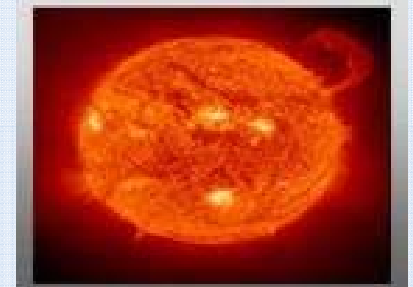
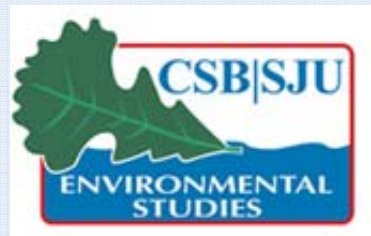


How We Use Energy and Why It Matters



Dr. Derek Larson

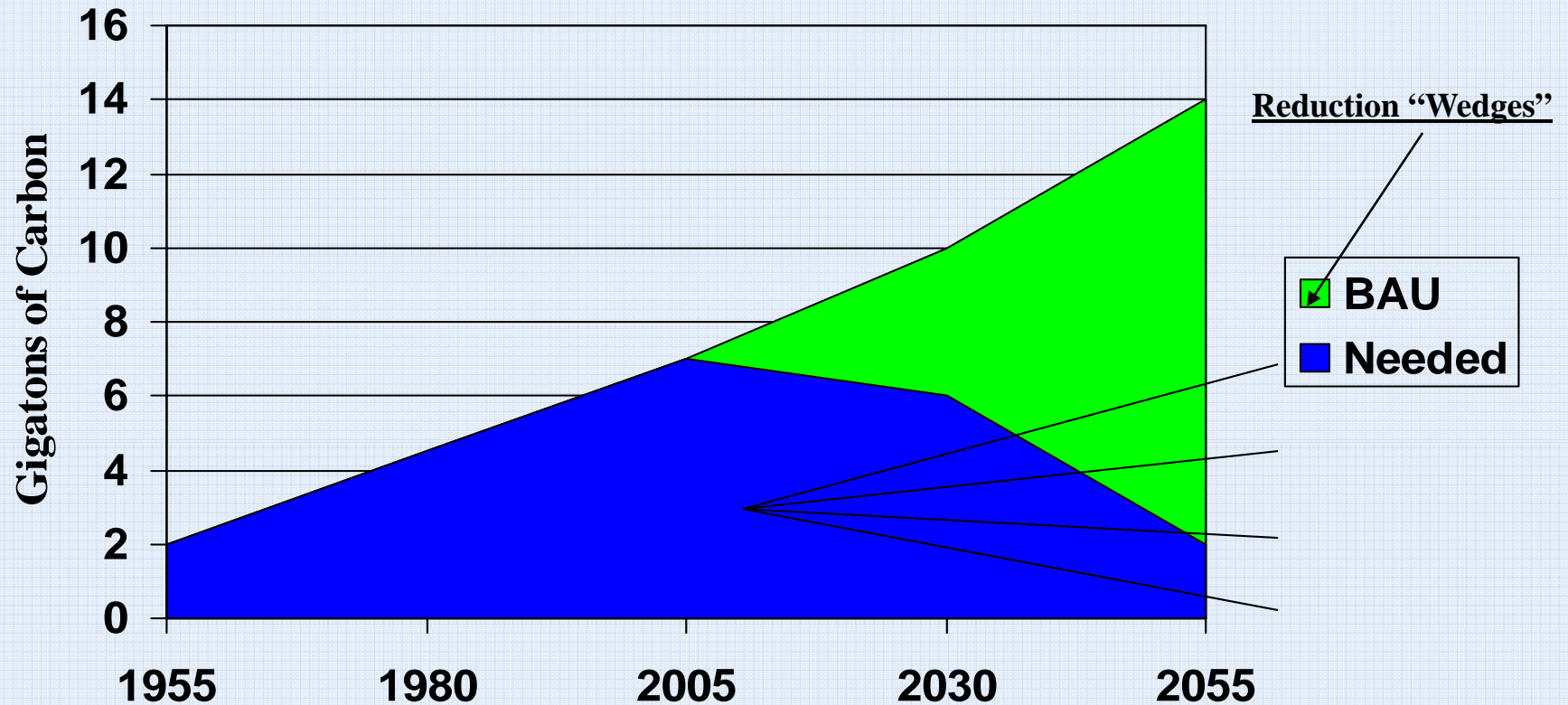
CSB/SJU Environmental Studies Department



Why energy matters

- We use energy 24 hours a day, every day for heat, light, moving water, transportation, manufacturing, and millions of other purposes.
- Energy consumption drives our 21st century technological society and economy. Without it we would have to live a 19th century lifestyle.
- Energy is expensive, accounting for ~9% of the US GDP in 2008 or ~\$4,000 per capita.
- Energy security presents a major challenge as we import ~30% of our total energy used.
- Our use of fossil-fuel based energy is a major contributor to global climate disruption that threatens the future of billions of human and other life forms.
- Learning to use energy more efficiently– and developing the technologies to support that effort –could revitalize the American economy.

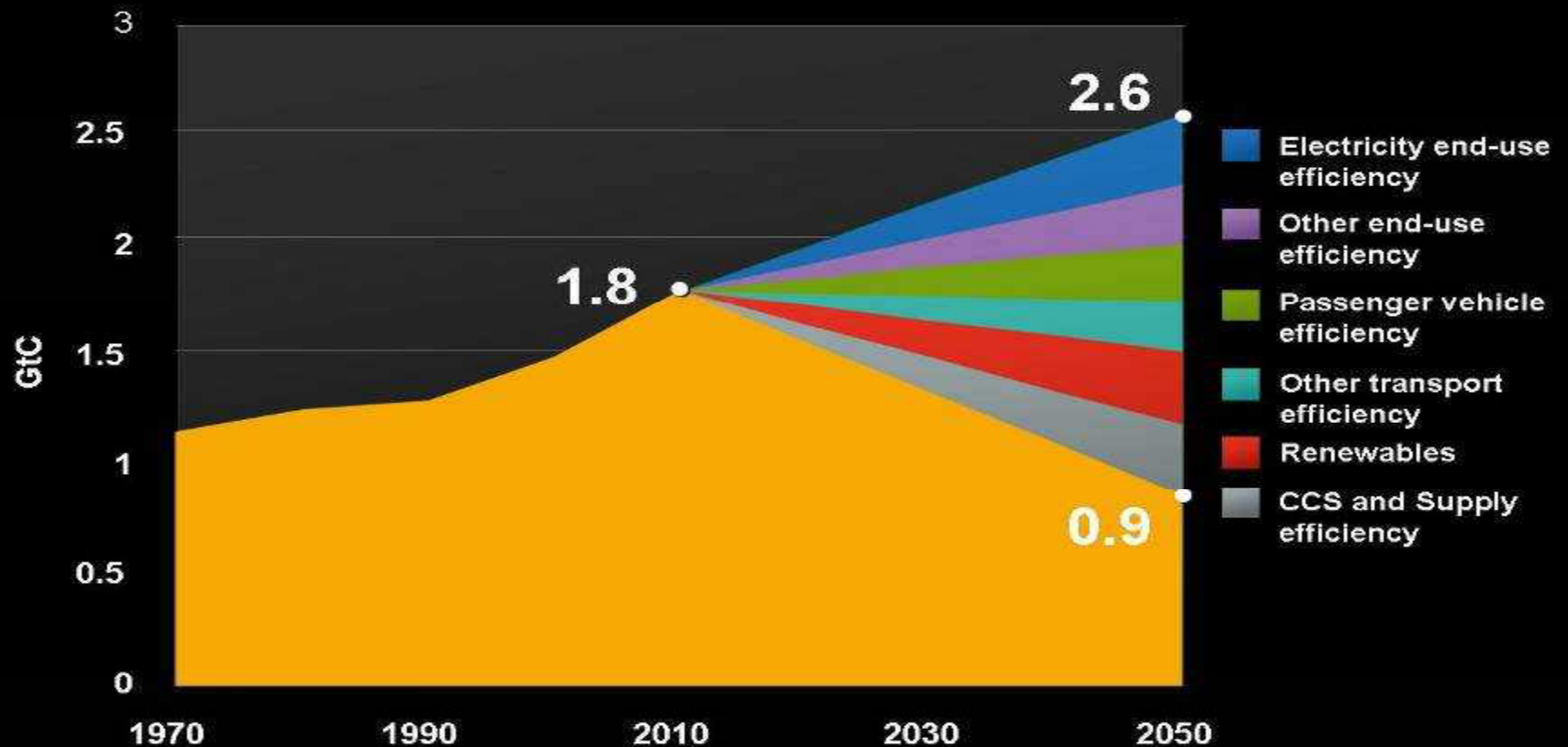
What “business as usual” will bring



Atmospheric CO₂ concentrations exceeding 500ppm by 2055,
a 100% increase over 50 years

“Wedges” to stabilize US emissions

U.S. Stabilization



But how do we get there really?

There are many paths to reducing our dependence on high-carbon energy sources. Rather than a single “silver bullet” we will have to adopt a multi-faceted approach to energy conservation and alternative energy sources.

- **Demand reduction**
- **Efficiency increases**
- **Technological fixes**
- **Alternative sources**
- **Lifestyle and behavioral changes**

Any chance of success will require education to inform the public, grow the minds and skills that will create innovative solutions, and to develop leaders with the intellectual capacity and vision to understand the challenge and seek solutions that are environmentally, economically, and socially sustainable.

What is this “energy” anyway?

Physics

- *energy* is the ability to move matter (including heat) or perform work
- *kinetic* energy is energy in action (light, heat, motion, etc.)
- *potential* energy is energy in storage (capacity to release kinetic energy)

Note: “power” is not the same as “energy” despite common usage! Power is the *rate at which energy is consumed*, while energy is the *ability to do work*. Electrical *energy* use is typically noted in kilowatt-hours (with the time factor) while electrical *power* (rate of production or consumption) is simply rated in watts or kilowatts.

Primary vs. Secondary Energy

- *Primary energy* is that found in its natural state and not converted. It includes fossil fuels, biomass, nuclear fuels, and all renewables (including kinetic energy, as in wave motion).
- *Secondary energy* is primary energy that has been converted to a useable form, such as electricity, refined petroleum, or hydrogen.
- Energy analysts tend to cite *primary energy* when examining large scale issues (global demand, reserve estimation, sector capacity) and *secondary energy* when talking about smaller scale demands.

We will focus mostly on *secondary energy*, how it is produced and used, and what we might do with this information in the classroom.

TANSTAFL*

*There Ain't No Such Thing As A Free Lunch

Essential Thermodynamics

- The first law of thermodynamics (AKA “the law of conservation of energy”) states that *energy is neither created nor destroyed, but may be converted from one form to another.*
- The second law of thermodynamics states that *in any energy conversion some of the useable energy is always lost.*

Thermodynamics thus tells us that we cannot get something for nothing and that no process is 100% efficient. Converting from coal to steam to rotational motion to electricity, for example, will waste a large percentage of the primary energy present in the coal.

