Chapter 03

Energy

Section 3.1

Work

The man shown uses 40N of force to lift the box 1.5m off the ground. How much work did he do?

$$W = F \cdot d$$

A) 0 J

B) 1.5 J

C) 20 J

D) 40 J

E) 41.5 J

F) 60 J

A different, *much* cooler man uses 40N of force to push against the brick wall of a large building. After 2 minutes, he is feeling pretty tired. How much work did he do?

$$W = F \cdot d$$

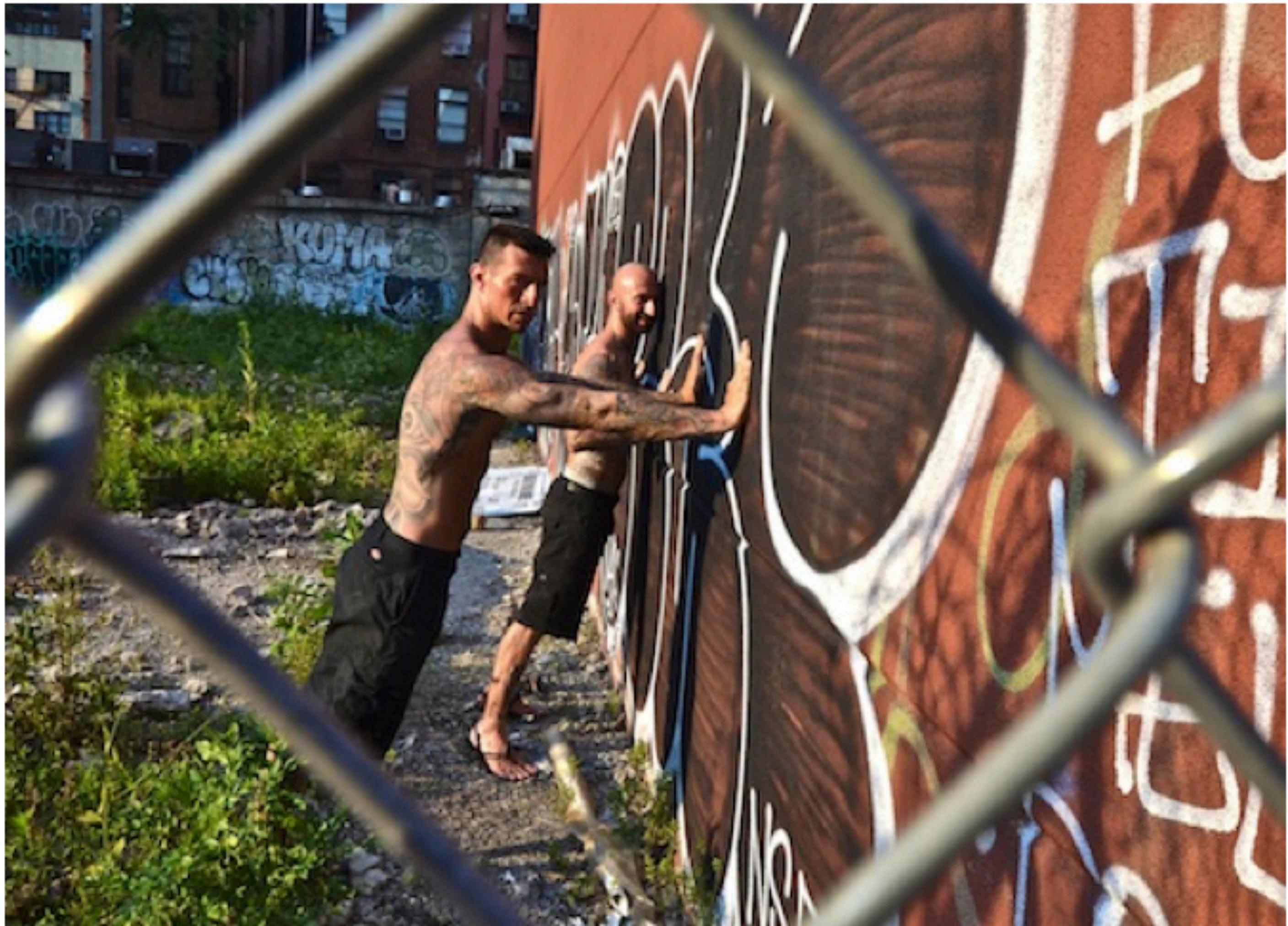
A) None

B) 20 J

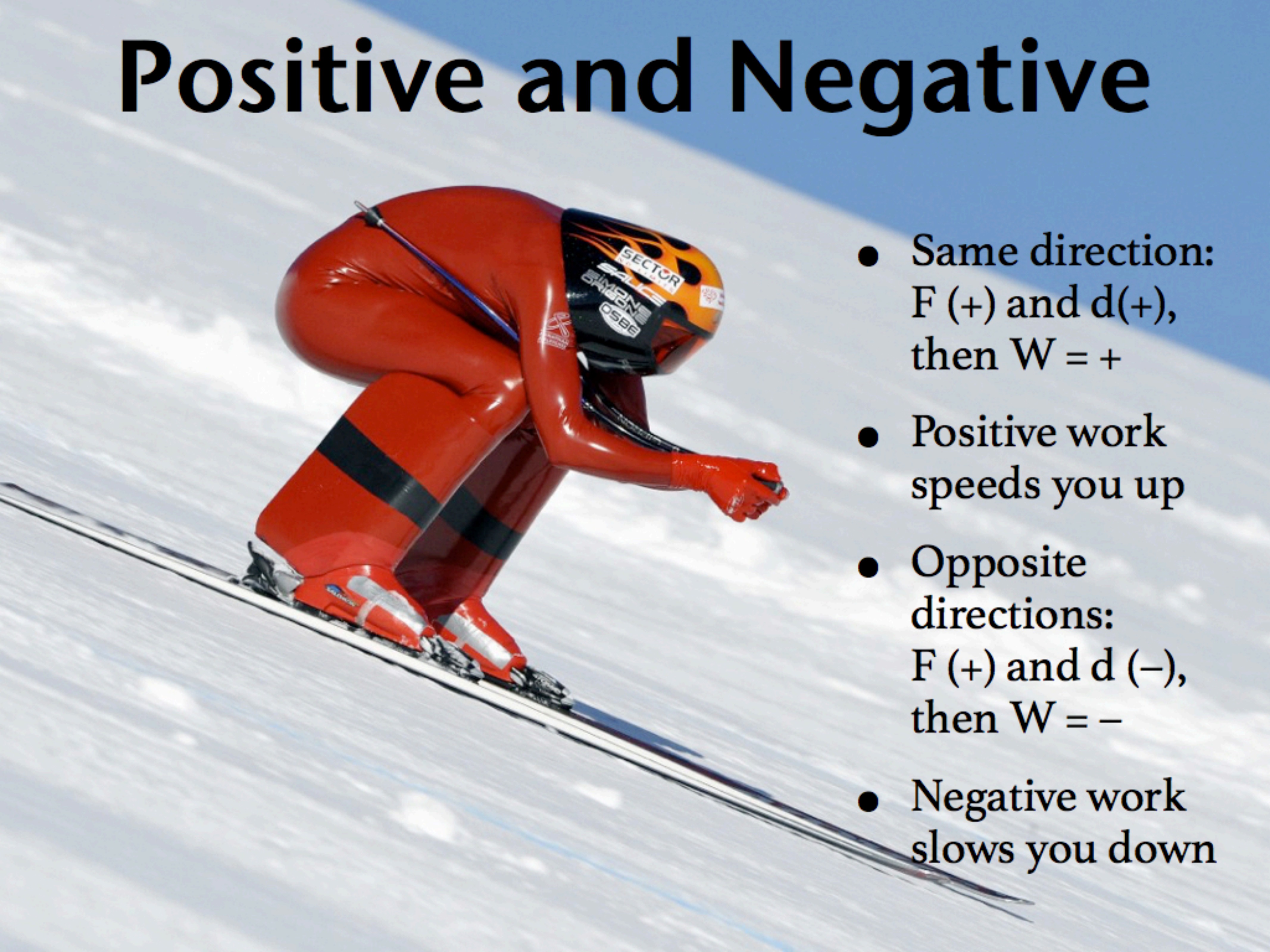
C) 40 J

D) 80 J

E) 4800 J



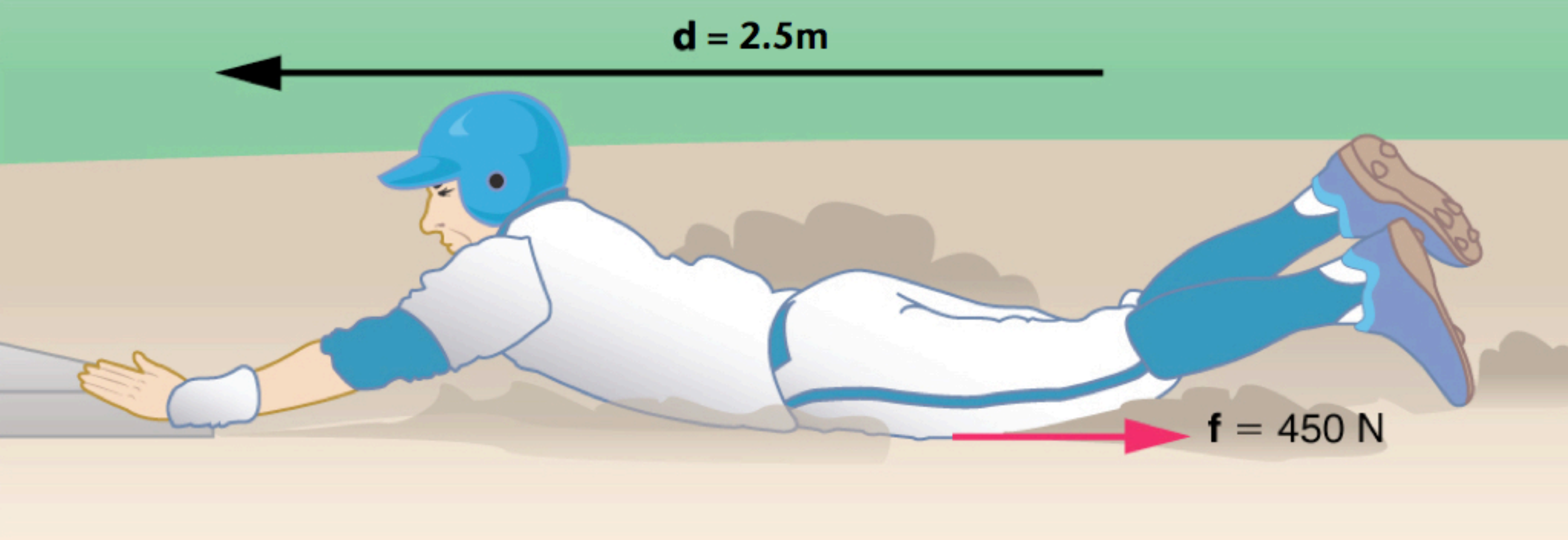
Positive and Negative



- Same direction: F (+) and d(+), then W = +
- Positive work speeds you up
- Opposite directions: F (+) and d (–), then W = –
- Negative work slows you down

A frictional force f = 450N acts on the player as he slides into second base, covering a distance d = 2.5m.

