# SSC 2030: Energy Systems & Sustainability

**3. Primary energy forms and uses**

**3.1:** Primary energy consumption (*conservation*!)

**3.2:** Units of energy and energy data

**3.3:** Energy density (aka heat content)

**3.4:** Global and regional sources of energy

**3.5:** UK energy use today

**3.6:** Primary energy: UK vs. Denmark vs. US

**3.7:** Primary energy: France vs. India vs. China

**3.8:** Trends in US energy use

**3.9:** Vermont energy statistics

# 3. Primary energy forms and uses

**3.1: Energy 'consumption'**

- Remember that energy is conserved.
- Humans transfer & transform energy.
- Transformation from primary energy to used energy is inefficient
- Human energy use has increased through time

## Energy 'consumption'

We say that, "The US **consumes** more energy per capita than any other nation on earth."

- But, that's incorrect.

**The 1st law of thermodynamics:**
Energy is neither created nor destroyed, but **transformed or transferred**.

So, the US transforms or **converts** more energy…

How? For example:

**Combustion:** fuel → heat energy ---> electricity
*chemical energy*

**Hydroelectric:** potential energy → kinetic energy → electricity

**Wind power:** kinetic energy → electricity



## Let's start with the fuels

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**Primary energy**

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## Primary energy

**Primary energy:**

- *Total energy content of the energy source.*
- *Naturally occurring energy stores or energy carriers.*

Primary energy is the **fuel** that we **convert** to make the electricity, heat or work that we use.

"Energy in the form that it is first accounted for in a statistical energy balance, before any transformation to secondary or tertiary forms of energy.

For example, coal can be converted to synthetic gas, which can be converted to electricity; in this example, coal is **primary** energy, synthetic gas is **secondary** energy, and electricity is **tertiary** energy."

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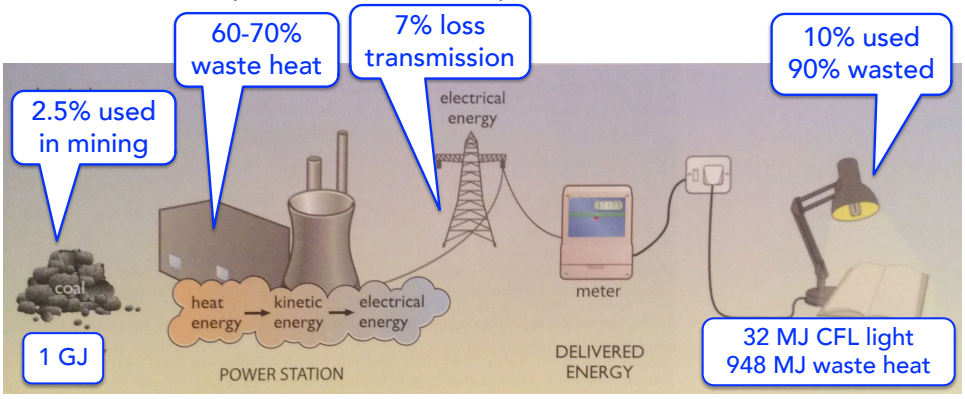
## Conversion of primary to useful energy

**Transformation** of energy, from one form to another, and **transfer** of energy from generator to user, both result in losses.

- Overall, this process is **inefficient**, particularly for electricity.

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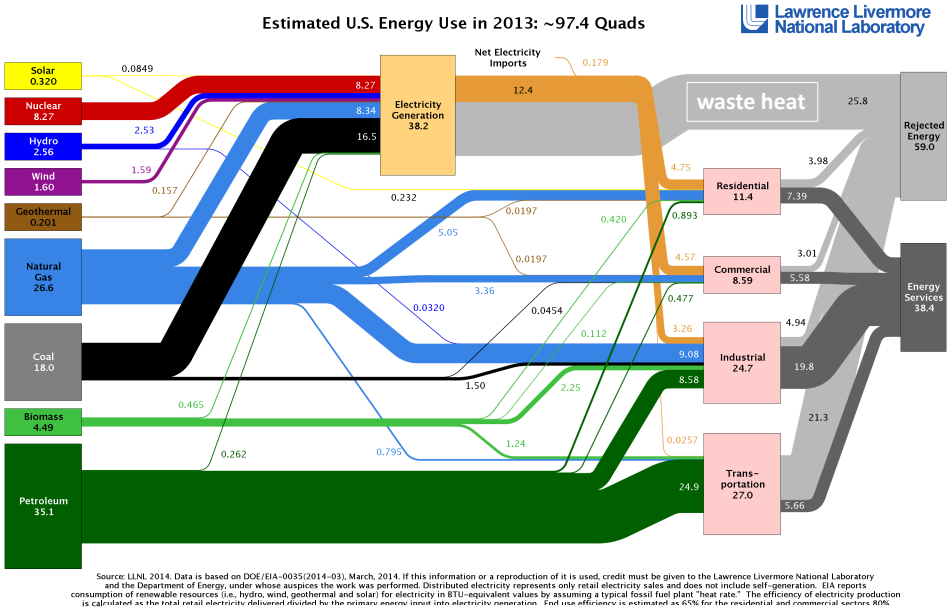
# Energy flow maps sources to uses

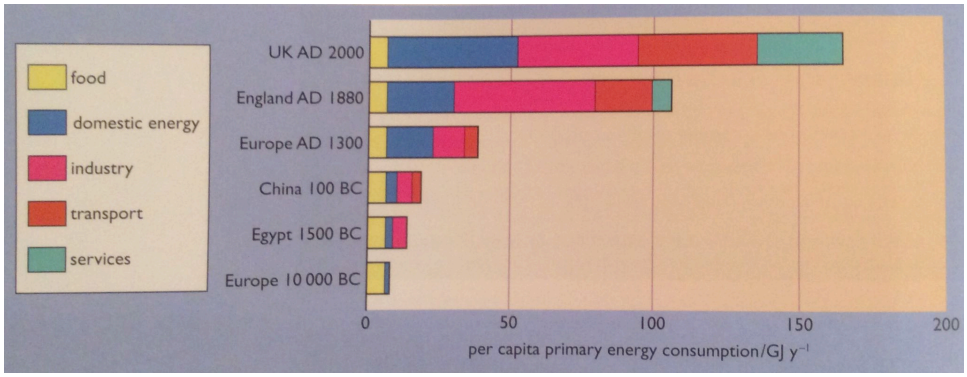



https://flowcharts.llnl.gov/content/energy/energy_archive/energy_flow_2013/2013USEnergy.png

# Energy use has increased over time

**Why?**

- New technologies: fire → steam → electricity → etc.
- New uses: 'services' include our computers & nifty new devices
- Rapidly growing human population

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# 3. Primary energy forms and uses

### 3.2: Units of energy and energy data

- *Energy is an amount while power is a rate*
- Units… many different units
- Heat content: a measure of fuel's energy

## Let's compare everyday fuels

Comparing everyday amounts of gasoline, oil and coal:

| | Joule | Btu | Calorie (kcal) | kWh |
|---|---|---|---|---|
| Full gas tank | 1,570,893,171 | 1,488,857 | 375,192,000 | 436 |
| Gallon of gas | 130,907,764 | 124,071 | 31,266,000 | 36 |
| *Barrel of gas | 5,498,126,100 | 5,211,000 | 1,313,172,000 | 1,527 |
| *Barrel of crude oil | 6,119,580,000 | 5,800,000 | 1,461,000,000 | 1,700 |
| Coal, 2000 lb | 21,896,490,300 | 20,753,000 | 5,299,756,000 | 6,082 |

** 1 barrel = 432 US gallons or 159 L*

*So, it's clear that we're going to have to have a basic understanding of units & simple conversion math ('energy arithmetic') even in this course.*

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## Units of energy vs. power

***See:*** *APS physics link for more information*

| | | |
|---|---|---|
| **Energy:** | J | Joule |
| | Btu | British thermal unit |
| | kW-hr | kilowatt-hour |
| | cal | calorie |
| | Cal (or kcal) | kilocalorie |
| | ft-lb | foot-pound |
| | TOE | ton oil equivalent |
| | TCE | ton coal equivalent |
| | Quad | = quadrillion Btu = 1 E15 Btu = 1.056 EJ |
| | Therm | = 100,000 Btu |
| **Power:** | W | watt |
| | HP | horsepower |

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## Scientific notation & metric prefixes

**Table 2.1** Prefixes

| Letter | Prefix | Multiply by[2] | As power of ten |
|---|---|---|---|
| μ[1] | micro | one-millionth | $10^{-6}$ |
| m | milli | one-thousandth | $10^{-3}$ |
| k | kilo- | one-thousand | $10^{3}$ |
| M | mega- | one million | $10^{6}$ |
| G | giga- | one billion (one thousand million) | $10^{9}$ |
| T | tera- | one trillion (one million million) | $10^{12}$ |
| P | peta- | one quadrillion (one billion million) | $10^{15}$ |
| E | exa- | one quintillion (one billion billion, or one million million million) | $10^{18}$ |

[1] Letter *mu* in the Greek alphabet.
[2] Note the general rule that ea multiplier is a thousand times the

| number | scientific notation |
|---|---|
| 2 | 2 E0 |
| 300 | 3 E2 |
| 3,421.768 | 3.421768 E3 |
| -53,000 | -5.3 E4 |
| 6,720,000,000 | 6.72 E9 |
| 0.2 | 2 E-1 |
| 0.00000000751 | 7.51 E-9 |

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## Often confused…

Units can be confusing. Here are two frequent issues:
- When is a ton a tonne?
- What's the difference between m & M?

| | | | |
|---|---|---|---|
| **1 tonne** | 1000 kg | 2200 lb | ←metric or SI |
| **1 ton** | 1016 kg | 2240 lb | ←imperial |
| **1 short ton** | 907 kg | 2000 lb | ←standard US |

| | | |
|---|---|---|
| **m** | milli- | 1 E-3 |
| **M** | mega- | 1 E6 |
| **MM** | Mega- | 1 E6 |

And writers are often sloppy:
- Furnace output in Btu probably means Btu/hour;
- Energy use in kW probably means kWh; and
- MMBtu should be interpreted as million Btu.

