Back to the Future on the Back of an Envelope

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Cityscapes Then (~1900) and Now

Global and US Population Clock

https://www.census.gov/popclock/

China – 1.38 billion India – 1.28 billion EU – 510 million

Global Energy Use

World Total	**556 EJ**
China	**128 EJ**
US	**95 EJ (17%)**
EU	**69 EJ**
India	**30 EJ**

Data from BP *2017 Statistical Review of World Energy*

ExaJoule = 10^{18} Joules
1 EJ ~ 1 Quad (used in the US energy industry)
A Quad is quadrillion (10^{15}) BTU

The US with

4.4% of the world's population

uses

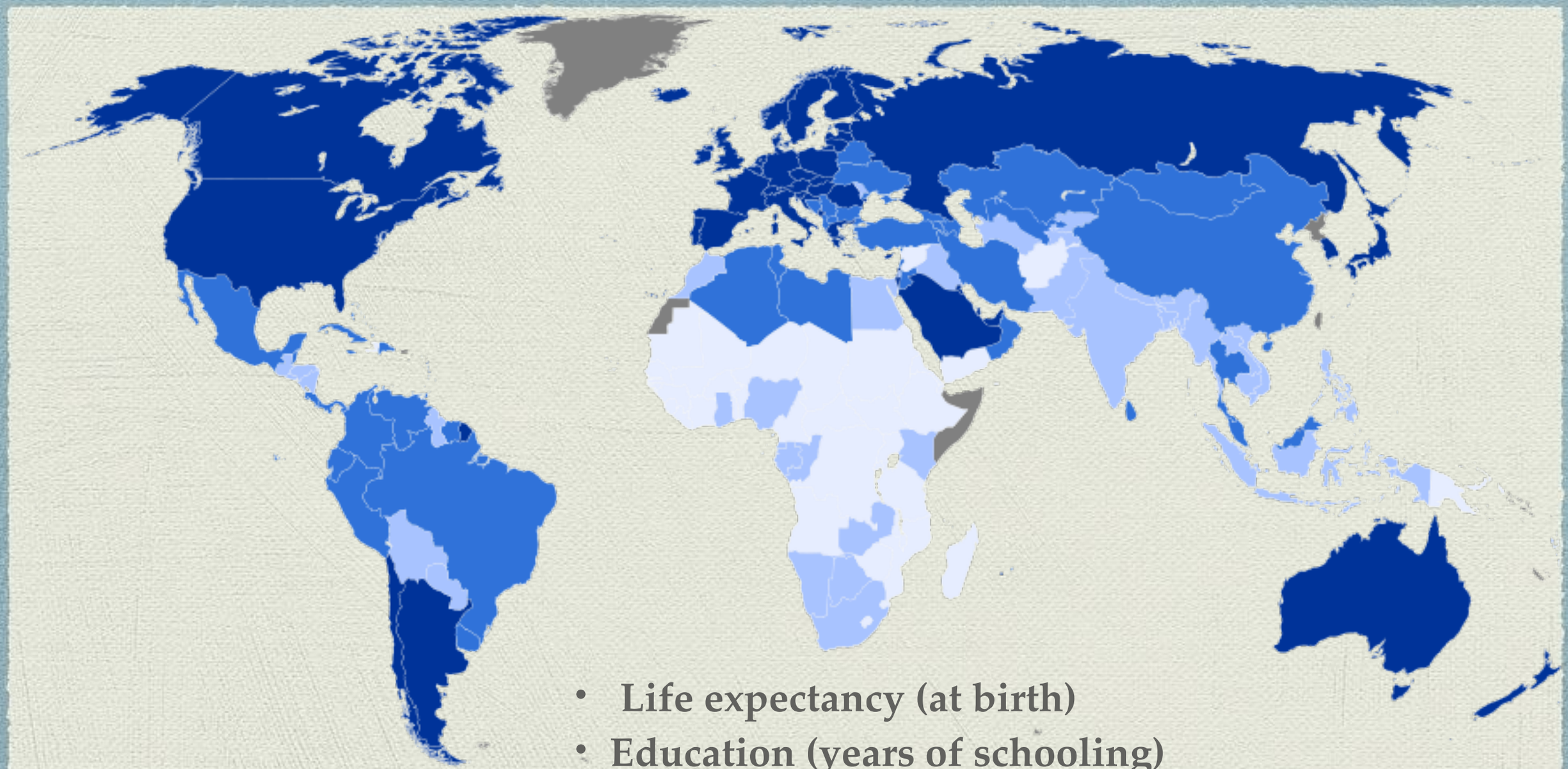
17% of its energy resources

Per Capita Energy Use

World: 556×10^{18} EJ / 7.4×10^{9} people = 75×10^{9} = **75 GJ/person**
US: 95×10^{18} EJ / 325×10^{6} people = 292×10^{9} = **292 GJ/person**
EU: 69×10^{18} EJ / 510×10^{6} people = 135×10^{9} = **135 GJ/person**
China: 128×10^{18} EJ / 1.38×10^{9} people = 93×10^{9} = **93 GJ/person**
India: 30×10^{18} EJ / 1.28×10^{9} people = 23×10^{9} = **23 GJ/person**