Calculate the amount of work done on the player by friction.



Power

$$P = \frac{work}{time} = \frac{W}{t}$$

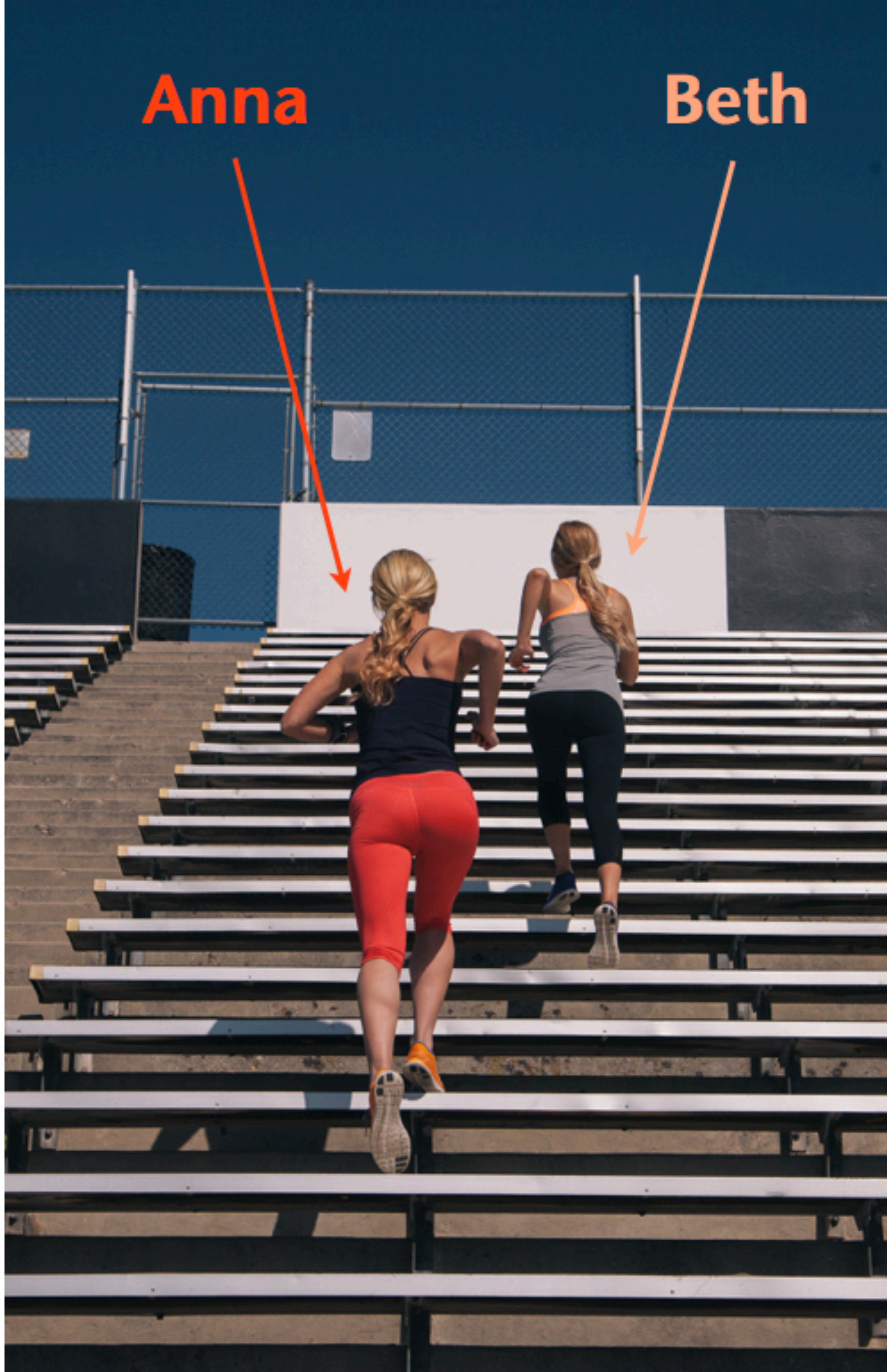
- Power = work per time , or rate at which work is done
- Watt = W = (Joule)/(second)
- kilowatt = kW = 1000 Watts

Running up the stairs in one minute (60 sec), Anna develops 40 Watts of power. Anna's friend Beth weighs a little more, but it only takes her 55 seconds to run the same set of stairs.

A) Beth develops greater power than Anna.

B) Beth develops the same 40W of power as Anna. If the stairs are the same, it does not matter who runs up them! Or down them.

C) Beth develops less power than Anna.



Horsepower

- 1 hp = 746 W
- Historical artifact!
- James Watt made the comparison, by literally making the comparison
- He estimated that an average pony could lift 220 lb through 100 ft per minute, working a 4 hour shift
- Poor pony!
- No ponies were harmed in the making of this slide

Section 3.2

Motion, Position, and Energy

What is Energy?

- Energy is a property
- An object's energy enables it to do work
- Doing work on an object changes its energy

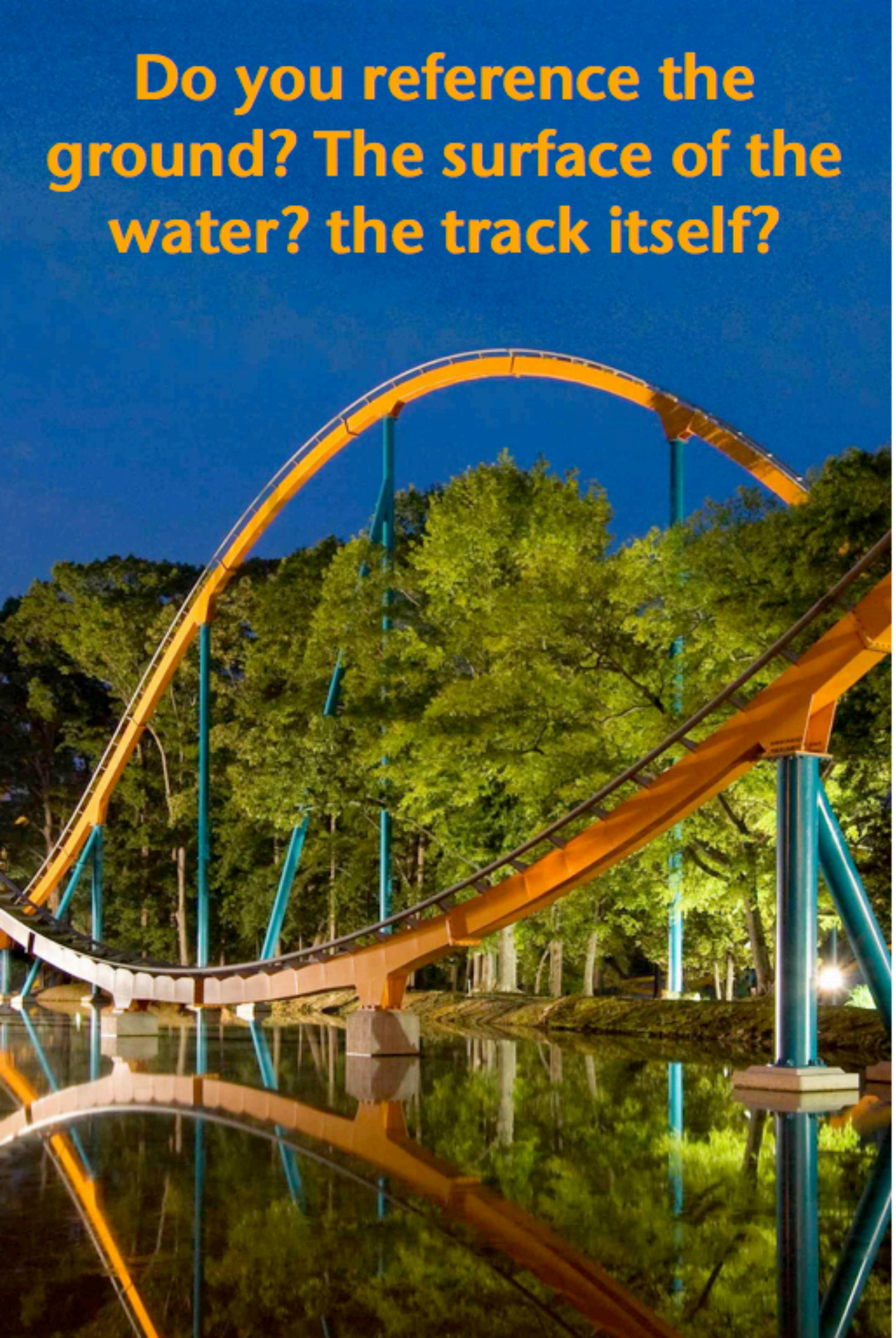
Potential Energy: The Energy of Position

- Several types: gravitational, electrical, magnetic, spring
- All depend on where, not how fast
- An object at rest can still have PE

Potential energy stored in the stretched bowstring will be converted to kinetic energy when the string is released.