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## Watts (W) vs. kilowatt-hour (kWh)

**Watt:** *the rate at which energy is being transformed or converted from one form to another*
- *unit of **power***
- *one joule per second*

600 W heater?
- Transforms energy to heat at a rates of 600 joules each second

Global consumption of 15.9 TW of energy?
- We convert 15.9 million million joules of primary energy each second to electricity, heat, etc.,.

**Kilowatt-hour:** *the amount of energy being converted in one hour, at a rate of one kilowatt (1 E3 W)*
- *unit of **energy***
- *1 kWh = 3.6 MJ*

3 kW clothes dryer used for 40 minutes?
- Converts 2 kWh of electricity into heat energy
  - [ =(2/3 hr)(3 kW) = 2 kWhr]

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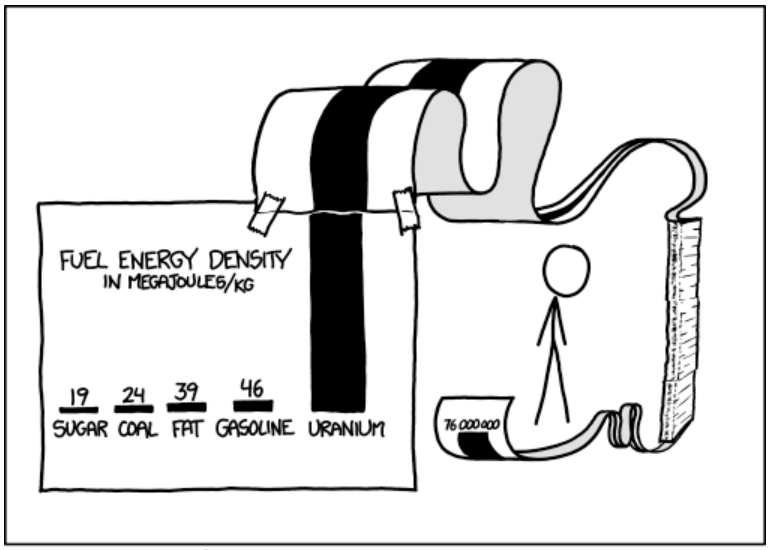
# 3. Primary energy forms and uses

**3.3: Energy density (aka heat content)**

## Relative energy densities




SCIENCE TIP: LOG SCALES ARE FOR QUITTERS WHO CAN'T FIND ENOUGH PAPER TO MAKE THEIR POINT *PROPERLY.*

Energy Systems & Sustainability, 2/e, Chapter 4; http://xkcd.com/1162

## Chemical energy density

Storing energy is **'expensive'** in terms of quantities of chemical or potential energy needed.

| fuel (=chemical energy) | MJ/kg | pounds to store 10 gas gallon equivalents |
|---|---|---|
| hydrogen gas | 130 | 22 |
| natural gas | 55 | 52 |
| gasoline | 45 | |
| oil | 42 | 68 |
| coal | 28 | 105 |
| ethanol | 27 | |
| wood | 15 | 191 |
| lead-acid batteries | | 6,578 |
| water at 80c | | 11,440 |
| pumped storage (h = 370 m) | | 762,667 |

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## HHV vs. LHV heat values?

There are two 'flavors' of heat values (or energy densities) for combusted fuels.

**HHV (high heat values)** used when the steam is condensed after use; condensing steam to water releases additional energy.

- Aka HCV or GCV

**LHV (low heat values)** used when the steam is not condensed after use.

- Aka LCV or NCV

| Fuel | HHV (MJ/kg) | LHV (MJ/kg) |
|---|---|---|
| hydrogen | 141.80 | 119.96 |
| methane | 55.50 | 50.00 |
| propane | 50.35 | 46.35 |
| diesel | 44.80 | 43.40 |
| wood | 21.20 | 17.0 |

Energy Systems & Sustainability, 2/e, Chapter 4; wikipedia

## Comparing heat contents (energy density)

| | Btu/gallon (gross) | Btu/gallon (net) |
|---|---|---|
| Auto gasoline | 125,000 | 115,400 |
| hydrogen | 134,200 | 113,400 |
| Diesel fuel | 138,700 | 128,700 |
| biodiesel | 126,206 | 117,093 |
| methanol | 64,600 | 56,560 |
| ethanol | 84,600 | 75,670 |
| gasohol | 120,900 | 112,417 |
| Aviation gas | 120,200 | 112,000 |
| propane | 91,300 | 83,500 |
| butane | 103,000 | 93,000 |
| Jet fuel (naptha) | 127,500 | 118,700 |
| Jet fuel (kerosene) | 135,000 | 128,100 |
| Crude petroleum | 138,100 | 131,800 |
| Residual fuel oil | 149,700 | 138,400 |
| Distillate fuel oil | 138,700 | 131,800 |

| Gaseous & solid fuels | Btu/_____ |
|---|---|
| Natural gas, wet | 1,109 Btu/ft3 |
| Natural gas, dry | 1,027 Btu/ft3 |
| Natural gas, compressed | 20,551 Btu/lb |
| Liquid natural gas | 90,800 Btu/gallon |
| Anthracite coal | 21.7 E6 Btu/short ton |
| Lignite/bit coal | 21.0 E6 Btu/short ton |

*Net = water's heat of vaporization is subtracted from gross energy content*

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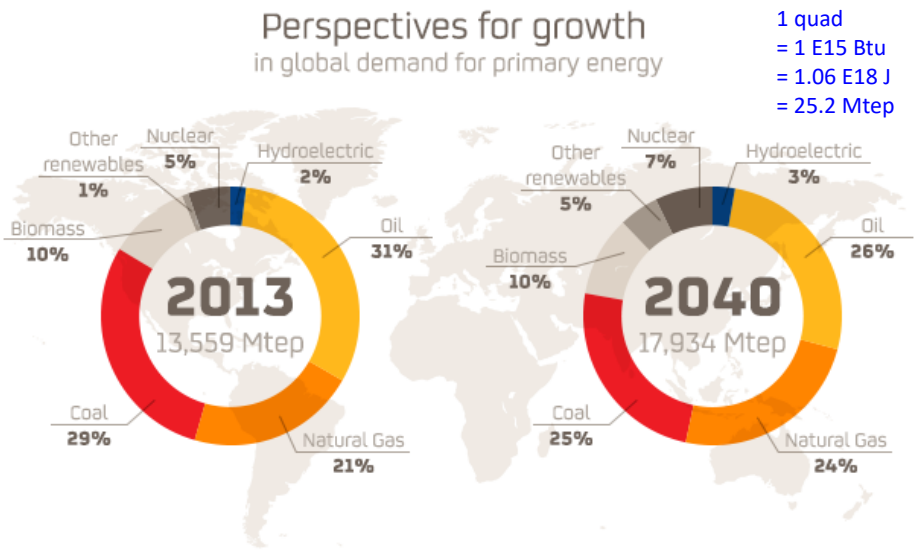
## 3. Primary energy forms and uses

### 3.4: Global and regional sources of energy

- Current global use and projections
- Energy inequity
- Use of renewable energy?

## Predicted growth

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## The 14%

A small part of the world's population uses most of its energy resources.

| | Population (global %) | Energy produced (%) | Energy consumed (%) | Primary energy consumption per capita** | GDP per capita** |
|---|---|---|---|---|---|
| Wealthiest* | 14% | 31% | 41% | 3.1 | 3.4 |
| Others | 86% | 69% | 59% | 0.7 | 0.5 |

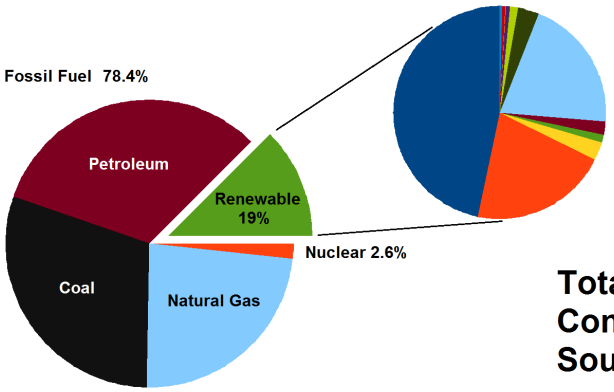
* USA, Canada, Western Europe, Australia, New Zealand, Japan

** As a multiple of the global average

Energy Systems & Sustainability, 2/e, Chapter 2 / Table 2.3

## Global use of renewable energy resources

Breaking out **renewable energy**.




