GREEN ENERGY

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My Definition of Green Energy

- Clean – no emissions or residuals
- Abundant/Perpetual/Inexhaustible
  - Fuel is essentially free
  - Creating energy has a capital cost, but no incremental direct cost
- Wind, solar, and other potential energy (hydro, tidal, thermal,…)
- Not
  - Natural gas
  - Nuclear
  - Biofuels

GREEN ENERGY IN THE HOME INCLUDING PERSONAL TRANSPORTATION

Who's Got What? And Why?

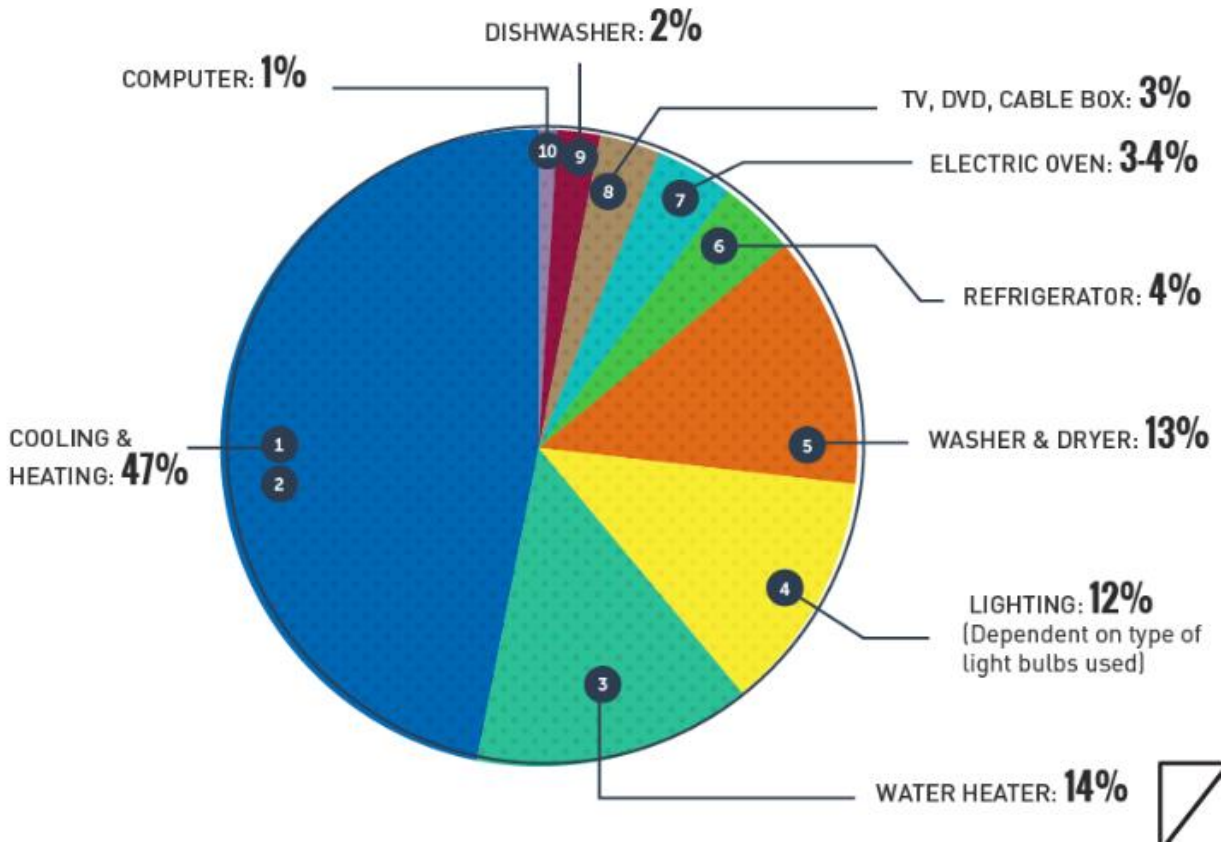
- LED bulbs
- Programmable thermostat
- Double pane/Low E windows
- Foam insulation
- Cape Light Compact audit
- Heat pump HVAC
- Heat pump hot water heater
- Solar panels
- Home battery backup
- Electric car

Syllabus – Green Energy in the Home

- Energy Sources and Usage
- Going Green Requires Going Electric
  - Assumptions about electric power
  - Approaches
    - Conversion to electric
    - Conservation/increased efficiency
  - Technologies

