PHYS 371 Introduction to Energy

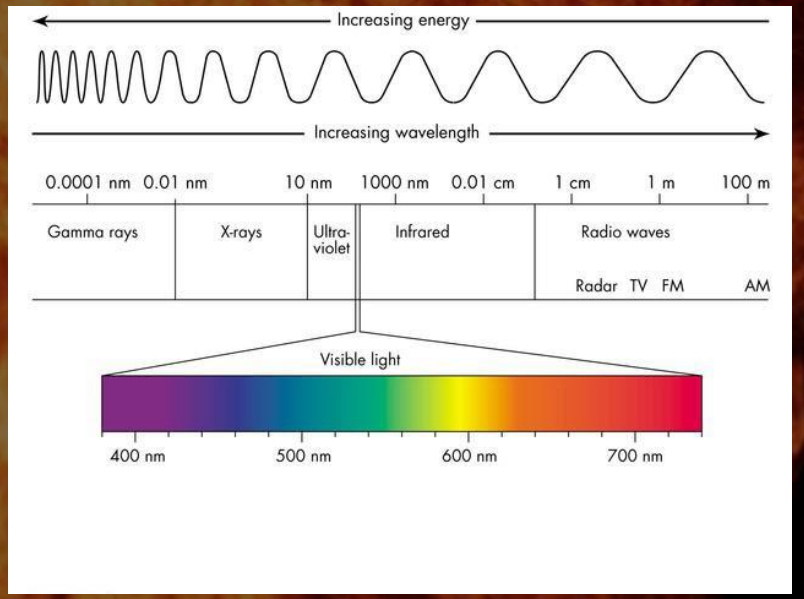
LECTURE 12: THERMAL ENERGY - **HEATING, VENTILATION, AND AIR CONDITIONING (**HVAC)

MONDAY, OCTOBER 4, 2021

Write your questions in the TopHat discussion

The hot body emits electromagnetic waves that are absorbed by other body.
No medium is required for electromagnetic waves to propagate.
Different names are used for electromagnetic waves of different wavelengths: radio waves, microwaves , infrared radiation , visible light , ultraviolet radiation , X-rays, and gamma rays.

Radiation



A shorter wavelength (or higher frequency) corresponds to a higher energy. Because more heat is radiated at higher temperatures, higher temperatures produce more intensity at every wavelength but especially at shorter wavelengths.

Image Source: https://sites.google.com/a/coe.edu/principles-of-structural-chemistry/relationship-between-light-and-matter/electromagnetic-spectrum

Thermal Radiation

https://energyeducation.ca/encyclopedia/Radiation

Thermal radiation is one type of electromagnetic radiation that is talked about in great detail. In terms of heat transfer, radiation is the emission of thermal energy in the form of infrared waves.[6] Generally, thermal radiation and infrared waves are referred to simply as "heat". Since heat is carried by electromagnetic waves, it does not need a physical medium to transfer it. Instead it radiates through space - this is how the Earth is heated by the Sun despite space being a vacuum.[7]

All objects at normal temperature emit thermal radiation; however it is not visible to the naked eye. Infrared cameras are able to pick up this invisible radiation and digitally convert it into a visible image (such as the one shown in Figure 4). Sometimes this radiant heat is visible. For example, a candle radiates heat. It also gives out visible light, which corresponds with the temperature of the flame. The flame burns hottest at the wick, and gives off blue or white light as it is on the higher end of the visible light spectrum. Surrounding the wick, the flame is yellow and then red in appearance, which is at the lower end of the visible light spectrum. The region surrounding the flame gives off no light as it emits infrared waves, but feels warm to the touch.