Gravitational PE

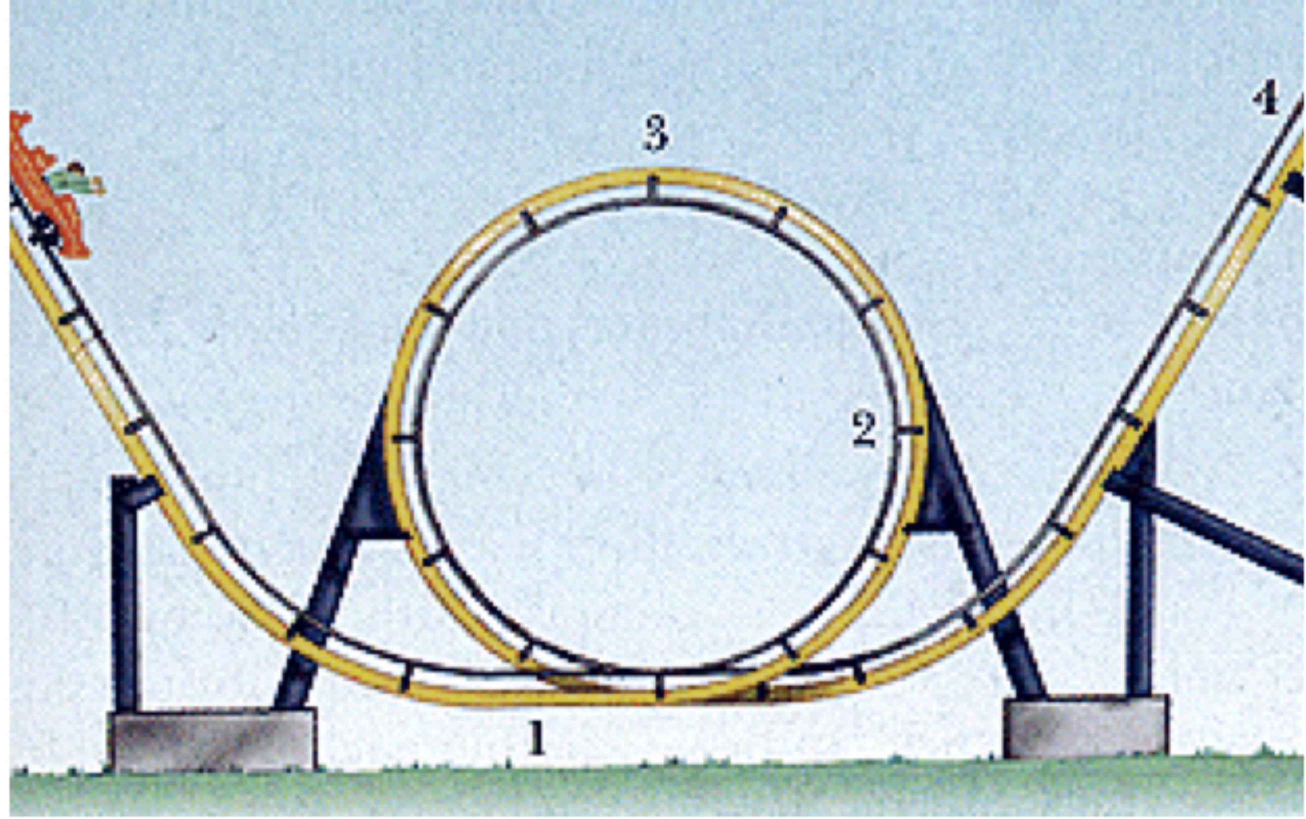
- PE is a form energy, so it should look like work
- Units of PE are same as KE are same as work: Joule = N·m



PE is Relative

- There is no location you can point to and say, "$PE = 0$ right here, all the time."
- Think of h as the **change in position**, not the absolute position
- You may want the floor to be h=0, or you may want the tabletop to be h=0
- The situation should determine where it makes sense to have h=0

Compare using point 1 as your reference level for PE with using point 3.



A) The PE will be the same no matter where you declare $h = 0$. $PE_1 = PE_2 = PE_3$ for the coaster car.

B) If you use point 1 for reference, PE_1 is some positive value, and $PE_2 = 0$, and PE_3 is negative.

C) When you use point 3 for reference, $PE_3 = 0$, and both PE_1 and PE_2 will be negative.

D) When you use point 3 for reference, $PE_3 = 0$, but both PE_1 and PE_2 will be positive!

Kinetic Energy: The Energy of Motion

- $KE = \frac{1}{2}mv^2$
- No motion, no KE: object at rest has KE = 0
- KE can only be (+), cannot be (–)

The skier shown has a mass of 55kg. She is moving at 12m/s. What is her kinetic energy?

$$KE = \tfrac{1}{2}mv^2$$

Answer numerically.

A car traveling north has 365kJ of kinetic energy.

True or false: the same car traveling at the same speed, but headed south, will have –365kJ of kinetic energy.

$$KE = \tfrac{1}{2}mv^2$$

Same KE?

Ball	Mass (kg)	Speed (m/s)	KE (J)
Football	0.426	10	21.3
Basketball	0.625	8.25	21.3
Tennis	0.057	27.35	21.3
Golf	0.046	30.5	21.3
Baseball	0.142	17.34	21.3

Section 3.3 Energy Flow

Work and Energy

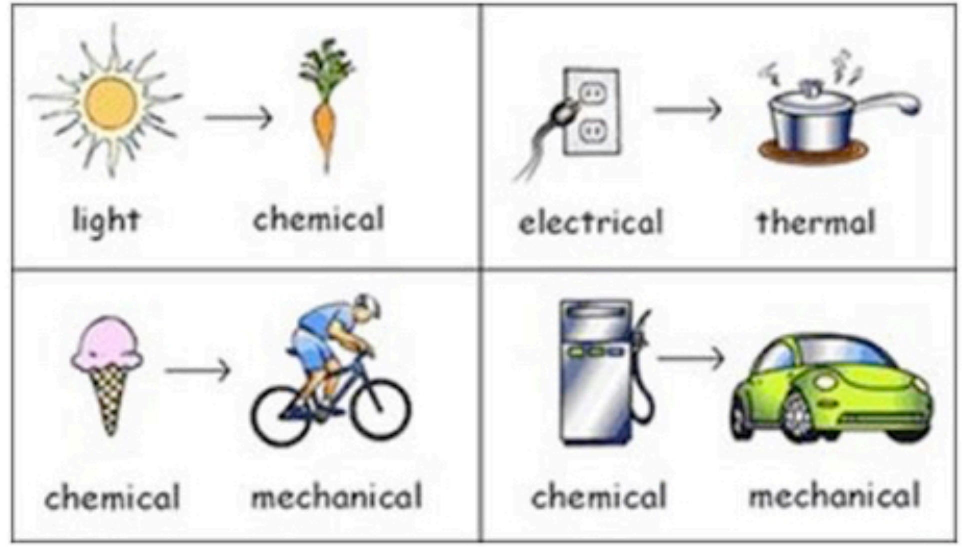
- Doing work on an object changes its energy: $W = \Delta E$
- You can re-write Newton #2 to say this: $\frac{1}{2}m(v_i)^2 + W = \frac{1}{2}m(v_f)^2$
- Now separate PE from the rest of the work being done: $(PE_i + KE_i) + W_{nc} = (PE_f + KE_f)$

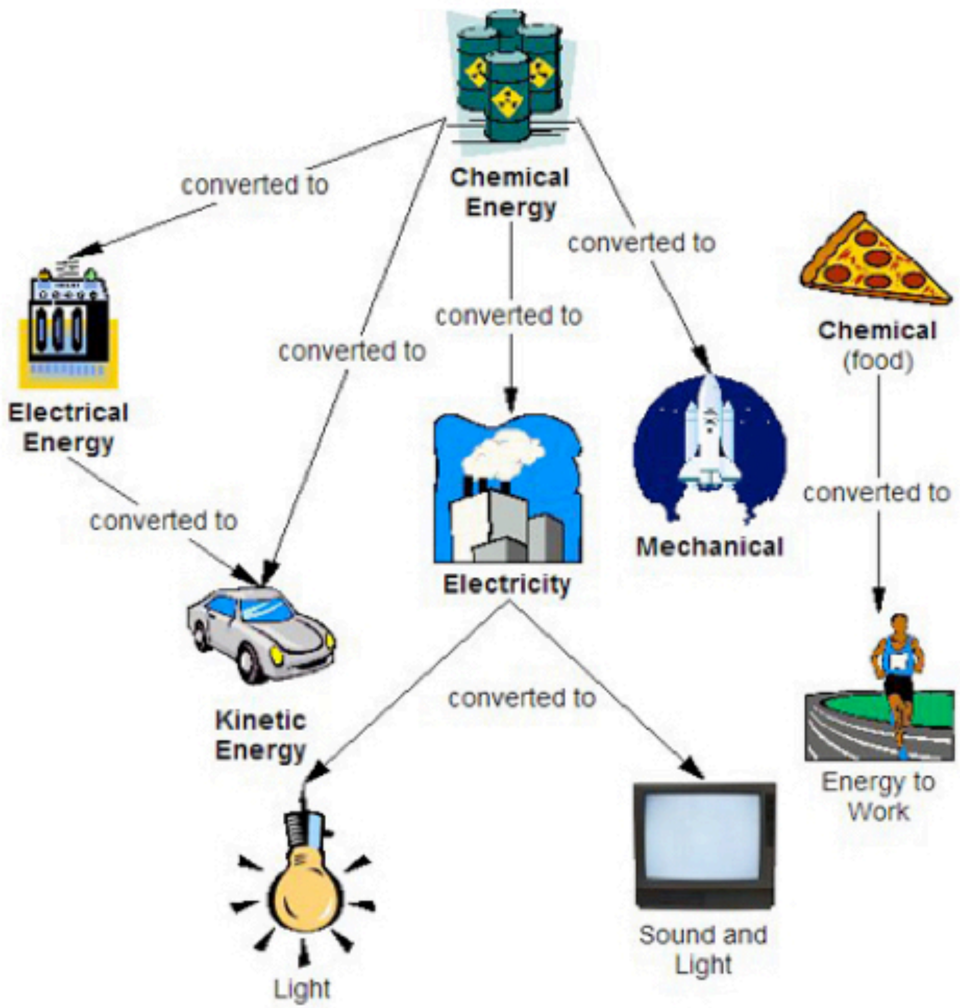
A standard hockey puck ($m = 0.160$kg) has an initial speed $v_i = 20$m/s. How much work will the force of friction do on the puck to bring it to rest ($v_f = 0$)?

$$\tfrac{1}{2}m(v_i)^2 + W = \tfrac{1}{2}m(v_f)^2$$
$$W = \tfrac{1}{2}m(v_f)^2 - \tfrac{1}{2}m(v_i)^2$$
$$W = 0 - \tfrac{1}{2}(0.160\text{kg})(20\text{m/s})^2$$
$$\text{W} = -\tfrac{1}{2}(0.160)(400)\text{J}$$

A) –320J
B) –32J
C) 0J
D) +32J
E) +320J
F) +640J

Energy Forms





- Different forms ≠ different kinds
- Different forms means energy arises for different reasons
- All forms are interchangeable

Kitten says he gets his energy from sleeping. Sasquatch says he got his energy from the food he ate. Who is right?