Uses of Energy in the Home *

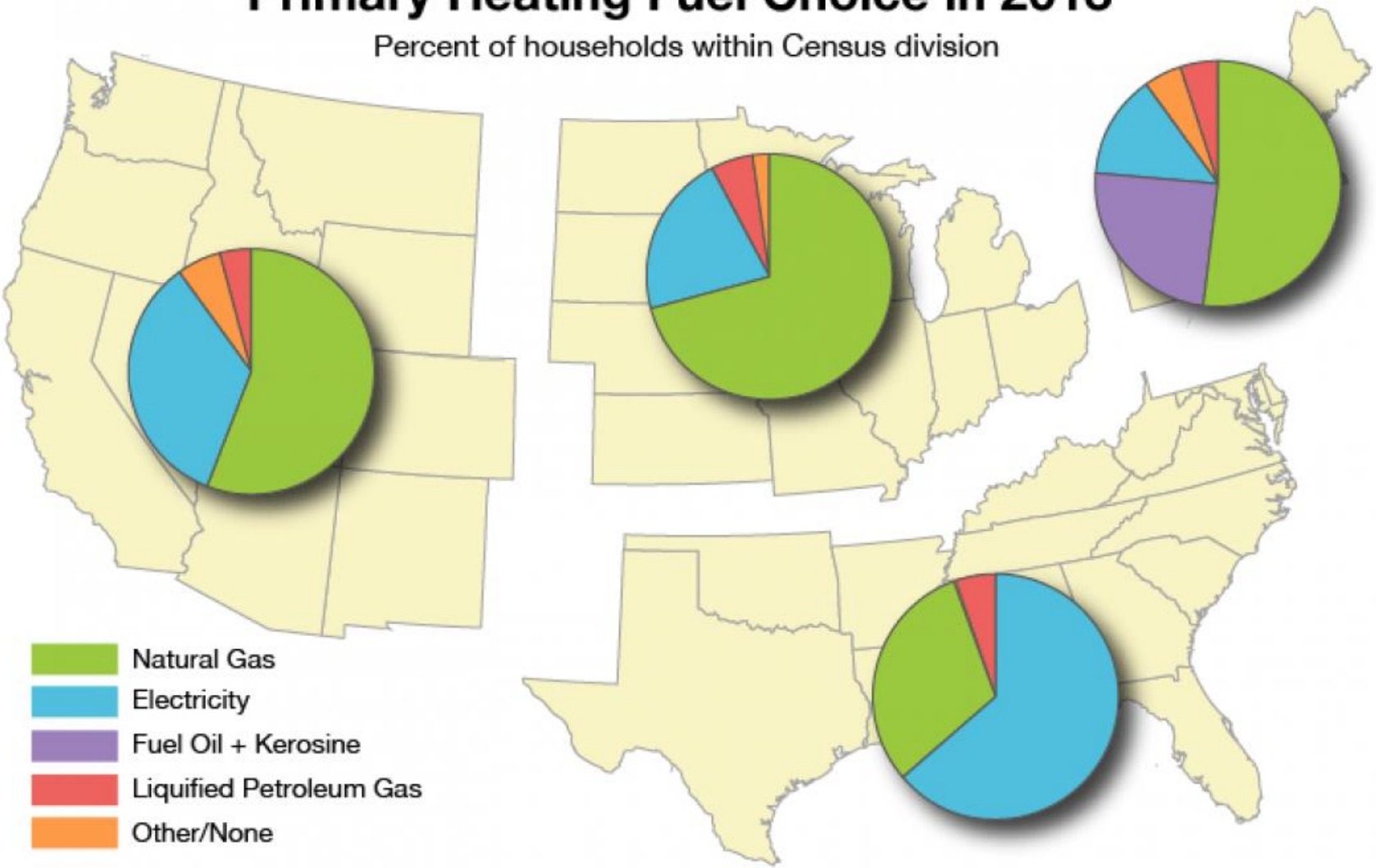
* Your energy use for personal transportation is roughly equivalent to your use in the home!



https://www.visualcapitalist.com/what-uses-the-most-energy-home/

Primary Heating Fuel Choice in 2013

Percent of households within Census division



Data Source: U.S. Energy Information Administration

Home Energy Audit – Cape Light Compact

- Immediate savings for free
  - LED bulbs, advanced power strips, programmable thermostats
  - Low flow shower heads, aerators
- Assessment of needs
  - Free air sealing
  - Subsidized insulation
  - Generous rebates for HVAC and water heaters
  - 0% interest loans
- Supplier of green energy - Rates
- Special programs for low- and moderate-income customers
- Quick reference: Energy Star – Home Energy Yardstick