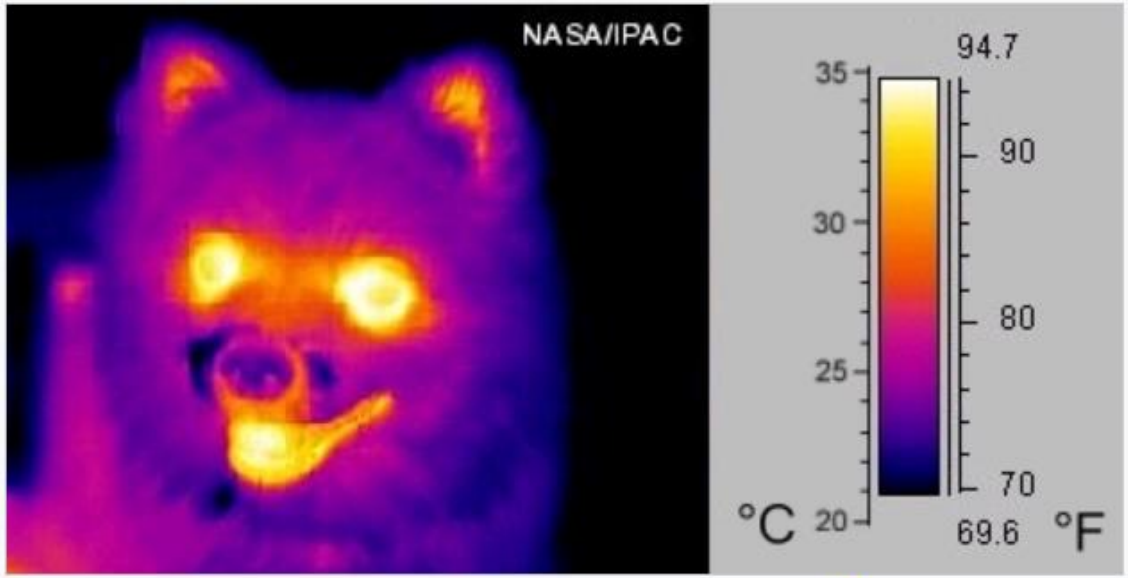
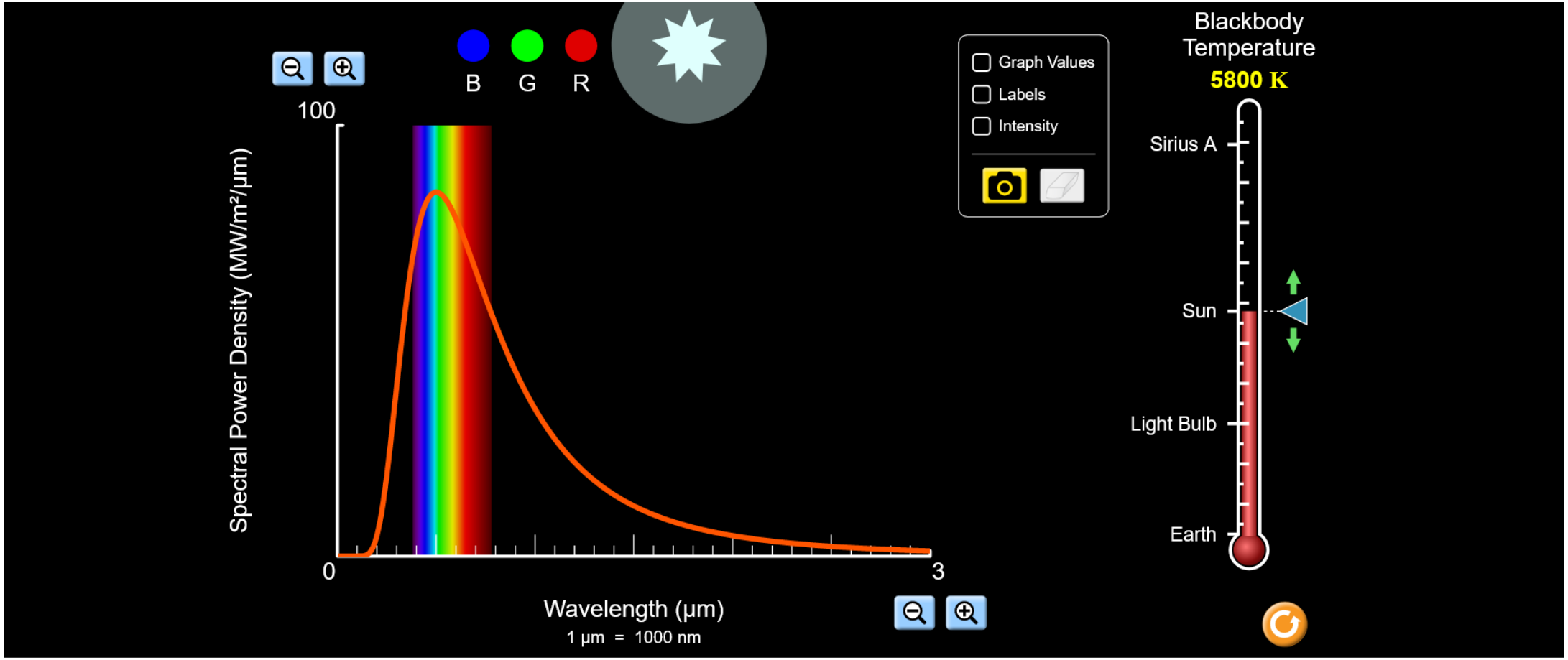


Figure 4. A dog as seen in the infrared spectrum.[8]

Blackbody radiation

https://phet.colorado.edu/sims/html/blackbody-spectrum/latest/blackbody-spectrum_en.html