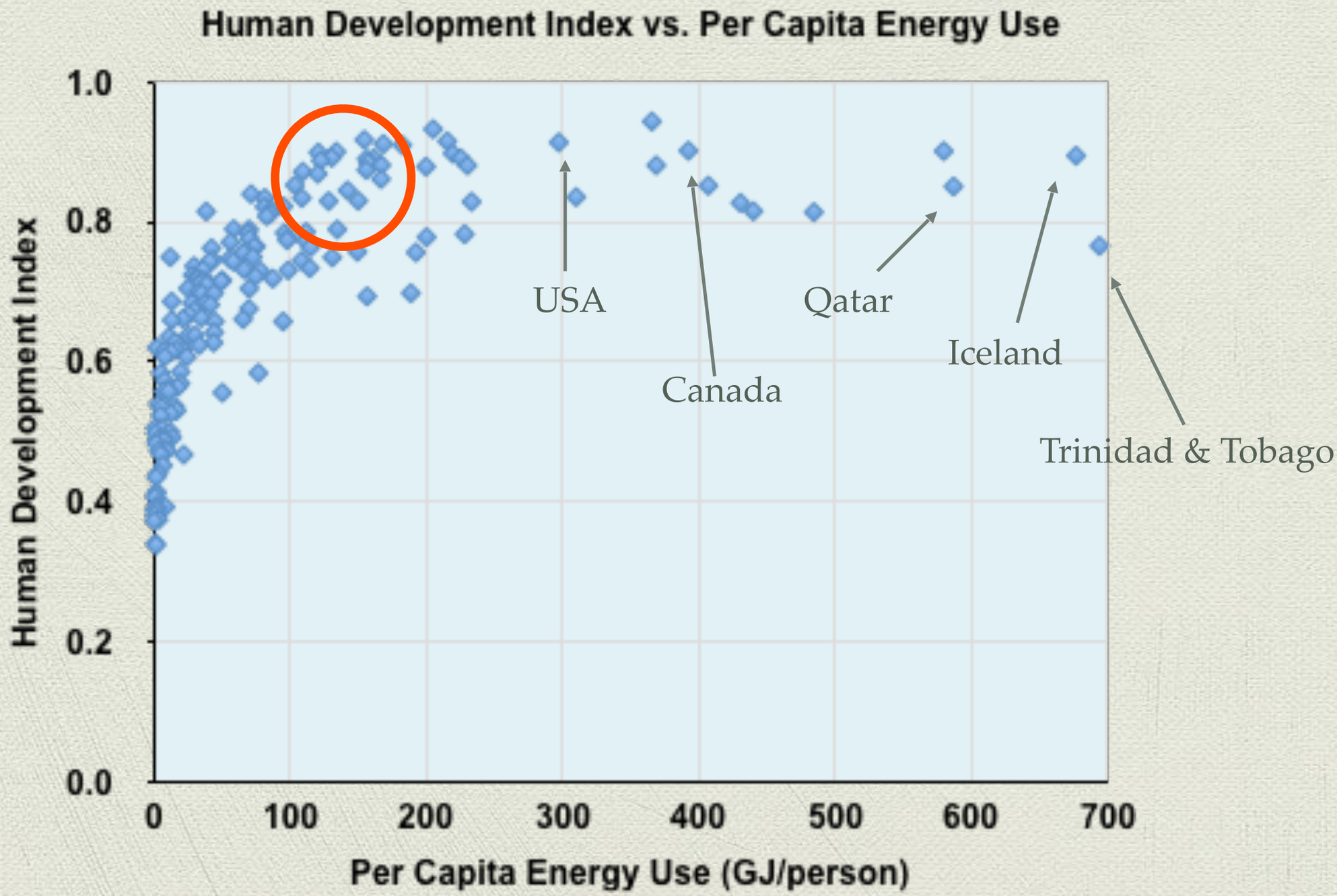
2 GJ is the heat produced by burning a tank of gasoline