Units of energy

Many different units are used to measure and discuss energy, ranging from the “electronvolt” of atomic physics to the “megaton” of atomic weapons.

Common units that appear in discussions of energy in the U.S. will include

- *Joules*, the basic energy units of the metric system (the force of one Newton acting through one meter)
- *calories* (metric) and *Btus* (imperial), both measures of thermal energy
- *kilowatt-hours*, the standard unit of electrical production and consumption over time
- *barrels* of oil (standardized to 42 US gallons)
- *therms* of natural gas (approx. 100 cubic feet)
- *cubic feet* of natural gas (expressed in thousands as “MCF”)
- *short tons* of coal (2,000 lbs in US)
- *tons of cooling capacity* (energy required to melt 2,000 lbs of ice in 24 hours)

Units of energy: the BTU

Working with the many different fuels requires converting figures to a common unit. In Europe this is typically the Joule but in the US we use the British Thermal Unit (Btu) for conversion. A Btu is *the amount of heat necessary to raise one pound of water by 1 degree Fahrenheit*. Using Btus as common units allows us to compare the energy content of various fuels and to calculate equivalent energy content for different sources.

Frequently used Btu equivalencies include

- 1,055 Joules = 1 Btu
- 1 cubic ft natural gas = 1,128 Btu
- 1 therm natural gas = 100,000 Btu
- 1 kWh electricity = 3,412 Btu
- 1 gallon propane = 91,000 Btu
- 1 gallon gasoline = 124,000 Btu
- 1 gallon heating oil (diesel) = 139,000 Btu
- 1 barrel crude oil = 5.8 million Btu
- 1 short ton of coal = 20.17 million Btu

Units of energy: conversion

Comparing different fuels requires converting to common units.
This is most often done using the Btu in the United States.

Example: an older home is still heated with oil and used 100 gallons last January.
How can we decide if switching to another fuel makes economic sense?

100 gallons heating oil	=13,900,000 Btu=	(at \$1.73/gallon)
4073 kWh electricity	=13,900,000 Btu=	(at \$.085/kWh)
152 gallons propane	=13,900,000 Btu=	(at \$1.51/gallon)
147 therms gas	=13,900,000 Btu=	(at \$1.03/therm)

Q: Which fuel makes the most sense to the home owner economically, assuming appliances of equivalent efficiency?

Units of energy: conversion

Comparing different fuels requires converting to common units.
This is most often done using the Btu in the United States.

Example: an older home is still heated with oil and used 100 gallons last January.
How can we decide if switching to another fuel makes economic sense?

100 gallons heating oil	=13,900,000 Btu=	\$173 (at \$1.73/gallon)
4073 kWh electricity	=13,900,000 Btu=	\$346 (at \$.085/kWh)
152 gallons propane	=13,900,000 Btu=	\$230 (at 1.51/gallon)
147 therms gas	=13,900,000 Btu=	\$143 (at 1.03/therm)

A: This calculation helps explain why most homes in our area are heated with natural gas. But why do most rural homes use propane rather than oil?

Units used in this workshop

- We will be focusing on electrical energy, so will be using *kilowatt-hour (kWh)* most often.
- The kilowatt-hour (kWh) represents production or use of 1,000 watts over a period of one hour...or one watt over 1,000 hours.

Example: a single 100 watt incandescent light bulb uses 1 kWh over 10 hours, the same amount of energy that would be consumed by ten 10 watt CFL bulbs over 10 hours.

- When talking about motor fuels we will use *barrel (bbl)* which is 42 US gallons.

Scaling units: electricity

Watt: one joule per second, a unit of power named for Scottish inventor James Watt

- 4 W - the power consumption of an incandescent night light
- 14 W - the power consumption of a typical compact fluorescent light bulb
- 60 W - the power consumption of a typical incandescent light bulb
- 120 W - power output of 1 m² solar panel in full sunlight (approx. 12% efficiency)
- 745.7 W – equivalent to 1 horsepower

kilowatt (10³ or 1,000 watts)

megawatt (10⁶ or 1,000,000 watts)

gigawatt (10⁹ or 1,000,000,000 watts)

terawatt (10¹² or 1,000,000,000,000 watts)

petawatt (10¹⁵ or 1,000,000,000,000,000 watts)

Scaling units: electricity

Kilowatts are used for small-scale demand (i.e. residential) and production (i.e. solar PV, medium-sized wind turbines).

watt

kilowatt (10^3 or 1,000 watts)

- 1.366 kW - power received from the sun at the earth's orbit by one square meter
- 11.4 kW - average power consumption per person in the United States

megawatt (10^6 or 1,000,000 watts)

gigawatt (10^9 or 1,000,000,000 watts)

terawatt (10^{12} or 1,000,000,000,000 watts)

petawatt (10^{15} or 1,000,000,000,000,000 watts)

Scaling units: electricity

Megawatts are used to measure production of commercial-scale power plants, wind turbines, and solar farms.

watt

kilowatt (10^3 or 1,000 watts)

megawatt (10^6 or 1,000 kilowatts or 1,000,000 watts)

- 1.5 MW - peak power output of a typical commercial-scale wind turbine
- 600 MW- planned capacity for Monticello nuclear power plant
- 2,400 MW- combined capacity of three generating units at Sherco coal plant

gigawatt (10^9 or 1,000,000,000 watts)

terawatt (10^{12} or 1,000,000,000,000 watts)

petawatt (10^{15} or 1,000,000,000,000,000 watts)

Scaling units: electricity

Gigawatts are used when discussing large electrical grids or massed demand on a regional/national scale.

watt

kilowatt (10^3 or 1,000 watts)

megawatt (10^6 or 1,000,000 watts)

gigawatt (10^9 or 1,000 megawatts or 1,000,000,000 watts)

- 2.074 GW - peak power generation of [Hoover Dam](#)
- 55 GW - peak daily electrical power consumption of [Great Britain](#) in November [2008](#)

terawatt (10^{12} or 1,000,000,000,000 watts)

petawatt (10^{15} or 1,000,000,000,000,000 watts)

Scaling units: electricity

Terawatts are used when calculating very large scale demand, as for a nation or continent.

watt

kilowatt (10^3 or 1,000 watts)

megawatt (10^6 or 1,000,000 watts)

gigawatt (10^9 or 1,000,000,000 watts)

terawatt (10^{12} or 1,000 gigawatts or 1,000,000,000,000 watts)

- 1 TW- peak power of a typical lightning bolt (but for nanoseconds)
- 3.34 TW - average total (gas, electricity, etc) power consumption of the [U.S.](#) in [2005](#)
- 15 TW - average total power consumption of the human world in [2004](#)

petawatt (10^{15} or 1,000,000,000,000,000 watts)

Scaling units: electricity

Petawatts are used only in extreme calculations on a planetary scale.

watt

kilowatt (10^3 or 1,000 watts)

megawatt (10^6 or 1,000,000 watts)

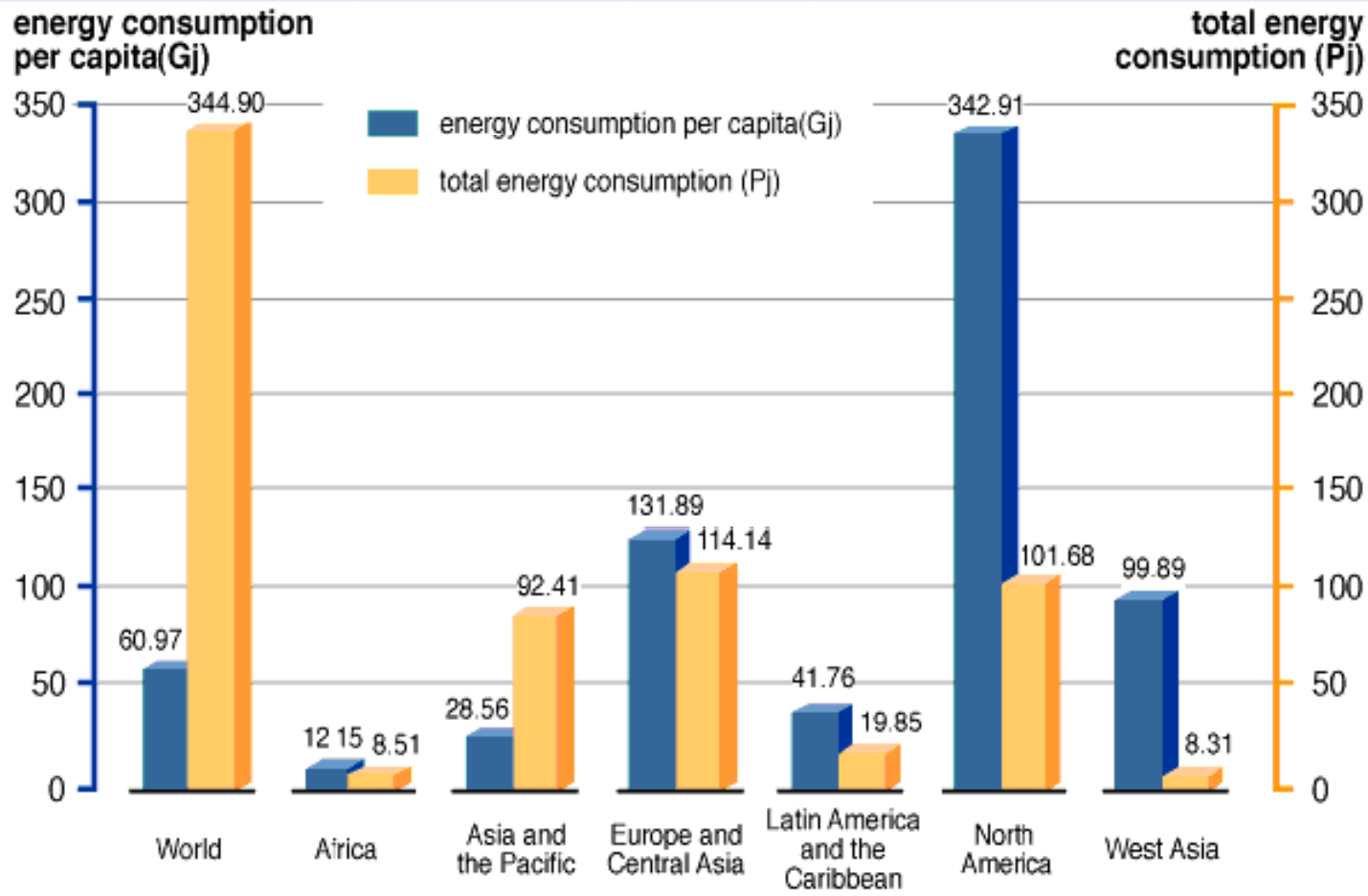
gigawatt (10^9 or 1,000,000,000 watts)

terawatt (10^{12} or 1,000,000,000,000 watts)

petawatt (10^{15} or 1,000 terawatts or 1,000,000,000,000,000 watts)