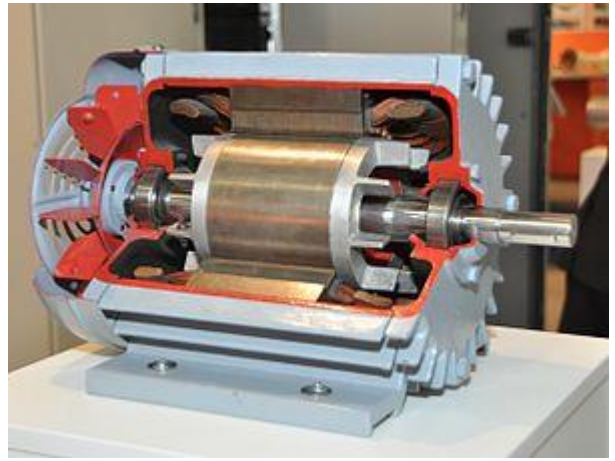
Emerging Technologies in the Home

- Electric motors for transportation and power
- Heat pumps for heating and cooling
- LEDs for lighting
- Improvements in your home's thermal envelope
- Improved control systems

- Solar panels for generating electricity

Electric Motors

- Consume over ½ the electricity generated in the US
- Vehicles
- Large and small appliances
- Yard equipment
- Tools
- Electronics
- Generators



History of Electric Motors

- "Brushed" DC motor developed by Von Siemens in late 1800s
  - 75 – 80% efficient, subject to wear
- AC Induction motor developed by Tesla in 1924
- Brushless - invented in 1962 Wilson/Trickey
  - These were solid state motors (controlled by semiconductor "chips")
  - Newest microcontrollers enable 98% efficiency in small motors
  - Microcontroller captures position and controls PWM of motor
  - Quiet, frictionless, sparkless, cool, more efficient, reliable
- New products enabled (with improved battery technology) :
  - Bladeless fans, electric vehicles, cordless power tools, etc

Electric Cars

- A 2018 study from the University of Michigan found that electric vehicles cost less than half as much to operate as gas-powered cars. The average cost to operate an EV in the United States is $485 per year, while the average for a gasoline-powered vehicle is $1,117.
- Maintaining an electric car, according to some estimates, will cost about one-third the current cost of maintaining a gasoline-powered car.

Internals of the Electric Car

- Battery pack
- Inverter
- Induction motor
  - RMF – Rotating Magnetic Field
- Other
  - Transmission
  - Open differential
  - Regenerative braking
- https://youtu.be/3SAxXUIre28


SECRETS OF TESLA MODEL S

Electric versus Internal Combustion Motors

- Path to Lower Production Cost
- Lower Maintenance Costs
  - Simple drive train
  - Rotational energy
  - Minimal ancillary components
- High efficiency (95% versus 25%)
  - Solid state motor
  - Regenerative braking

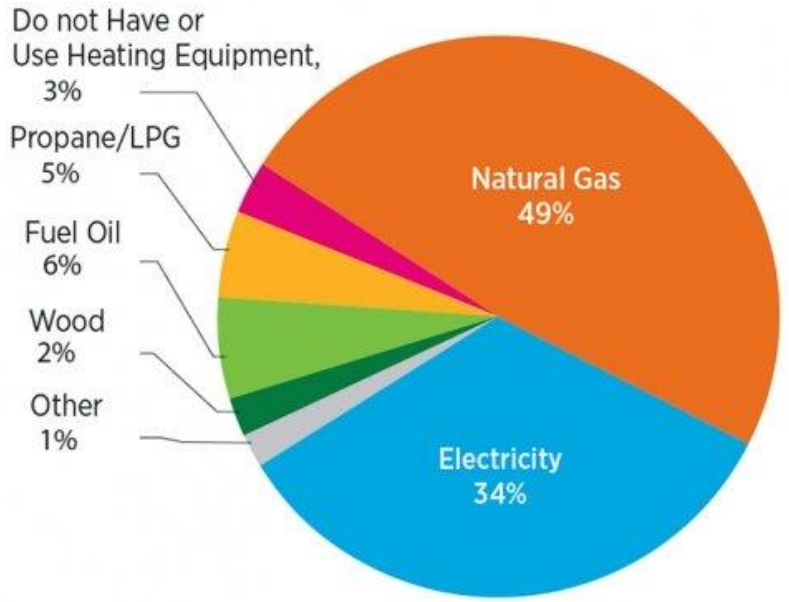
Payback – Electric versus ICE Car

- X = difference in upfront cost
- Y = difference in usage cost/time period
- X/Y = number of payback time periods to recover upfront difference
- Initial cost
  - Kia Soul - $17,500
  - Kia Soul, electric - $34,000 - $7,500 = $26,500
- Operating cost
  - Fuel for 15K miles: Gas – $1,500, Electric - $579
  - Maintenance: Gas - $1,186, Electric - $982 (or $474)
- Payback
  - $9,000 / $1,125 = 8 years or $9,000 / $1,603 =5.6 years

  - https://newsroom.aaa.com/tag/gas-cost/
  - https://auto.howstuffworks.com/will-electric-cars-require-more-maintenance.htm

Traditional Heating

- Fuel combustion
  - Solid: wood, peat, coal
  - Liquid: oil
  - Gas: natural gas, propane
- Heat transfer
  - To air or to water
  - Blown or pumped
- Heat conversion
  - Atmospheric (70%)
  - Condensing/controlled (90%)
- Electric baseboard



