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# ENERGY OVERVIEW

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## Learning Outcomes

- Review energy units like BTUs, Joules, and Quads and apply “horse sense” to energy problems.
- Understand different energy types, including fossil fuels, nuclear, and renewables.
- Analyze the quantities and fractions of energy used in the US, including the concept of “rejected energy”.
- Understand growing energy demands in BRICS countries and the challenges facing the global energy sector.

## Reading

- Foundations of Spiritual and Physical Safety: with Chemical Processes; Start of Chapter XII through Section XII.1

```
# import needed packages
import numpy as np
import matplotlib.pyplot as plt
```

## 1 Units Review

- BTUs: British Thermal Units
  - Energy required to raise 1 pound of water by 1 degree Fahrenheit
- Calories
  - Energy required to raise 1 gram of water by 1 degree Celsius
- Joules
  - 1 calorie = 4.184 Joules
- Watts

- Power or rate of energy use in Joules per second
- A human can generate about 300 Watts of power on an exercise bike for a sustained time period
- Kilowatt-hours
  - Energy used by a 1 kW device in 1 hour
- Quad: 1 quadrillion BTUs
  - This is the amount of energy in 170 million barrels of oil

## 1.1 Example Unit Problems

How many BTU's to heat 1 L of water from 60°F to 212°F?

```
Cp = 4186 # J/kgK, specific heat of water
#specific heat of water in BTU/lbmF
Cp_BTU = 1.0 # BTU/lbmR, specific heat of water
rho = 1000 # kg/m^3, density of water
vol = 1/1000 # m^3, volume of water (1 L)
mass = rho*vol*2.20462 # lbm, mass of water (1 L)
E = Cp_BTU*mass*(212 -60)
print(f'Energy required to heat 1 L of water from 60F to 212F: {E:0.0f} BTU')
```

Energy required to heat 1 L of water from 60F to 212F: 335 BTU

How many BTUS's to vaporize that same 1L of water at 212°F?

```
#water heat of vaporization
Hvap = 970.3 # BTU/lbm, 2260 kJ/kg
E = Hvap*mass
print(f'Energy required to vaporize 1 L of water: {E:0.0f} BTU')
```

Energy required to vaporize 1 L of water: 2139 BTU

## 2 Energy Types

- Fossil
  - Coal
  - Oil
  - Natural Gas
  - Tar Sands
- Nuclear
- Solar
  - Photovoltaic
  - Concentrated Solar Power
- Renewable
  - Wind
  - Hydro
  - Geothermal
  - Biomass
  - Ocean



Figure 1: Estimate US Energy Consumption. Source: [https://flowcharts.llnl.gov/sites/flowcharts/files/2022-04/Energy\\_2021\\_United-States\\_0.png](https://flowcharts.llnl.gov/sites/flowcharts/files/2022-04/Energy_2021_United-States_0.png)

### 3 US Energy by Source with Losses

How many cubic miles of oil are used in the US in a year?

#### Note

About 1 cubic mile

There are significant losses in use of the energy. For example, a coal plant is only about 33% efficient in converting the energy in coal to electricity. A gasoline engine is only about 20% efficient in converting the energy in gasoline to motion. The rest is lost as heat.

#### 3.1 Energy loss example

The energy density of gasoline is about 45 MJ/kg. If a car gets 30 miles per gallon (at 60 miles per hour), how many MJ of energy are used to go 30 miles? What is the efficiency of the car?

How will you set this up?

#### Note

Assumptions:

