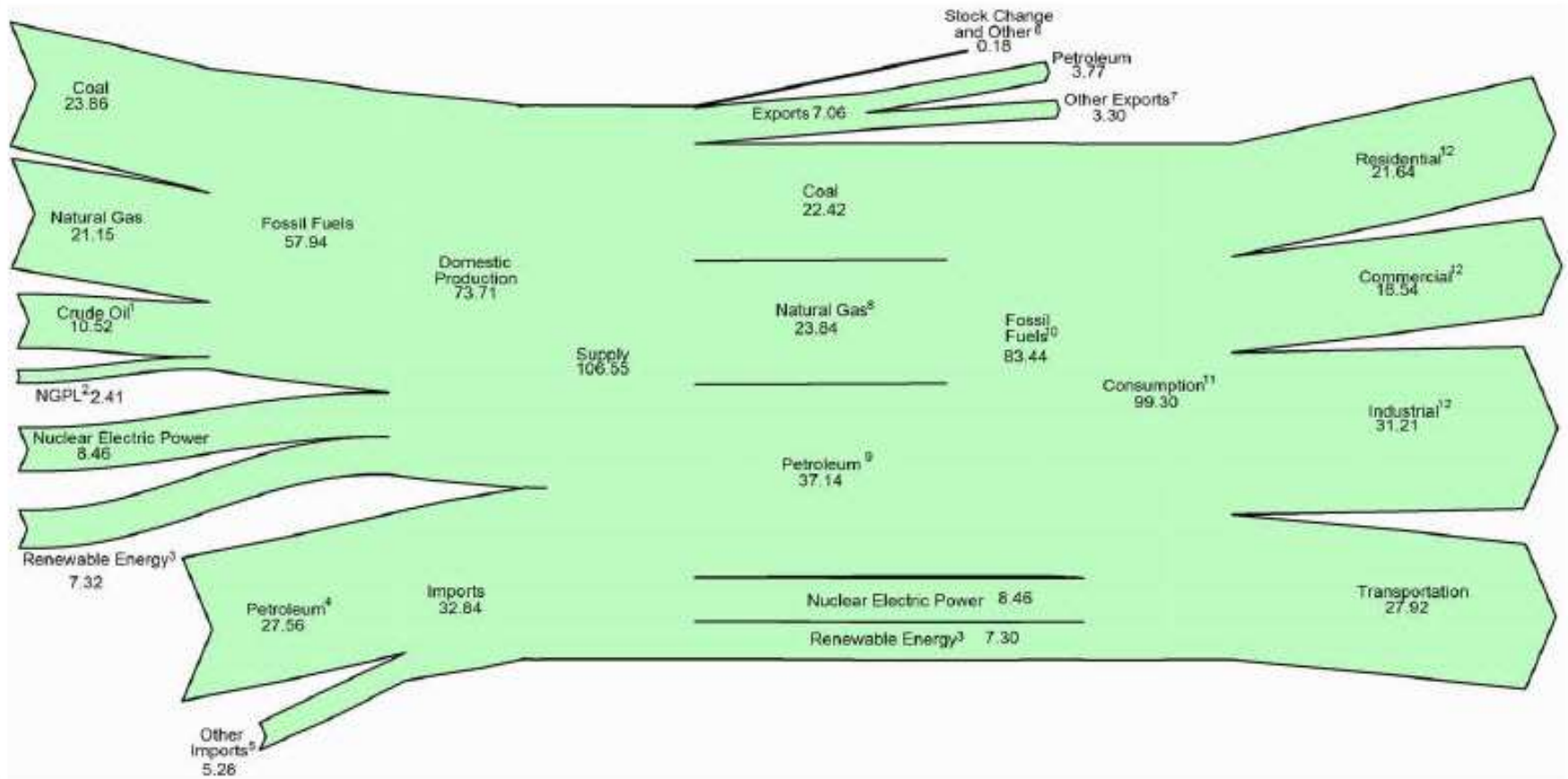
# US Energy Scenario



**Source:** [http://www.eia.doe.gov/cneaf/alternate/page/renew\\_energy\\_consump/figure1.html](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

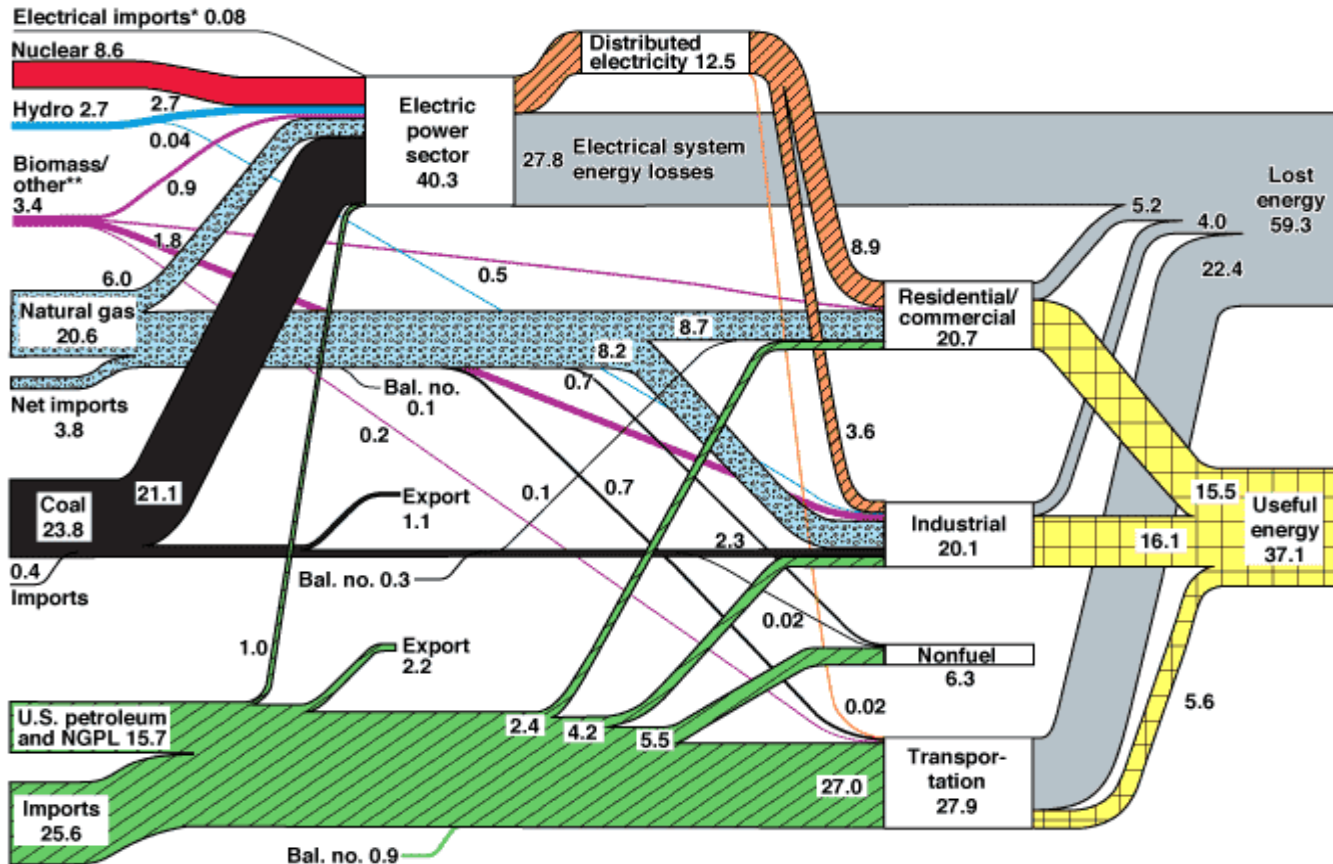


Source: EIA

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

# US Energy Scenario

## U.S. Energy Flow Trends – 2002 Net Primary Resource Consumption ~103 Exajoules



Source: Production and end-use data from Energy Information Administration, *Annual Energy Review 2002*.