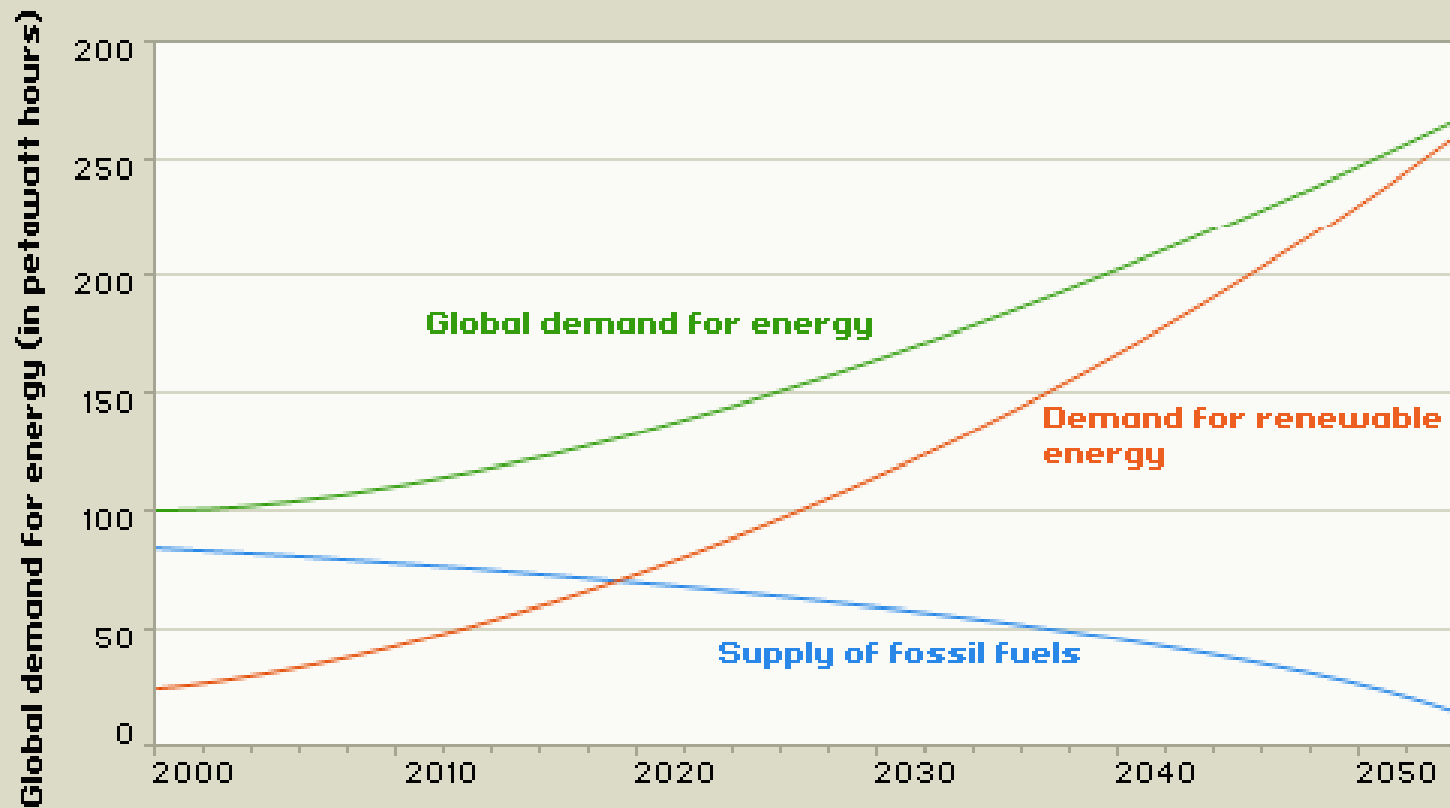
- 1.4 PW - estimated heat flux transported by the [Gulf Stream](#).
- 174 PW - total power received by the [earth](#) from the [sun](#)