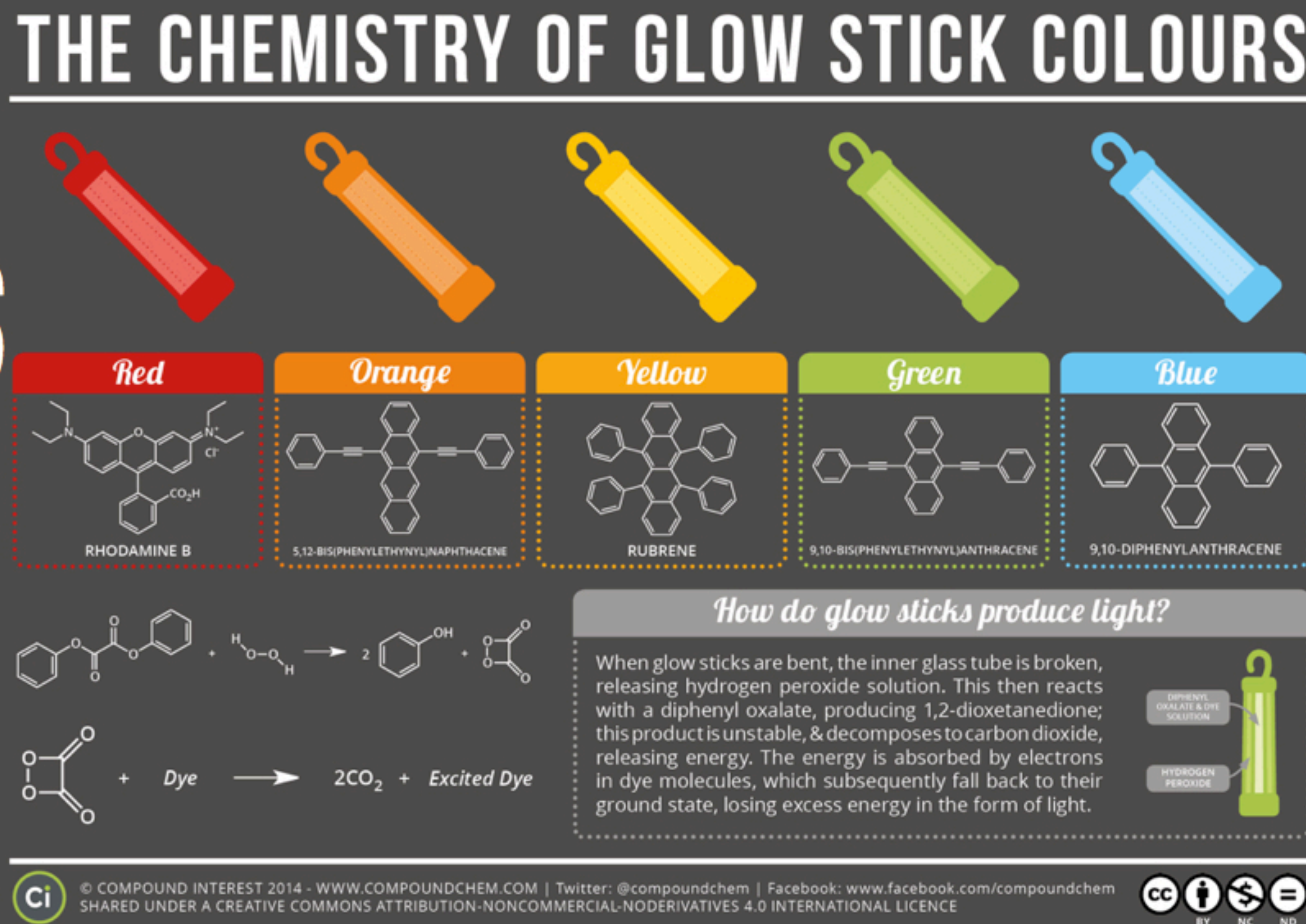
A) Kitten B) Sasquatch C) Both D) Neither

Mechanical Energy

- Kinetic energy, gravitational PE, spring PE
- Mechanical has to do with the overall bulk motion or position of an object

Chemical Energy

- Form of potential energy: stored by atoms/molecules
- Chemical potential can be released in a chemical reaction
- Logs in the fireplace: the flames you see and the heat you feel are the energy being released as the wood burns (which is a chemical reaction between the wood and the oxygen in the air)

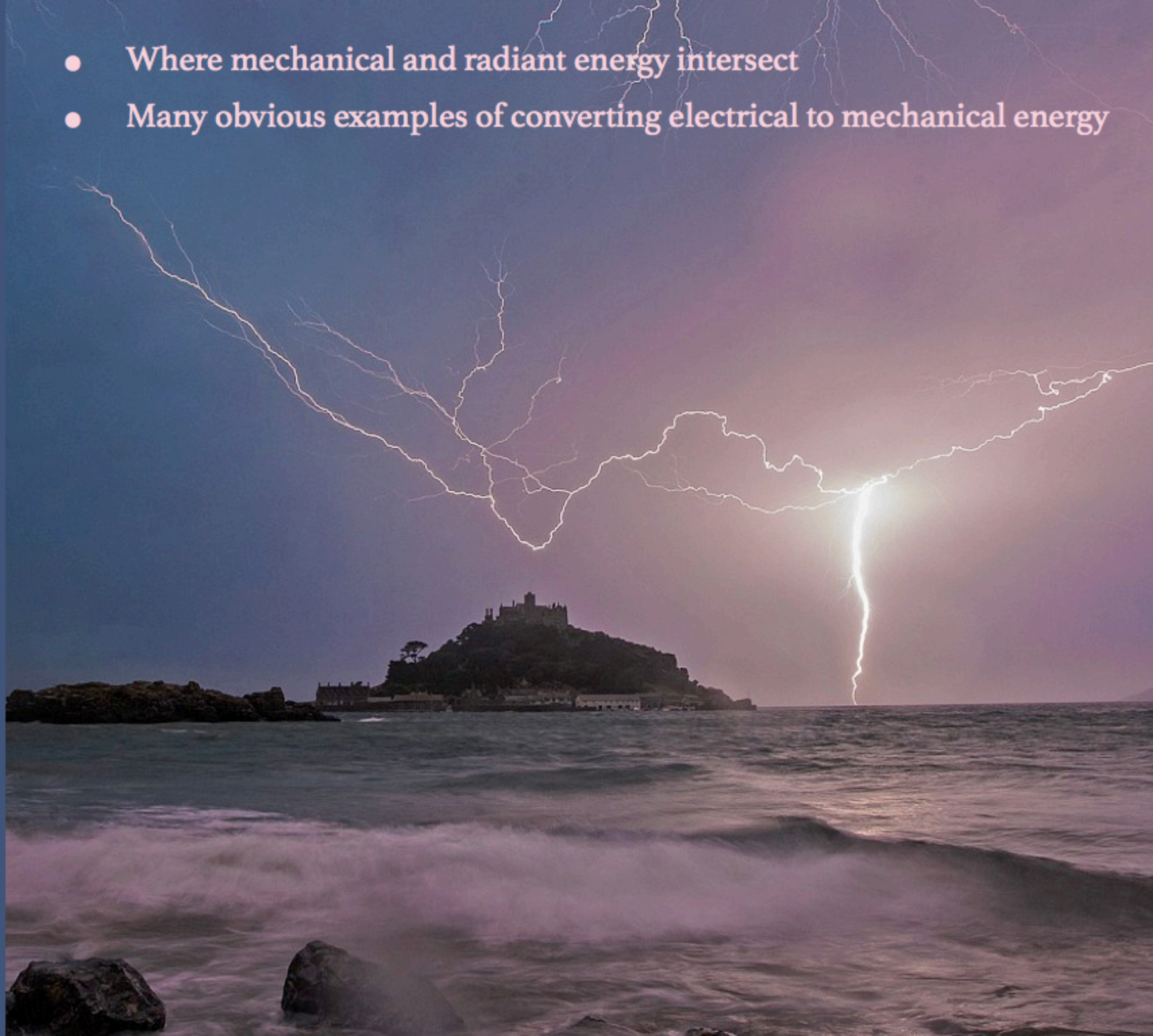


Radiant (Electromagnetic) Energy

- Visible light, but actually all of the electromagnetic spectrum
- Infrared, visible, UV are actually all the same thing
- Ultimate source of this energy is electron vibrations

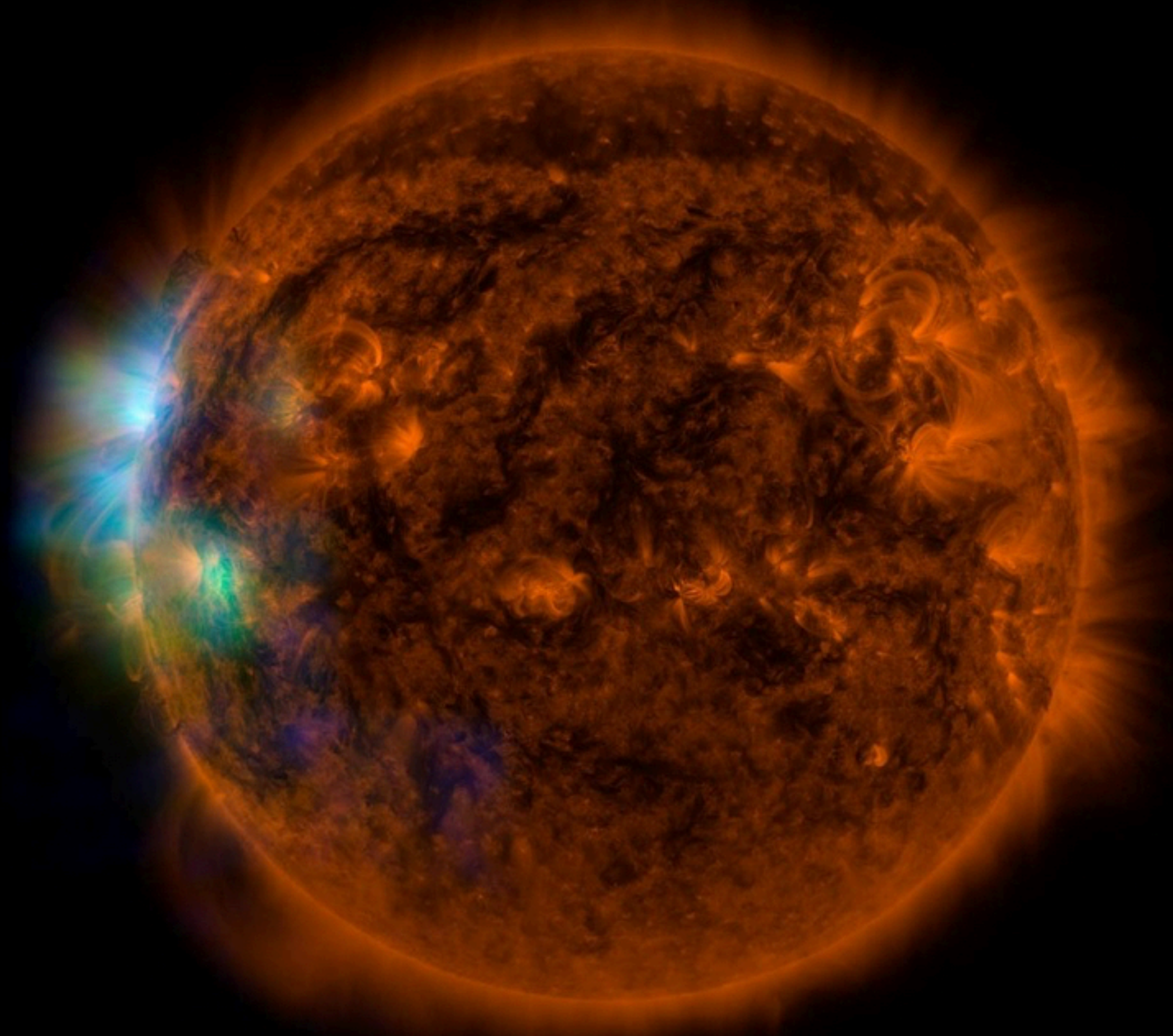
Electrical Energy

- Where mechanical and radiant energy intersect
- Many obvious examples of converting electrical to mechanical energy