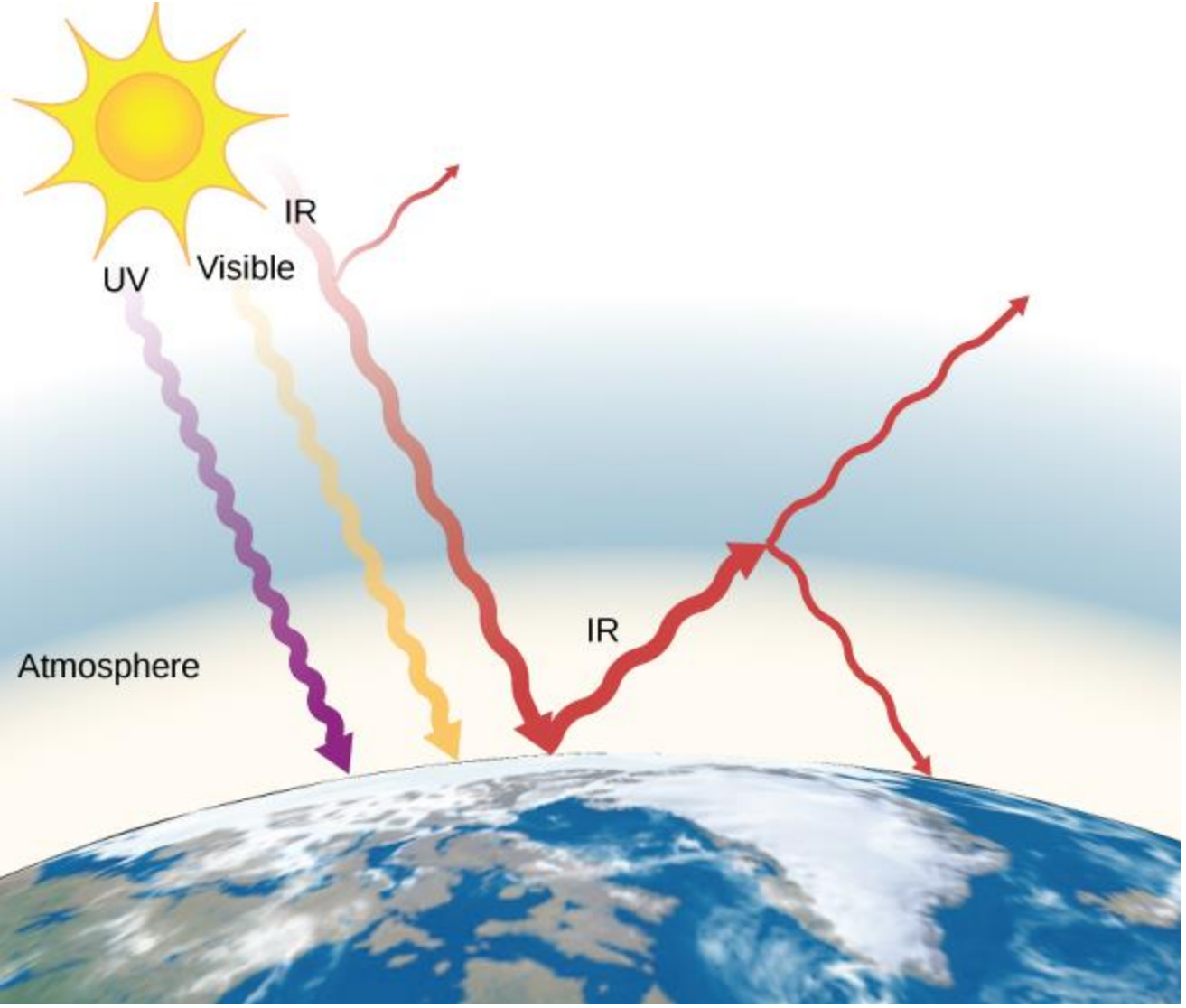


Radiation to Earth	176 000 TW
World Power use	16 TW
Canadian Power use	0.330 TW

Solar radiation delivers a lot of ambient power



Greenhouse effect



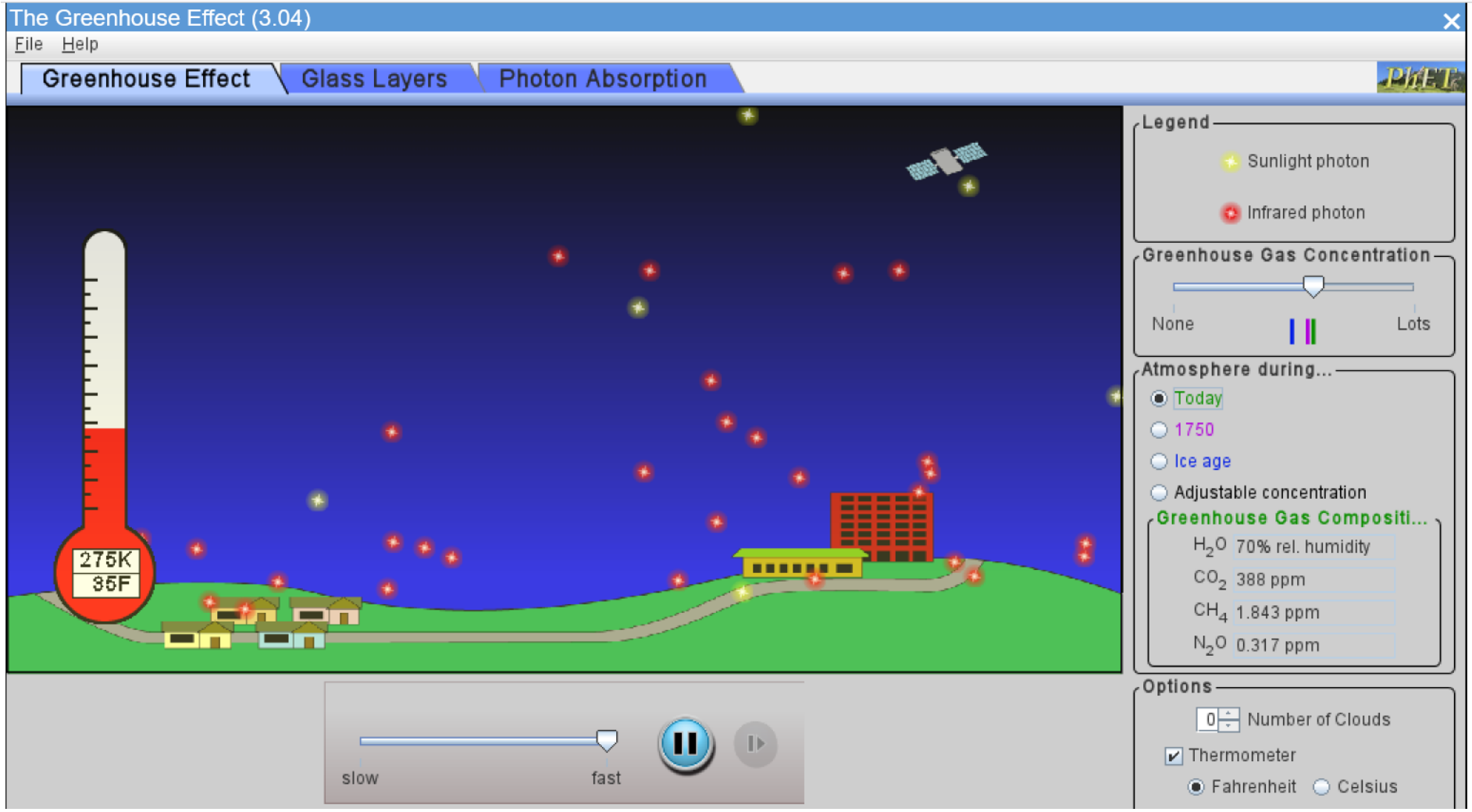
The often-mentioned **greenhouse effect** is directly related to the variation of Earth's emissivity with wavelength. The greenhouse effect is a natural phenomenon responsible for providing temperatures suitable for life on Earth

The greenhouse effect is the name given to the increase of Earth's temperature due to absorption of radiation in the atmosphere.

The atmosphere is transparent to incoming visible radiation and most of the Sun's infrared. The Earth absorbs that energy and re-emits it. Since Earth's temperature is much lower than the Sun's, it re-emits the energy at much longer wavelengths, in the infrared. The atmosphere absorbs much of that infrared radiation and radiates about half of the energy back down, keeping Earth warmer than it would otherwise be. The amount of trapping depends on concentrations of trace gases such as carbon dioxide, and an increase in the concentration of these gases increases Earth's surface temperature .