Global energy consumption

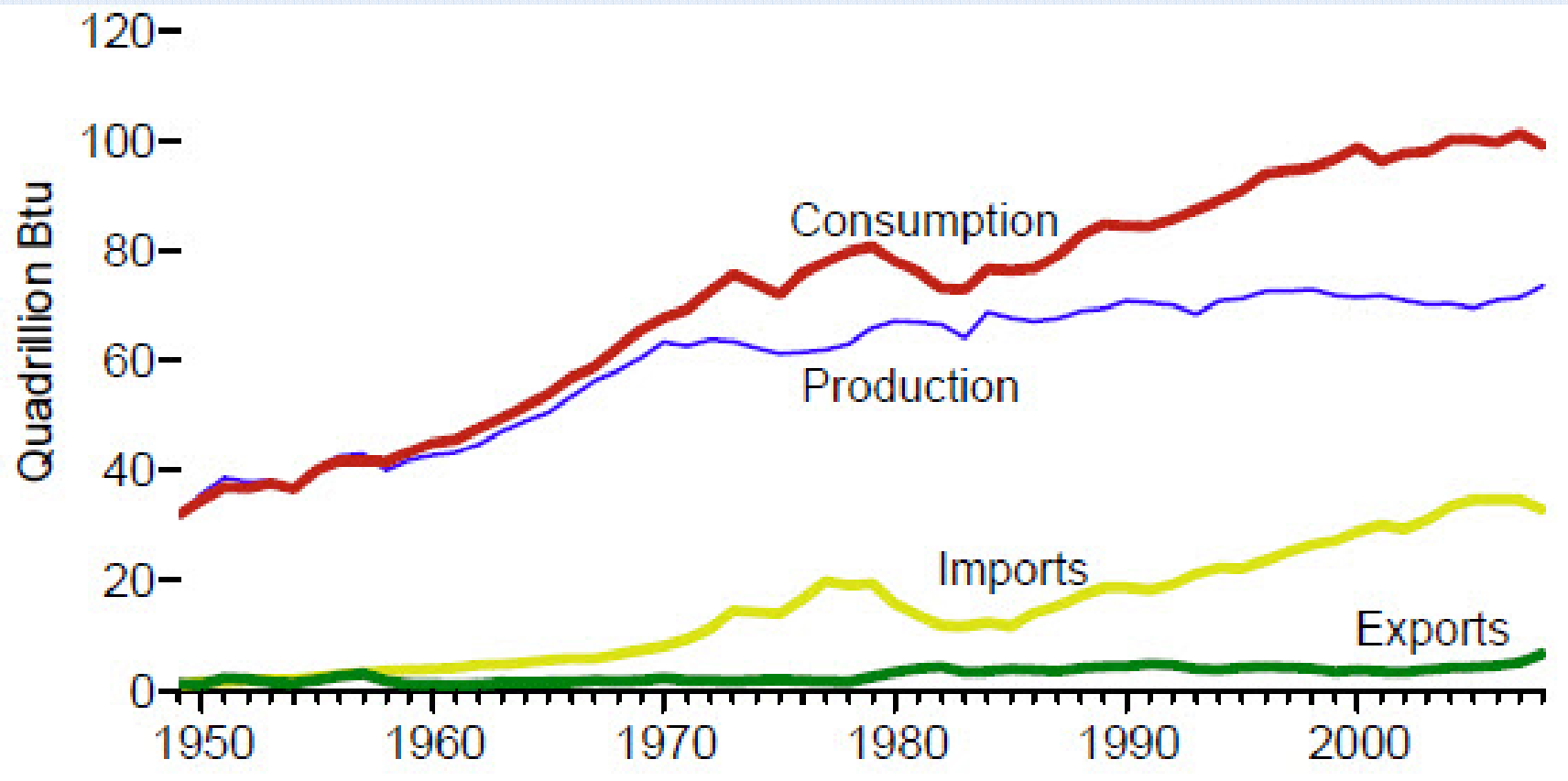


Global energy demand trends

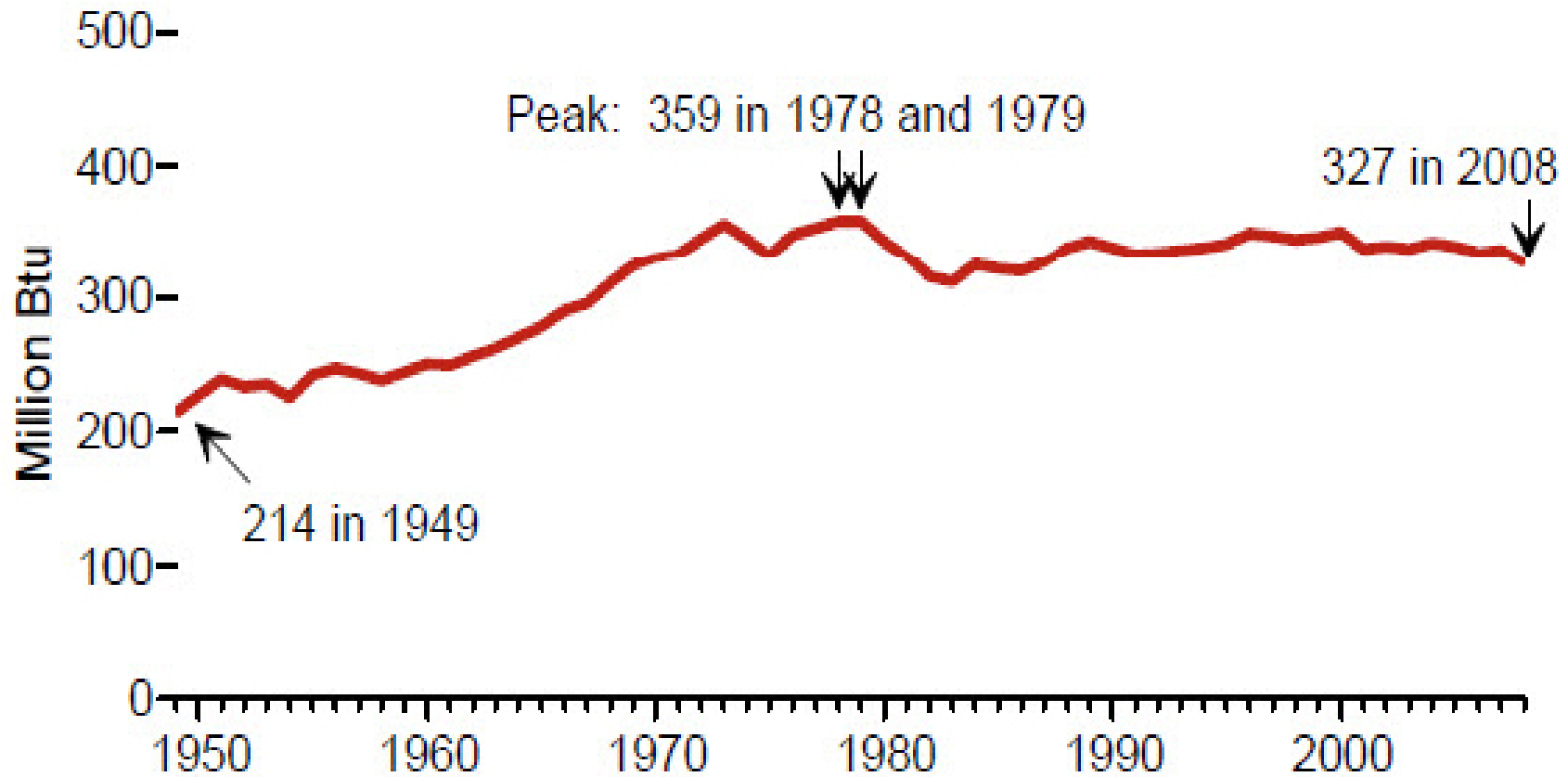
Global demand for energy



US primary energy overview

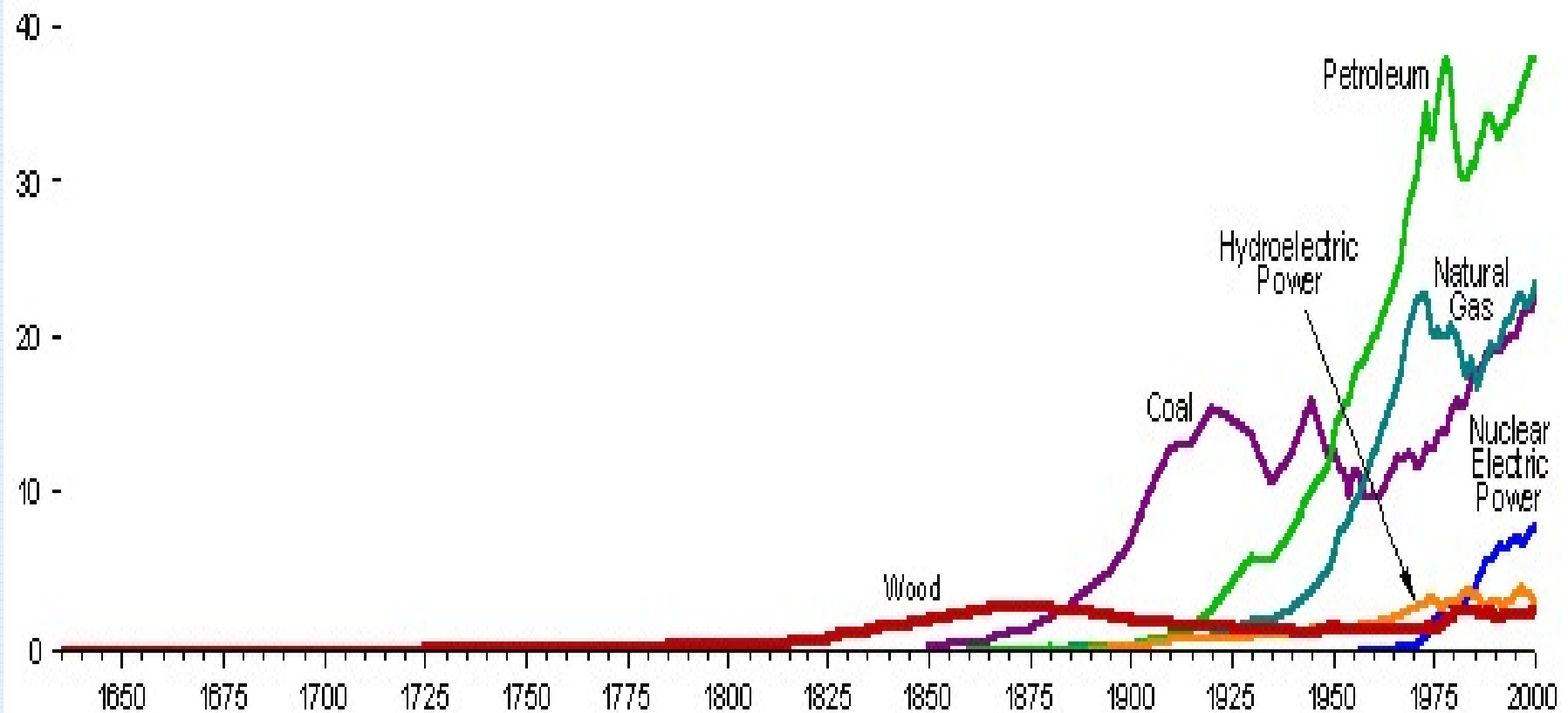


US per capita consumption



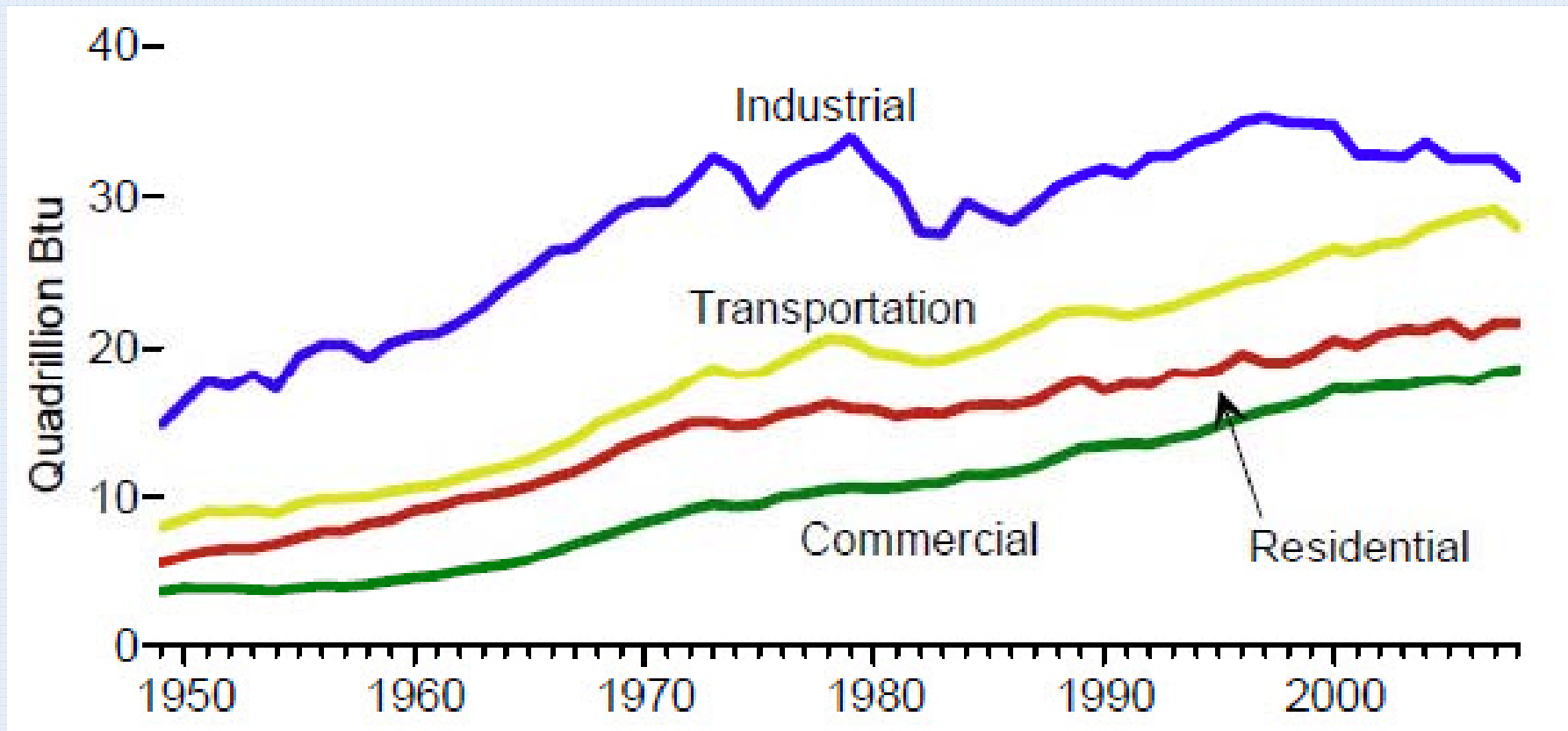
US energy consumption by source

(quadrillion Btu)



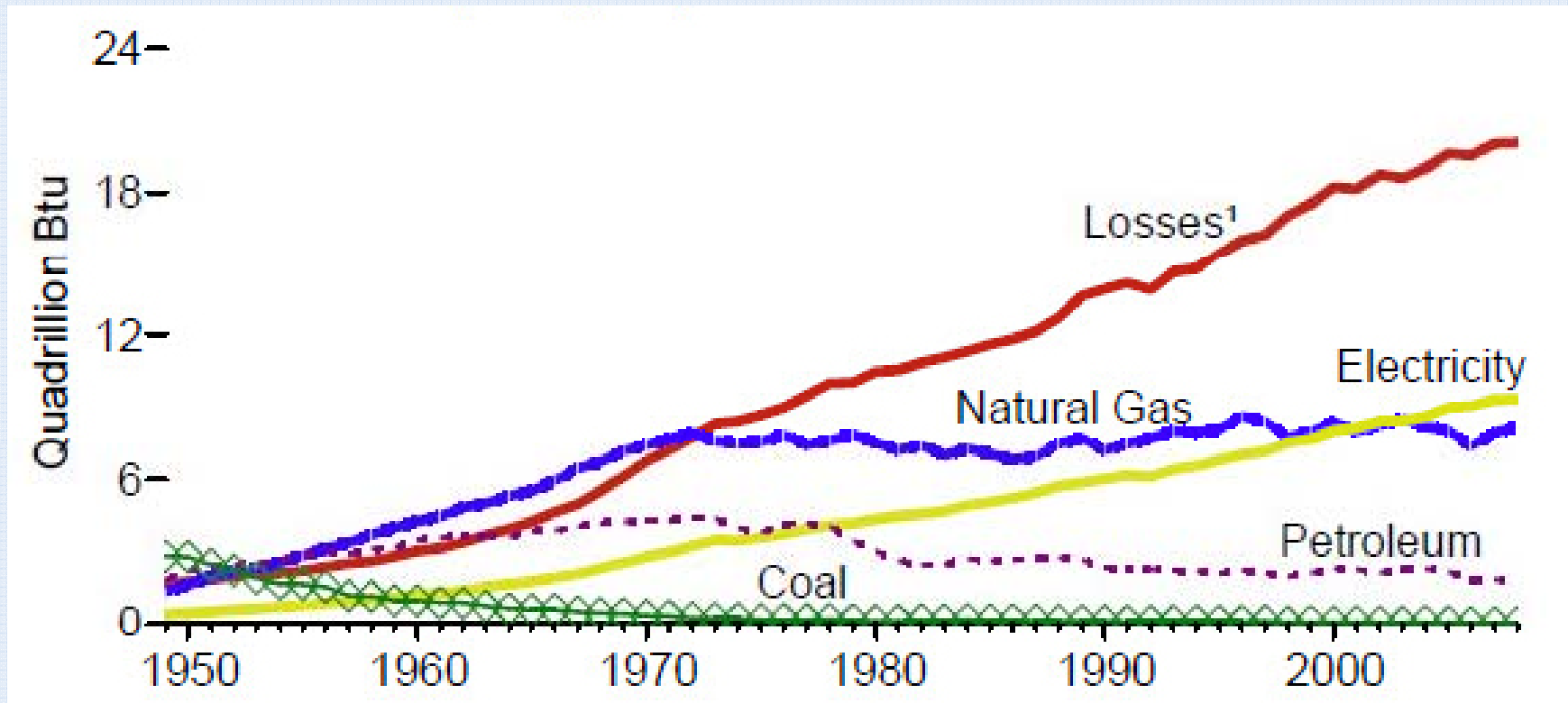
Source: <http://www.eia.doe.gov/aer/eh/frame.html>