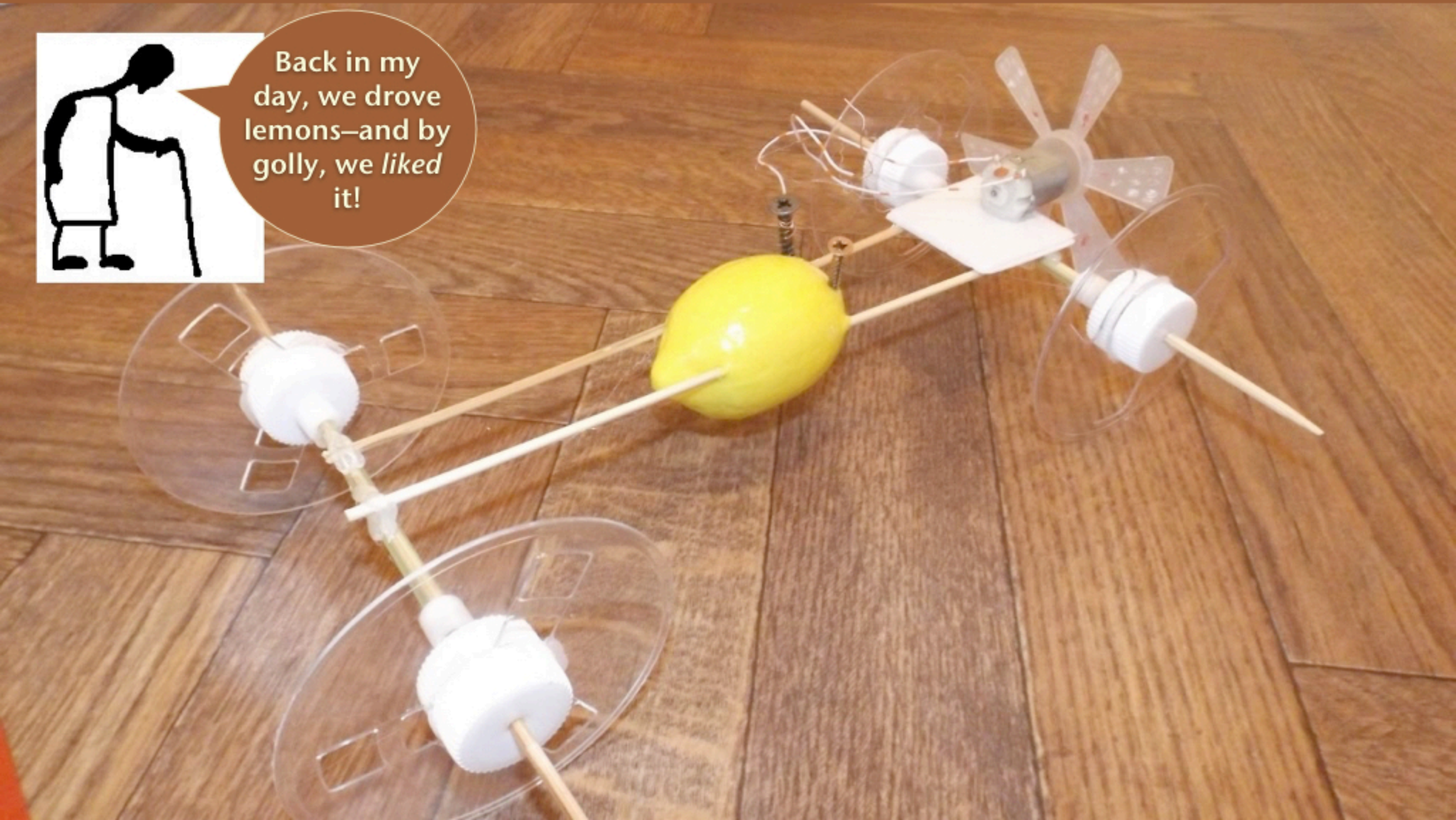
Nuclear Energy

- It's the nucleus, not the electrons here
- If a nucleus is unstable, it will try to get stable
- It will release energy and/or particles to reconfigure itself



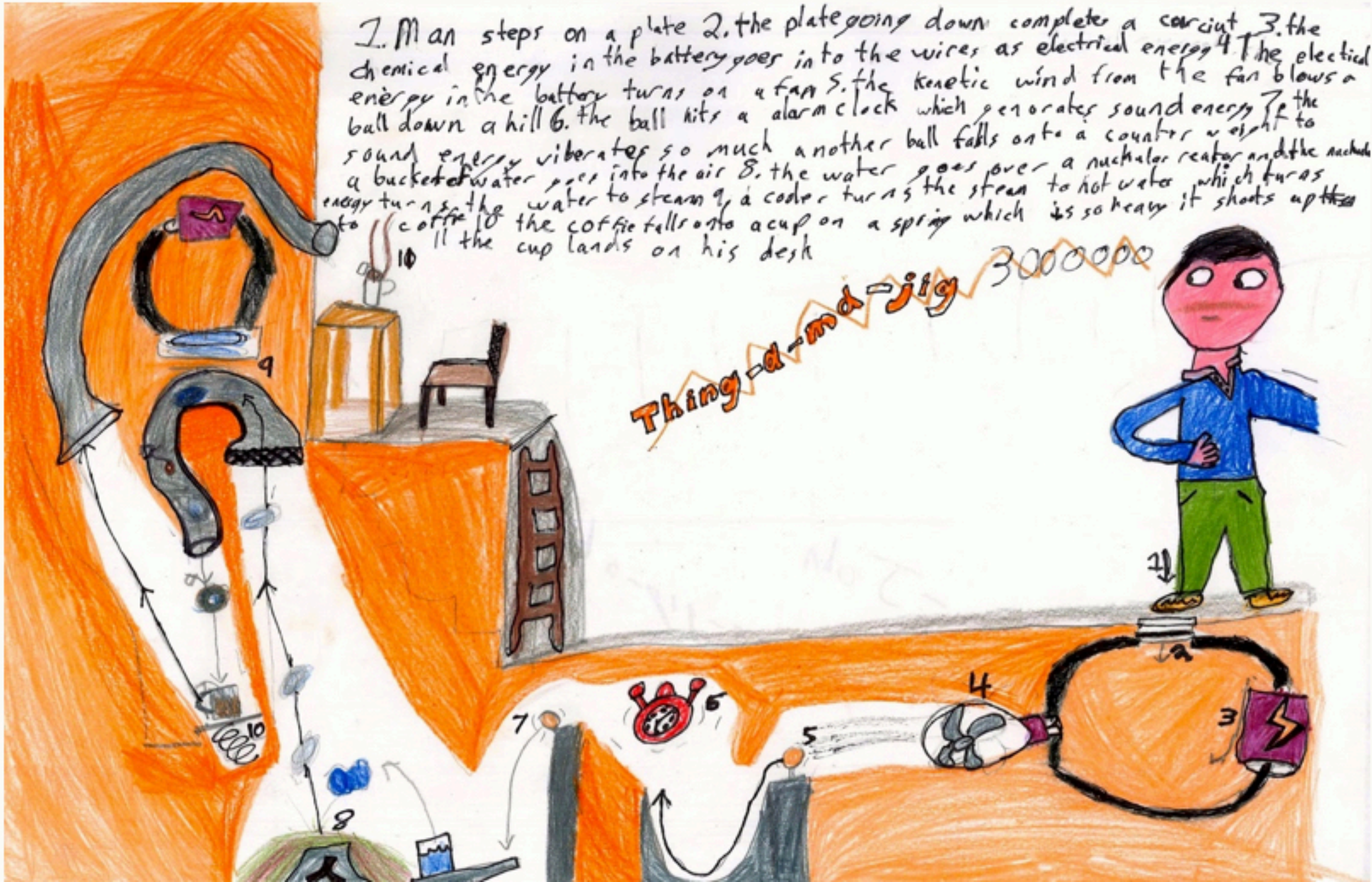
True or false:

Chemical energy can be transformed into electrical energy. Also, electrical energy can be transformed into mechanical energy.



Energy Conversion

- All forms are interchangeable
- Turn on the light: electrical energy converted to light (radiant energy)*
- Eat breakfast, walk across campus: chemical energy converted to mechanical energy*
- Drive across town: chemical energy converted to mechanical energy*
- Turn on the radio: radiant energy converted in mechanical energy
- *Plus radiant energy in the form of heat. There's always waste heat. Always.