- Force from drag is  $F_d = 1/2 \rho v^2 C_d A$ , where  $\rho$  is air density,  $v$  is velocity,  $C_d$  is drag coefficient, and  $A$  is frontal area. The drag coefficient for a car is about 0.3, the frontal area is about 2 m<sup>2</sup>, and the air density is about 1.2 kg/m<sup>3</sup>.
- The resistance from rolling friction,  $F_r = C_r mg$ , where  $C_r$  is the coefficient of rolling friction,  $m$  is mass, and  $g$  is acceleration due to gravity. The coefficient of rolling friction is about 0.01 for cars and the mass of the car is about 1500 kg.
- The energy of a moving car is  $E = 1/2 mv^2$ .
- The energy of a force acting over a distance is  $\int F dx$ .

```

vel = 60*5280/3600/3.281 # m/s, velocity of car
masscar = 1500 # kg, mass of car
Cr = 0.01 # rolling resistance coefficient
Cd = 0.3 # drag coefficient
gravity = 9.81 # m/s^2, gravity
Fr = masscar*gravity*Cr # N, rolling resistance force
rho_air = 1.2 # kg/m^3, density of air
Area = 2 # m^2, frontal area of car
Fd = 0.5*Cd*Area*rho_air*vel**2 #N, drag force
dis = 30*5280/3.281 # m, distance to travel
Work = (Fr + Fd)*dis + 1/2*masscar*vel**2 # J, work done
print(f'Work done to move car 30 miles at 60 mph: {Work/1e6:0.0f} MJ')

# efficiency of car
rhogas = 700 # kg/m3, density of gasoline
volgas = 1/264.172 # m3, volume of gasoline

```

```
Egas = 45e6*rhogas*volgas # J, energy in gasoline
print(f'Energy in 1 gallon of gasoline: {Egas/1e6:0.0f} MJ')
print(f'Efficiency of car: {Work/Egas*100:0.1f}%')
```

Work done to move car 30 miles at 60 mph: 20 MJ  
 Energy in 1 gallon of gasoline: 119 MJ  
 Efficiency of car: 16.9%

## 4 BRICS

The BRICS countries (Brazil, Russia, India, China, South Africa) are expected to use more energy as development continues.

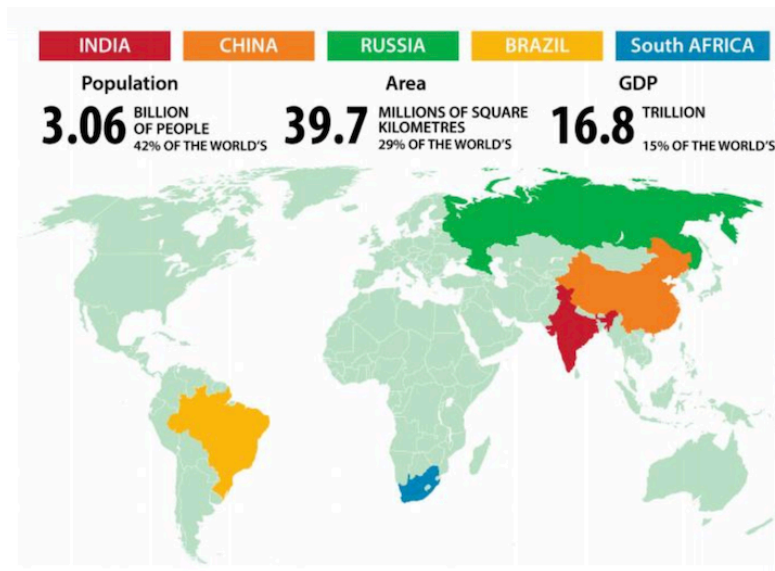


Figure 2: Population and GDP of the BRICS countries. Source: <https://unacademy.com/content/upsc/study-material/international-relations/importance-of-brics-for-india/>

## 5 Increasing Energy Use

## 6 Energy per Person

## 7 Inflation Reduction Act (2022)

The Inflation Reduction Act (IRA) is a United States federal law enacted on August 16, 2022. It is the most significant piece of climate legislation in U.S. history. The IRA provides \$369 billion in climate change programs over 10 years. It also includes provisions to lower healthcare costs, reduce the federal deficit, and invest in domestic energy production.

### 7.1 Key provisions of the IRA include:

- **Tax credits for renewable energy:** The IRA extends and expands tax credits for solar, wind, and other renewable energy sources. This includes a 30% investment tax credit (ITC) for solar projects and a production tax credit (PTC) for wind projects.
- **Electric vehicle incentives:** The IRA provides tax credits for electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs).