**Renewable**

| | |
|---|---|
| Traditional biomass | 9% |
| Bio-heat | 2.6% |
| Ethanol | 0.34% |
| Biodiesel | 0.15% |
| Biopower generation | 0.25% |
| Hydropower | 3.8% |
| Wind | 0.39% |
| Solar heating/cooling | 0.16% |
| Solar PV | 0.077% |
| Solar CSP | 0.0039% |
| Geothermal heat | 0.061% |
| Geothermal electricity | 0.049% |
| Ocean power | 0.00078% |

**Total World Energy Consumption by Source (2013)**

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## 3. Primary energy forms and uses

### 3.5: UK energy use today

## UK energy use today

UK total primary energy consumption in 2009: **9000 PJ** (9000 E15 J)

- UK population was 62 million in 2009
- So, per capita energy use: 145 GJ per person

We're about to dive into some data that demonstrates:

- 8840 PJ of energy is provided
- 6021 PJ of energy is delivered
- There's a discrepancy of 2819 PJ
  - 5% (141 PJ) is used for shipping
  - **95% is lost in conversion & delivery**
  - Electricity generation is only 35% efficient

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## UK primary energy use & consumption

**Table 3.3** UK primary energy production and consumption, 2009

| Category | Energy source/PJ | | | | | Total[3]/PJ |
|---|---|---|---|---|---|---|
| | Coal | Oil | Natural gas | Primary electricity[1] | Renewables and wastes[2] | |
| Production (+) | 462 | 3129 | 2500 | 690 | 206 | 6988 |
| Imports (+)[4] | 1039 | 3511 | 1641 | 24[4] | 50 | 6264 |
| Exports (–) | –25 | –3244 | –494 | –13[4] | 0 | –3776 |
| Non-energy use (–) | 0 | –339 | –32 | 0 | 0 | –371 |
| Marine bunkers (–) | 0 | –110 | 0 | 0 | 0 | –110 |
| To stock (+/–) | –178 | 40 | –18 | 0 | 0 | –155 |
| **Total consumption[3]** | **1298** | **2988** | **3598** | **700** | **257** | **8840** |

[1] Refers to UK nuclear, hydro and wind generators. As explained in the previous chapter, the 'nuclear electricity' is treated as the equivalent primary energy input to produce it at an efficiency of 38%. The wind and hydro contributions are simply their electrical energy output.
[2] Includes other sources of renewable energy that are burned to produce electricity, for example landfill gas and municipal waste. They are treated here as being equivalent to the energy content of the fuel.
[3] Some totals may differ slightly from the sum of the items owing to rounding.
[4] To and from France through a cable under the English Channel.
Source: DECC, 2010a, Table 1.1.

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# UK delivered energy consumption

Here we can look at the types and amounts of fuels used by each **sector** in the UK.

- What stands out to you?

**Table 3.4** UK delivered energy consumption, 2009

| Sector | Fuel type/PJ | | | | | Total[2]/PJ |
|---|---|---|---|---|---|---|
| | Solid | Liquid | Natural gas | Electricity[1] | Renewables and heat | |
| Domestic | 29 | 126 | 1206 | 440 | 21 | 1821 |
| Services[3] | 4 | 54 | 297 | 335 | 29 | 720 |
| Transport | 0 | 2290 | 0 | 33 | 42 | 2366 |
| Industry | 71 | 226 | 410 | 352 | 54 | 1114 |
| **Total[2]** | **105** | **2696** | **1913** | **1160** | **147** | **6021** |

[1] Here treated as the energy content of the delivered electricity (i.e. 3.6 PJ for each TWh delivered).
[2] Some totals may differ slightly from the sums of the items owing to rounding.
[3] This includes public lighting and agriculture.
Source: DECC, 2010b, page 10.

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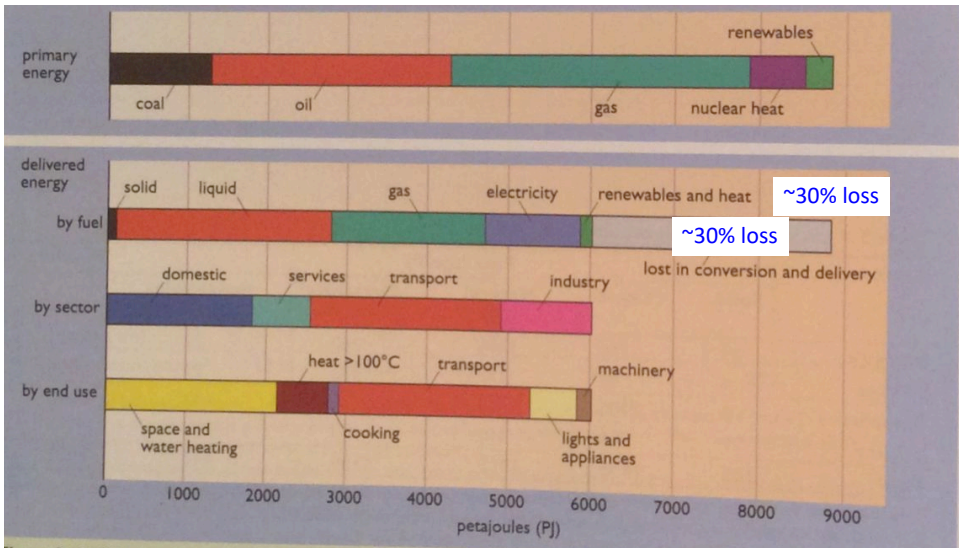
# UK primary vs. delivered energy

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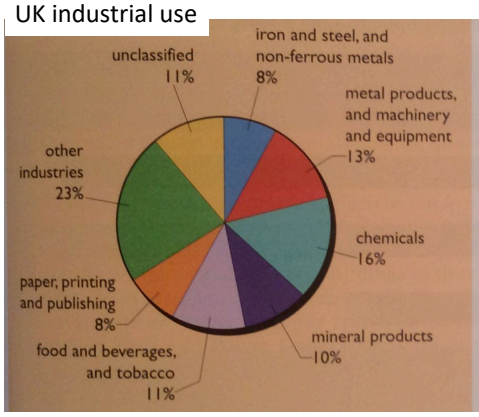
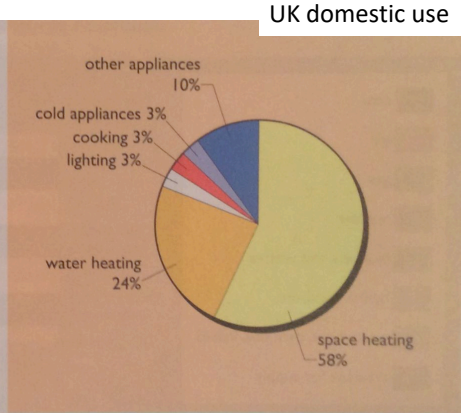
# UK industrial vs. domestic use

UK industrial use




UK domestic use

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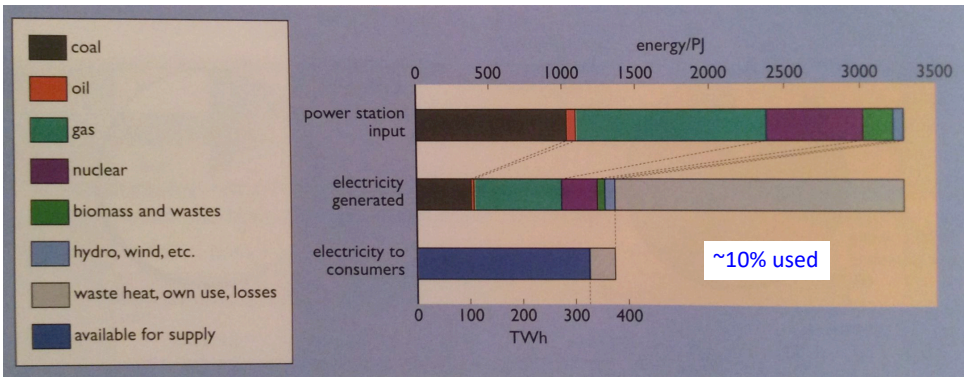
# UK generation & distribution of electricity

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## UK trends in energy use by sector

Energy use per capita has **only increased by about 50%** over the last 100 years.

- Industry has become more efficient.
- Transportation has doubled energy use; more autos.

**Table 3.5** Trends in UK delivered energy

| | Delivered energy/PJ | | |
|---|---|---|---|
| **Sector** | **1970** | **2009** | **Change 1970–2009** |
| Domestic | 1544 | 1821 | +18% |
| Services | 779 | 720 | –8% |
| Transport | 1179 | 2366 | +101% |
| Industry | 2612 | 1114 | –57% |
| **Total** | **6114** | **6021** | –2% |

Source: DECC 2010a, Table 1.1.5.



## 3. Primary energy forms and uses

**3.6: Primary energy: UK vs. Denmark vs. US**

- What's self-sufficiency?
- UK
- Denmark
- US

## The ideal primary energy profile?

What should a country's (or a region's or planet's) primary energy profile look like?

1. **Self-sufficient:** a good match between primary energy production & consumption.

$$\text{Self-sufficiency (\%)} = \left(\frac{\text{primary energy production}}{\text{primary energy consumption}}\right)(100)$$

2. **Low-carbon** & low polluting

3. **Sustainable** & local

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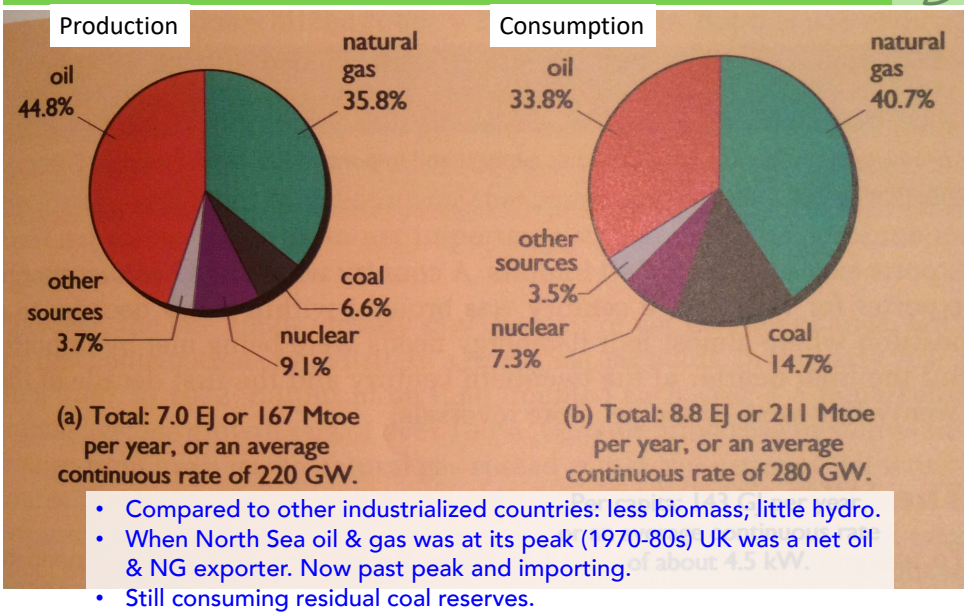
## Primary energy in the UK




- Compared to other industrialized countries: less biomass; little hydro.
- When North Sea oil & gas was at its peak (1970-80s) UK was a net oil & NG exporter. Now past peak and importing.
- Still consuming residual coal reserves.