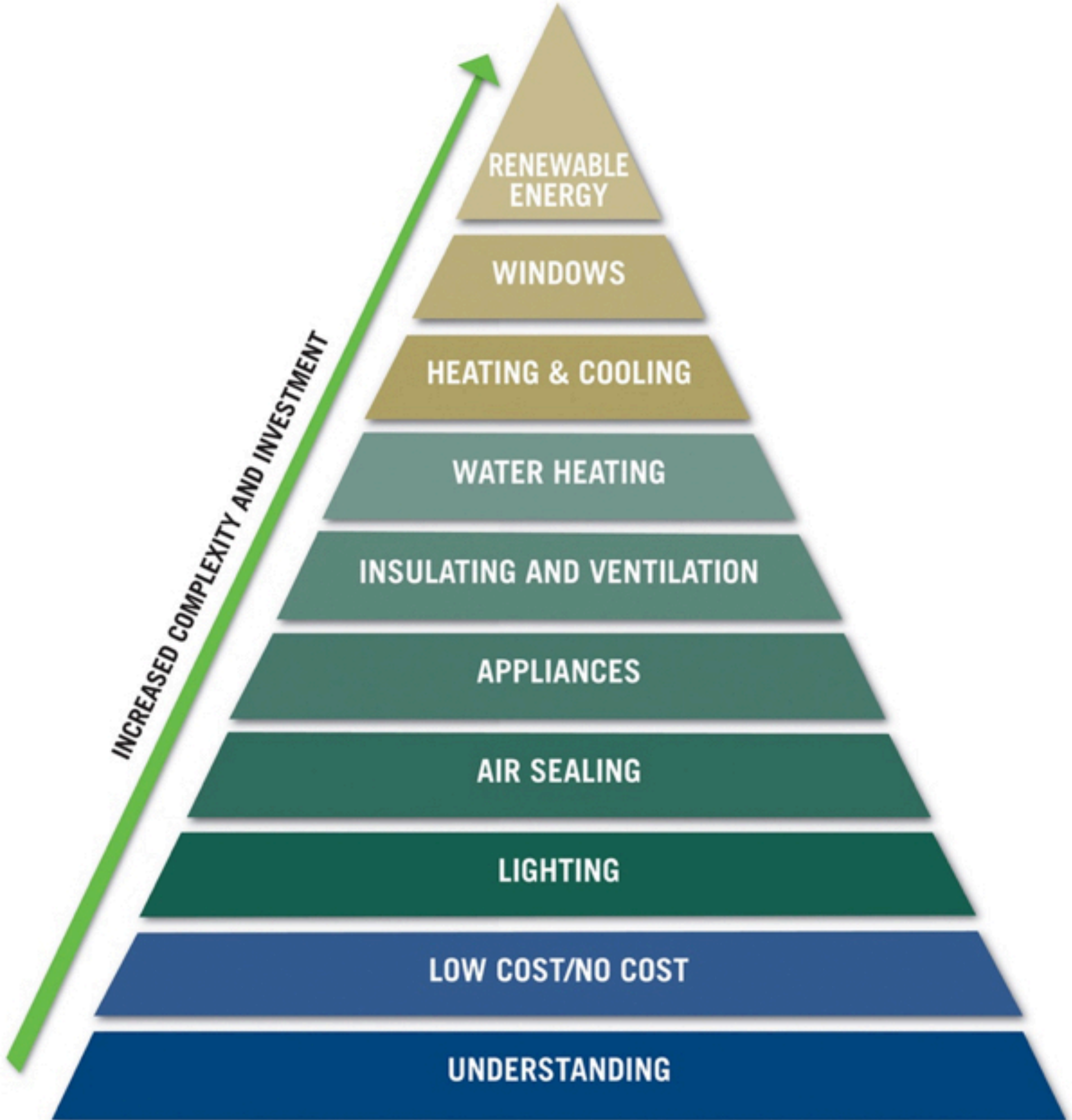


Conservation of Energy

- Move it, don't lose it
- Energy cannot be created or destroyed, but it can change form and/or be transferred form one object to another
- If you think you are seeing a violation of this law, look harder. The energy you think you lost might not be where you thought it should be, but it will be somewhere.

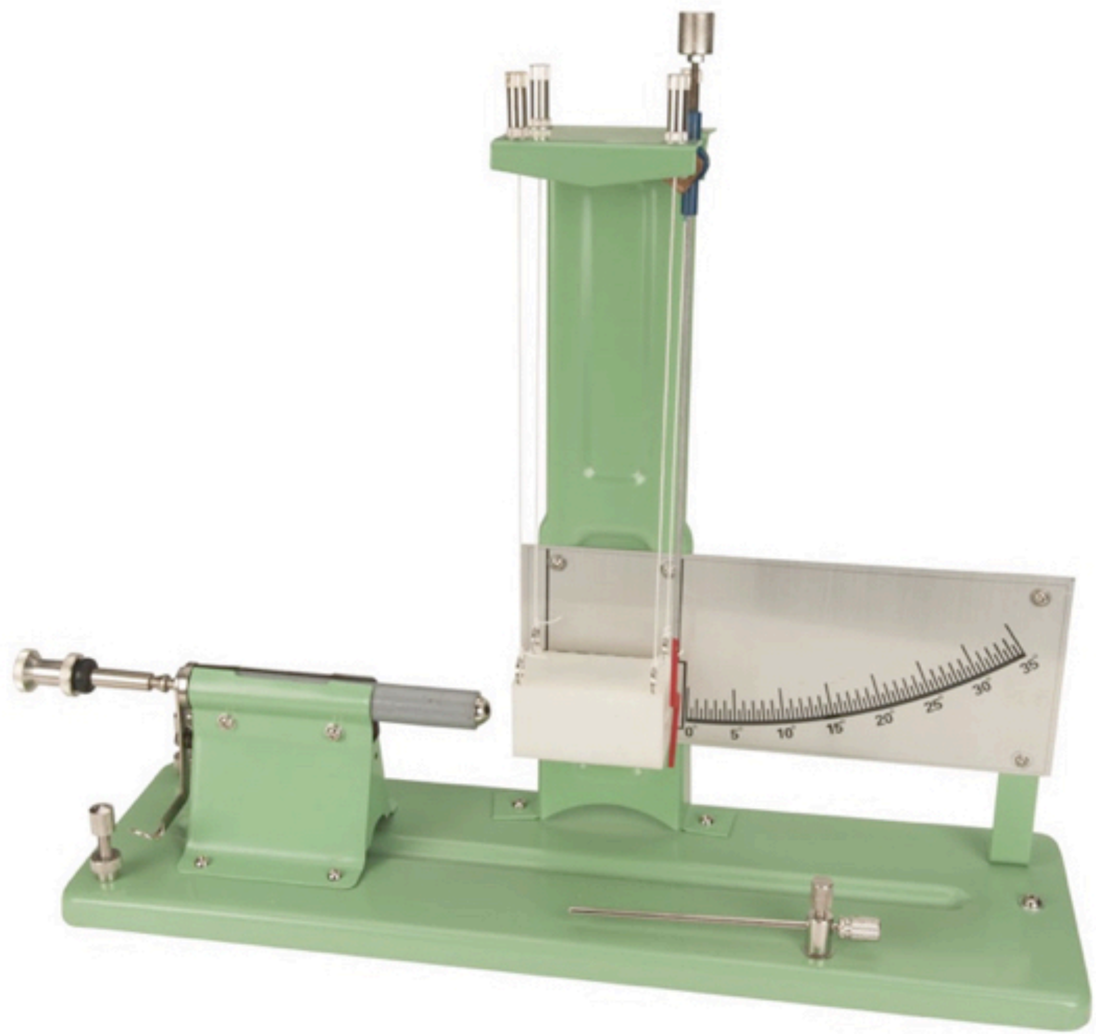
CONSERVATION PYRAMID

WHERE DO I BEGIN?

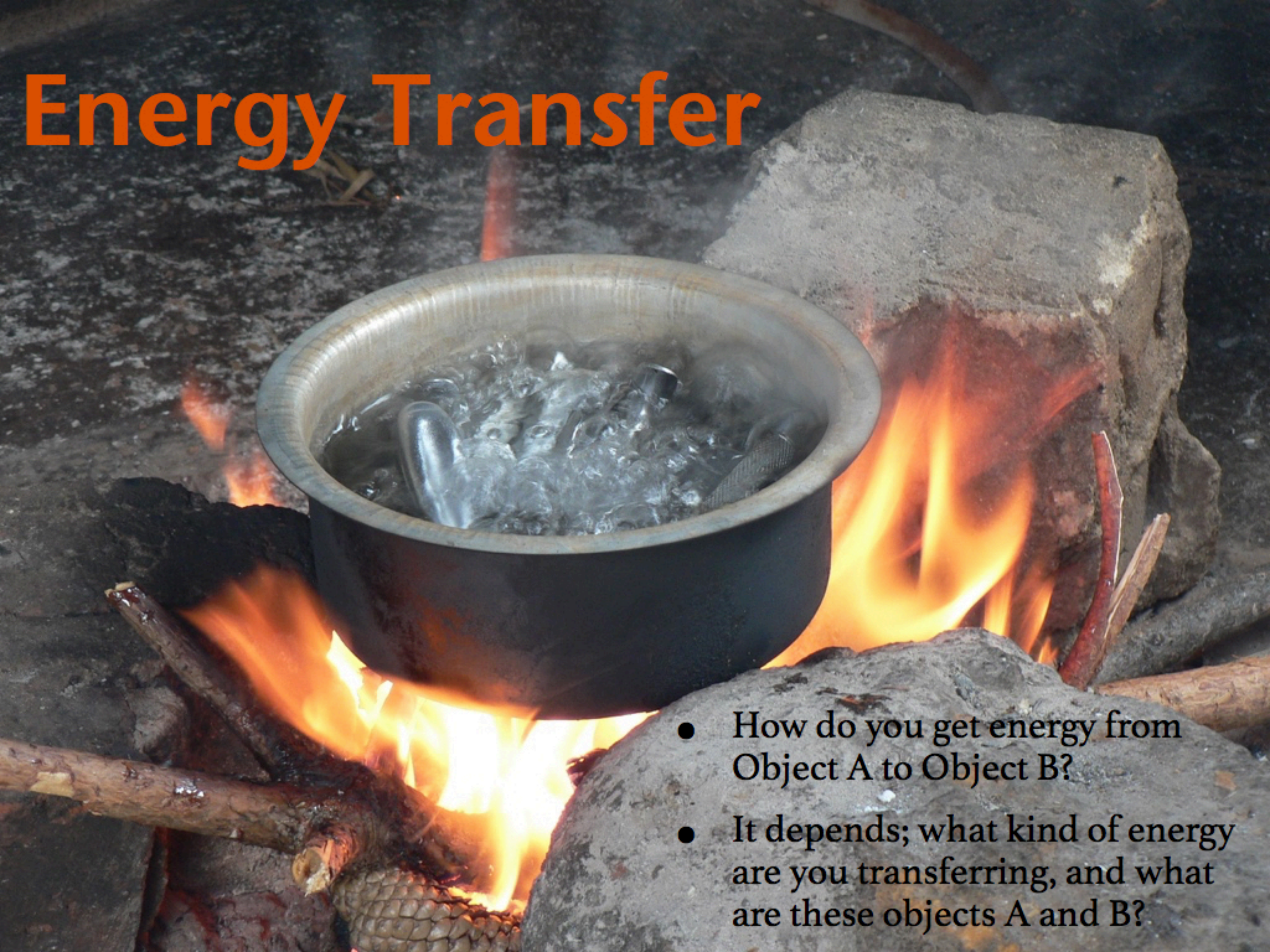


Ballistic Pendulum: Where does the energy go?