Energy.gov

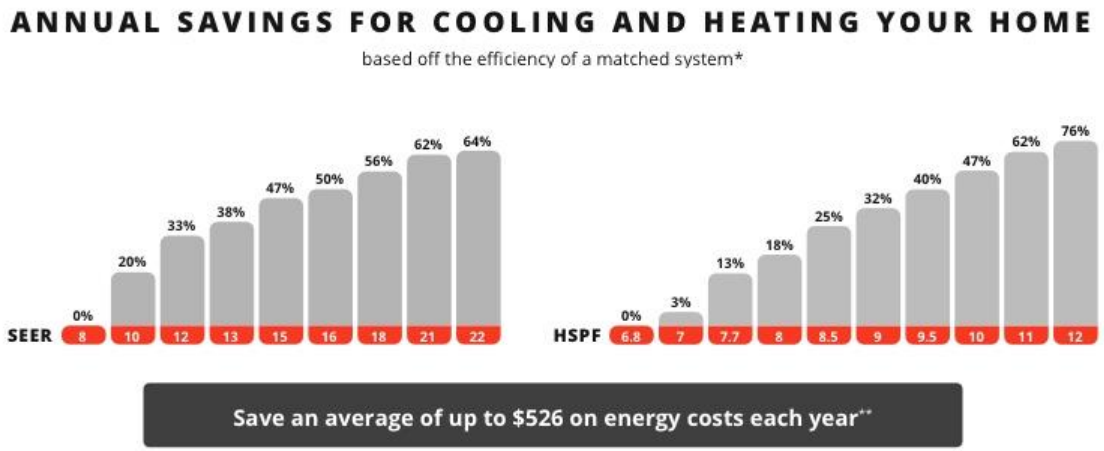
Projected 2019/20 Heating Costs by Fuel

Space Heating Fuel	Estimated Cost
Natural Gas	$1,082
Modern Wood Heating	$1,240
Air Source Heat Pump	$1,439
Heating Oil	$1,743
Propane	$2,307
Electric Baseboard (resistance)	$4,606

- Source: mass.gov

Heat Pumps: Heating, AC, Refrigeration, HW

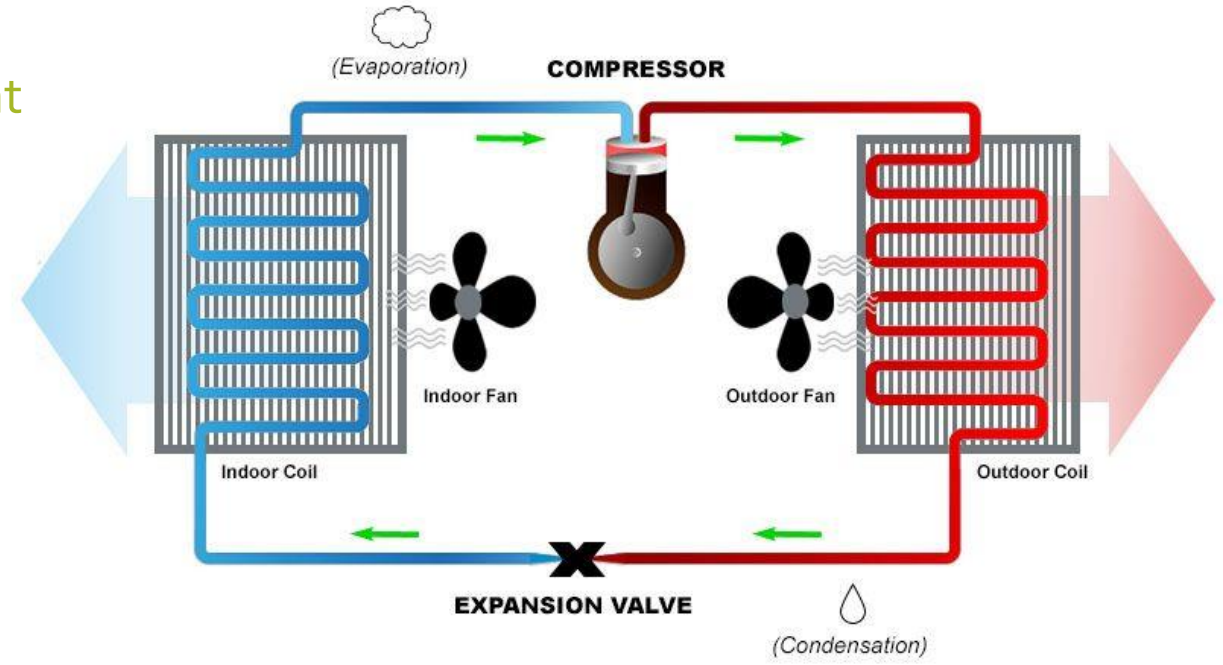
- Energy is used to move heat, not generate it
- 2-4 times the efficiency of resistive heating
- Tech improvements:
  - Variable speed fans
  - Variable speed pumps
  - "Cold" operation