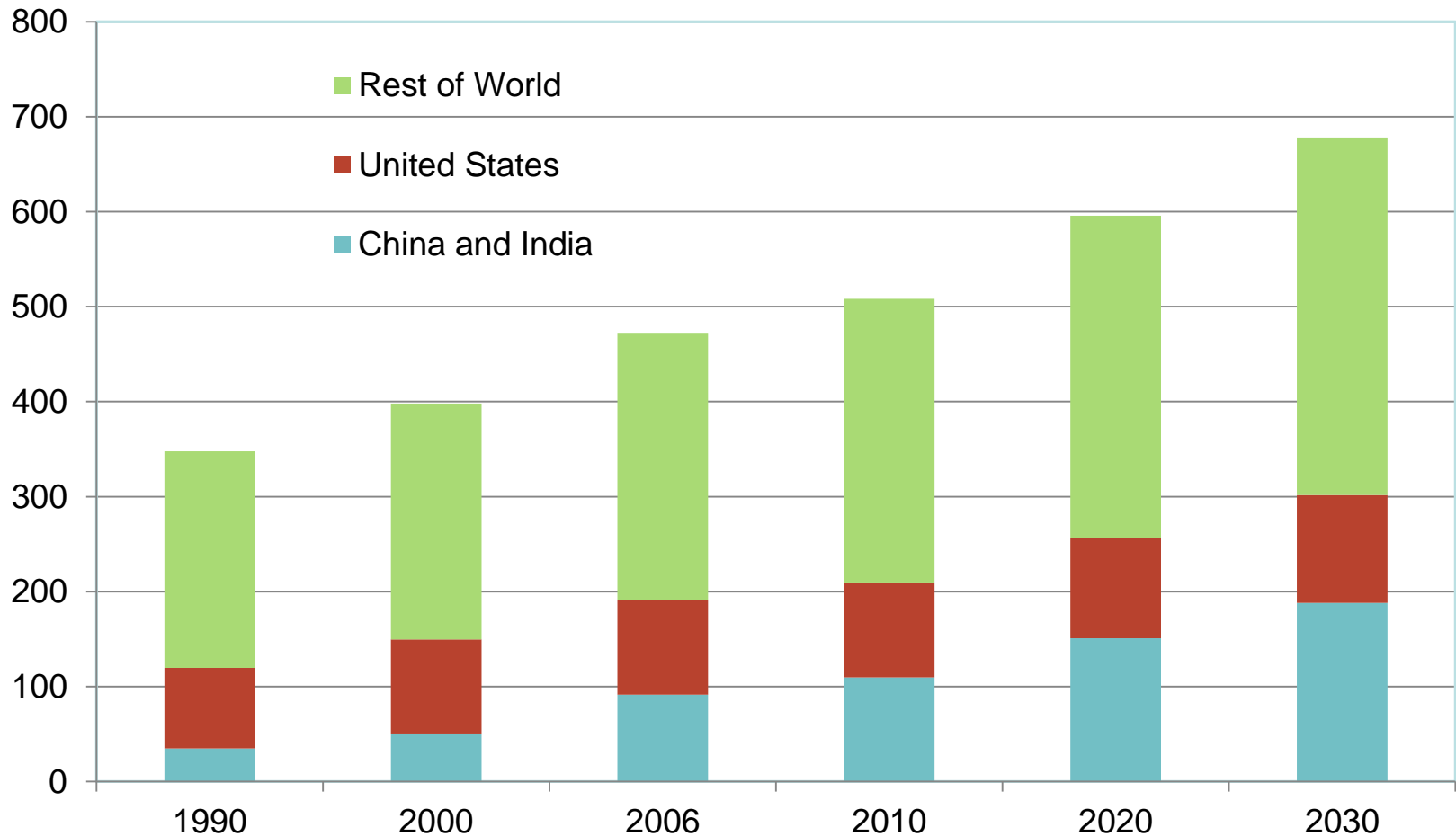
\*Net fossil-fuel electrical imports.

\*\*Biomass/other includes wood, waste, alcohol, geothermal, solar, and wind.

June 2004  
Lawrence Livermore  
National Laboratory  
<http://eed.llnl.gov/flow>

Source: <http://eed.llnl.gov/flow/02flow.php>

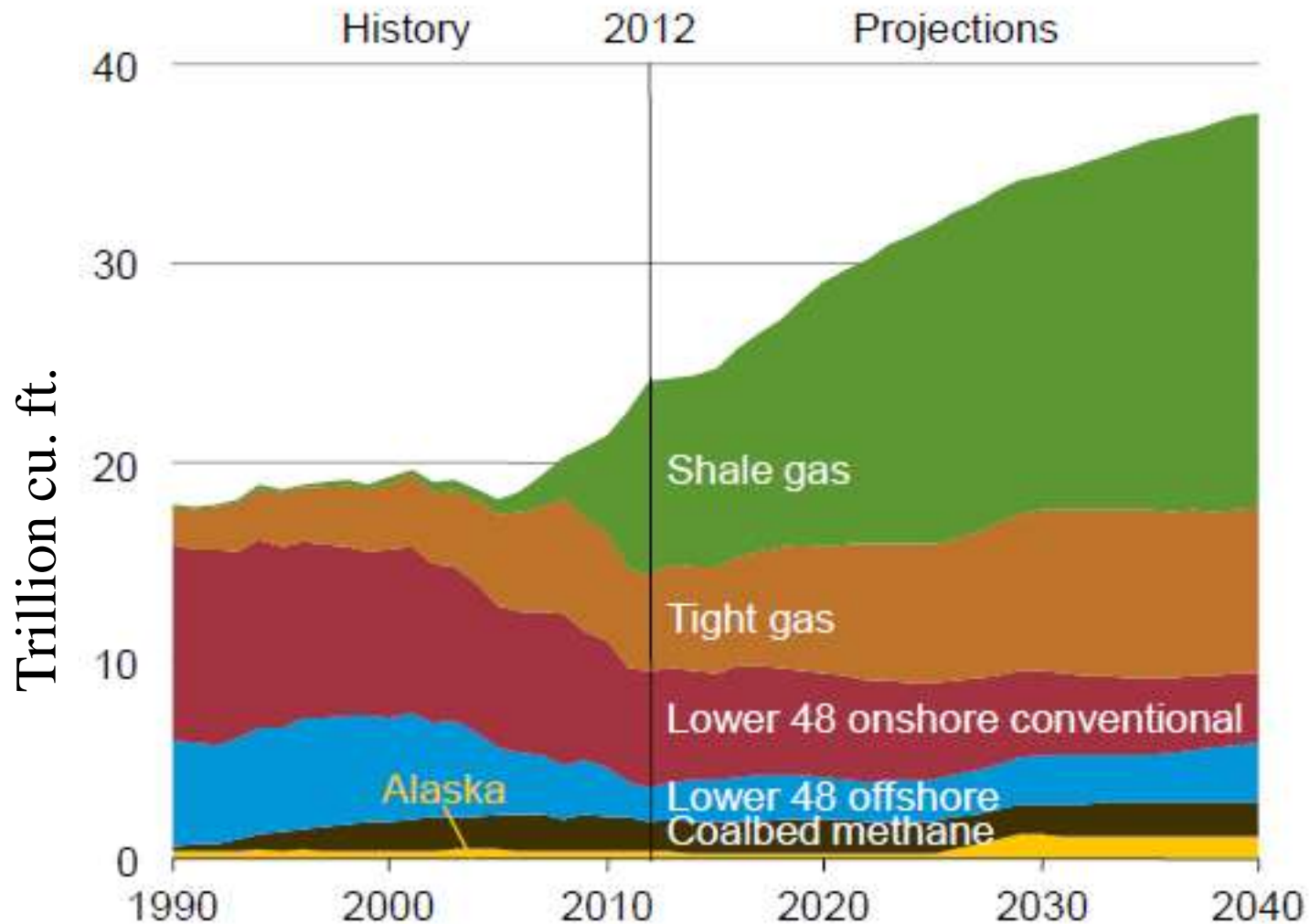
# World Energy Use



Source: EIA

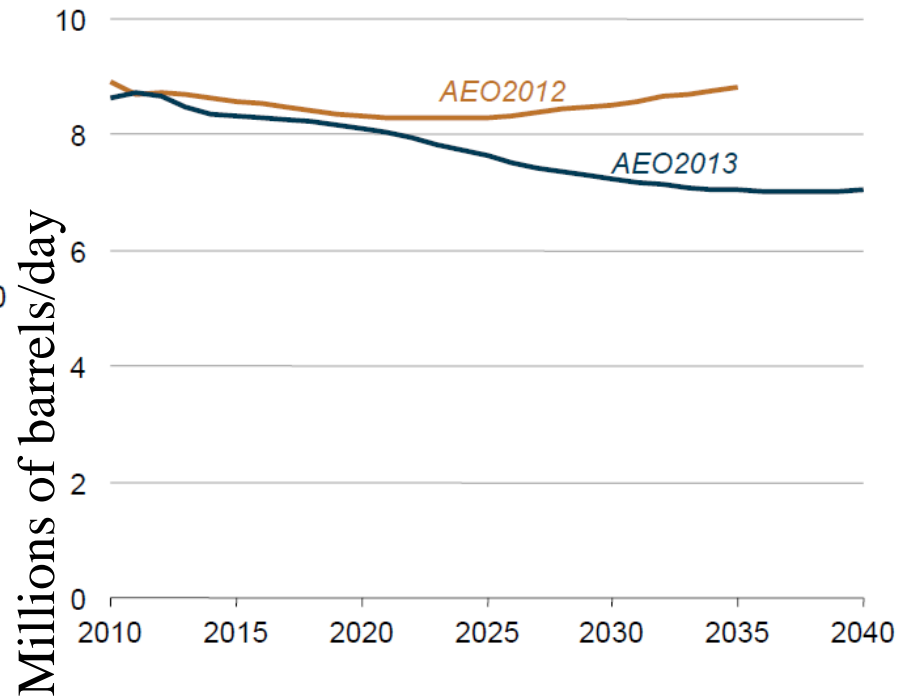
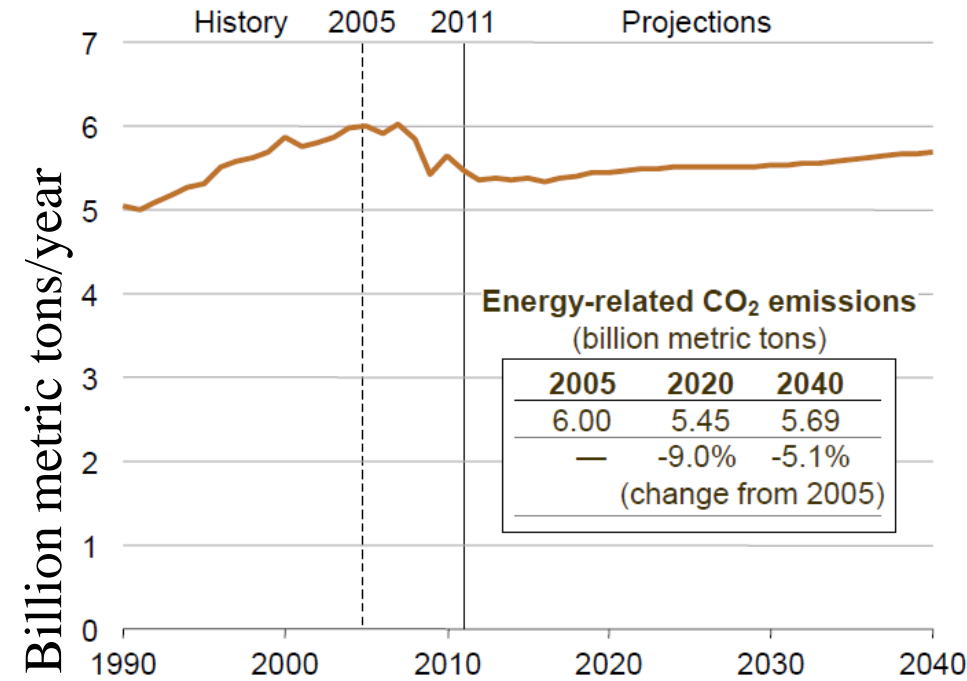