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## Changes in UK primary energy use

This graph of UK primary energy production & use shows how UK production & consumption have determined whether the country is a net importer or exporter.

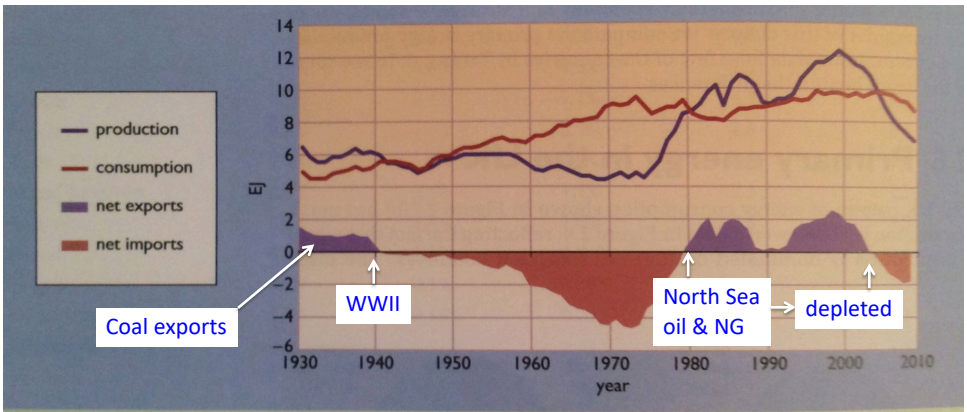


**Figure 2.8** UK: annual primary energy production and consumption, and net exports and imports, 1930–2009 (sources: DECC (DUKES), various years; DECC, 2010b and other years)

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## Influence of energy insecurity

The **UK** has been fuel secure; first coal, then North Sea oil & gas.

However, prior to 1970, **Denmark** imported nearly all its fuel, 95% oil

- When oil prices soared in the 1970s & 1980s Demark was forced to act and make changes:
  - Extreme energy conservation;
  - Power stations switched from oil to coal;
  - Expansion of use of CHP (combined use of heat & power);
  - Favored district heat over individual heating systems;
  - Requirements for insulation and building standards; &
  - More renewable energy, particularly wind & biomass.

Results? (2007)

- Energy use in Denmark has been stable since 1980.
- District heat was used in 60% of homes & made up 12% of delivered energy.
- CHP kept waste down to 22% vs. 32% in the UK.
- Renewable energy rose to 14%.
- Still dependent on oil, particularly for transportation.

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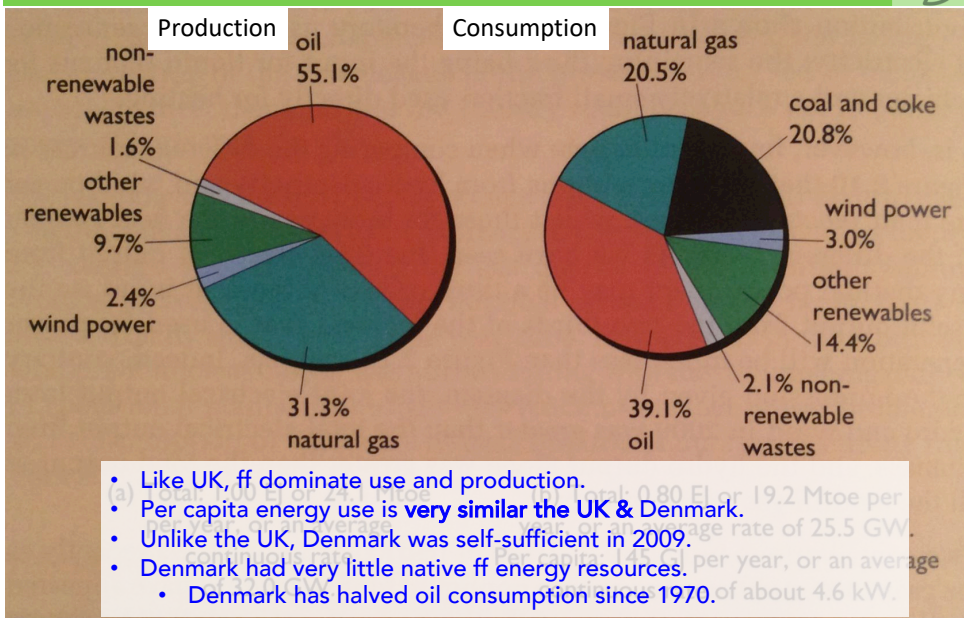
## Primary energy in Denmark




- Like UK, ff dominate use and production.
- Per capita energy use is **very similar the UK &** Denmark.
- Unlike the UK, Denmark was self-sufficient in 2009.
- Denmark had very little native ff energy resources.
  - Denmark has halved oil consumption since 1970.

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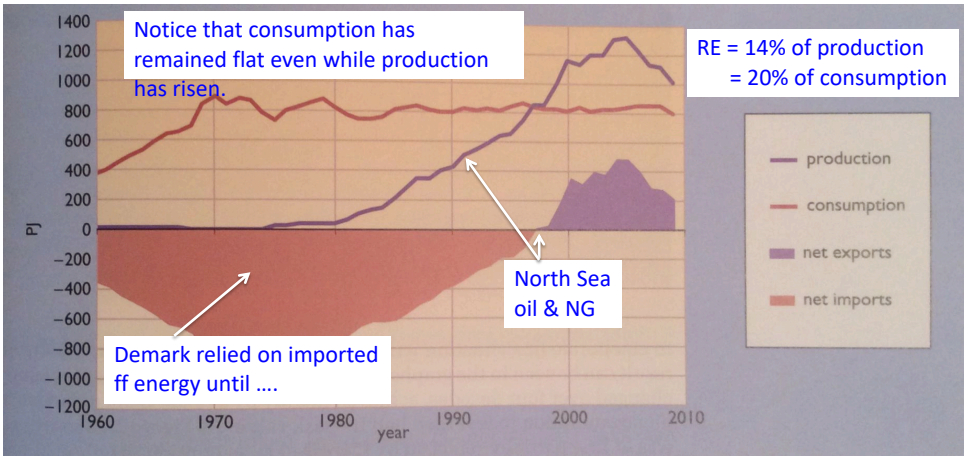
## Changes in Denmark's primary energy use

Denmark had little coal, and when they got North Sea oil & NG they made it last.

- To Denmark, it's obvious that the future is RE and conservation.

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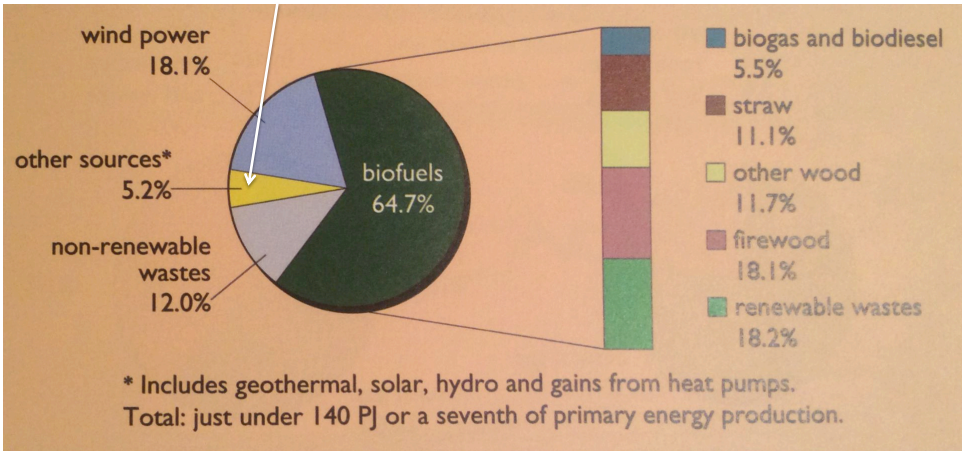
## RE in Denmark

By 2008, Denmark had made much greater use of renewable energy than the UK.

Use of heat pumps for space heating has contributed to conservation of fossil fuels and electricity.

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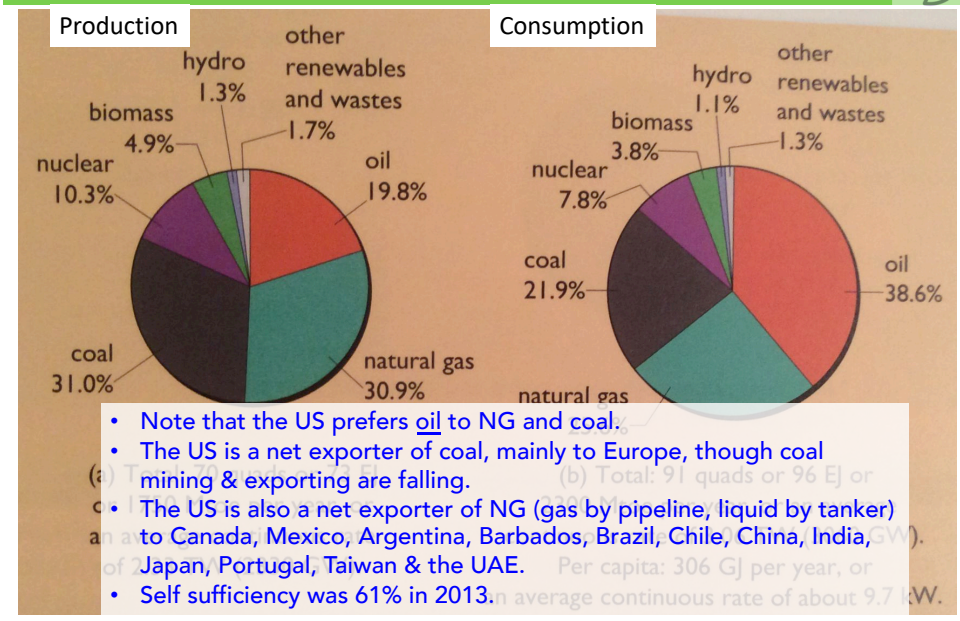
## Primary energy in the US




- Note that the US prefers oil to NG and coal.
- The US is a net exporter of coal, mainly to Europe, though coal mining & exporting are falling.
- The US is also a net exporter of NG (gas by pipeline, liquid by tanker) to Canada, Mexico, Argentina, Barbados, Brazil, Chile, China, India, Japan, Portugal, Taiwan & the UAE.
- Self sufficiency was 61% in 2013.