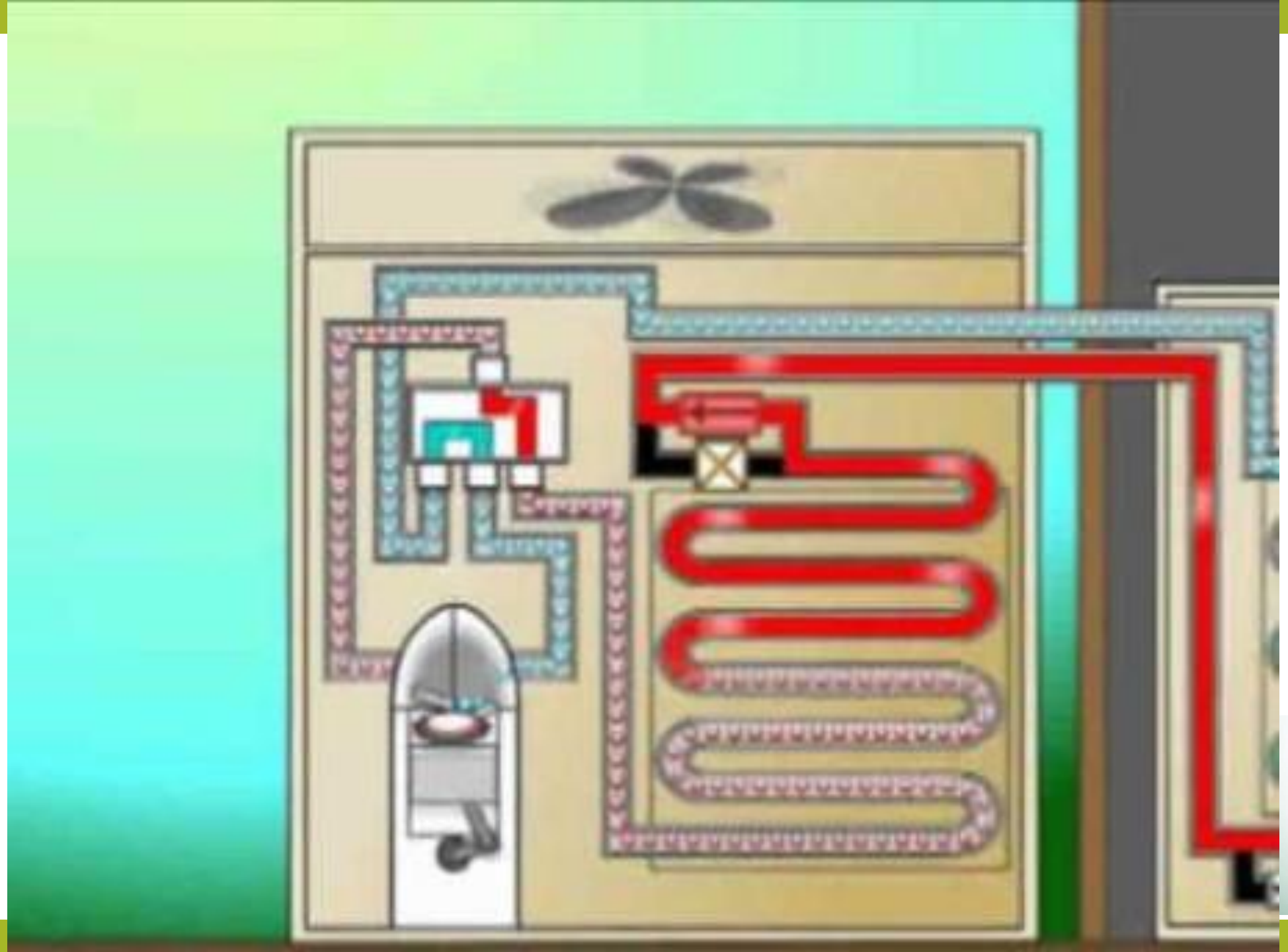


Trane.com

Internals of the Heat Pump

- Refrigerant – Hydrofluorocarbon (HFC – R134a versus R12)
- Compressor
  - Condensation –liquifies the refrigerant
- Expansion valve
  - Evaporation – cools the refrigerant
- Pumps, Fans, and Controller





Heat Pump versus Traditional Heating

- Uses electricity to transfer heat instead of generating it
- Not capped in terms of efficiency
- Can be applied to both heating and cooling
- Slower in producing heat