# US Natural Gas Production



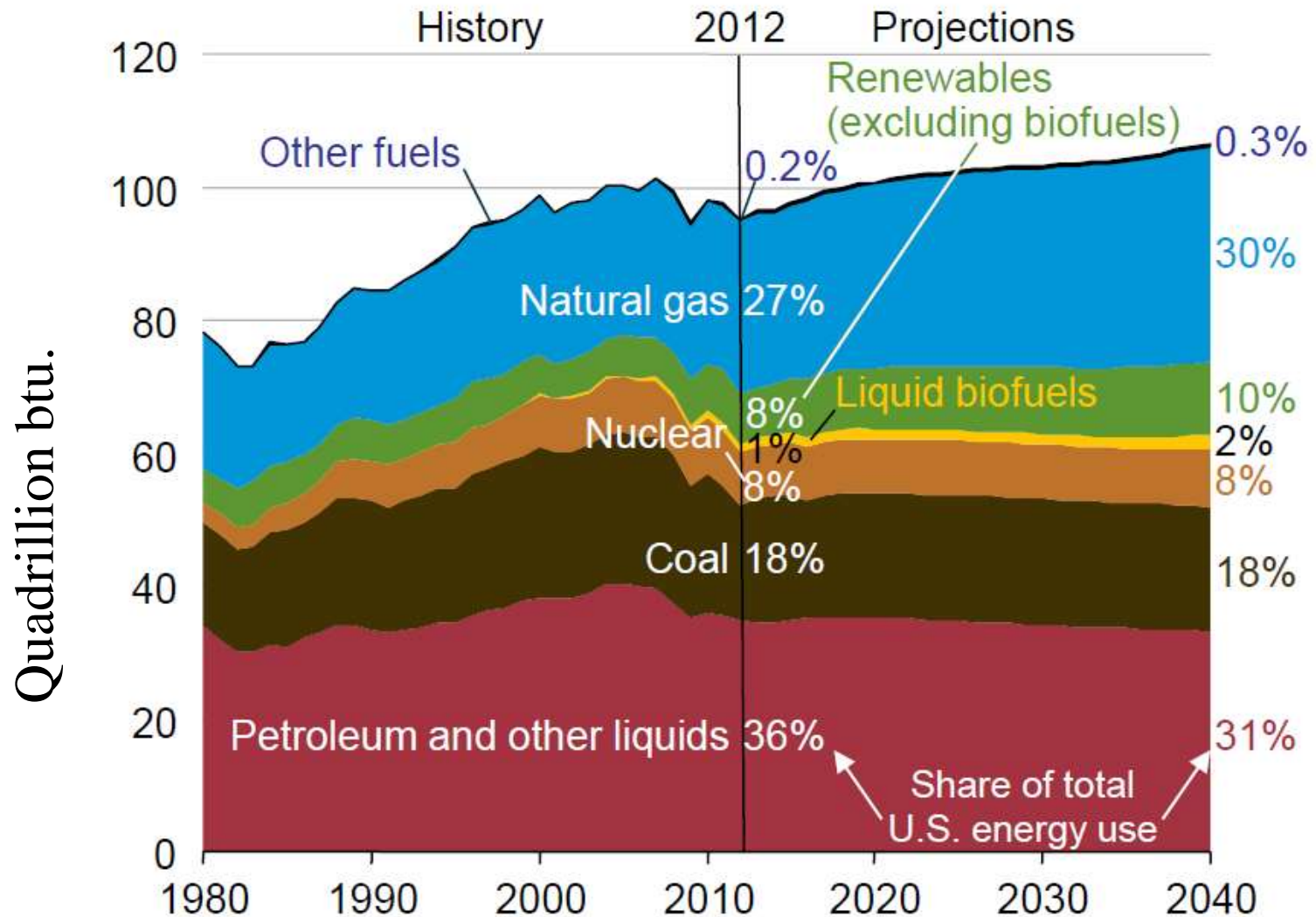
Source: EIA, 2013 outlook report

# US CO<sub>2</sub> Liquid Fuels consumption and CO<sub>2</sub> Emission



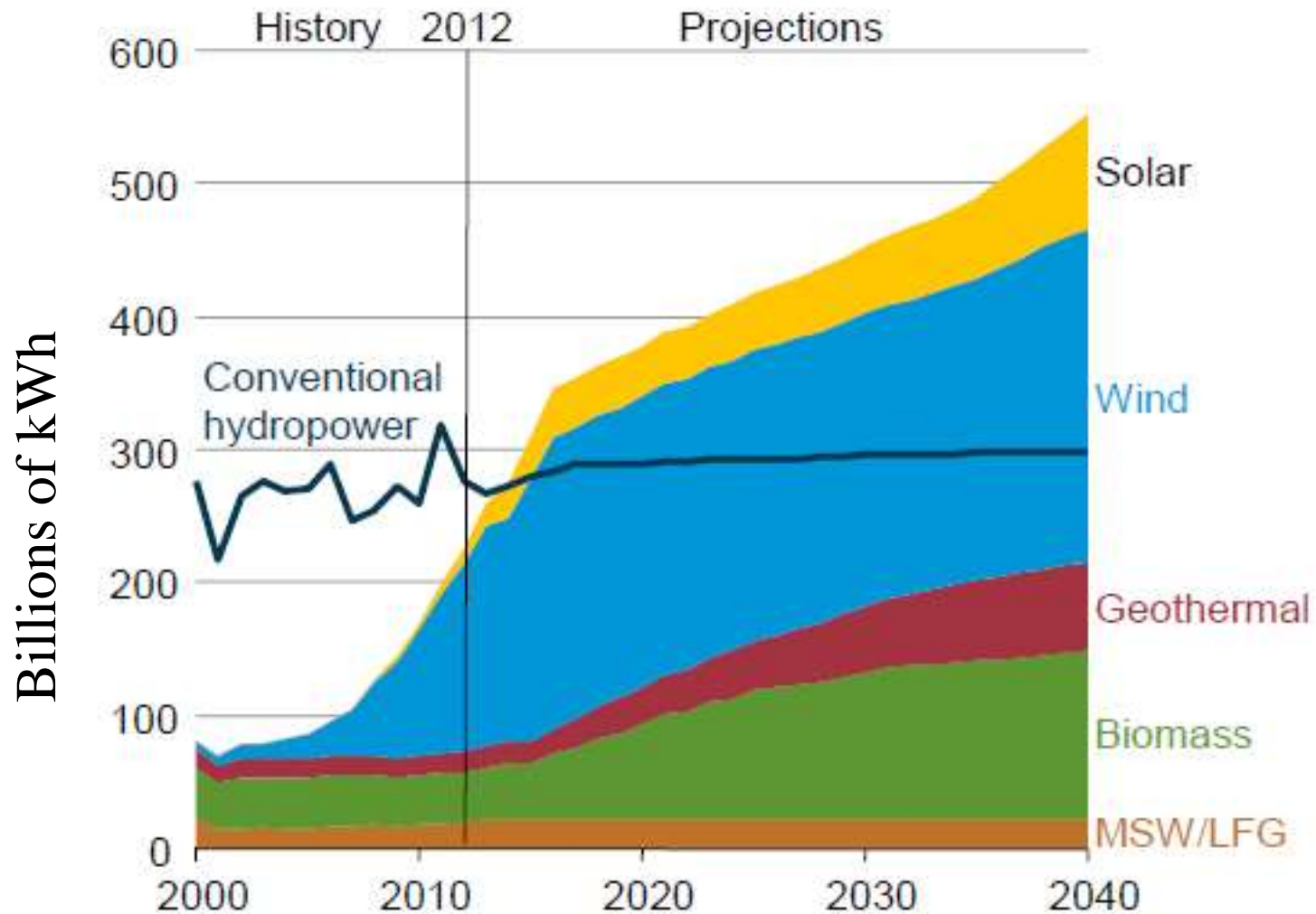
Source: EIA, 2013 outlook report

# US Primary Energy Consumption by Fuel



Source: EIA, 2014 outlook report

# Renewable Electricity Generation



Source: EIA

# Need for Sustainable Biobased Economy

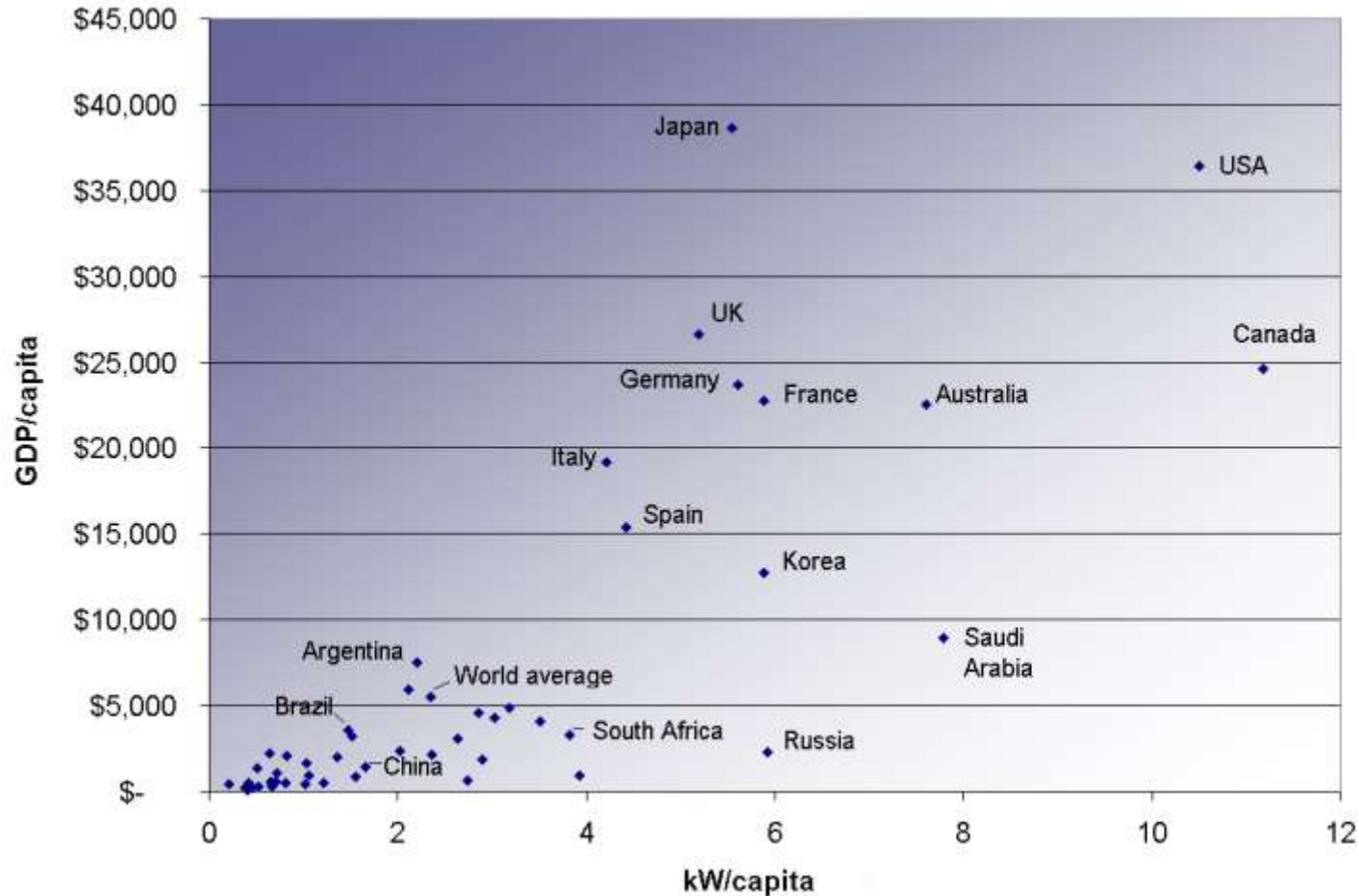