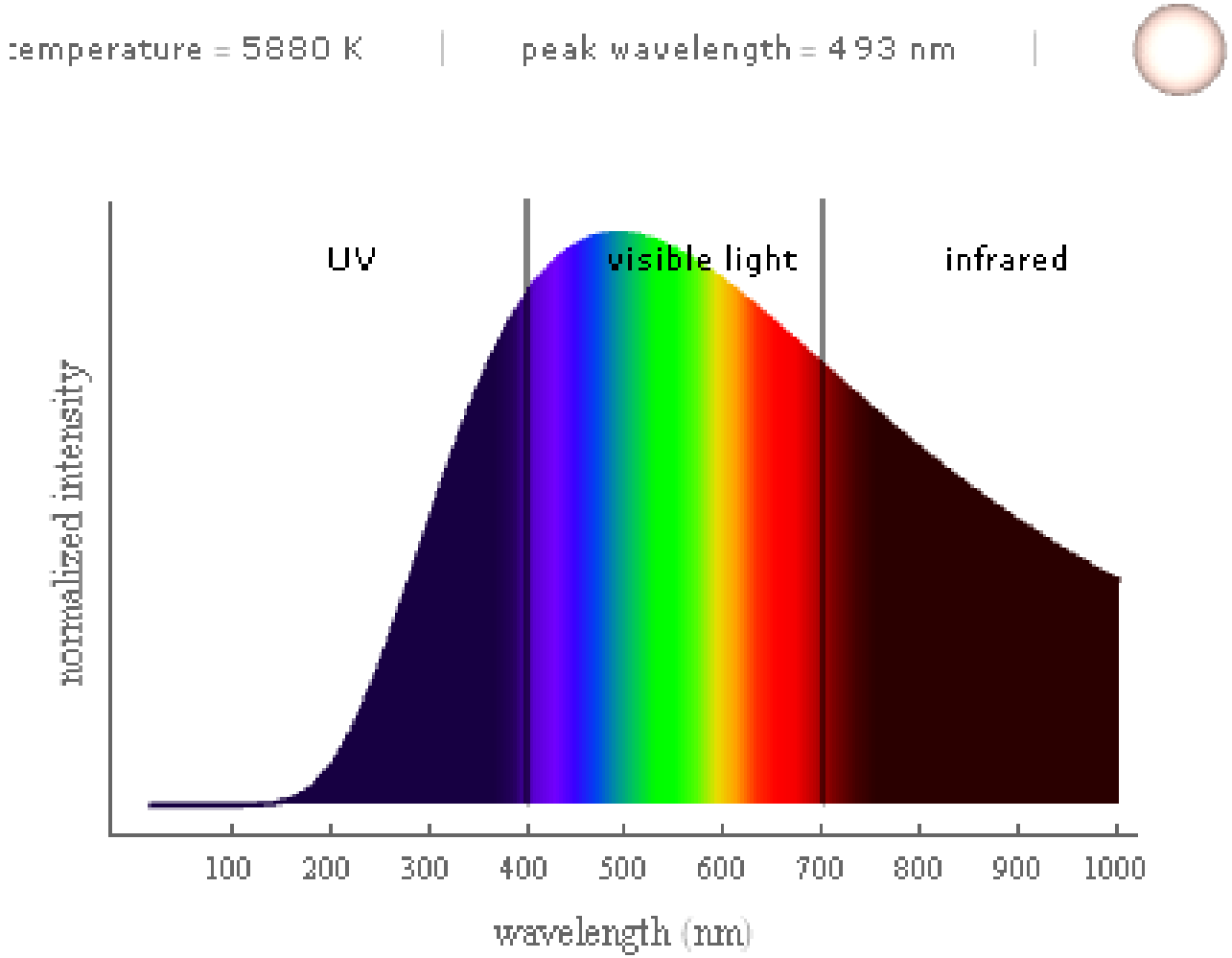
Mechanisms of Heat Transfer. (2020, November 5). Retrieved September 30, 2021, from https://phys.libretexts.org/@go/page/4349

Greenhouse effect



https://phet.colorado.edu/sims/cheerpj/greenhouse/latest/greenhouse.html?simulation=greenhouse