- Compress spring: stored spring PE
- Release spring: PE converted to KE of the ball
- Ball collides with block: some energy transferred to block
- Ball+block: KE converted to gravitational PE
- Angle indicator lets you calculate how much gravitational PE
- You never have as much PE at the end as you predict (from knowing the spring constant and the masses)



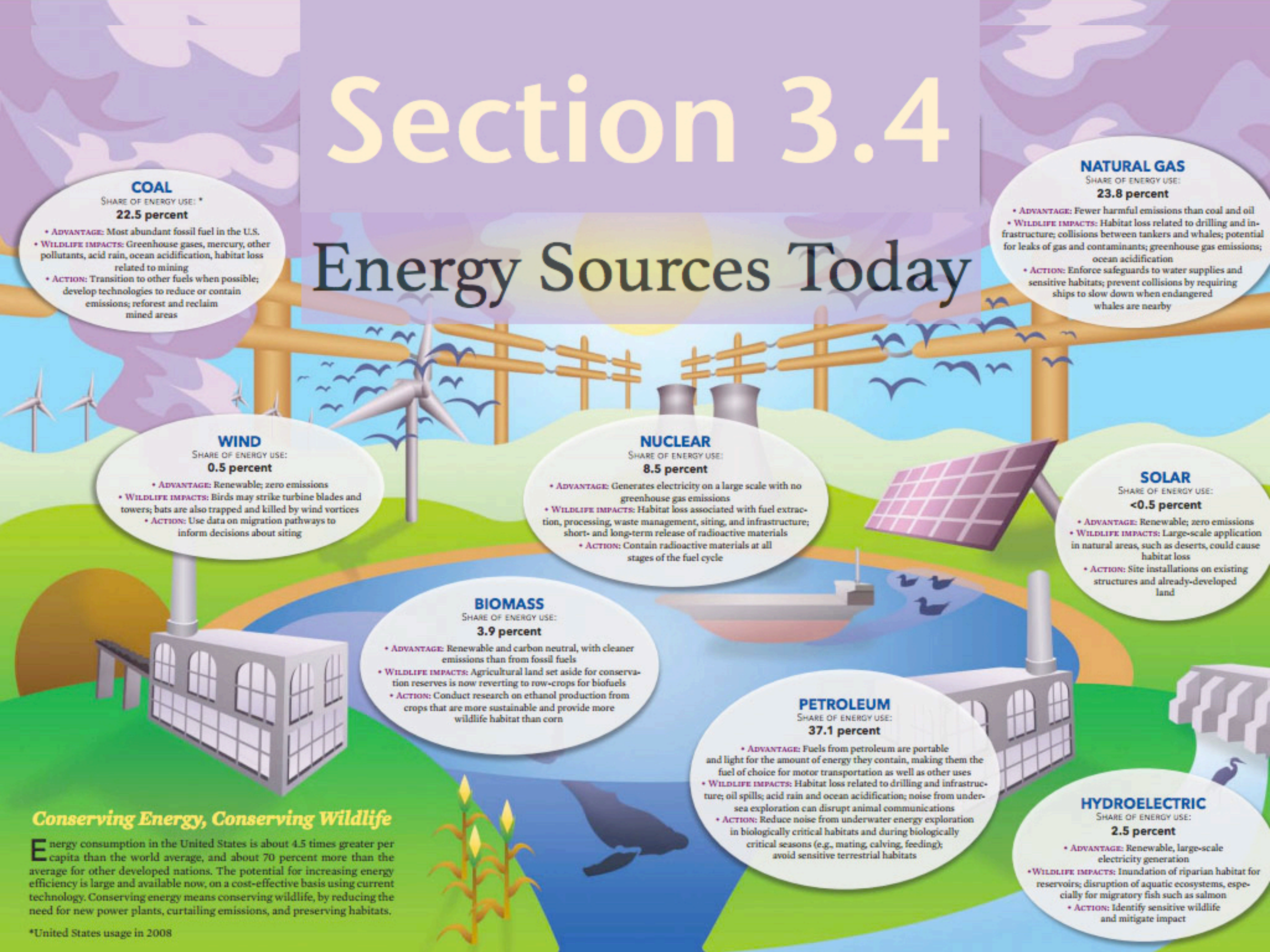
Energy Transfer



- How do you get energy from Object A to Object B?
- It depends; what kind of energy are you transferring, and what are these objects A and B?

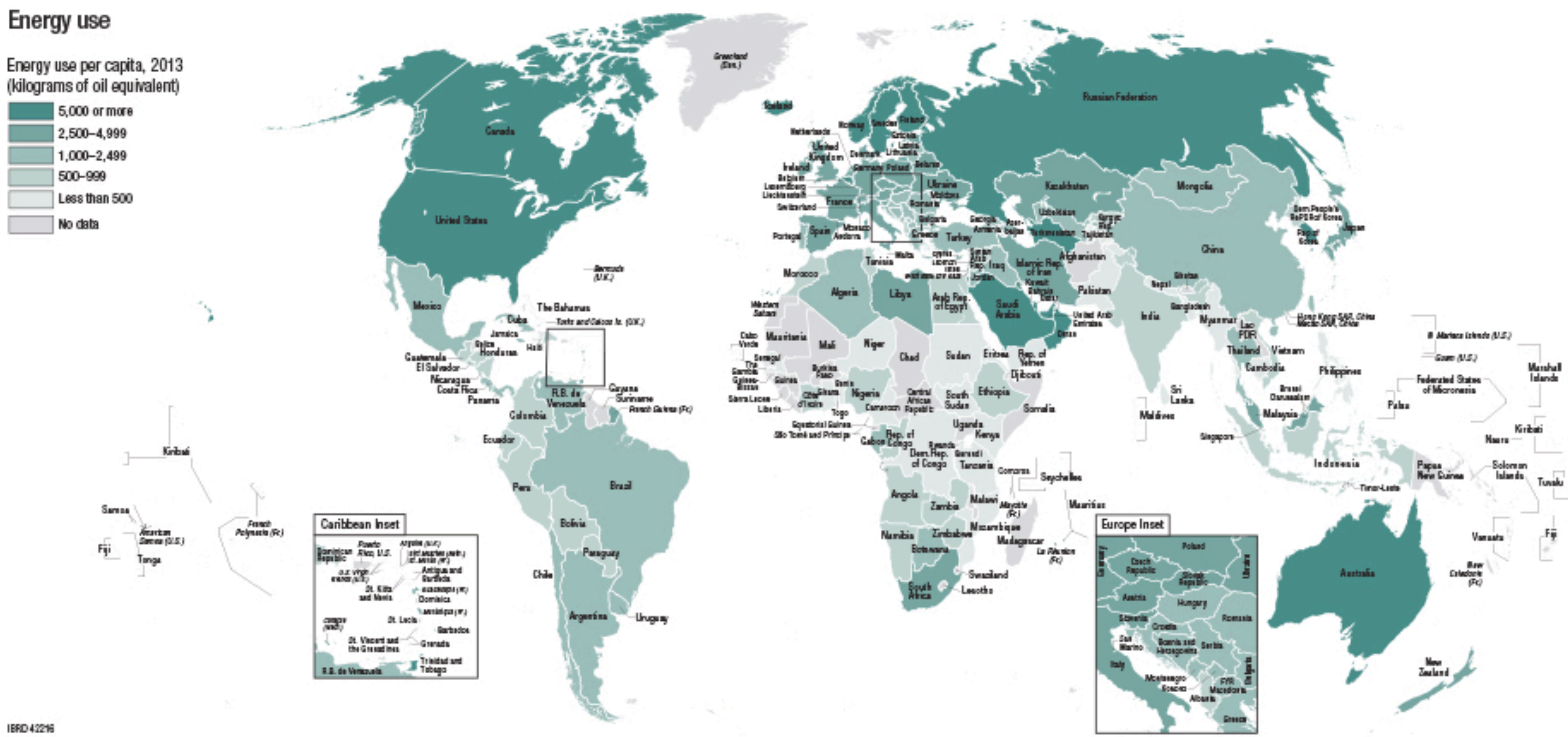
Section 3.4

Energy Sources Today



True or false:

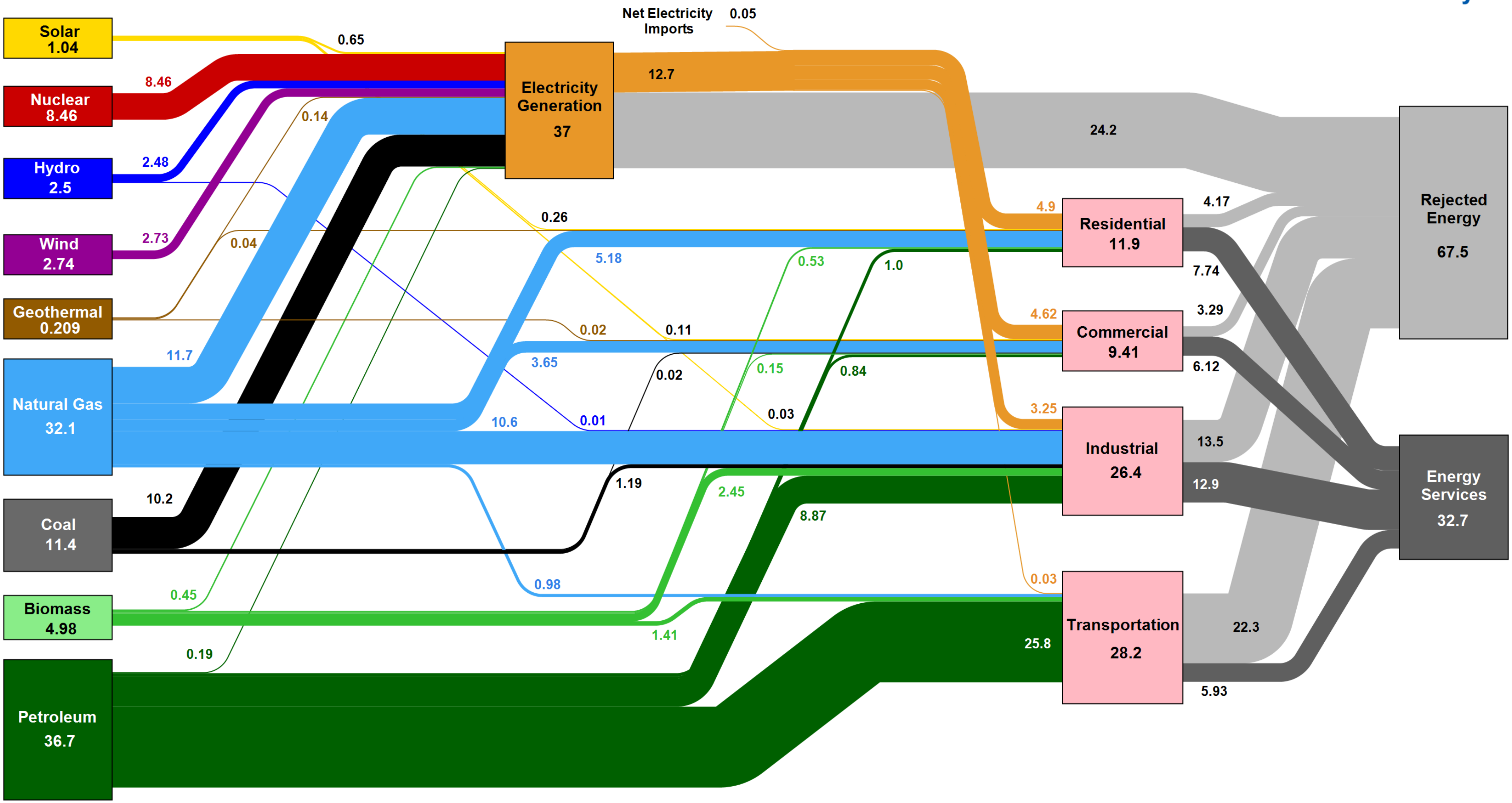
In 2013, the United States (with 5% of the global population) consumed 18% of the world's energy.