Three important considerations

- Energy resources and their contribution
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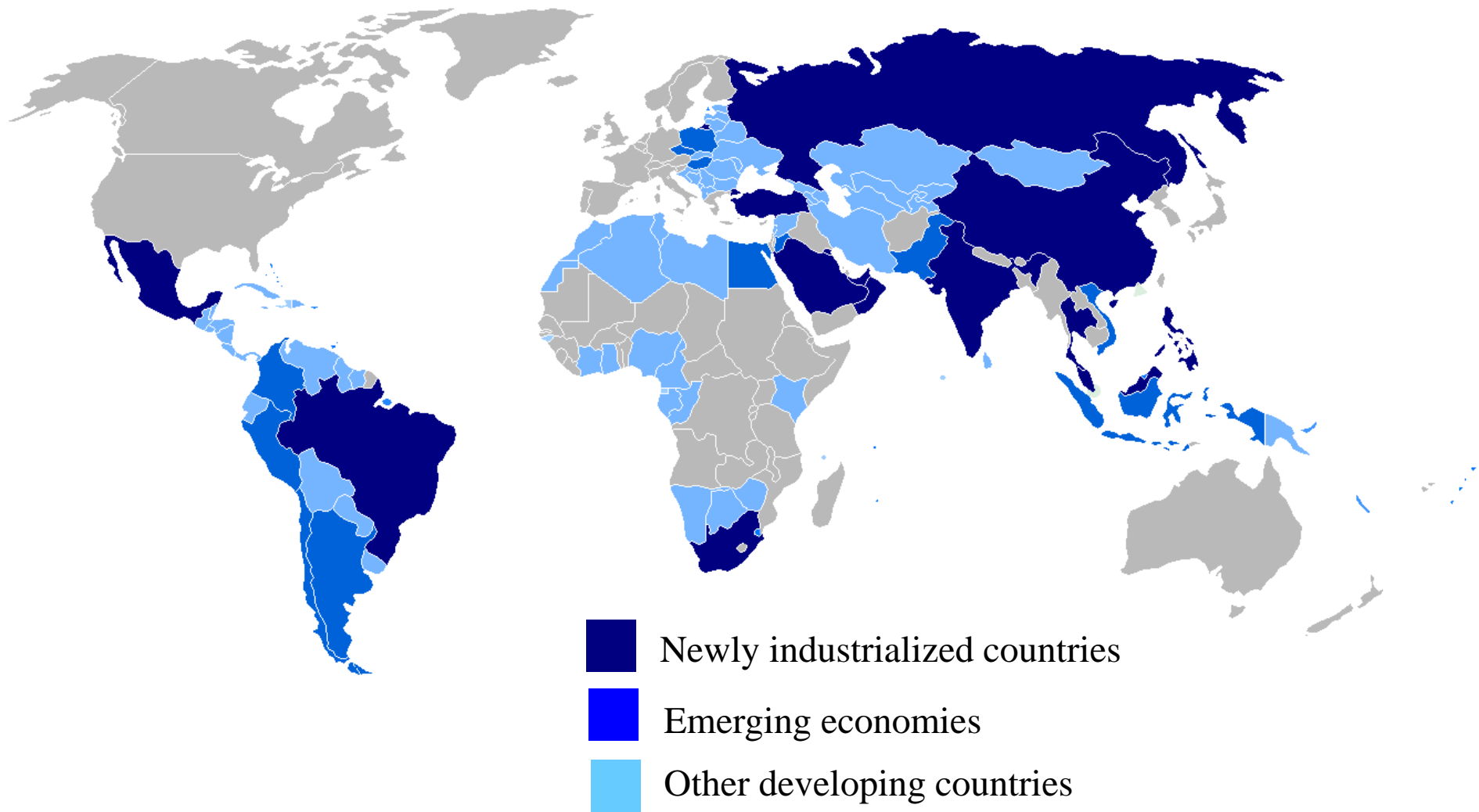
# Energy Consumption and Economy

Energy is the real currency of economies.



Source: Frank van Mierlo , [http://en.wikipedia.org/wiki/Image:Energy\\_consumption\\_versus\\_GDP.png](http://en.wikipedia.org/wiki/Image:Energy_consumption_versus_GDP.png)