Blackbody radiation, no special wavelength given off



Temperature (°C)
550
630
680
740
770
800
850
900
950
1000
1100
1200
1300

Hot enough to see



Sun is hot enough to give off light:

$$3.85 \times 10^{26} W$$

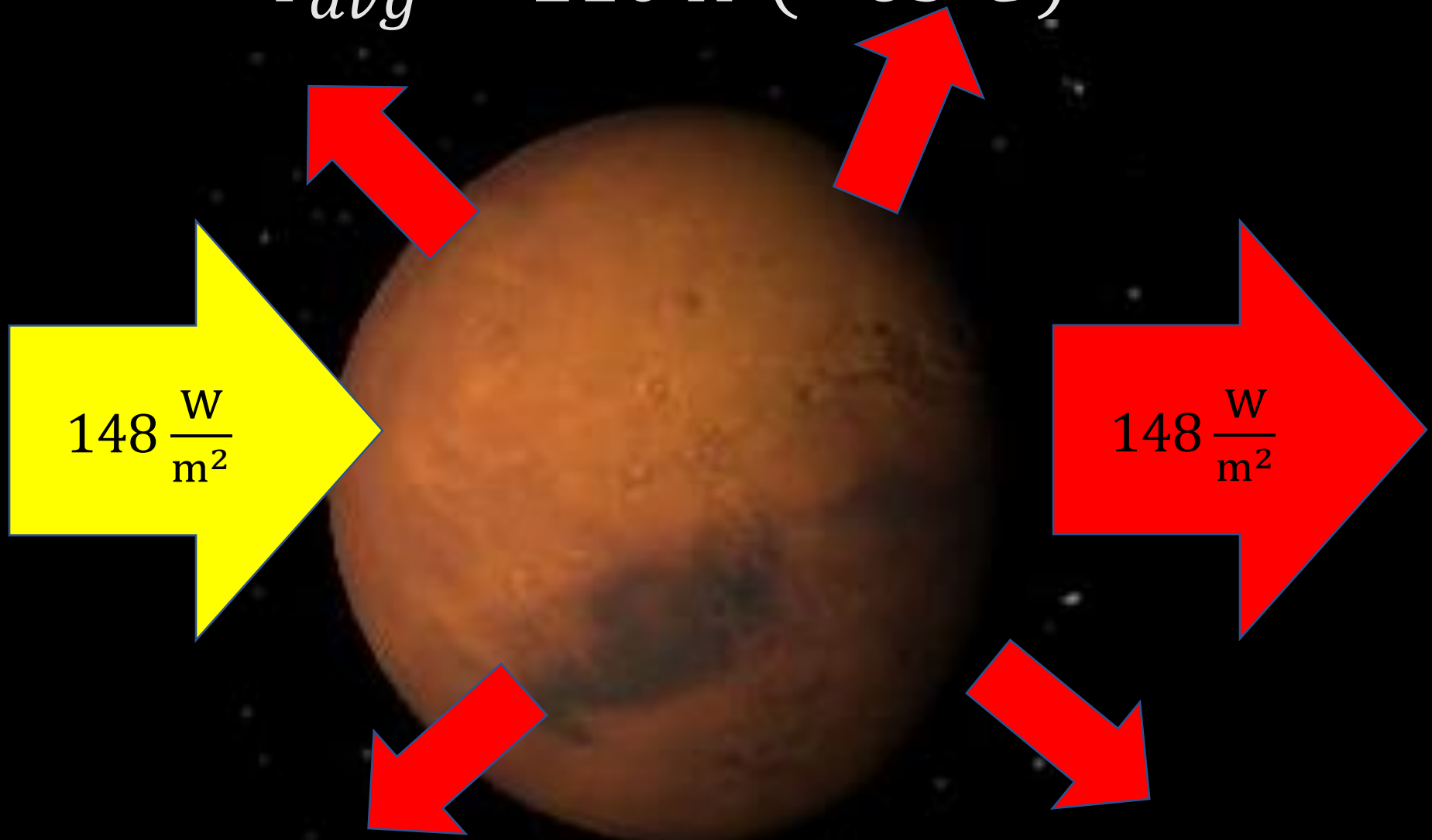
Mercury works!