US energy consumption by sector



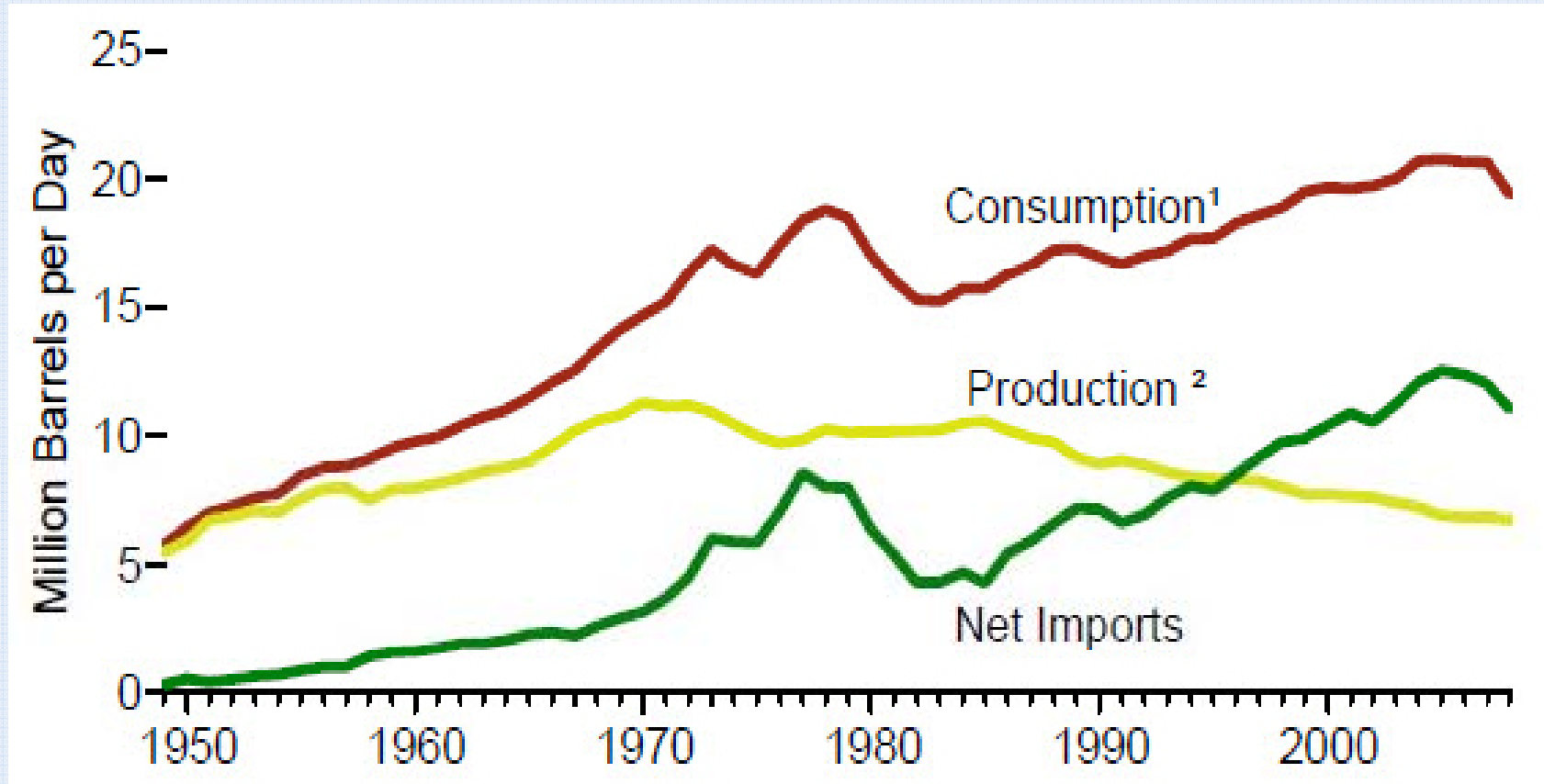
US energy consumption by source

(residential and commercial)



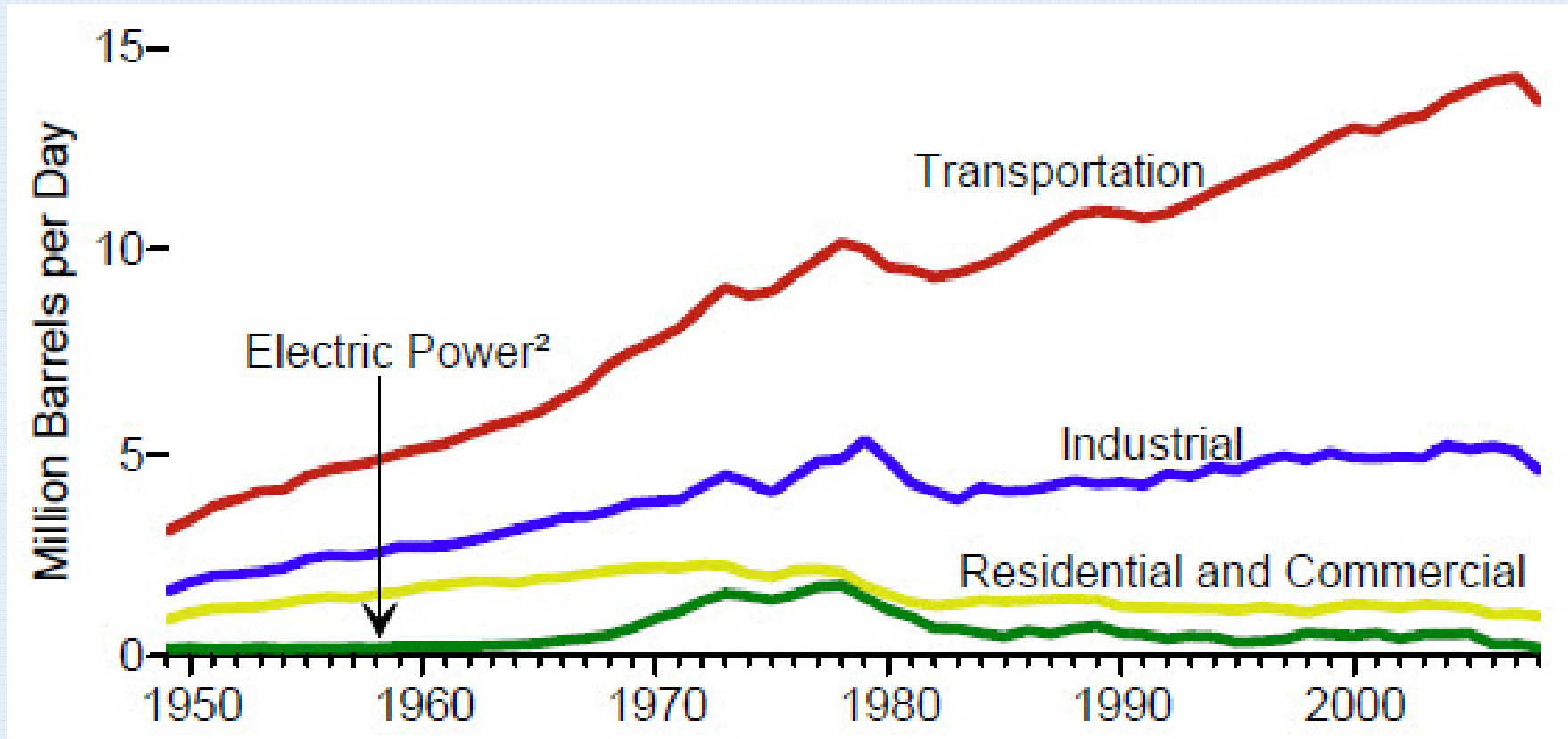
Note: "losses" include energy lost during generation, transmission, and distribution of electricity

US petroleum production & consumption



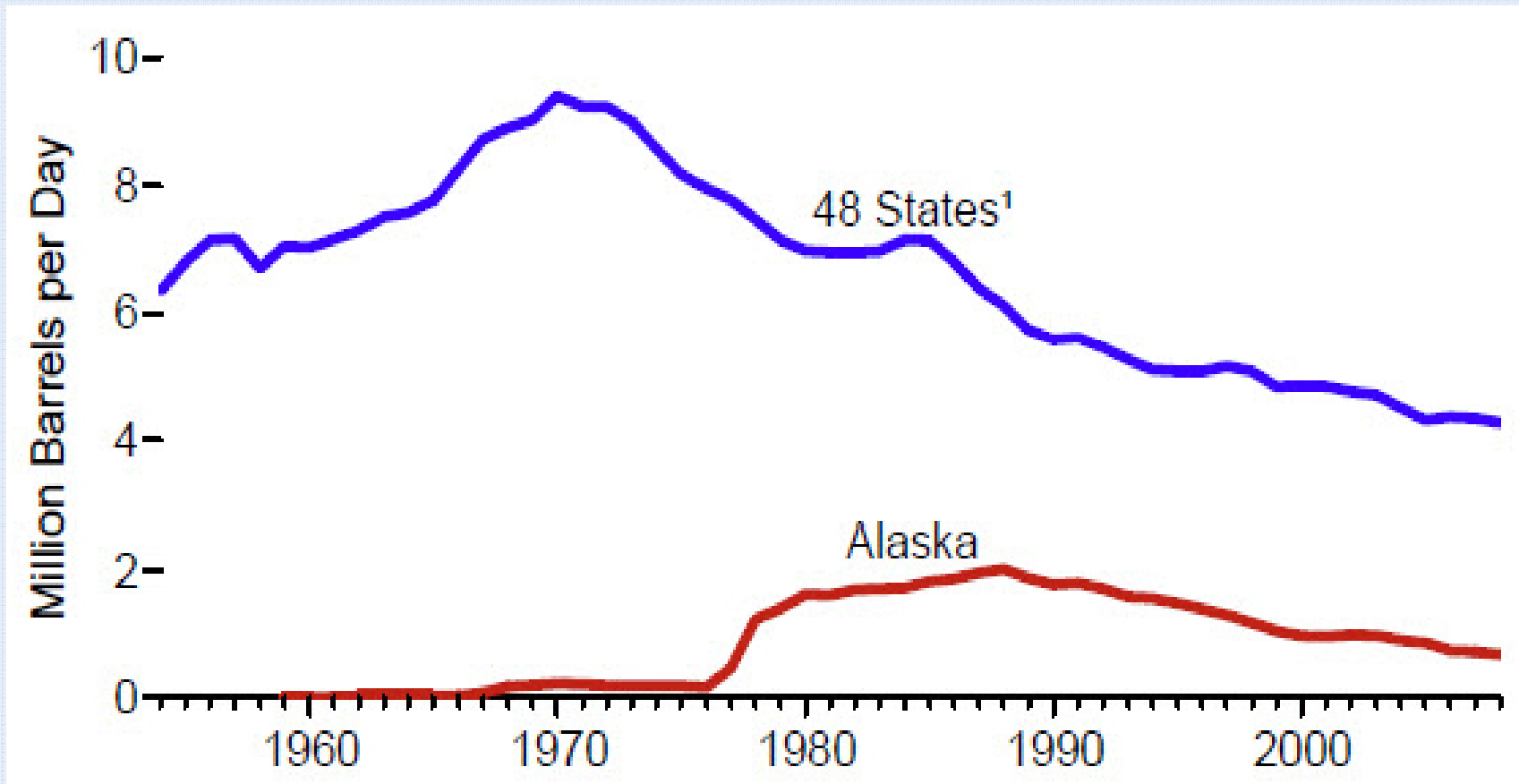
Note: U.S. petroleum production peaked at 11.3 million barrels per day in 1970. By 1996, net imports exceeded production.