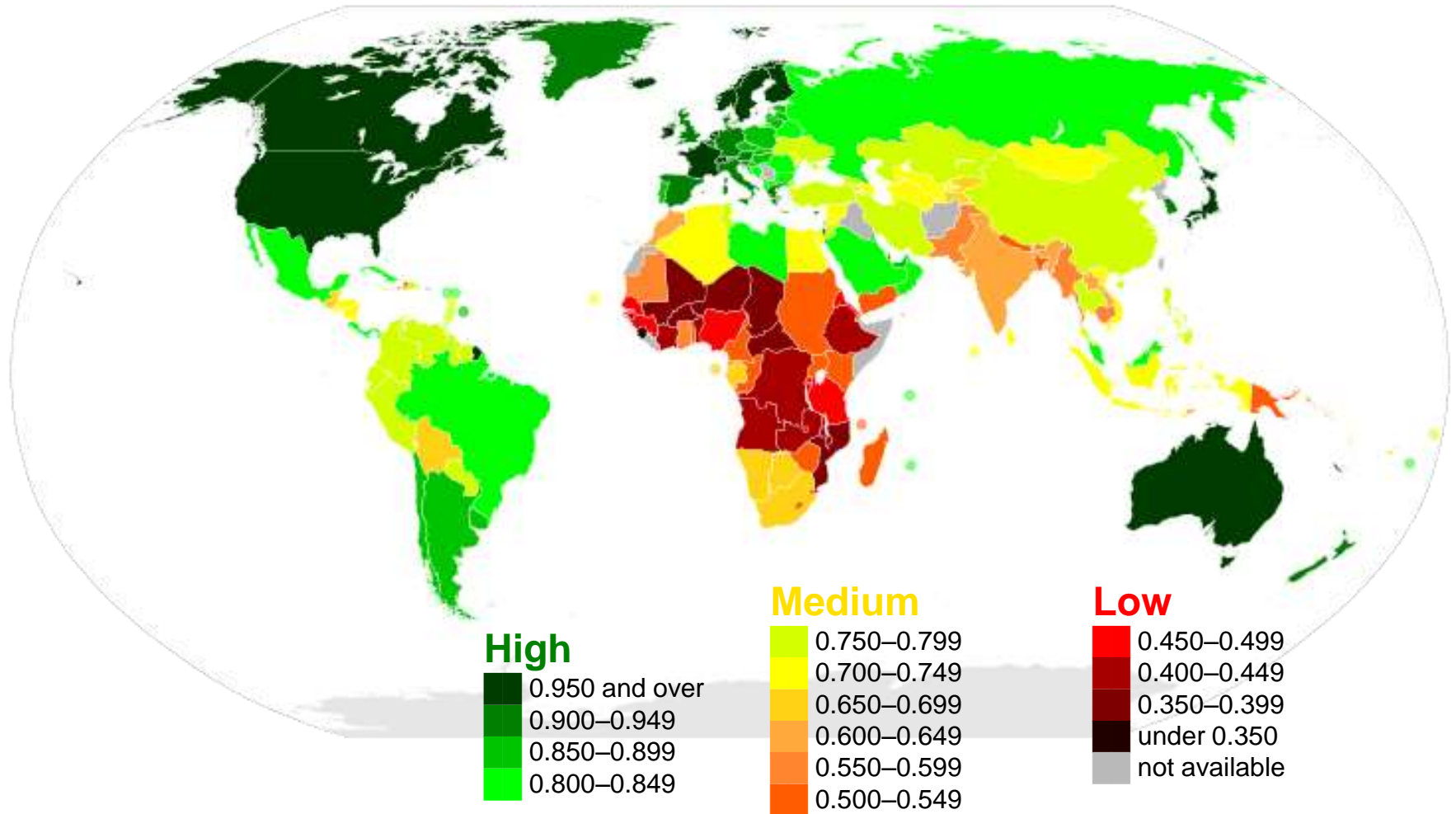
# World emerging economies



Source: [http://en.wikipedia.org/wiki/Image:World\\_population.PNG](http://en.wikipedia.org/wiki/Image:World_population.PNG)



# World human development index

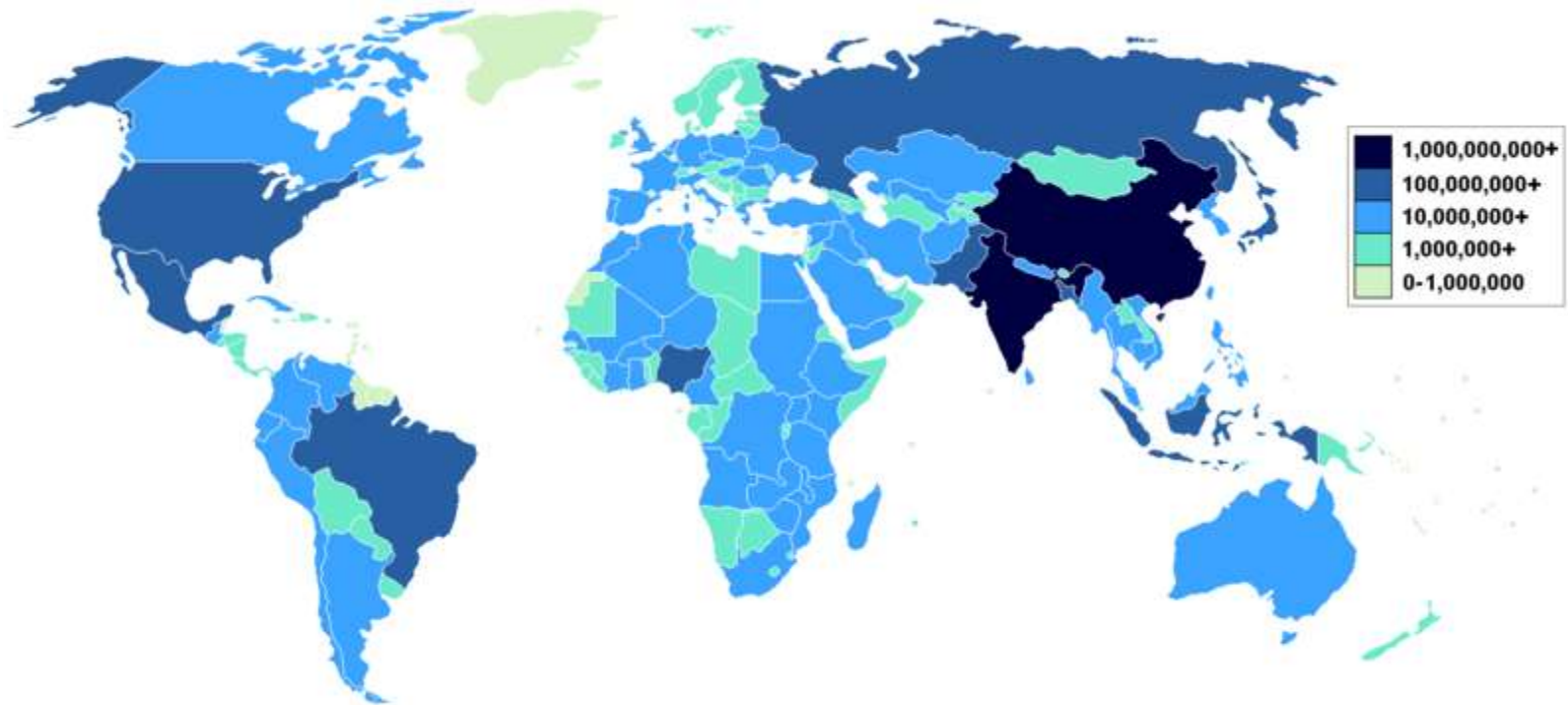


Source: [http://en.wikipedia.org/wiki/Image:UN\\_Human\\_Development\\_Report\\_2007\\_%282%29.svg](http://en.wikipedia.org/wiki/Image:UN_Human_Development_Report_2007_%282%29.svg)

Data: Human Development Report, 2007.



# World population



Source: [http://en.wikipedia.org/wiki/Image:World\\_population.PNG](http://en.wikipedia.org/wiki/Image:World_population.PNG)

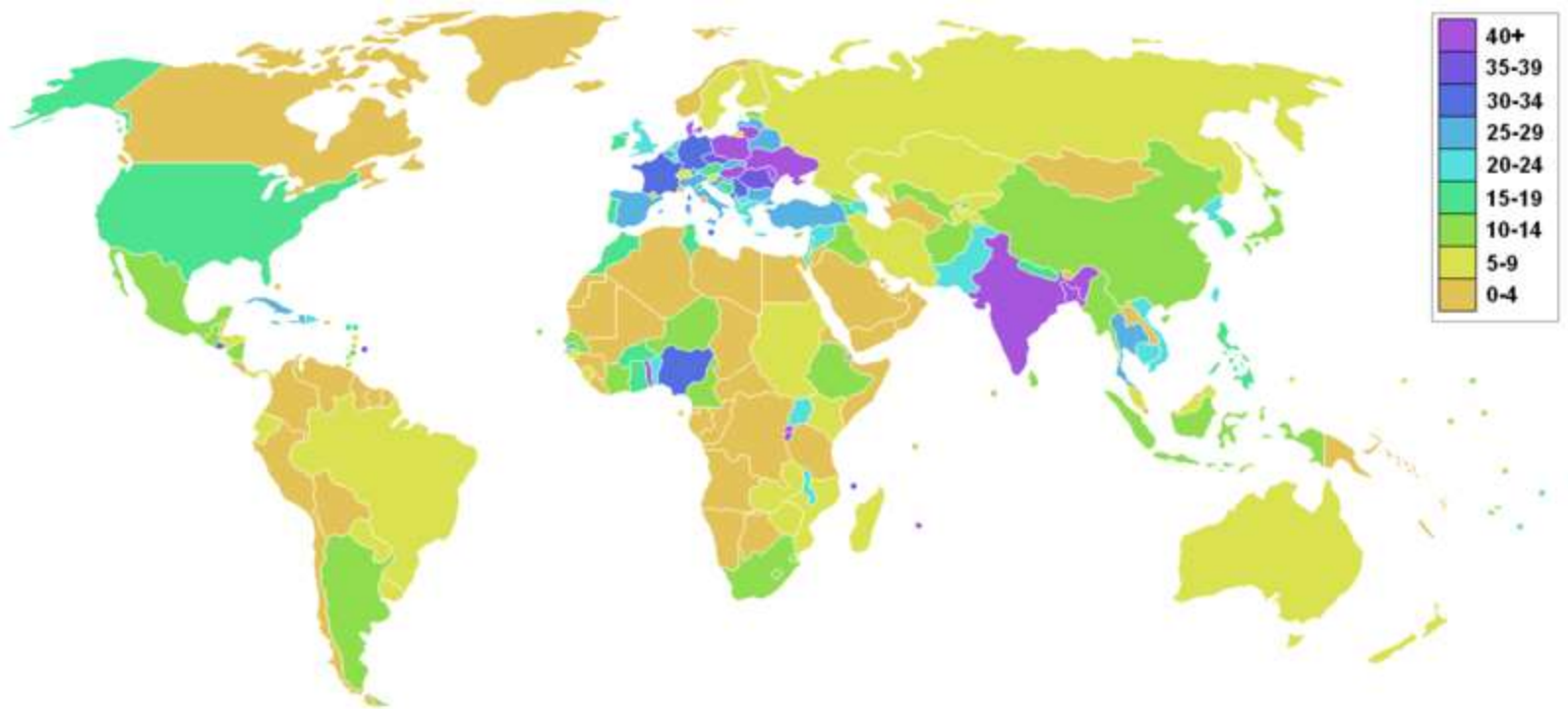
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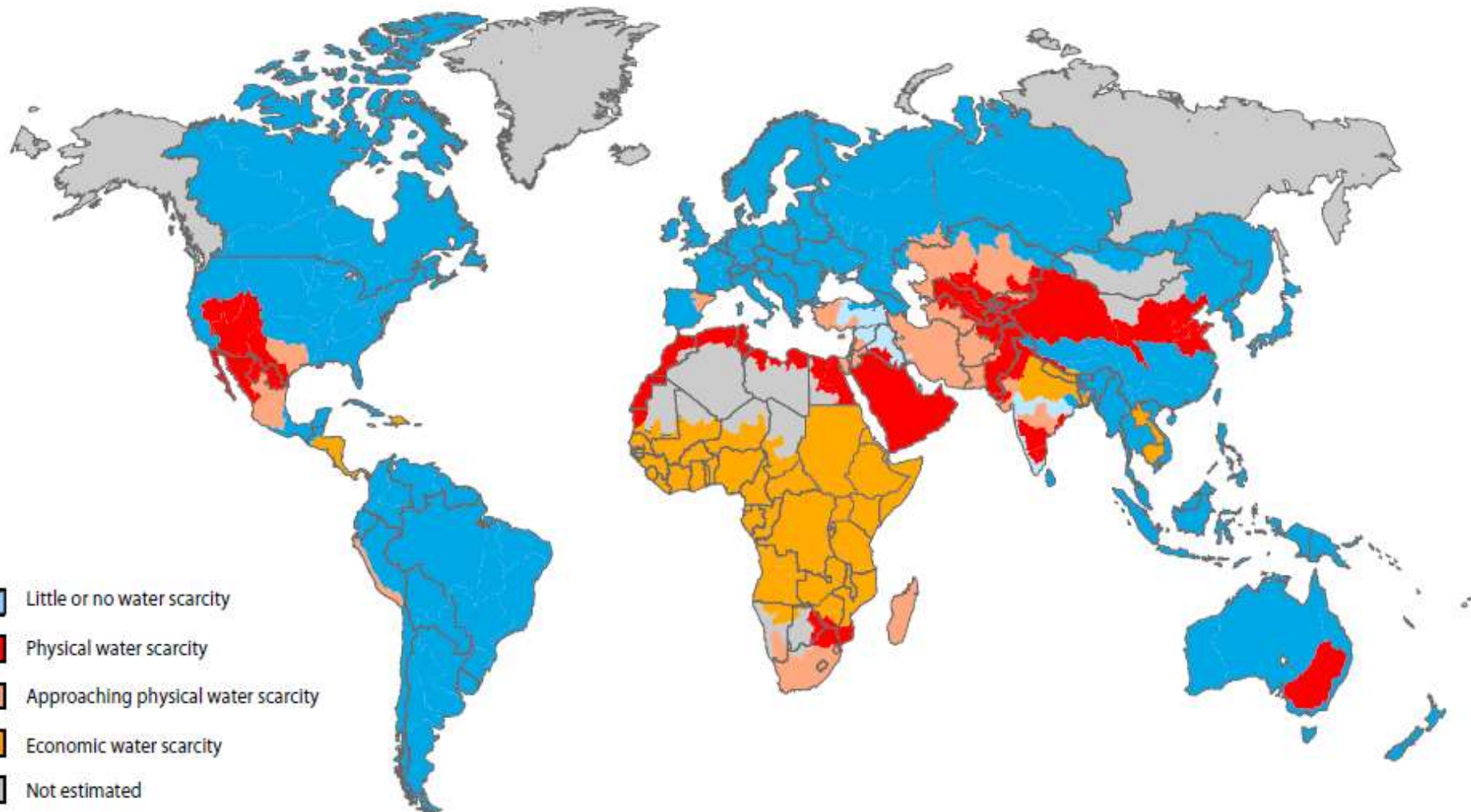
# Arable land in world