### Primary energy consumption by energy source, world

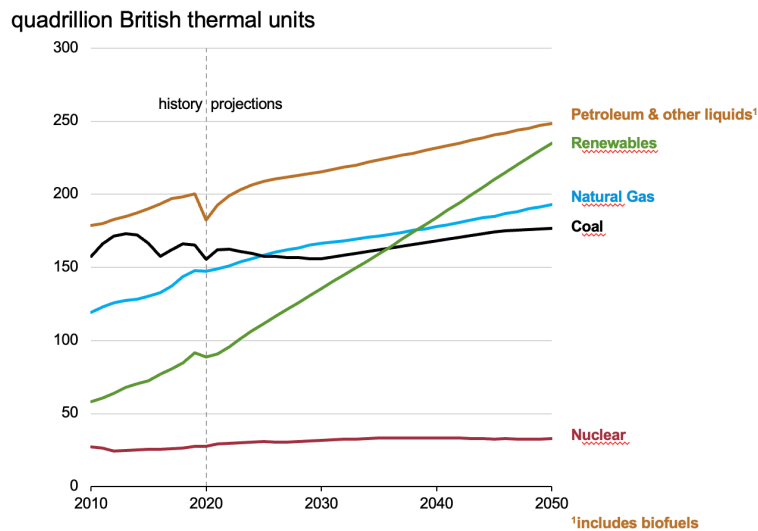


Figure 3: Primary energy consumption by energy source. Credit [EIA.org](https://www.eia.org), International Energy Outlook 2021

Figure 4: Energy use per person, source: <https://ourworldindata.org/energy-access#>.

- **Energy efficiency programs:** The IRA includes funding for energy efficiency programs, such as rebates for energy-efficient appliances and home retrofits.
- **Carbon capture and storage:** The IRA provides tax credits for carbon capture and storage (CCS) projects, which can help reduce greenhouse gas emissions from fossil fuel power plants.

## 8 IRA Expected Environmental Benefits

- **Reduction in greenhouse gas emissions:** The IRA is expected to reduce U.S. greenhouse gas emissions by about 40% by 2030 compared to 2005 levels.
- **Increased renewable energy generation:** The IRA is expected to increase the share of renewable energy in the U.S. electricity mix to about 70% by 2030.
- **Job creation:** The IRA is expected to create millions of jobs in the renewable energy sector, including jobs in manufacturing, installation, and maintenance of renewable energy systems.

## 9 Energy Future

The US Energy Information Administration (EIA) is a government organization that provides data and analysis on energy production, consumption, and trends. The EIA provides projections of energy consumption and production through 2050 and can be found on their website: <https://www.eia.gov/outlooks/aeo/>

Figure 5: Energy related CO2 emissions, source: <https://www.eia.gov/outlooks/aeo/>

Some Comments:

- Total CO2 emissions are expected to decline despite the increase in energy use and population

- Coal is declining due to its challenges:
  - Mercury, SO<sub>x</sub>, NO<sub>x</sub>, CO<sub>2</sub>, and particulates
- Natural Gas is increasing due to its lower emissions, abundance, and economics
- Petroleum will face a slow decline but there is not yet a feasible replacement as a transportation fuel and as a raw material for chemical production
- Transition to renewables will not/cannot happen on order of 10 years (maybe even 30) without societal upheaval
- Nuclear is a viable option but has its own challenges
- Energy storage is likely to grow in importance
- Ultimately, we'll need to use many forms of energy

D&C 104: 17 Says: "For the earth is full, and there is enough and to spare; yea, I prepared all things, and have given unto the children of men to be agents unto themselves."

And the next verse says: "Therefore, if any man shall take of the abundance which I have made, and impart not his portion, according to the law of my gospel, unto the poor and needy, he shall, with the wicked, lift up his eyes in hell, being in torment."

## 10 Energy Ethics

Per the AIChE Code of Ethics (<https://www.aiche.org/about/code-ethics>), and the National Society of Professional Engineers (<https://www.nspe.org/resources/ethics/code-ethics>) engineers should "hold paramount the safety, health, and welfare of the public."

How does that ethics code apply to helping developing nations get access to energy?

### Action Items

1. Analyze the LLNL 2023 Energy Consumption chart and determine the percentage of US energy generated from fossil fuels versus renewables.
2. Personal Reflection: Research why Ireland has seen a substantial increase in GDP per capita while maintaining relatively low energy use per person compared to the US. Write a descriptive paragraph.