Hot Water Heater

- Gas
  - Traditional 50% Efficiency
  - Energy Star: 67% + (intermittent pilot, flue damping, blowers/power venting)
- Electric
  - Traditional: 80% Efficiency
  - Energy Star: 200%+ using heat pump technology
  - Traditional now: 92% and heat pump now 3.6 UEF first hour.
- Cost differences of electric alternatives
  - Operating – $490 versus $150 per year
  - Installation – $700 versus $1,500

Payback – Heat Pump Hot Water Heater

- X = difference in upfront cost
- Y = difference in usage cost/time period
- X/Y = number of payback time periods to recover upfront difference

Example

- X = $1,500 - $700 = $800
- Y = $490 - $150 = $340 per year
- Payback = $800/$340 = 2.35 years

Lighting Technology

- Candle
  - Egyptians, 3000 BC
  - Beeswax, animal fat, fire
- Incandescent
  - Edison, 1897
  - Tungsten filament, current
- Florescent (CFL)
  - Hewitt, 1901
  - Mercury vapor, current
- Light Emitting Diode (LED)
  - Holonyak, 1962
  - Gallium arsenide, current

Lightbulb Jokes

- Q: How many nuclear engineers does it take to change a light bulb? A: Seven. One to install the new bulb and six to figure out what to do with the old one for the next 10,000 years.

- Q: How many politicians does it take to change a lightbulb? A: Two. One to change it, and another one to change it back again.

- Q: How many economists does it take to change a light bulb? A: None. If the light bulb needed changing the market would have already done it.

- Q: How many climate change skeptics does it take to change a lightbulb? A: None. It's too early to say if the light bulb needs changing.

Cost Comparison of Lighting Technolgies

LED vs CFL vs Incandescent Cost	**Incandescent**	**CFL**	**LED**
Watts used	60W	14W	7W
Average cost per bulb	$1	$2	$4 or less
Average lifespan	1,200 hours	8,000 hours	25,000 hours
Bulbs needed for 25,000 hours	21	3	1
Total purchase price of bulbs over 20 years	$21	$6	$4
Cost of electricity (25,000 hours at $0.15 per kWh)	$169	$52	$30
Total estimated cost over 20 years	**$211**	**$54**	**$34**