**Source:** [http://en.wikipedia.org/wiki/Image:Arable\\_land\\_percent\\_world.png](http://en.wikipedia.org/wiki/Image:Arable_land_percent_world.png)

**Data:** CIA Factbook

# 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.

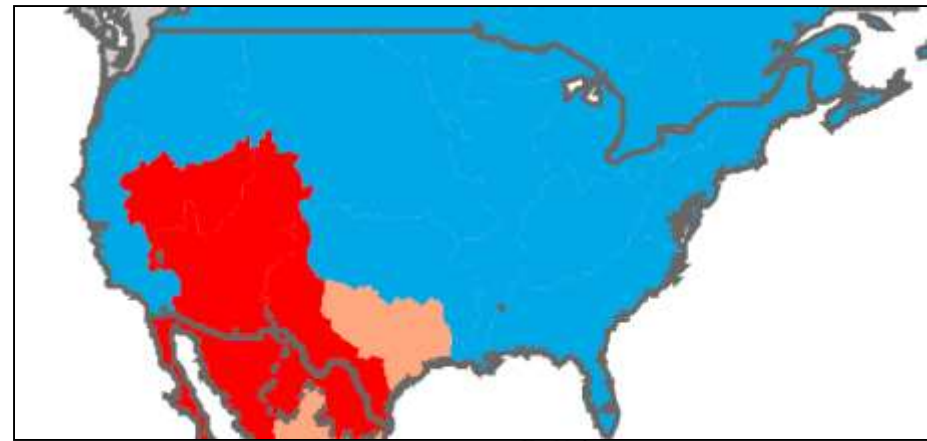
Blue: Water resources available. <25% is withdrawn for human purposes.

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

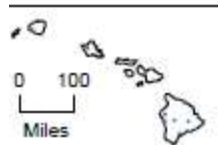
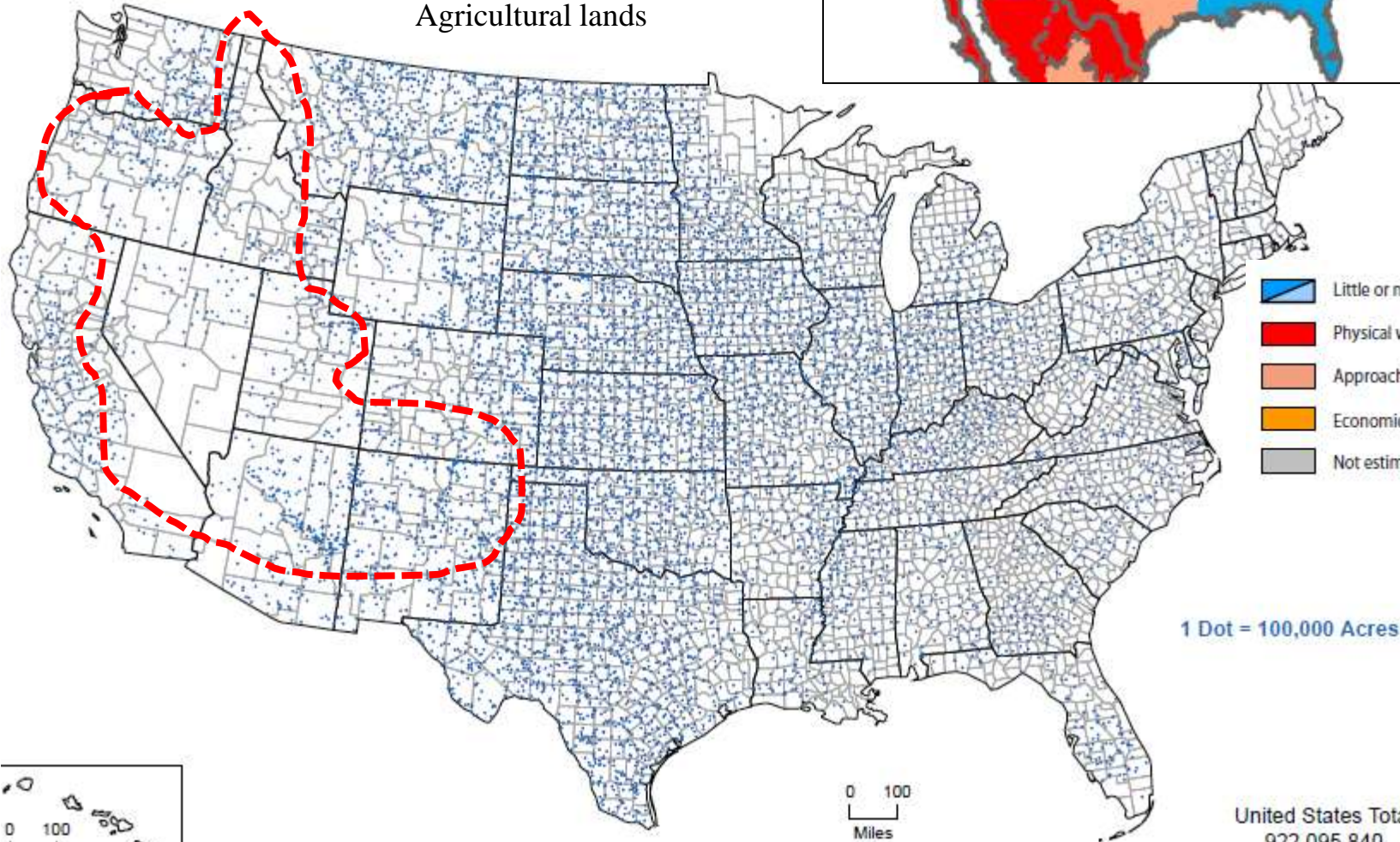