US petroleum consumption by sector



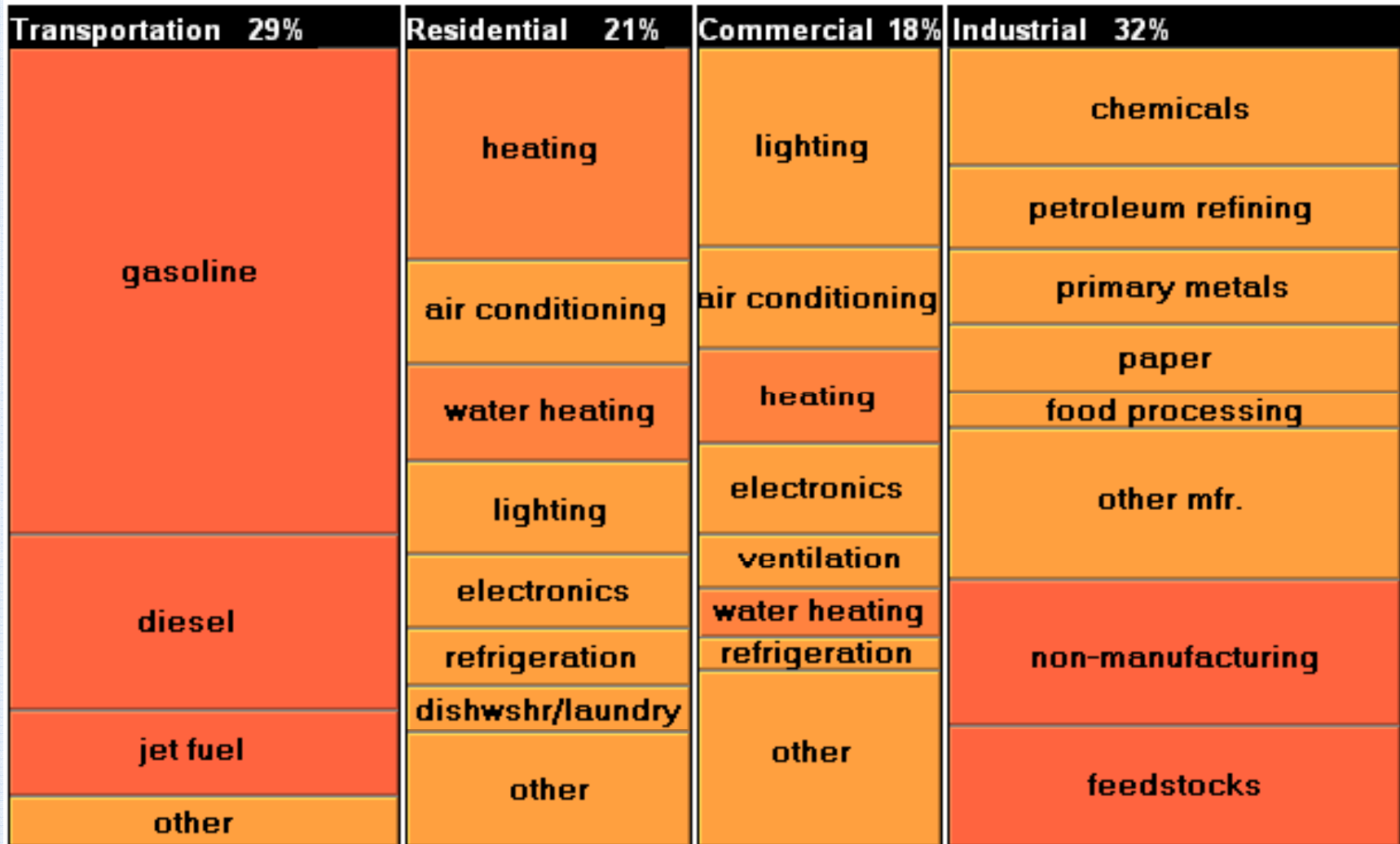
In 2008, 13.7 million barrels per day of petroleum products were consumed for transportation purposes, accounting for 70 percent of all petroleum used.

US petroleum production



US production peaked in the 48 States at 9.4 million barrels per day in 1970. Alaskan production peaked at 2.0 million barrels per day in 1988; in 2008, Alaska's production had declined 66% from its peak level.

U.S. Energy Consumption, by End-Use

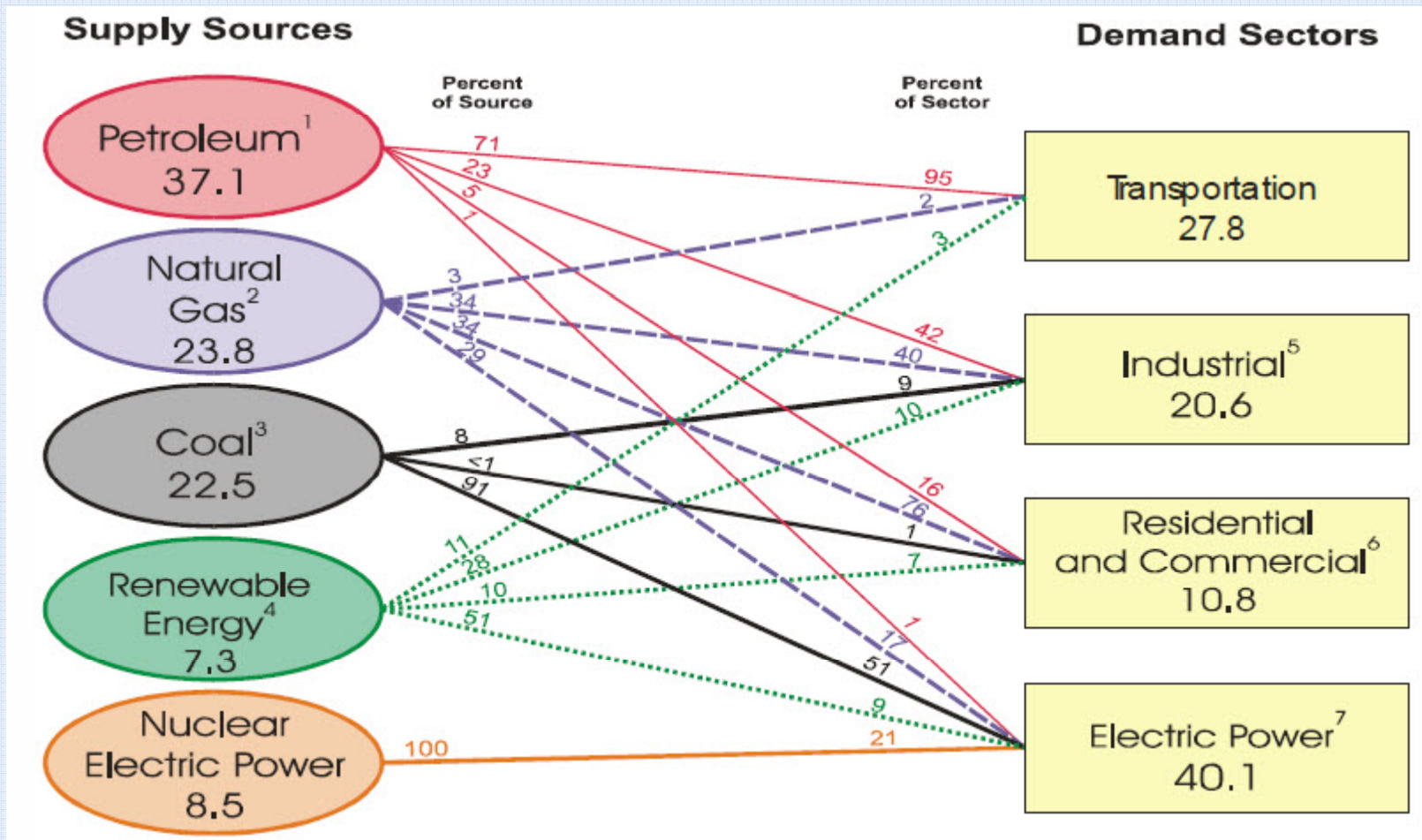


Fuel source:

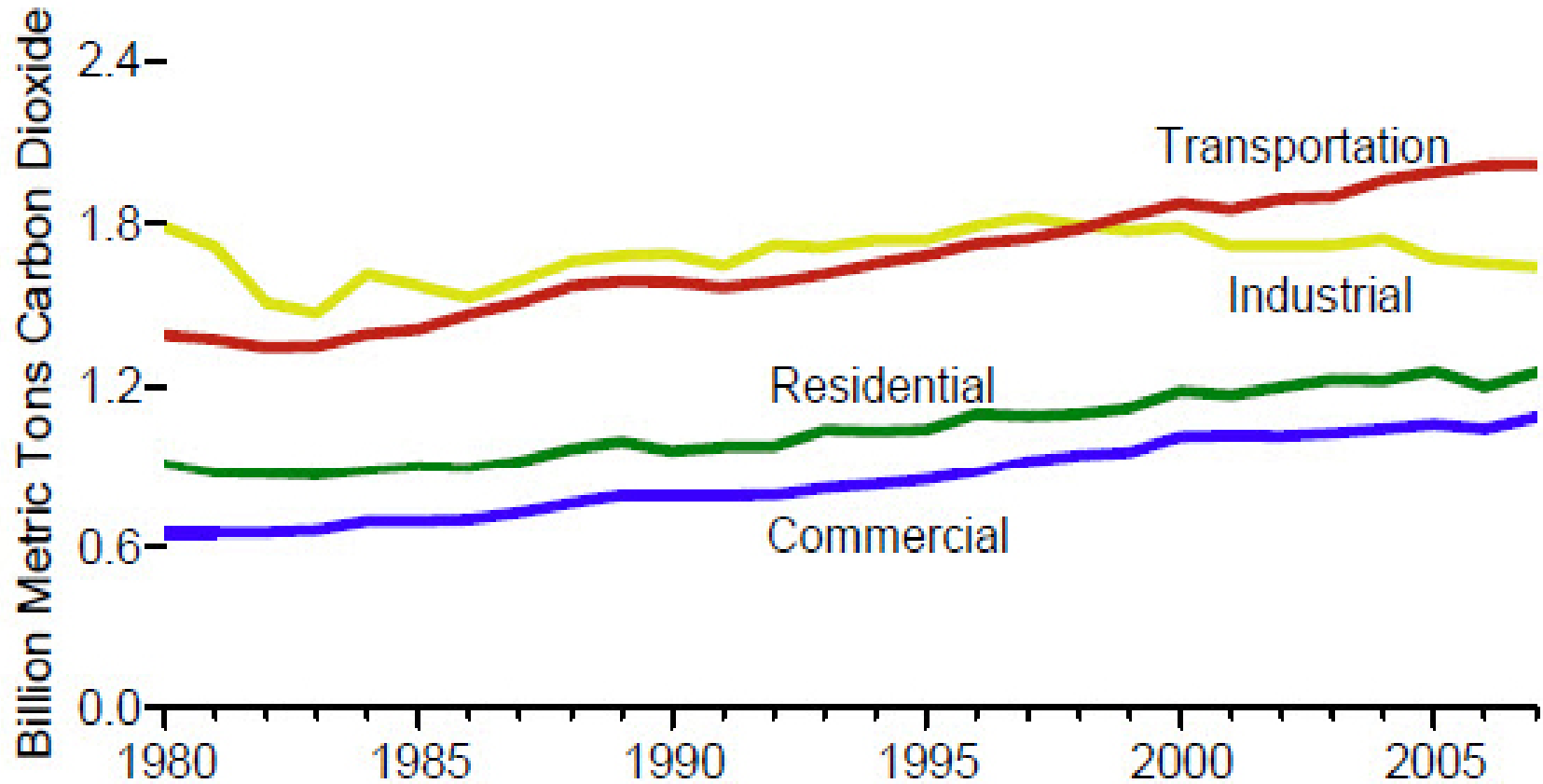
- primarily petroleum
- primarily natural gas
- mix: natural gas, coal, nuclear, hydroelectric, renewables

US net energy supply and demand

(2008)



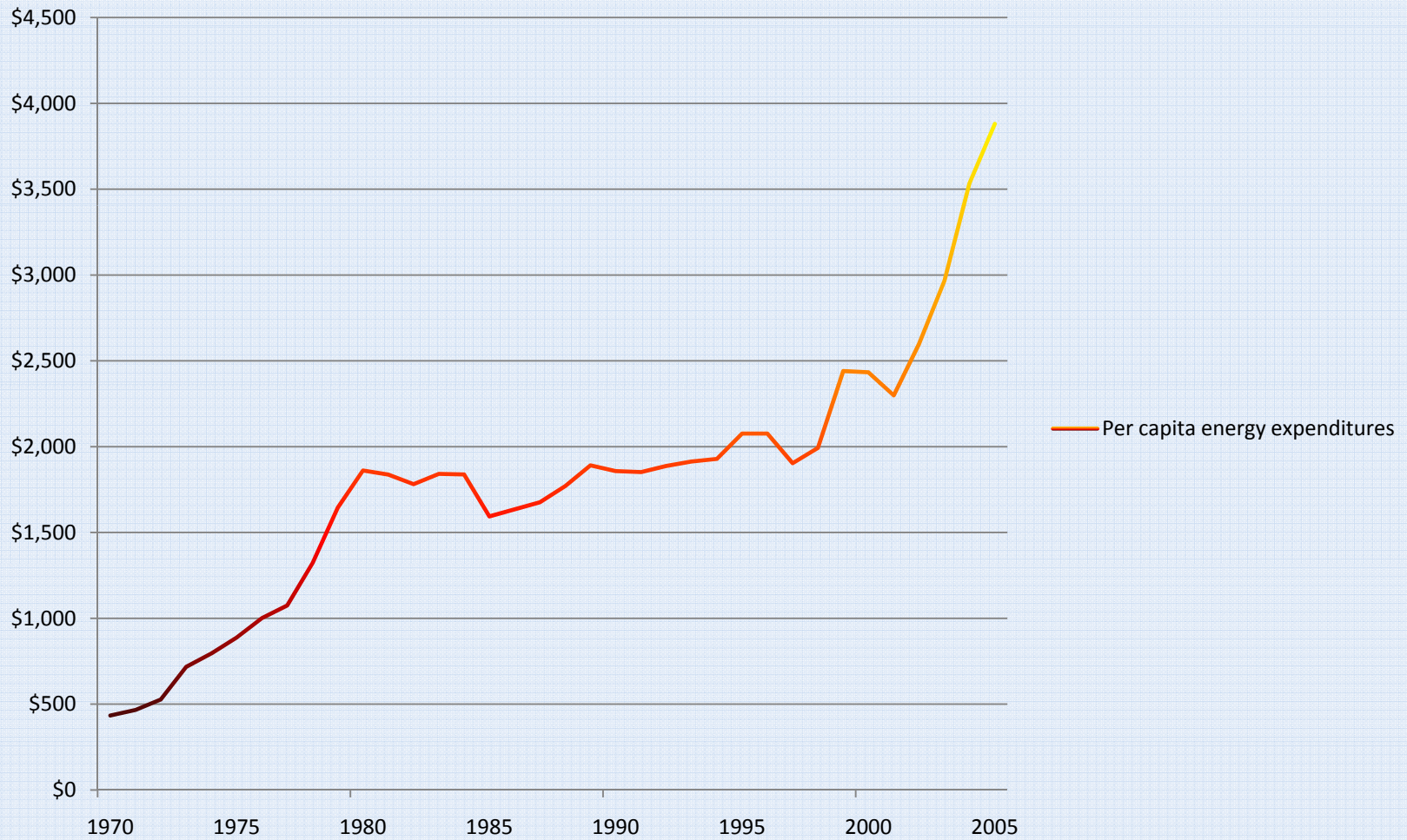
US CO2 emissions from energy use



Source: <http://www.eia.doe.gov/aer/ep/images/figure65.jpg>

Rising financial costs

Per capita energy expenditures



Rising financial costs

- **In 2006 the US spent \$1.15 trillion on energy**
 - **That's \$3,881 for every American**
 - **Or 8.8% of GDP**

The risks of business as usual

- Rising energy costs as % of GDP and household budgets
- Energy shortages (rationing, blackouts, etc.)
- Social injustice resulting from American per capita consumption
- Opportunity costs of *not* developing green technology for export
- National security threats resulting from reliance on imports
- Increasing costs of maintaining relationships with foreign suppliers
- Destabilization of US economy
- Political/economic sanctions from community of nations
- Collapse of US energy system and widespread civil disorder
- Compounding effects of global climate disruption

The answer?

We must educate all American citizens to make them aware of the consequences of their energy choices.

Why not do this while also advancing other educational goals?

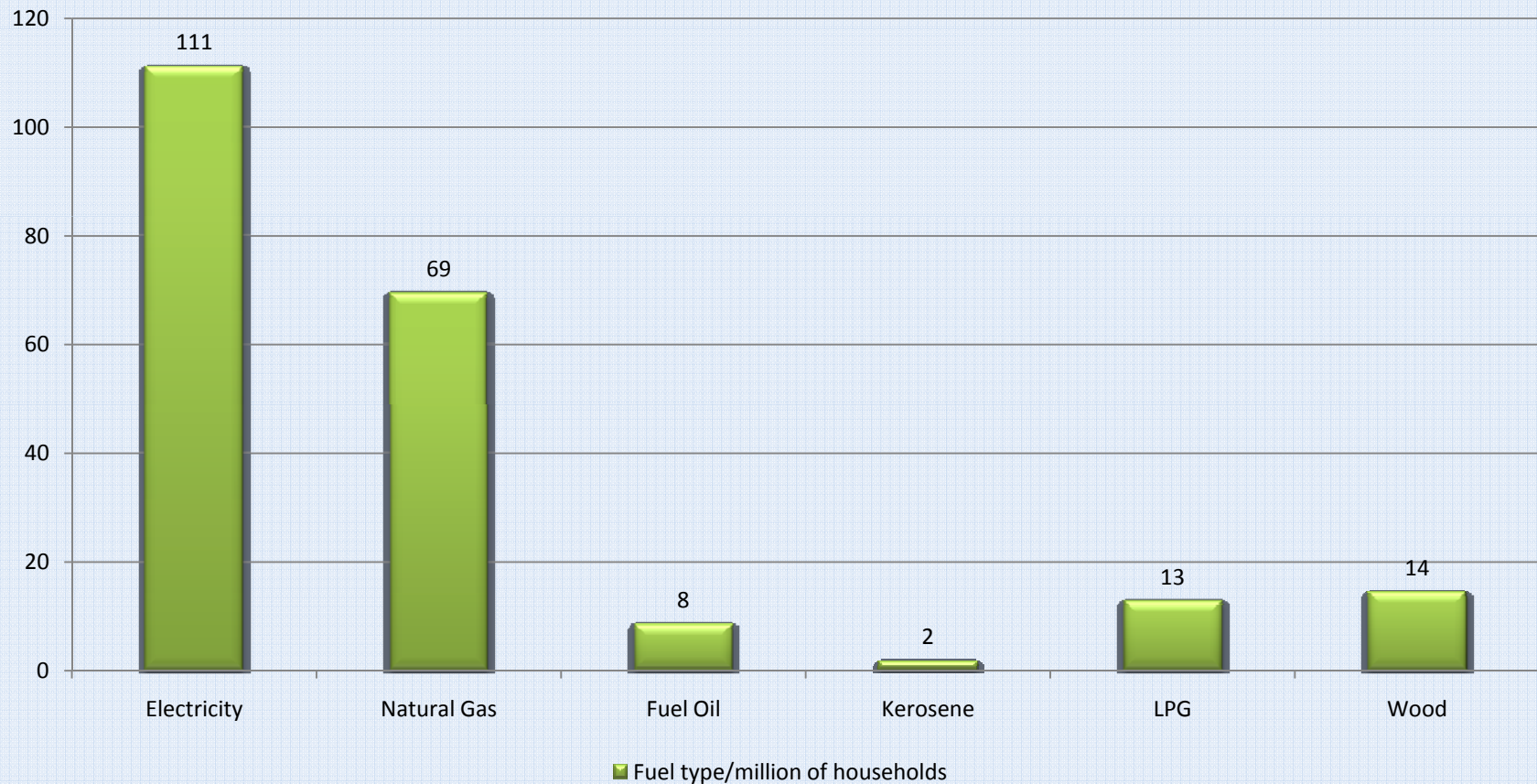
- Math, Science, Geography, Economics, Finance, Government
- Art? English? Physical Education? Psychology? Business?
- Green schools?
- Green cities?
- Green states?