Payback Period – Incandescent versus LED

- Initial cost

  X = $4 – $1 = $3

- Operating cost per month at about 3.5 hours/day

  Y = (100 * 60 * $.21) - (100 * 7 * $.21) = $1.20 - $0.15

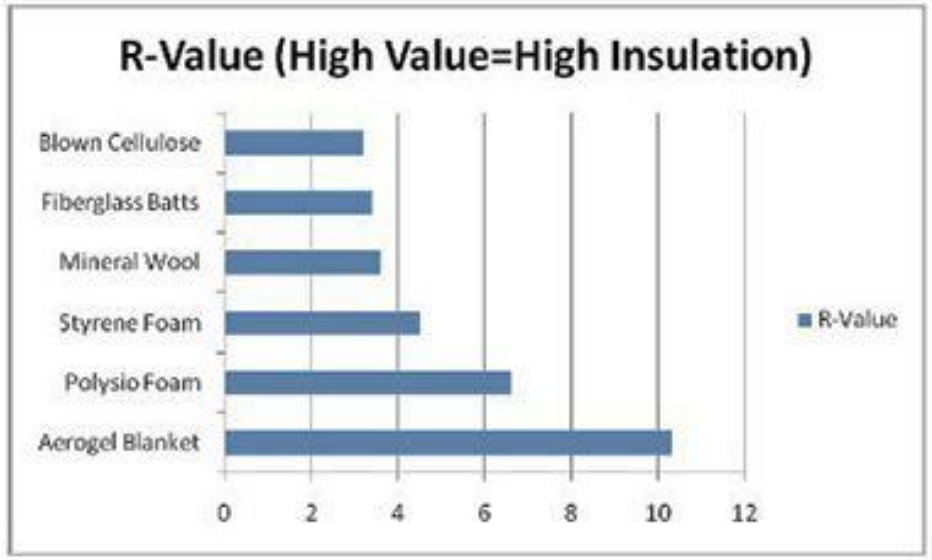
  = $1.05 per month

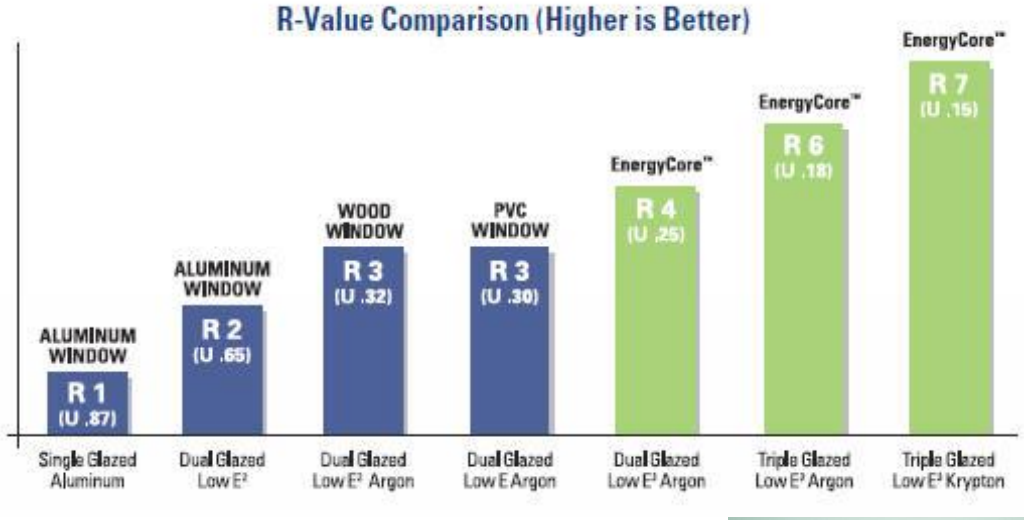
- Payback in < 3 months

Improvements in Thermal Envelope

Exfiltration and Insulation

- 40% of energy loss is through exfiltration (leakage through gaps)
  - Pressure testing is now required for new construction by code (< 3 ACH)
  - As are sealing methods
- Improvements in thermal resistance of materials
  - Insulation
  - Glass