HDI Quartiles

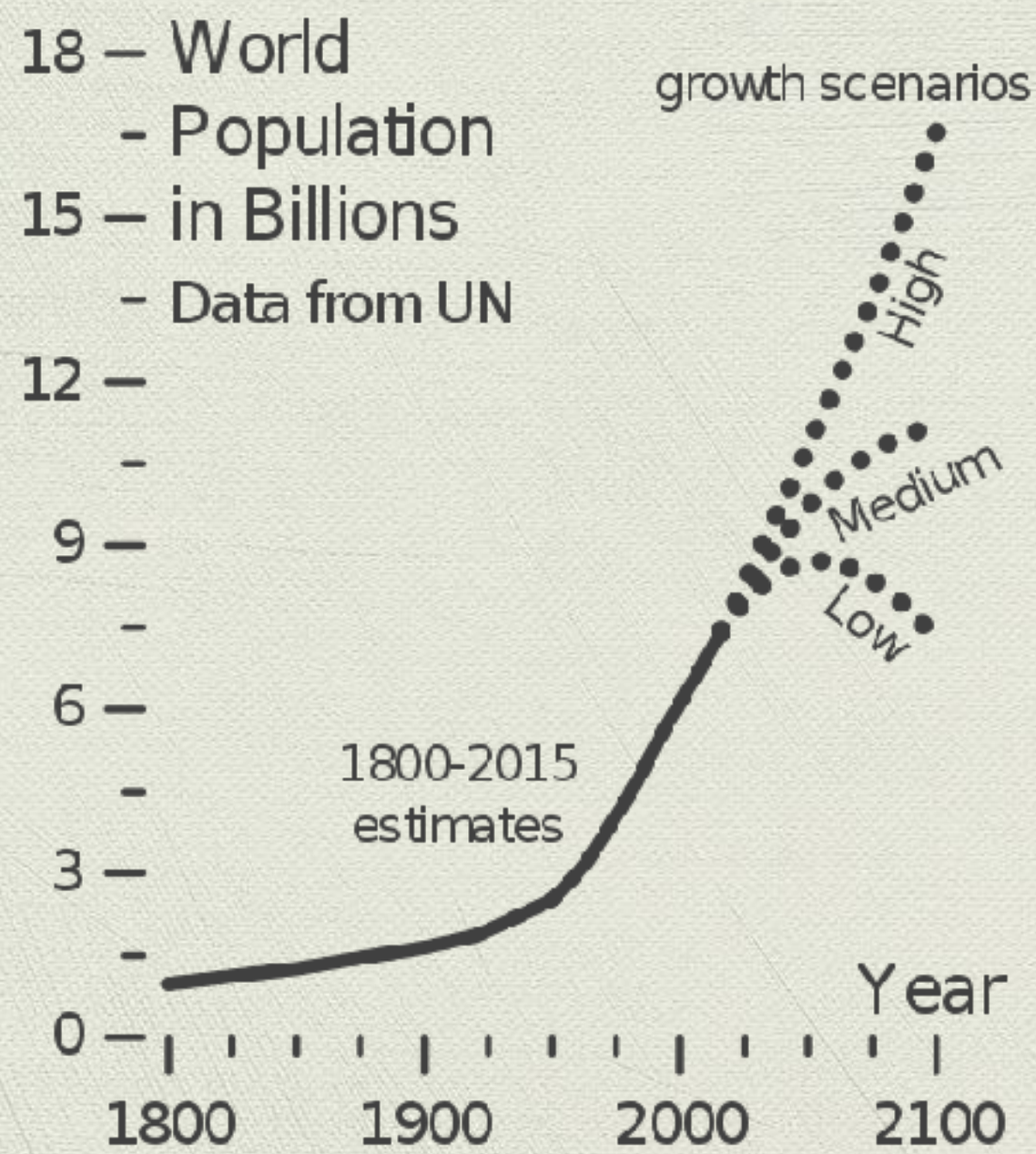


- Life expectancy (at birth)
- Education (years of schooling)
- Per capita income (GDP divided by the population)