# Resources: World Water Stress

Water stress map



Agricultural lands

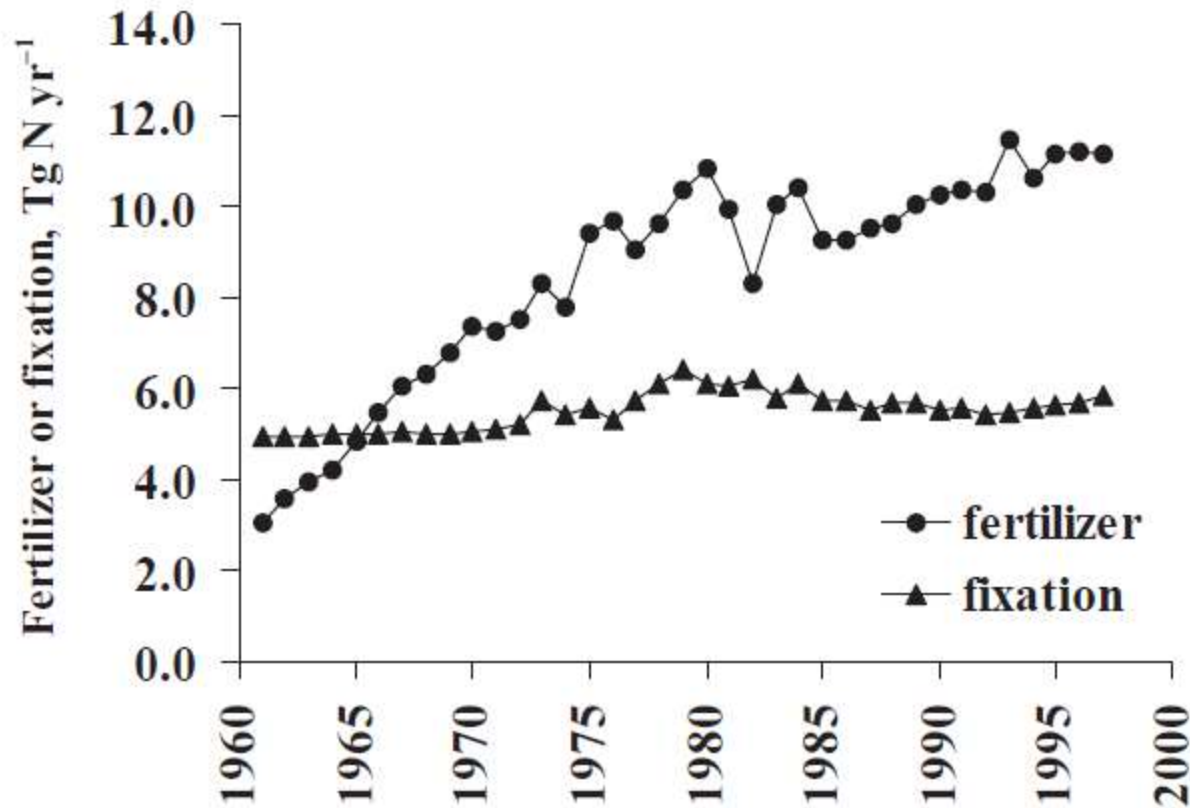


# EROEI and EROWI for Different Fuels

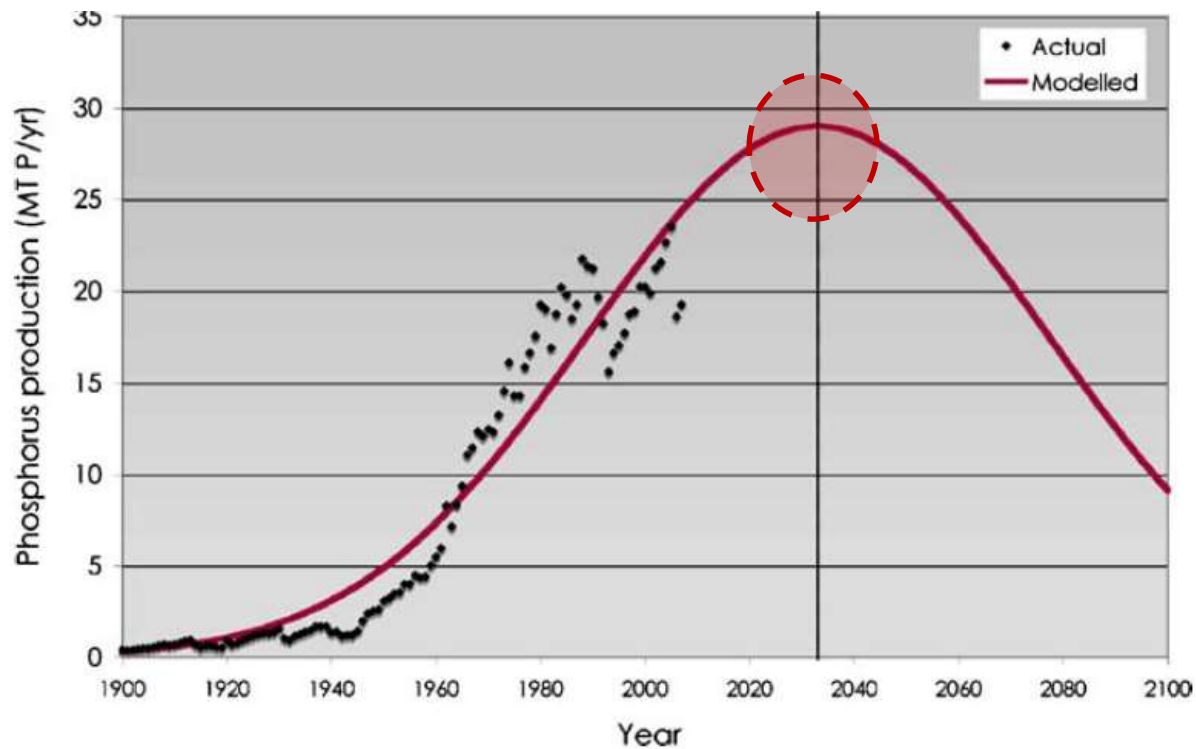
	Water usage (L/MJ)	EROWI (MJ/L)	EROEI (MJ/MJ)	Net EROWI
Nuclear Electric	1.162(0.145)	0.861(1.517)	10	0.775 (1.137)
Coal Electric	0.560(0.488)	1.786 (2.049)	-	-
Conv. Diesel	0.0035	285.3	5.01	228.4
Biodiesel				
Rapeseed	100-175	0.010-0.0057	2.33	0.0057-0.0033
Algae (Ponds)	20.142*	0.004965	3.33	0.03475
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)

- Nitrogen supply and use.



## Peak phosphorous?





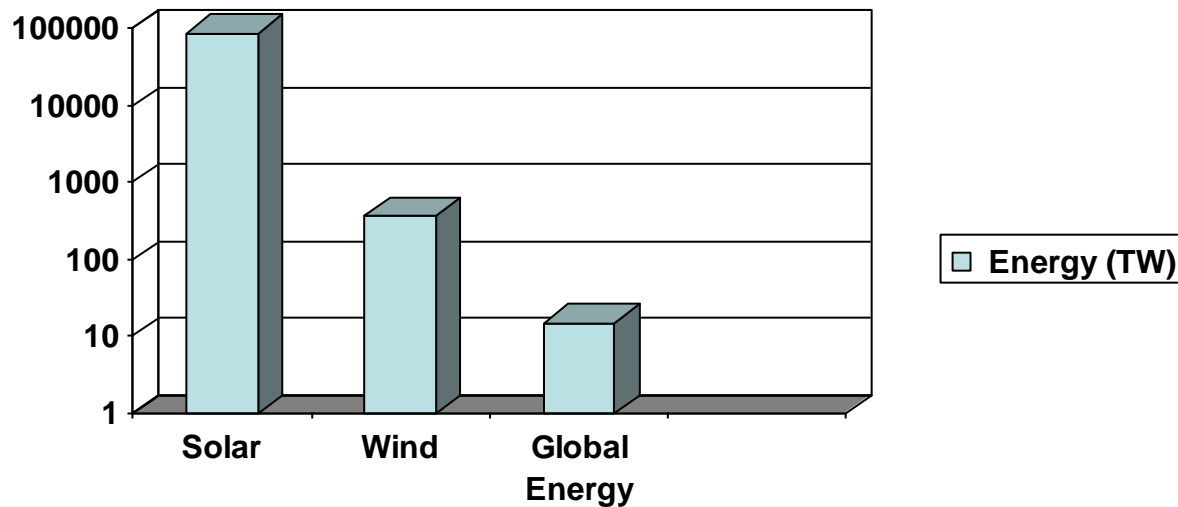
# Impact of Global Climate Change on Agriculture