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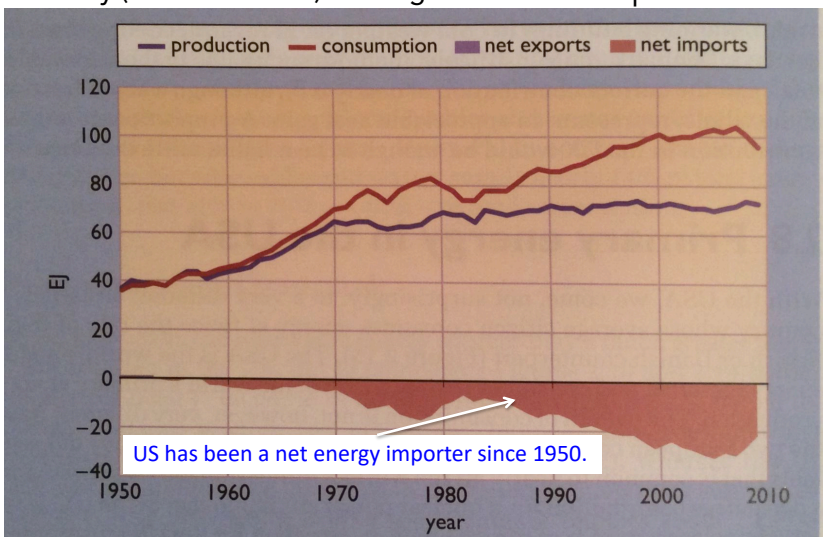
## Changes in US primary energy use

Our consumption has continued to rise.

- Recently (not shown here) fracking has increased exports.

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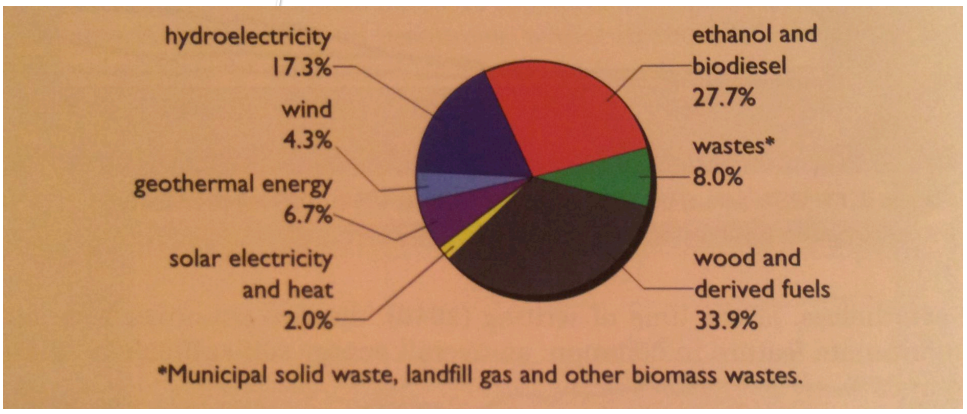
## RE in the US

By 2009, the US produce about 8% of energy with renewable resources.

- Ethanol use is a result of government subsidies and the farm lobby.
- 2019: RE up to 11% in the US

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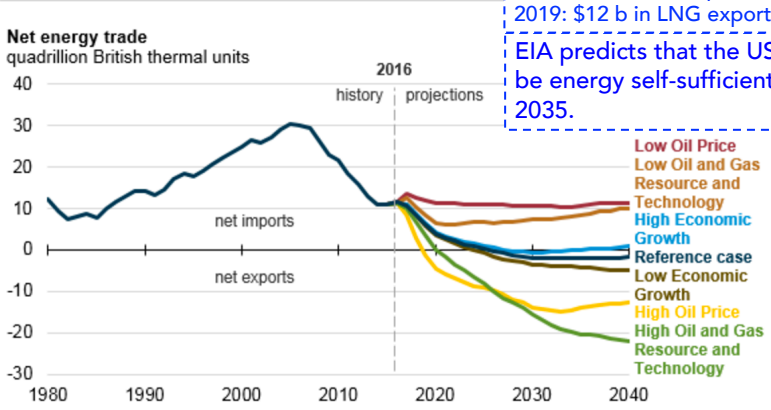
## US predicted net energy exporter: 2017

JANUARY 5, 2017

### EIA's AEO2017 projects the United States to be a net energy exporter in most cases

Dec 2018: net oil exporter
2019: $12 b in LNG exports

EIA predicts that the US could be energy self-sufficient by 2035.




Source: U.S. Energy Information Administration, *Annual Energy Outlook 2017*

EIA's *Annual Energy Outlook 2017* (AEO2017), released this morning presents updated projections for U.S. energy markets. This AEO is the first to have projections through 2050 in the AEO tables.

https://www.eia.gov/todayinenergy/detail.php?id=29433

## Recent energy use in the US

https://www.eia.gov/energyexplained/?page=us_energy_home

## Comparing the UK, Denmark & US

Fossil fuel use is similar across the board.

- Consumption much higher in the US.
- Only Denmark is self-sufficient.
- Denmark produces and uses more renewable energy.

| | Fossil fuels (% primary consumption) | Per capita use (GJ/year) | Self-sufficiency (%) | RE (% produc.) | RE (% consump.) |
|---|---|---|---|---|---|
| UK | 89.2 | 143 | 79.5 | 3.7 | 3.5 |
| Denmark | 80.4 | 145 | 125.0 | 13.7 | 19.5 |
| US | 86.1 | 306 | 76.9 | 7.9 | 6.2 |

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## 3. Primary energy forms and uses

**3.7: Primary energy: France vs. India vs. China**

- France
- India
- China
- Global future forecast?

## US & France (1970 – 2008)

**US:** Per capita energy use is high.

- Energy use rose across all energy sectors, averaging 40% increase.
- Service sector saw the largest increase.
- ~~50~~% 30% of electricity is generated with coal.
  - Coal-fired plants increased three-fold.
  - Electricity losses (27 EJ) are larger than total production in the UK.

**France:** Per capita energy use is also high.

- Energy use rose across all energy sectors:
  - By 75% to 2005, then decreased slightly.
- 75% of electricity is generated with nuclear power.
- Uses less NG than UK or US.

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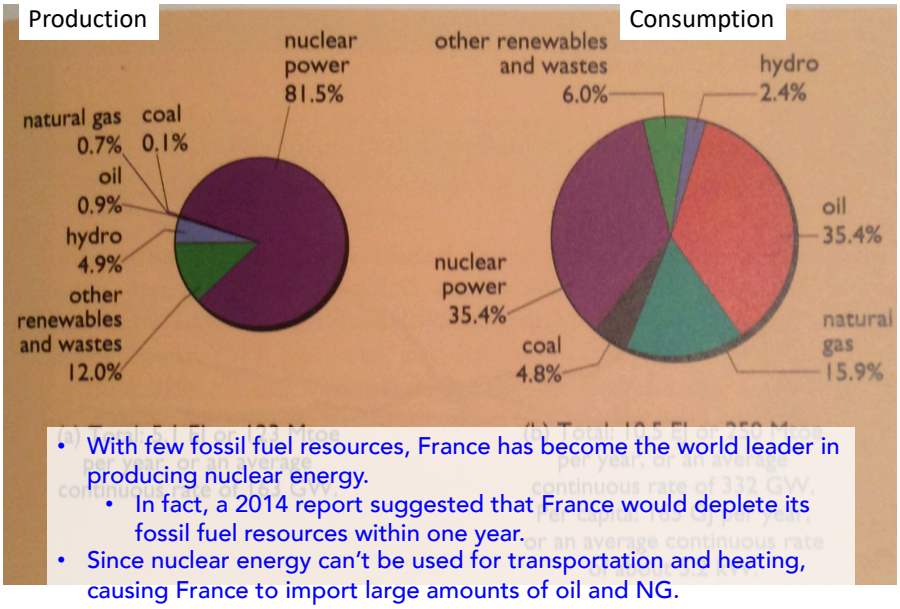
## Primary energy in France




- With few fossil fuel resources, France has become the world leader in producing nuclear energy.
  - In fact, a 2014 report suggested that France would deplete its fossil fuel resources within one year.
- Since nuclear energy can't be used for transportation and heating, causing France to import large amounts of oil and NG.

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## India

**India:** Overall, per capital energy use is very low, but rising.

- Population is massive.
- 25% live in cities where energy use is higher and growing quickly.
- 50% of population (mainly rural) still lack electricity.
- Coal is used for electricity
  - Efficiency is a low 28%
  - 25% of all electric production is lost.
- Agriculture uses 25% of all electricity; mainly for irrigation; diesel pumps are also used.
- About 25% of primary energy is biofuel / biomass.
- National programs push electrification and use of LNG vs. biomass.