HDI vs. Per Capita Energy Use



Global Population Estimates for 2100



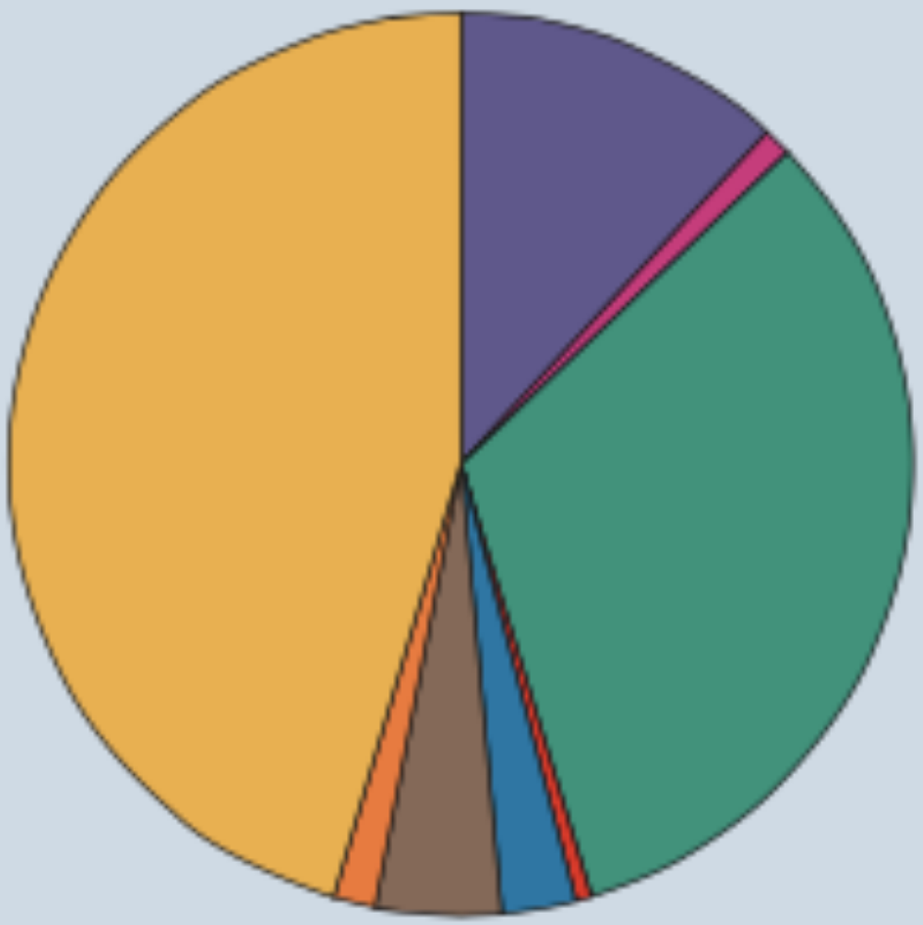
Global Energy Demand of 10 Billion People in 2100

10×10^9 people **X** 135×10^9 J/person

= 1350×10^{18} J

= 1350 EJ

Energy Water Nexus



2010 withdrawals by category, in million gallons per day

Public supply	42,000
Self-supplied domestic	3,600
Irrigation	115,000
Livestock	2,000
Aquaculture	9,420
Self-supplied industrial	15,900
Mining	5,320
Thermoelectric power	161,000

Values do not sum to 355,000 Mgal/d because of independent rounding

From http://pubs.usgs.gov/fs/2014/3109/pdf/fs2014-3109.pdf

US per capita for domestic and irrigation:
160 x 10^9 gal per day / 325 x 10^6 people
= 492 gal per day per person

Global total in 2100:
492 gal per day per person x 10 x 10^9 people
= 4920 x 10^9 gal per day

Multiply by 365 to get gal per year:
4920 x 10^9 gal per day x 365 days
= 1.8 x 10^{15} gal per year

Energy required for reverse osmosis desalination
5 kWh/m^3 = 68,000 J/gal

Total Energy Required:
1.8 x 10^{15} gallons per year x 68,000 J/gal
= 122 x 10^{18} = 122 EJ

Global Energy Requirement in 2100 (including energy for desalination)

1350 EJ

+122 EJ

1472 EJ

Earth at Night in 2100 (from *Pandora's Promise*)

Carbon Free Energy

- **Nuclear**
- **Hydroelectric**
- **Wind + Storage**
- **Solar + Storage**
- **Geothermal**
- **Fossil Fuels + CCUS**

ALL OF THE ABOVE

Carbon Free Energy

Rough Count:

2000 1 GW carbon free power plants in the world today.

Full disclosure:

Multiply solar capacities by 0.25 (the sun sets at night)

Multiply wind capacities by 0.35 (sometimes there's no wind)

So how much energy does a 1 GW power plant produce in a year?

$1\ \text{GW} = 1\ \text{GJ/s}$

$1\ \text{GJ/s} \times 10^9\ \text{J}/1\ \text{GJ} \times 60\ \text{s}/1\ \text{min}$

$\times 60\ \text{min}/1\ \text{hr} \times 24\ \text{hr}/1\ \text{day}$

$\times 365\ \text{day/year} \times 1\ \text{EJ}/10^{18}\ \text{J}$

$$= 0.0315\ \text{EJ/year}$$

1472 EJ needed divided by 0.0315 EJ/power plant

46,730 1 GW power plants needed

minus the 2000 that we have gives

44,730 1 GW power plants

divided by 83 years

539 power plants per year for the next 83 years

Estimating $2-5 billion per power plant

$2-5 billion / power plant x 539 power plants per year

= $1-3 trillion for each of the next 83 years

~1–3% of the GWP

Last year the world built the equivalent of 73

We better pick up the pace!