## 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>

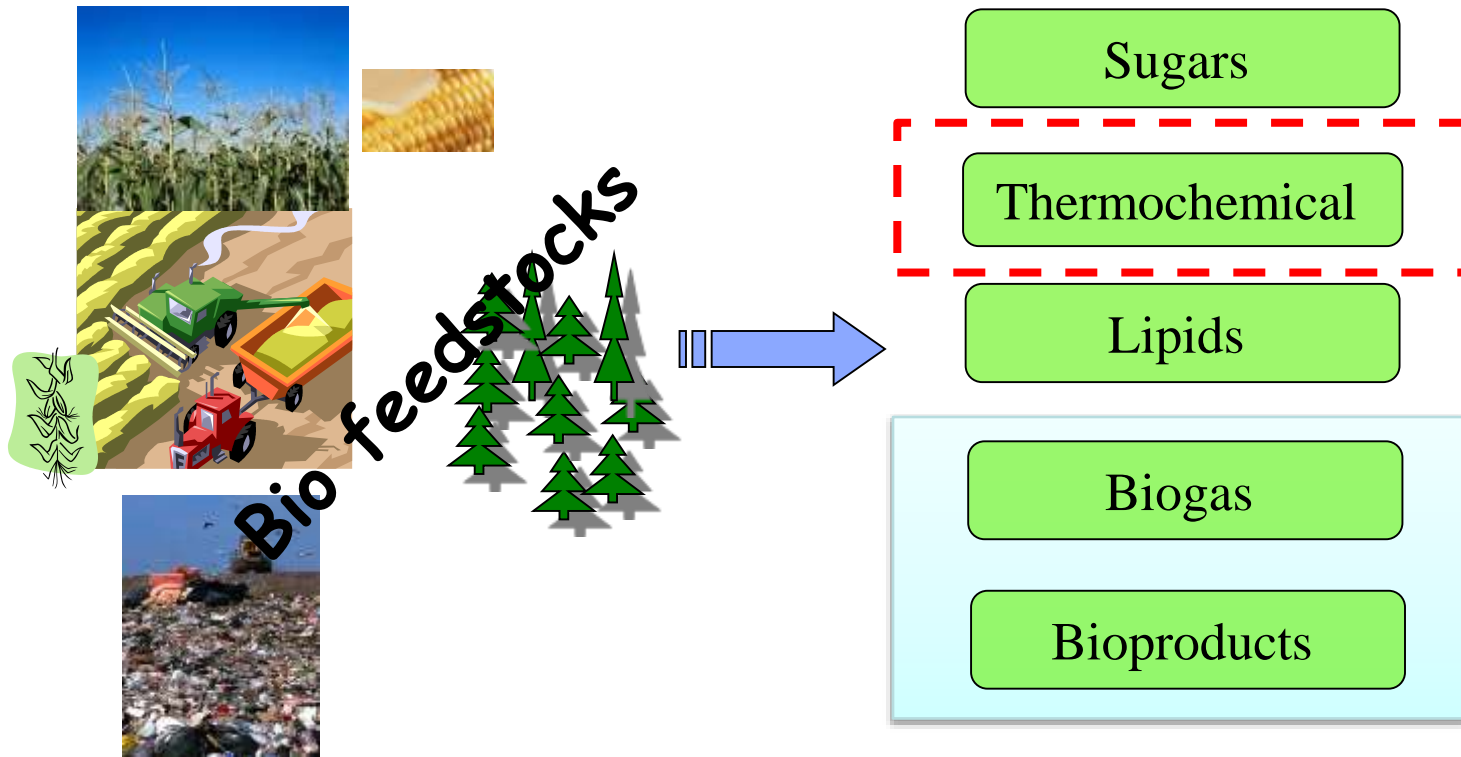
# Renewable Energy Availability



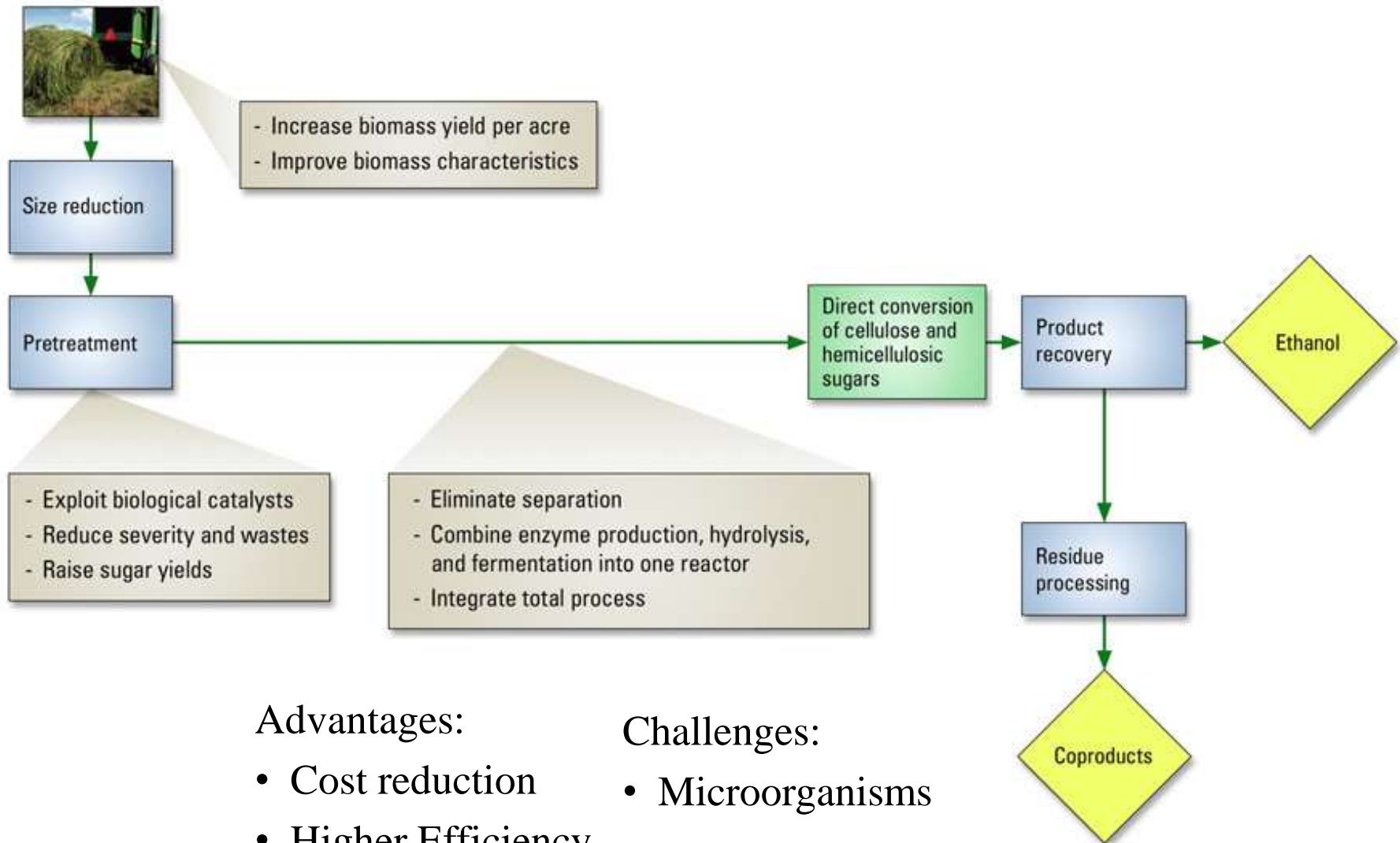
**Source:** Tester, Jefferson W.; et al. (2005). *Sustainable Energy: Choosing Among Options*. The MIT Press. [ISBN 0-262-20153-4](#).

# 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)



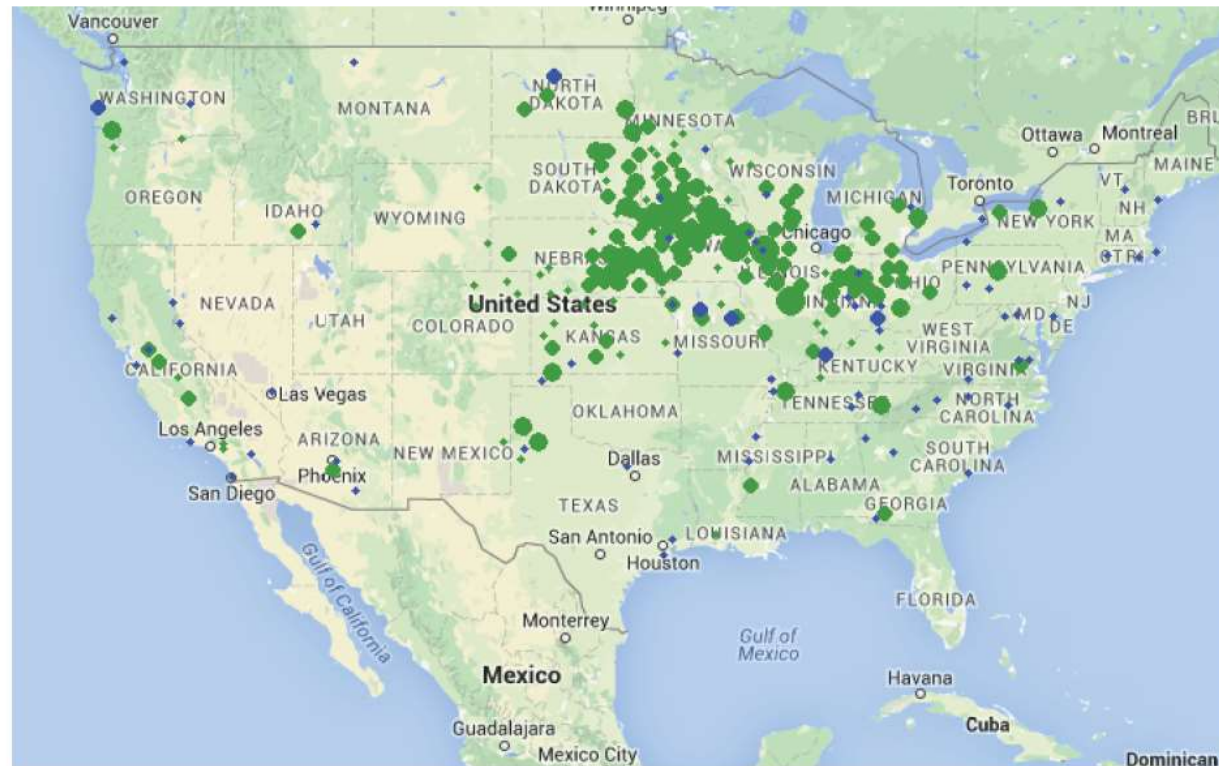
## Advantages:

- 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