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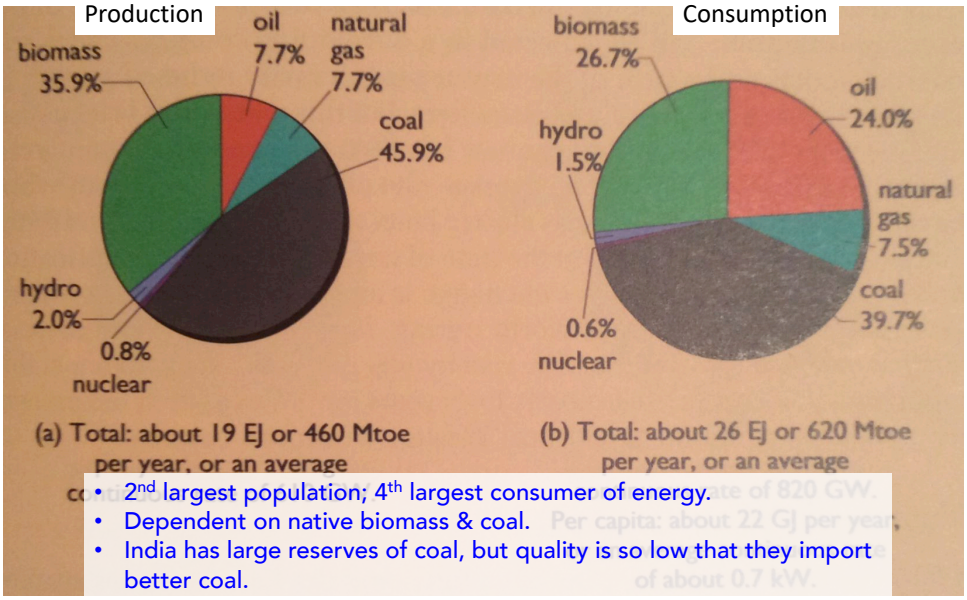
## Primary energy in India

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## China

**China:** Energy use low but rising.

- Population is massive: rose to 1.3 billion by 2006, 80% live in cities.
- In 2005, biomass still made up 20% of primary energy, and 50% of domestic fuel.
- From 1980 – 2006, primary energy use increased three-fold, and GDP increased 10-fold.
- From 1952 – 1978, energy / GDP ratio tripled, then fell with efficiency.
- Industrial energy use is massive & rose 4-fold from 1980 – 2006. 80% of all new energy use is industrial. Industry consumes 70% of all electricity, most generated from coal. (100 years of coal are left.)
  - In 2006, China produced many global goods: 50% of cement & glass; 35% of steel; 28% of aluminum.
- Agriculture uses 3.5% of all electricity, mainly pumping deep wells.
- Transportation is up from 0.8 to 5 EJ, nearly all petroleum.

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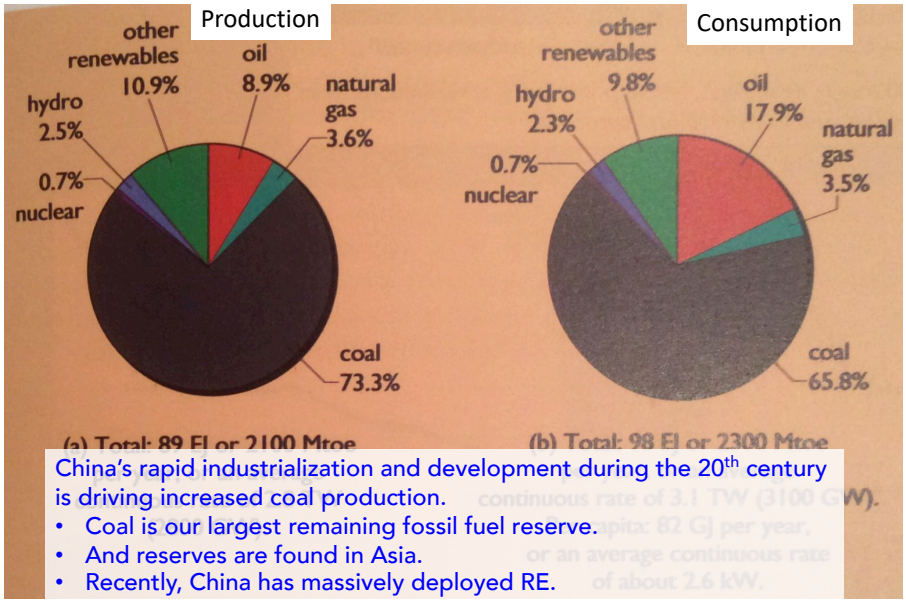
## Primary energy in China




China's rapid industrialization and development during the 20th century is driving increased coal production.

- Coal is our largest remaining fossil fuel reserve.
- And reserves are found in Asia.
- Recently, China has massively deployed RE.

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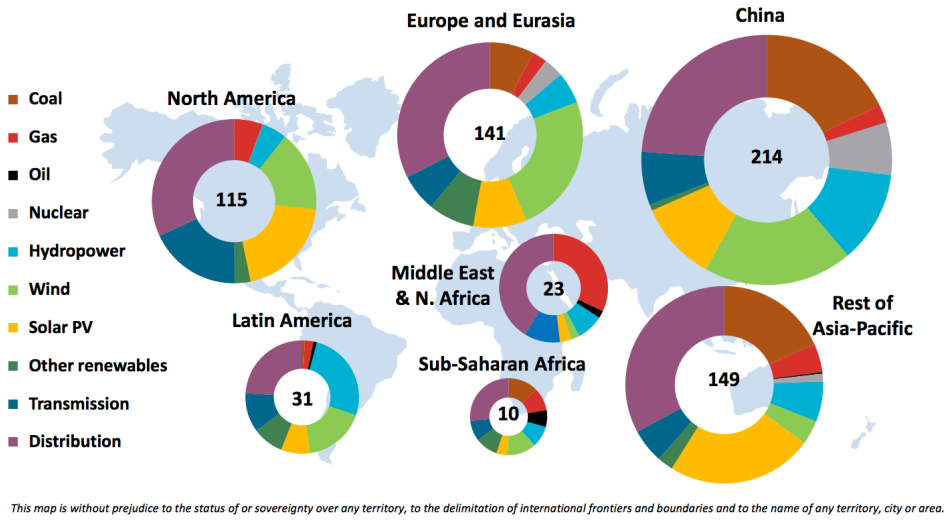
## How is this changing?

**Investment** in <u>electric</u> generation and networks for 2015 (IEA data).




*This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.*

http://www.eco-business.com/news/seven-charts-show-new-renewables-outpacing-rising-demand-for-first-time/

## 3. Primary energy forms and uses

### 3.8: Trends in US energy use

- Some increases in use and in efficiency
- Gains in efficiency lost to increased use for electronics
- Heating may be returning to electricity
- Manufacturing has become more efficient
- Transportation is a huge FF user

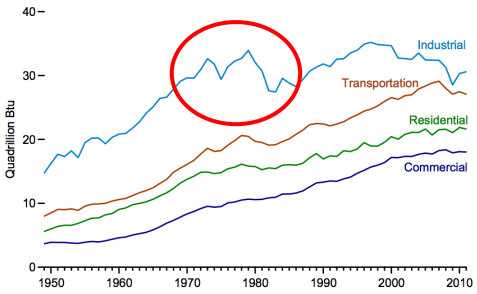
# Growth of consumption by sector

Not surprisingly, energy use most sectors has increased since WWII.

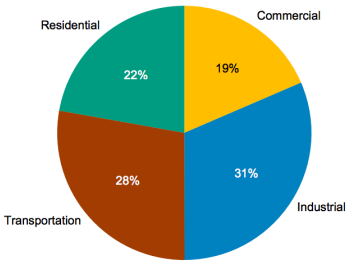
- Why does industrial use seem to be leveling off more than other uses?
- What was going on with industrial use in the late 1970s, early 1980s?

**Figure 2.1a Energy Consumption Estimates by Sector Overview**

**Total Consumption by End-Use Sector, 1949-2011**




**End-Use Sector Shares of Total Consumption, 2011**

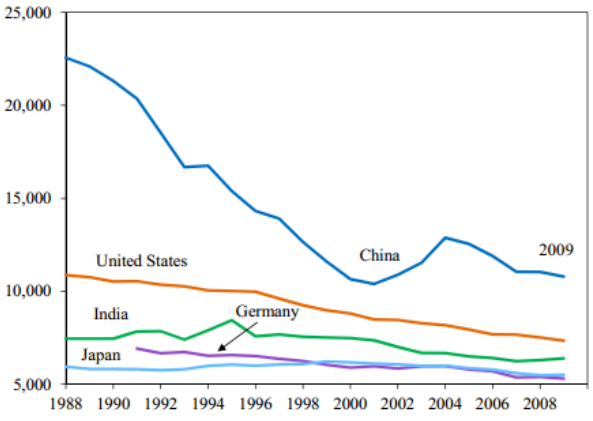



https://www.eia.gov/totalenergy/data/annual/pdf/sec2.pdf

# But efficiency evolves as well

Energy use / $GDP is a measure of a nation's energy efficiency **or** of the nature of the nation's economy.