$$T_{avg} = 440\ K\ (167°C)$$



Mars works!

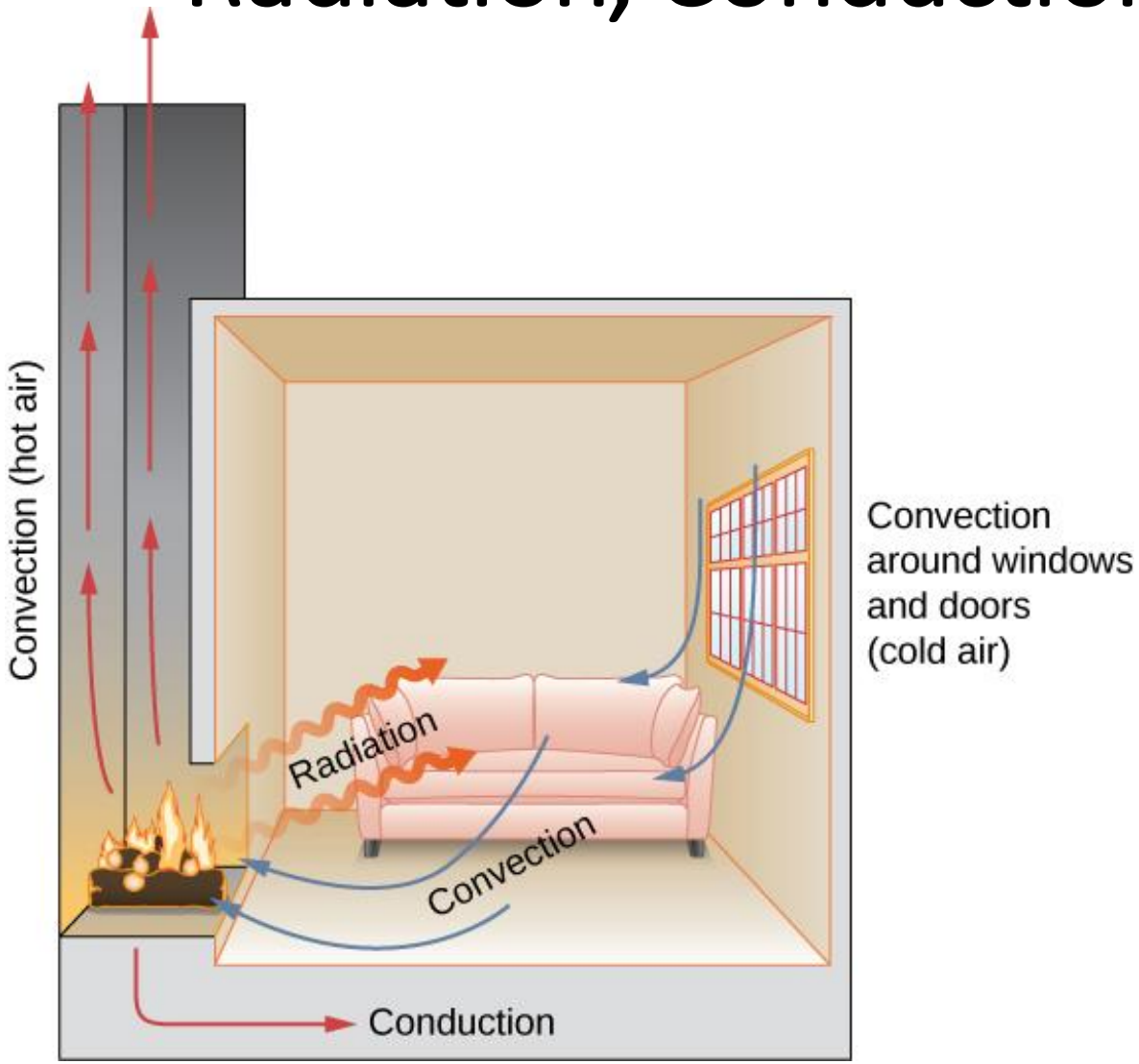
$$T_{avg} = 210\ K\ (-63°C)$$



Planet	Alb.	Calc. T	Meas. T
Mercury	0.12	440 K (167°C)	440 K (167°C)
Venus	0.75	232 K (−40°C)	735 K (462°C)
Earth	0.30	255 K (−18°C)	288 K (15°C)
Mars	0.15	210 K (−63°C)	210 K (−63°C)

Other planets less so, will improve that model later

Radiation, Conduction, Convection



In a fireplace, heat transfer occurs by all three methods: conduction, convection, and radiation. ***Radiation*** is responsible for most of the heat transferred into the room. Heat transfer also occurs through ***conduction*** into the room, but much slower. Heat transfer by ***convection*** also occurs through cold air entering the room around windows and hot air leaving the room by rising, up the chimney.

Example from daily life:
Conduction: Heat transfers into your hands as you hold a hot cup of coffee.
Convection: Heat transfers as the barista "steams" cold milk to make hot cocoa.
Radiation: Heat transfers from the Sun to a jar of water with tea leaves in it to make "Sun tea."

Mechanisms of Heat Transfer. (2020, November 5). Retrieved September 30, 2021, from https://phys.libretexts.org/@go/page/4349

Radiation, Conduction, Convection

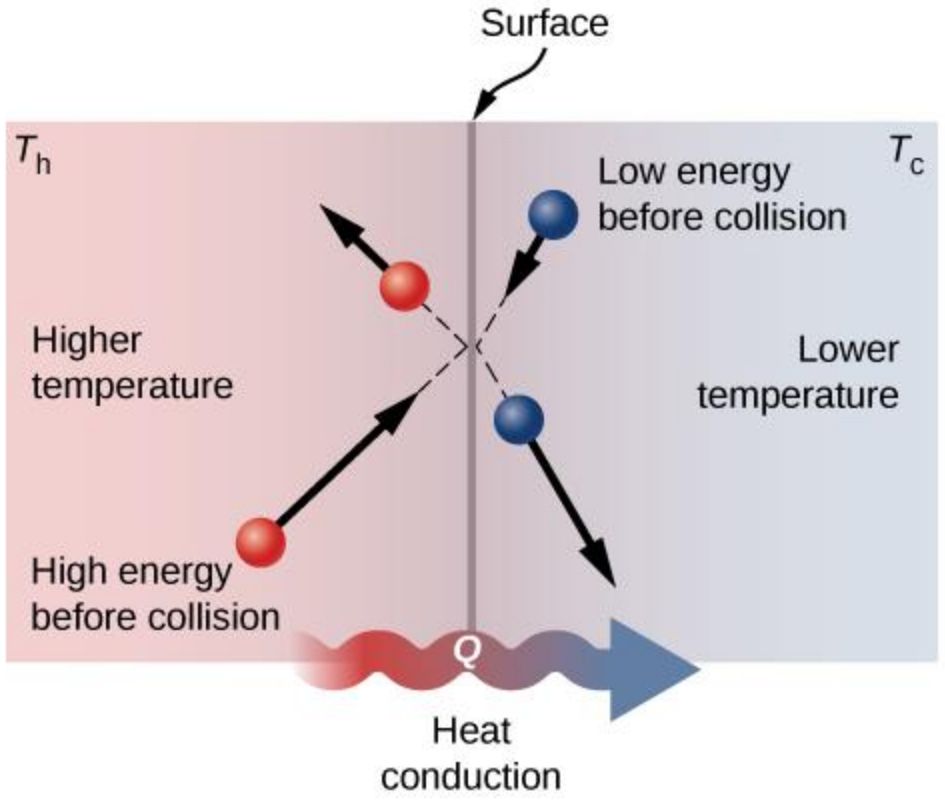
1.Conduction is heat transfer through stationary matter by physical contact. (The matter is stationary on a macroscopic scale—we know that thermal motion of the atoms and molecules occurs at any temperature above absolute zero.) Heat transferred from the burner of a stove through the bottom of a pan to food in the pan is transferred by **conduction**.