Source: US Energy Information Administration

Estimated U.S. Energy Consumption in 2019: 100.2 Quads

Lawrence Livermore National Laboratory

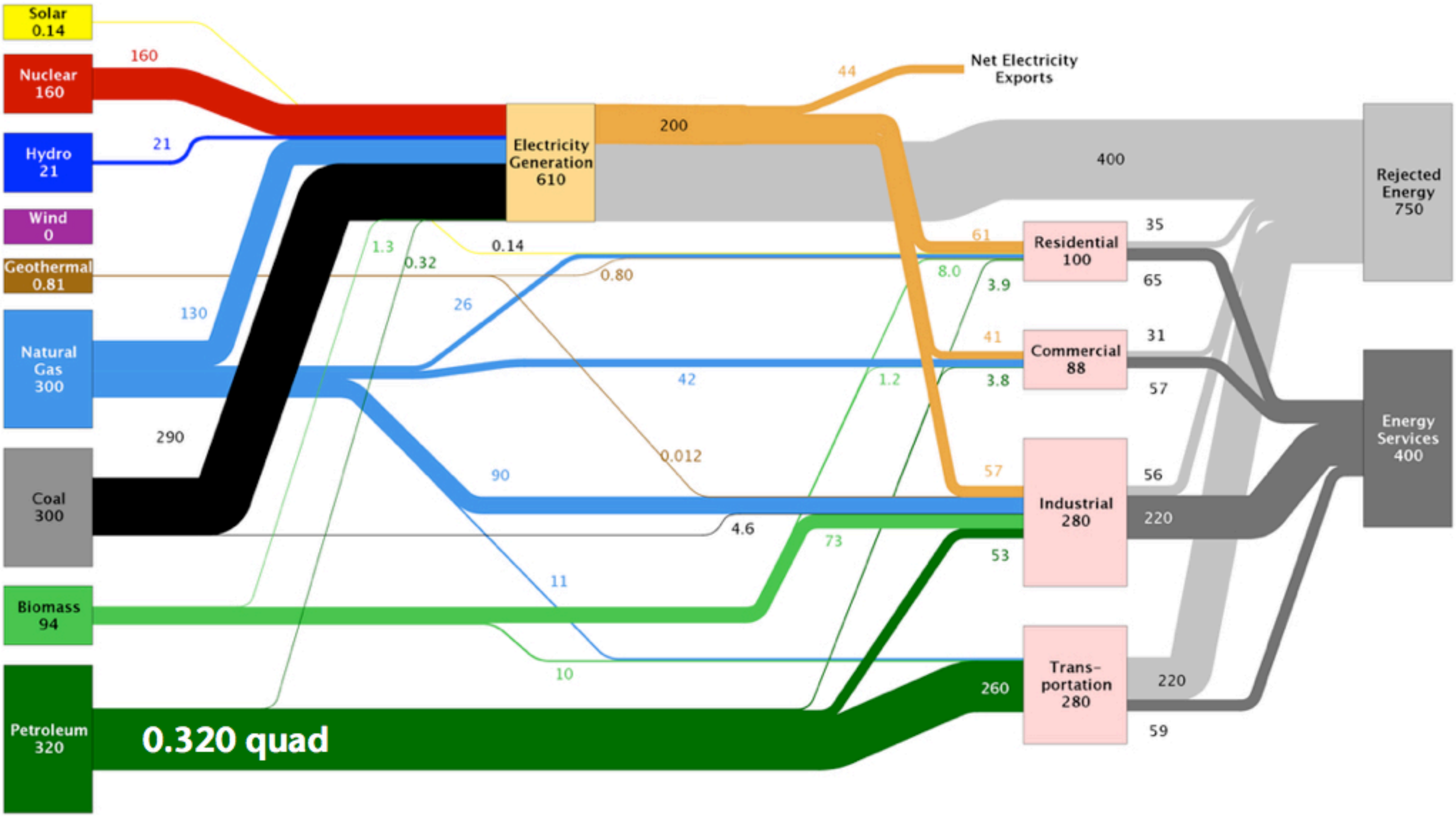


Source: LLNL March, 2020. Data is based on DOE/EIA MER (2019). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 21% for the transportation sector and 49% for the industrial sector, which was updated in 2017 to reflect DOE's analysis of manufacturing. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

Quad = unit of energy = 10^{15} (quadrillion) BTU = 1.055×10^{18} Joules

Estimated Arkansas Energy Use In 2012
~1200 Trillion BTU

Lawrence Livermore National Laboratory

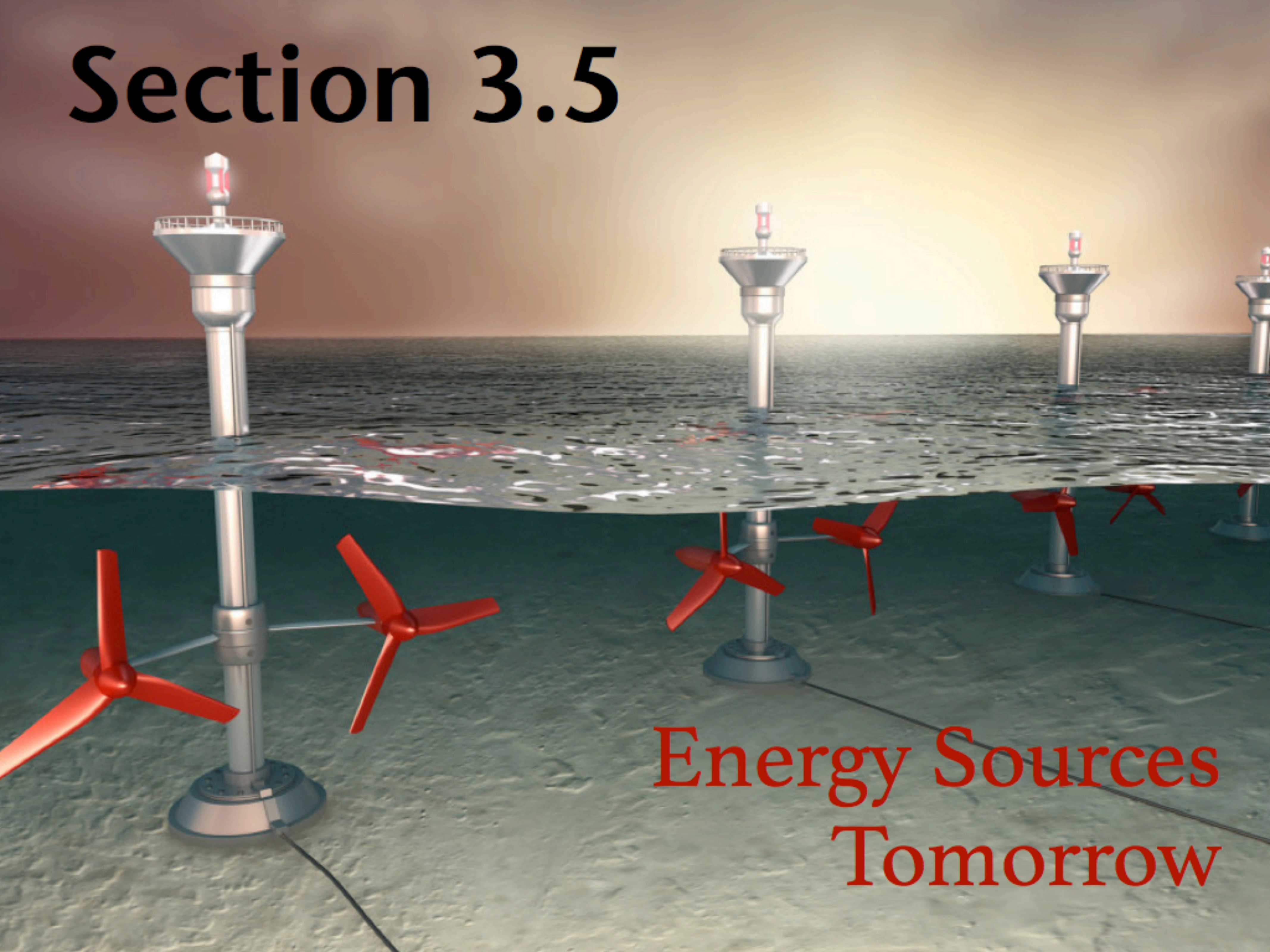


Source: LLNL 2013. Data is based on DOE/EIA-0214(2011), June 2013. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports flows for non-thermal resources (i.e., hydro, wind and solar) in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. Interstate and international electricity trade are lumped into net imports or exports and are calculated using a system-wide generation efficiency. End use efficiency is estimated for each sector as 65% residential, 65% commercial, 80% industrial and 21% transportation. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

1200 trillion = 1.2×10^{15} BTU = 1.2 Quads = 1.266×10^{18} Joules

Conserving Energy

- Not the same as conservation of energy!
- Do more with less: increase efficiency
- Just use less: why is this so difficult to understand?


Section 3.5
Energy Sources
Tomorrow

Not Much Changes

- What coal has lost, natural gas has gained
- About the same proportions in renewables