Energy Use per Dollar of GDP, Selected Countries, 1988–2009
British thermal unit per 2005 U.S. dollar



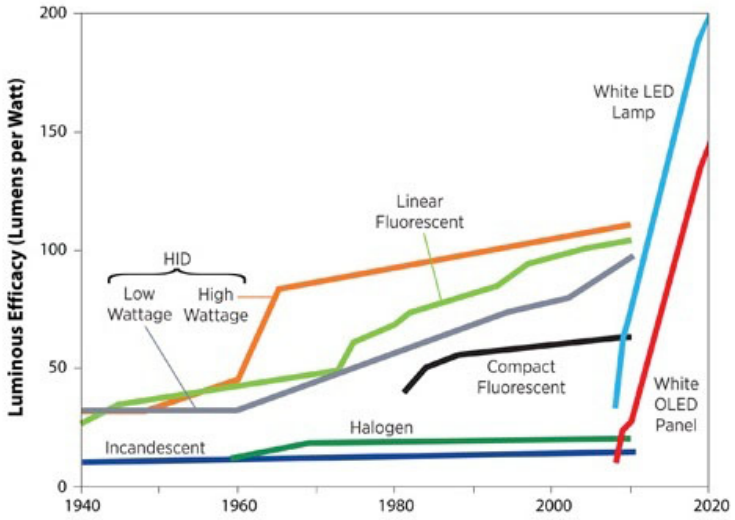

Source: Energy Information Administration, International Energy Statistics.

By the 1990s, the US was manufacturing less than China, but increasing energy costs and scarcity were causing the Chinese economy to become more efficient.

EIA

## Evolution of lighting technologies

Lighting technology continues to become more energy efficient.

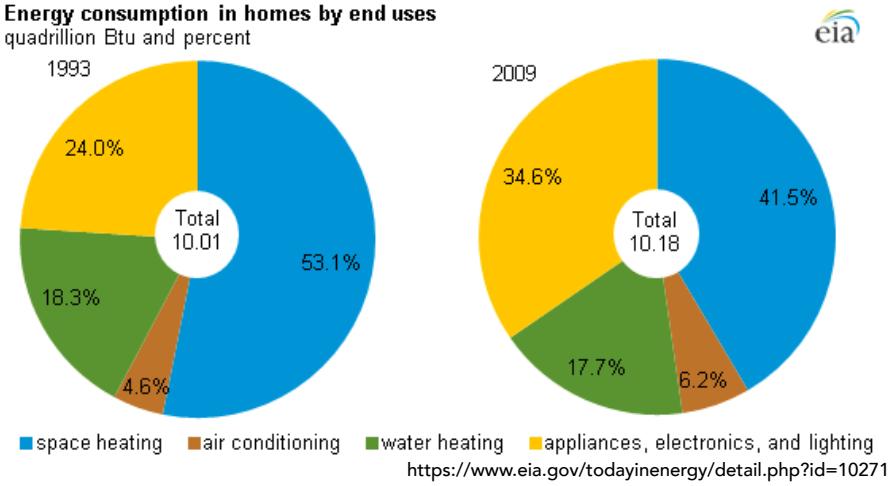



http://www.led-evolution.com/Technology/benefits-of-LED.html

## Domestic energy use

Energy use in homes hasn't changed dramatically, but use has shifted.

- Efficiency has increased, lowering energy use for heating and cooling.
- But energy use for 'electronics' has increased.



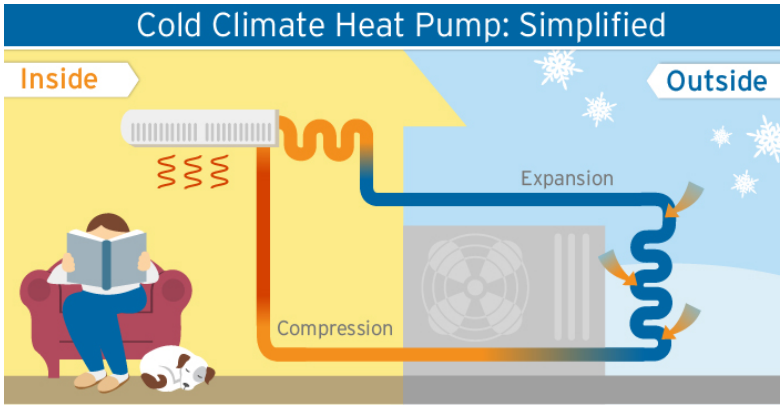

https://www.eia.gov/todayinenergy/detail.php?id=10271

## Heating fuels have also changed

Heating fuels have changed… and changed back!

wood → coal → oil → electricity → natural gas → (RE) electricity

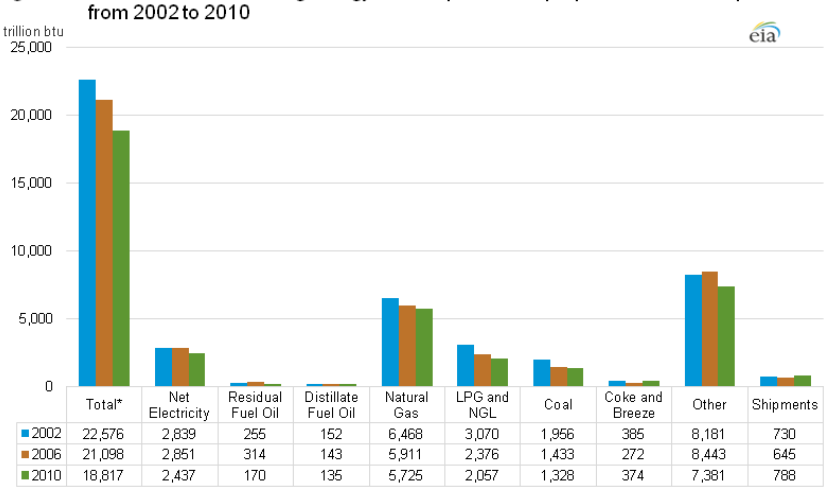
antiquity | 1700 - 1900 | 1900 - | 1970s | 1920 - | 2000s




Efficiency Vermont

## Manufacturing energy use down

Figure 1. Total U.S. manufacturing energy consumption for all purposes declined 17 percent from 2002 to 2010



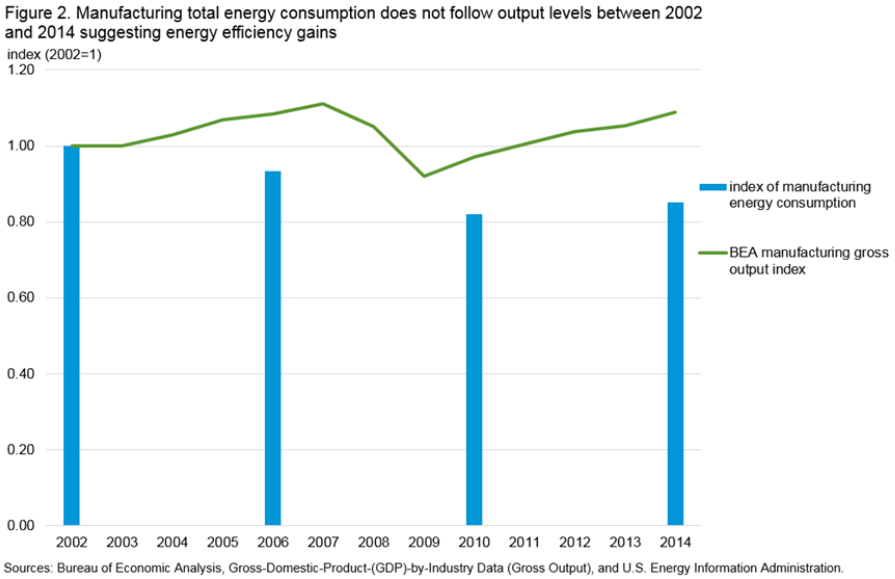

| | Total* | Net Electricity | Residual Fuel Oil | Distillate Fuel Oil | Natural Gas | LPG and NGL | Coal | Coke and Breeze | Other | Shipments |
|---|---|---|---|---|---|---|---|---|---|---|
| 2002 | 22,576 | 2,839 | 255 | 152 | 6,468 | 3,070 | 1,956 | 385 | 8,181 | 730 |
| 2006 | 21,098 | 2,851 | 314 | 143 | 5,911 | 2,376 | 1,433 | 272 | 8,443 | 645 |
| 2010 | 18,817 | 2,437 | 170 | 135 | 5,725 | 2,057 | 1,328 | 374 | 7,381 | 788 |

*Total is the sum of the energy sources minus the shipments. Shipments of energy sources produced onsite are those shipments produced or transformed onsite from the nonfuel use of other energy sources. Shipments are subtracted from the total to avoid duplication.

Source: U.S. Energy Information Administration, Manufacturing Energy Consumption Survey - Table 1.2: First Use of Energy for All Purposes (Fuel and Nonfuel), 2002, 2006, and 2010.

https://www.eia.gov/consumption/manufacturing/

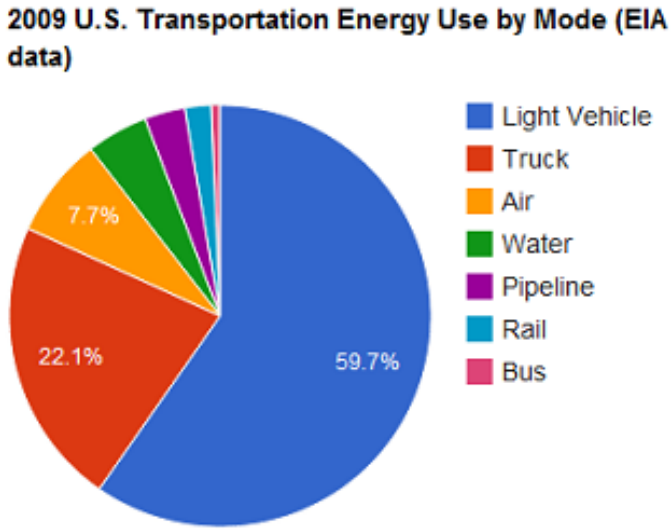
## Manufacturing output, not so clearly




EIA: https://www.eia.gov/consumption/manufacturing/reports/2014/pre_estimates/

## Transportation in the US

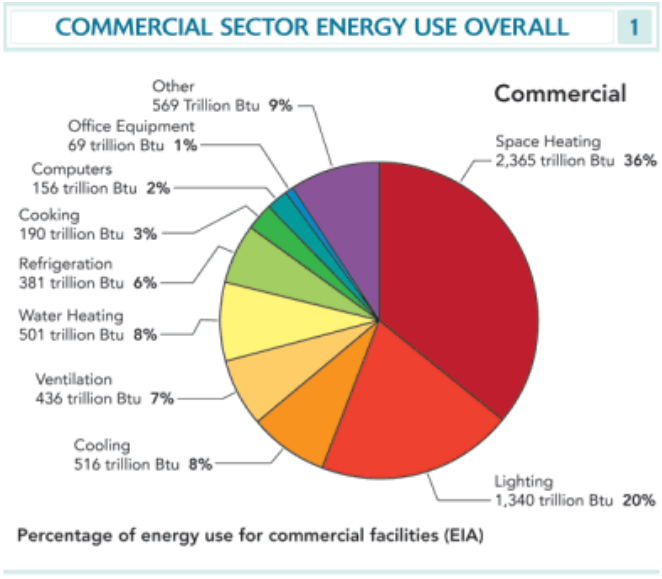
In the US, transportation is dominated by the private auto.




http://news.thomasnet.com/imt/2012/03/12/the-damage-done-gas-addiction-edition-how-detrimental-is-petrol

## Commercial services

Note that heating & lighting account for 2/3 of all energy use.