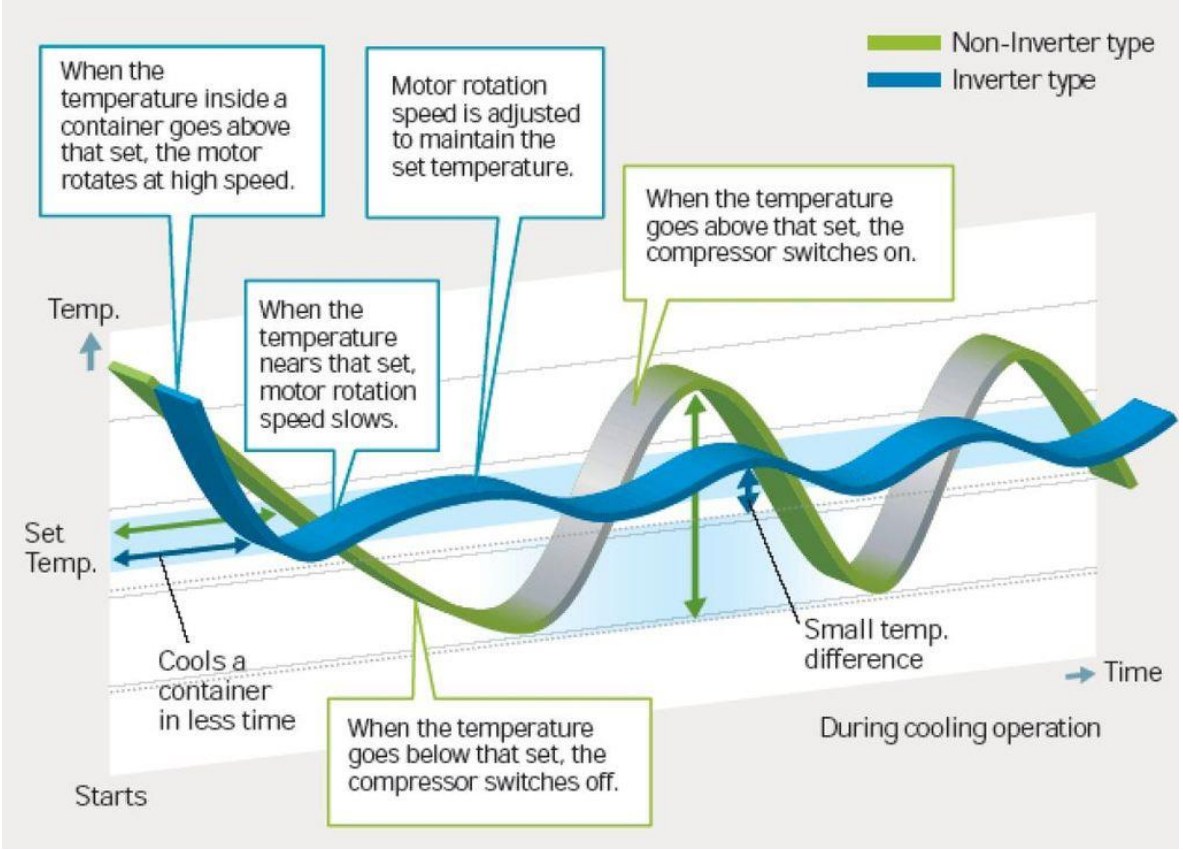




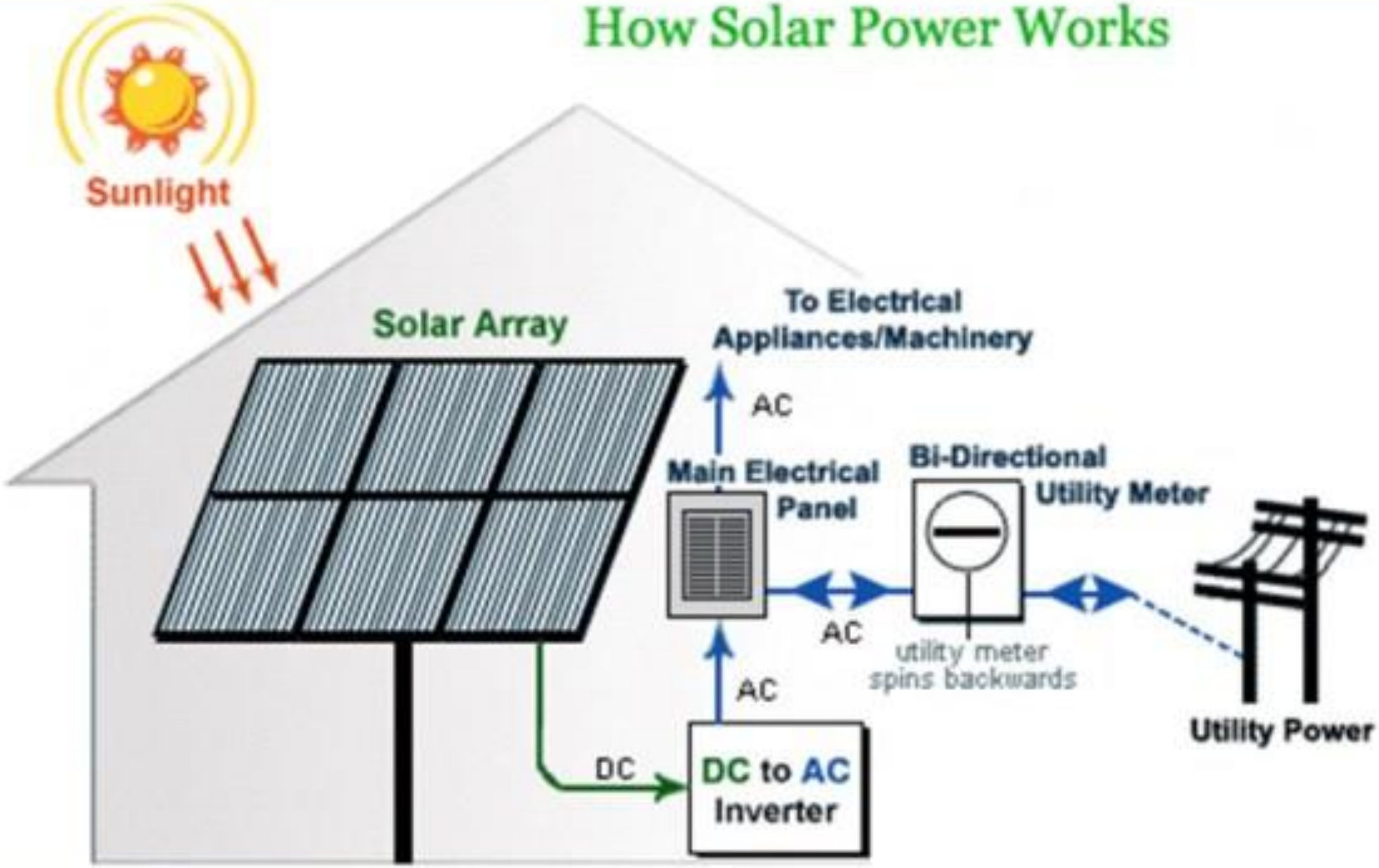
Controls

- Microprocessors are now in everything
- Enable precision control
  - Motors
  - HVAC
  - Many other devices
- Smart buildings
  - Thermostats
  - Lighting
  - Air and water flow
  - Proximity control

Example of Improved Control



How Solar Power Works



Electronics and You

Solar Panel Payback – 36 Panels

- Initial Cost
  - $40,000 less credits of $13,000 = $27,000
- Annual Benefit
  - SRECS - $3600/year for 10 years
  - Energy produced 12 MWhrs * $.21 = $2,500/year
- Payback
  - $27,000 / ($3,600 + $2,500) = 4.4 years

What Can You Do?

- Get an Energy Audit
- Convert to efficient lighting, its cheap and easy
- Seal and improve the insulation in you house
- Consider investing in Green appliances where the payback is reasonable

- How long will it take us to go Green?