Bringing It Home: Household Demand



Sources of residential energy

Fuel type/million of households



Note: all 111 million homes have electricity; the other fuels are for heating.

How we use energy at home

The US Energy Information Administration's *Residential Energy Consumption Survey* (RECS), conducted every four years, provides a wide range of data on household demand in great detail.

2005 RECS national averages

Total US households	111 million
Average members	2.57 per household
Average size	2,171 square feet
Energy consumption	95 million Btu per year
Energy per sq. ft.	43,000 Btu
Cost of energy	\$1,810 per year
Cost per sq. ft.	\$.83

What we use energy for...

End Use	Demand by %				
	1987	1990	1993	1997	2001
Air-Conditioning	15.8	15.9	13.9	11.8	16.0
Space Heating	10.3	10.0	12.4	11.4	10.1
Water Heating	11.4	11.2	10.3	11.0	9.1
All Appliances	62.5	63.0	63.4	65.9	64.7

Note: The largest use of electricity in the average U.S. household was for appliances (including refrigerators and lights), which consume approximately two thirds of all the electricity used in the residential sector

Where the energy goes

Use	Households owning	Percentage of electrical demand
Refrigerators	107 million	13.7
Air conditioning	80 million	16
Heating	44 million	10
Lighting	107 million	8.8
Water heating	41 million	9.1
Clothes dryer	61 million	5.8
Dishwasher	57 million	2.5
Range	60 million	2.8
Microwave	92 million	1.7
Television	106 million	2.9

Note: 2001 data for a total of 107 million households

Where we live matters too

Region	Floor space (sq. ft.)	Energy use (million Btu)	Net household cost (\$)	\$ per sq. ft.
Northeast	2,336	122	\$2,319	\$.99
Midwest	2,421	113	\$1,786	\$.74
South	2,161	79	\$1,758	\$.81
West	1,784	77	\$1,491	\$.84

Minnesota consumption averages

- Average Household Natural Gas Use (MCF) 105
- Average Household Natural Gas (Btu) 107,835,000
- Average Household Electricity Consumption (kWh) 10,000
- Average Vehicles Owned per Household 2
- Average Miles Traveled per Vehicle 12,500
- Average Miles Traveled per Gallon 22
- Average Gallons Consumed per Vehicle per Year 568

Estimate costs based on averages

Use	kWh used	Percentage of electrical demand	Cost at \$.08/kWh
Refrigerators	115	13.7	\$9.20
Air conditioning	136	16	\$10.88
Heating	85	10	\$6.80
Lighting	75	8.8	\$6.00
Water heating	77	9.1	\$6.16
Clothes dryer	50	5.8	\$4.00
Dishwasher	21	2.5	\$1.68
Range	24	2.8	\$1.92
Microwave	14	1.7	\$1.12
Television	25	2.9	\$2.00

Note: estimates based on annual averages for typical US household at MN rates

Estimating cost of operation from bills

Estimate based on national averages from EIA web site

Example: Your monthly bill shows total consumption of 1,000 kWh, billed at \$.08/kWh (net) for a total of \$80.

Based on national averages, refrigeration accounts for 13.7% of demand. So in this case, it's 13.7% of 1,000kWh, or 137kWh. At your rate that's \$.08x137kWh or \$10.96 to operate your refrigerator for the month.

Clothes dryers account for 5.8% of demand. So 5.8% of 1,000kWh is 58 kWh. At \$.08 per kWh, that's \$4.64 for a month of dry clothes.

Air conditioning is 16% of an average bill. What does it cost to run the A/C if your total consumption was 1,000 kWh as above?

Finding operating cost with a meter

Inexpensive point-of-use meters allow measurement of multiple parameters of any standard plug-in 120v load

- Calculate operating wattage
- Track cumulative kWh used over time
- Measure line voltage
- Measure supply frequency
- Measure load amperage



Estimating cost with a meter

The Kill-A-Watt meter retails for \$20, requires no batteries, and is simple to use.

To *estimate* cost of operation simply plug appliance into unit, switch appliance on, and record wattage during typical operation.

Example: an incandescent bulb draws 97 watts when hot, according to the meter. If it operates 4 hours per day, it will use 11,640 watt-hours in a month. Dividing the watt-hours by 1,000 yields 11.64 kWh, which would cost \$.93 at the \$.08/kWh rate used before. A dollar a month to keep the back porch light on for the dog each evening doesn't seem that bad.

Tracking cost with a meter

To *track* cost of operation simply plug appliance into unit, switch appliance on, and record wattage over a period of time that will capture normal usage patterns (a day, week, or month), then extrapolate to monthly results if necessary.

Example: your fancy new 54" plasma TV draws 293 watts when operating (but only 0.2 w in standby). Some days it isn't turned on at all, but on weekends you watch lots of movies. You track it for 30 days and find it used 23.44 kWh (about 80 hours of use), for a cost of \$1.87.

Calculating payback

How do you decide where to spend your upgrade money?

Simple payback calculation

energy saved times cost equals money saved
 $\text{kWh} \times \text{rate} = \$ \text{ savings}$

Example

- a hallway light operates 10 hours/day with a 60 watt incandescent bulb, drawing 219 kWh per year at a cost of \$17.52
- a 23 watt CFL yielding the same amount of light will use only 84 kWh per year at a cost of \$6.71 (saving you \$10.80 per year)
- The CFL costs \$1.50 and will pay for itself in six weeks of savings

Putting the meter to work

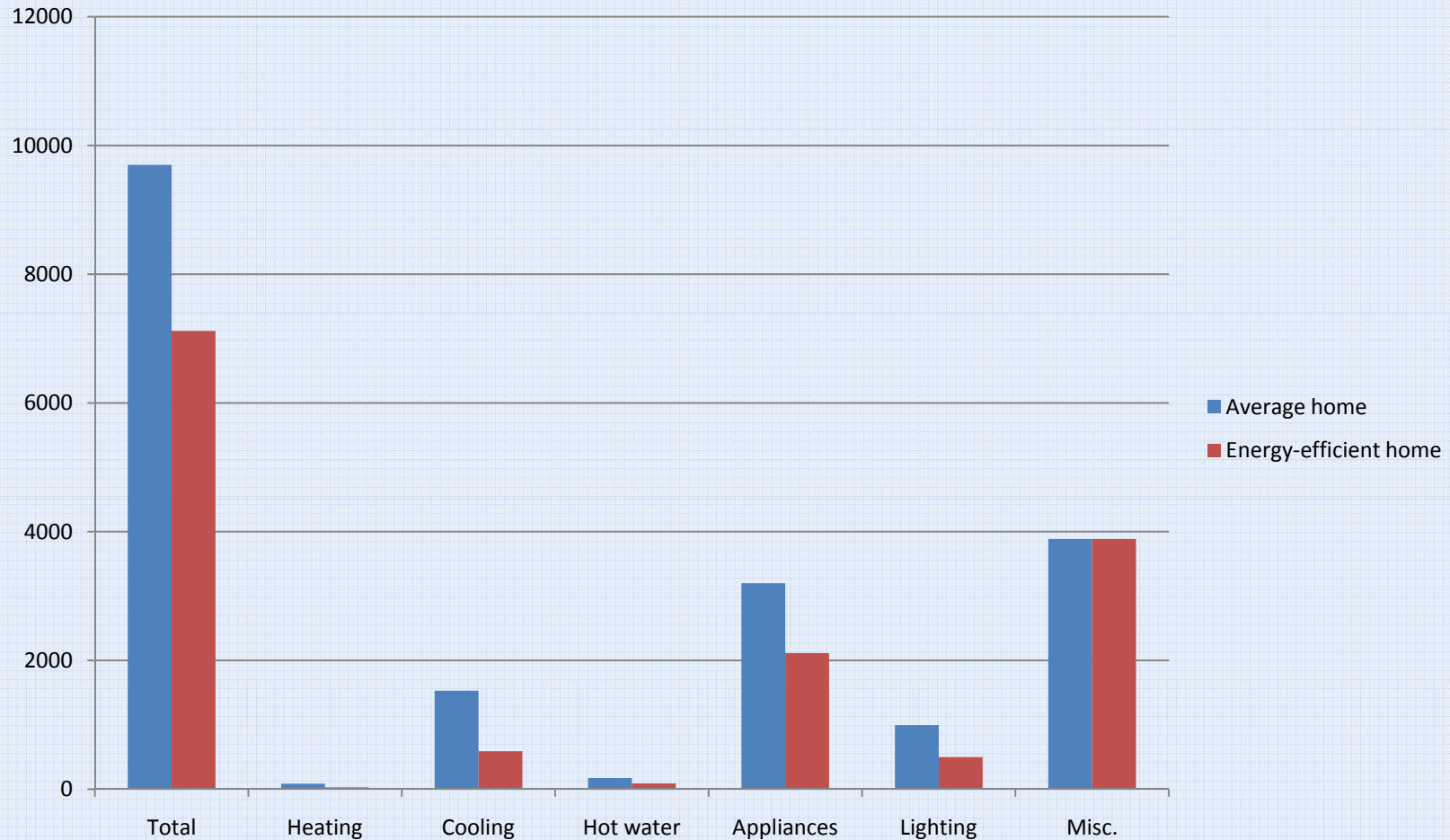
Metering can help you learn where your energy hogs are hiding

Example: You're considering upgrading your refrigerator when you remodel. The existing fridge is a fairly recent one, which you meter and find it uses 29 kWh in a month, or 348 kWh per year. At \$.08 it costs you \$27.84 to operate annually.

You also decide to meter the avocado gold "beer fridge" in your rec room find it consumes 175 kWh in a month, or 2,136 kWh per year. At \$.08/kWh you're paying \$170.88 annually to keep the beer cold.

Replacing the beer fridge with the newer model would save you \$143.04 per year, which could go toward a new Energy Star fridge for the kitchen, reducing your net energy for refrigeration by 72%!

Potential savings via efficiency upgrades



Annual electrical demand, typical St. Cloud area home vs. energy efficient home;
Overall reductions of 25% in demand are possible through simple upgrades.

Strategies for reducing residential demand

- **Conservation first**: the cheapest kWh is the one you never use!
- **Change behavior**: turn off lights, unused appliances, turn down heat, etc.
- **Automate controls**: programmable thermostats, motion/occupancy sensors, timers, etc.
- Trace and **eliminate phantom loads**
- **Identify energy hogs** and replace/eliminate
- Invest in high-priority **efficiency upgrades**
- Replace aging appliances with **Energy-Star alternatives**
- Get a professional **energy audit**

What about alternative energy sources?

- Wind power's great, right?
- What about solar in Minnesota?
- Wood? Corn? Biomass?
- Geothermal?
- Buying green power from the utility?
- Carbon offsets?



Why bother trying to save energy?

- To save money
- As a hedge against volatile energy prices
- To prepare for future carbon pricing
- To be more comfortable in your home
- To help reduce demand for dirty coal power
- To help reduce CO2 emissions
- To conserve resources for higher priorities
- For our children's sake
- Because it's the ethical thing to do