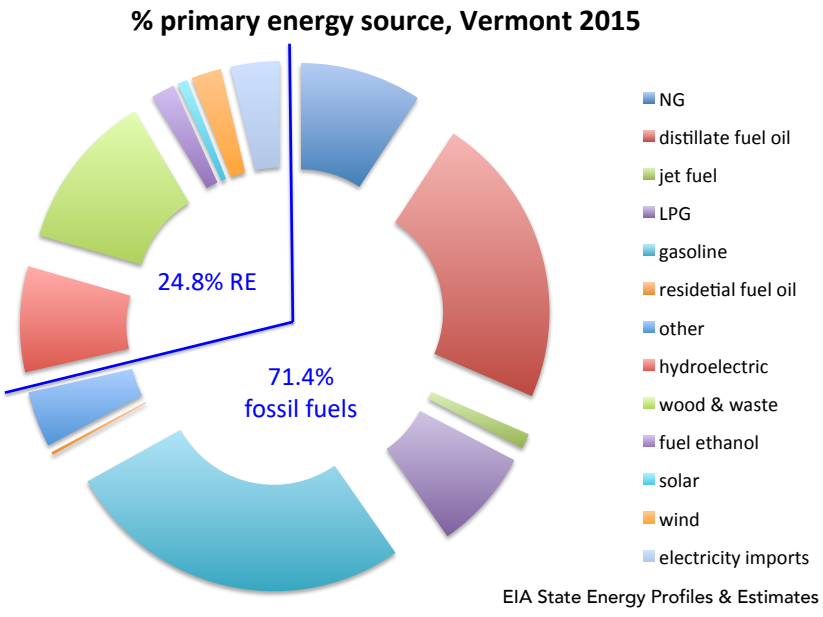

Energy Systems & Sustainability, 2/e, Chapter 3; EIA

## 3. Primary energy forms and uses

**3.9: Vermont energy statistics**

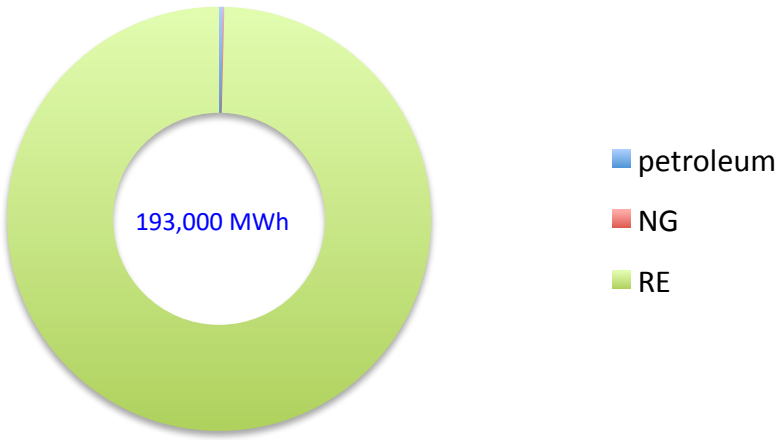
- *RE accounts for ~25% of primary energy*
- *Most electricity supply is RE*
- *Transportation and heating are FF dependent*
- *Energy production and consumption are low.*
- *Energy costs are high*
- *Vermont's Comprehensive Energy Plan is agressive*

## Vermont primary energy use (2015)



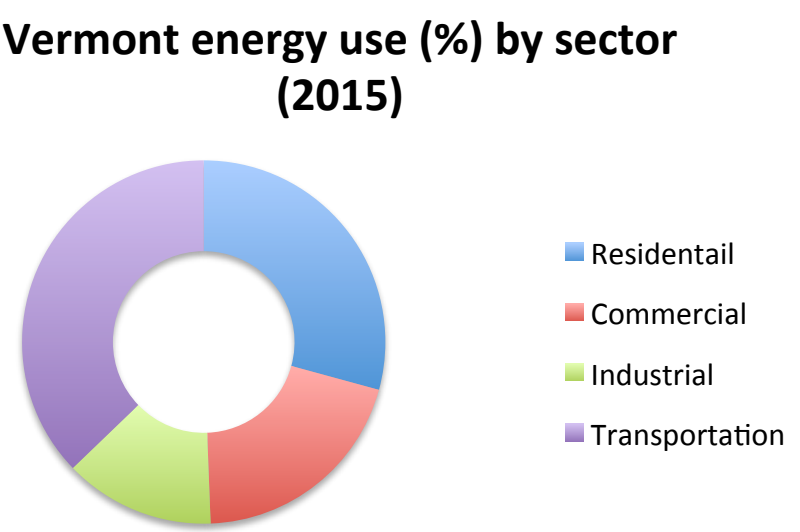

EIA State Energy Profiles & Estimates

## Vermont primary energy use (2015)




EIA State Energy Profiles & Estimates

## Vermont energy use by sector (2015)




EIA State Energy Profiles & Estimates

## Vermont energy stats (2015)

- One in 6 Vermont households uses **wood products** as their primary heating source.
- **Vermont produces less than 35% of its electricity** & depends on power from the New England grid and Canada.
- In 2016, nearly all of Vermont's in-state net electricity generation was produced by **renewable energy**, including hydroelectric, biomass, wind, and solar resources.
- In the years 2011 through 2016, Vermont installed 59.2 megawatts of **commercial-scale solar photovoltaic** capacity, 26.8 megawatts in 2016 alone.
- Vermont has enacted **the nation's first integrated renewable energy standard** (RES), which makes utilities responsible both for supplying renewable electricity and for supporting reductions in customers' fossil fuel use.

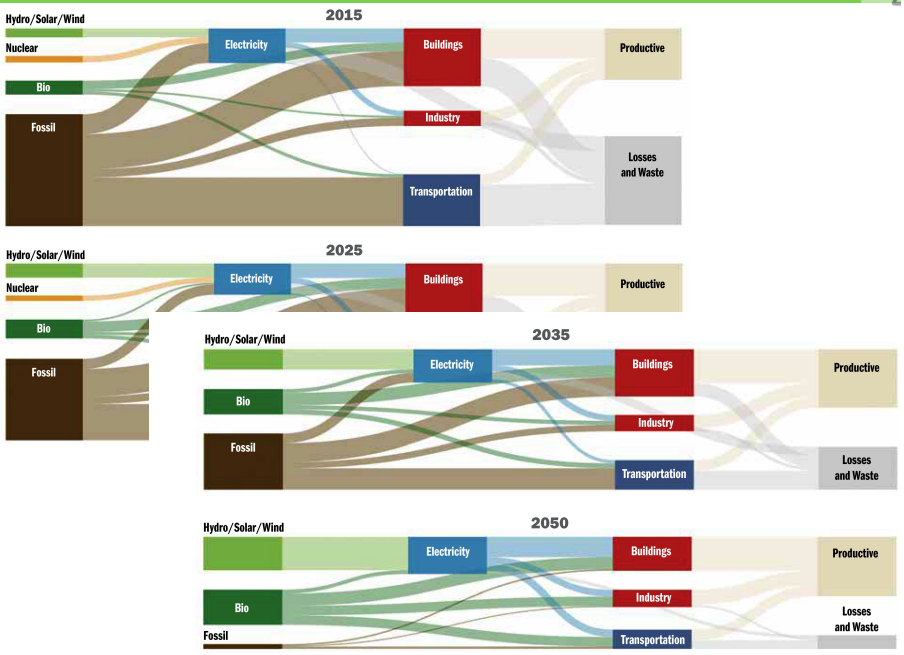
EIA State Energy Profiles & Estimates

# Vermont energy stats (2015)

| | value | US ranking |
|---|---|---|
| Population | 600,000 | |
| Labor force | 300,000 | |
| GDP | $31.1 billion | 51 |
| Average temperature | 44.7 F | 43 |
| Average rainfall | 39.1 inches | 24 |
| Per capita income | $50,321 | 20 |
| Total energy consumption | | 50 |
| Energy consumption per capita | 211 million Btu/year | 44 |
| Energy cost per capita | $4,273 | 9 |
| Energy production | | 47 |
| Electricity production | | 50 |
| RE production | 204,000 MWh | |
| RE consumption | 24.9% of all energy consumption | 8 |
| Electricity costs | | 8 |
| Energy intensity | 8,1000 Btu/$ GDP | |
| Total carbon emissions | 6 millionn metric tonnes $CO_2$ | 50 |

EIA State Energy Profiles & Estimates

# Vermont Comprehensive Energy Planning




http://www.vtenergydashboard.org/90-by-2050/detail/2016-comprehensive-energy-plan