2.Convection is the heat transfer by the macroscopic movement of a fluid. This type of transfer takes place in a forced-air furnace and in weather systems, for example.

3.Heat transfer by **radiation** occurs when microwaves, infrared radiation, visible light, or another form of electromagnetic radiation is emitted or absorbed. An obvious example is the warming of Earth by the Sun. A less obvious example is thermal radiation from the human body.

Mechanisms of Heat Transfer. (2020, November 5). Retrieved September 30, 2021, from https://phys.libretexts.org/@go/page/4349

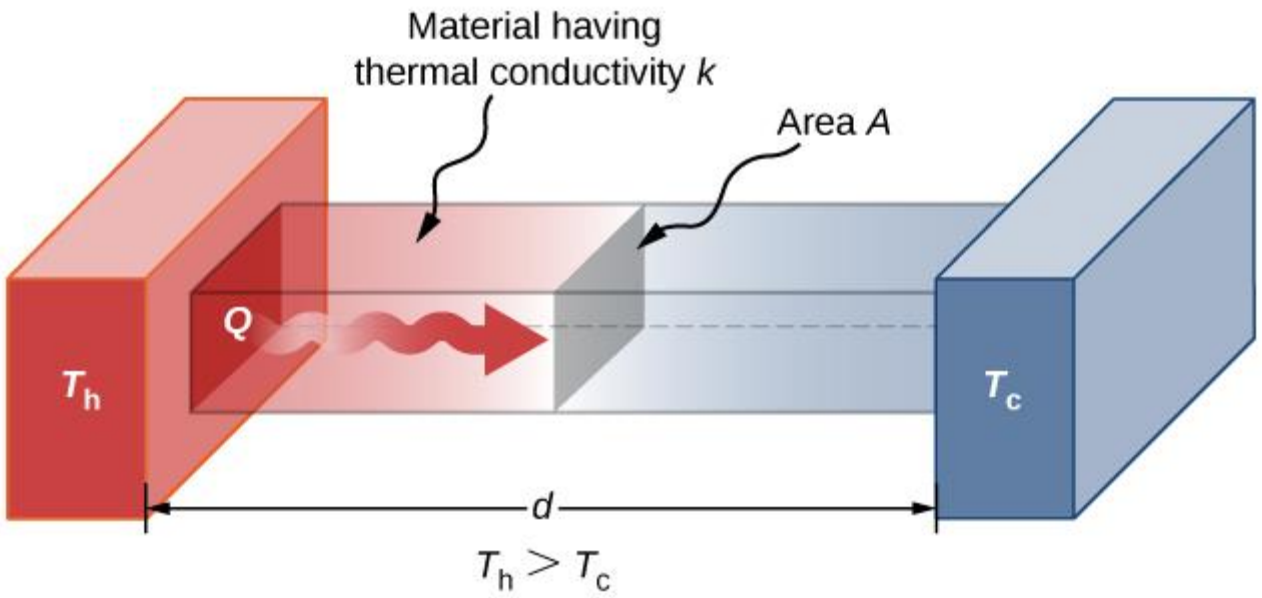
Heat Conduction



Molecules in two bodies at different temperatures have different average kinetic energies. Collisions occurring at the contact surface tend to transfer energy from high-temperature regions to low-temperature regions. In this illustration, a molecule in the lower-temperature region (right side) has low energy before collision, but its energy increases after colliding with a high-energy molecule at the contact surface. In contrast, a molecule in the higher-temperature region (left side) has high energy before collision, but its energy decreases after colliding with a low-energy molecule at the contact surface.

Mechanisms of Heat Transfer. (2020, November 5). Retrieved September 30, 2021, from https://phys.libretexts.org/@go/page/4349

Heat Conduction



Heat conduction occurs through any material, represented here by a rectangular bar, whether window glass or walrus blubber.

$$P = \frac{kA(T_h - T_c)}{d}$$

where P is the power or rate of heat transfer in watts or in kilocalories per second, A and d are its surface area and thickness, as shown in the figure, Th−Tc is the temperature difference across the slab, and k is the thermal conductivity of the material.

Mechanisms of Heat Transfer. (2020, November 5). Retrieved September 30, 2021, from https://phys.libretexts.org/@go/page/4349

https://energyeducation.ca/encyclopedia/Thermal_conduction#cite_note-1

Thermal conduction

Thermal conduction is the diffusion of thermal energy (heat) within one material or between materials in contact. The higher temperature object has molecules with more kinetic energy; collisions between molecules distributions this kinetic energy until an object has the same thermal energy throughout. *Conduction is the main mode of heat transfer between or inside solid materials*. Conduction allows gas and electric stoves heat up pans. Buildings lose much of their heat by conduction, the pockets of air in insulation prevents this loss by stopping conduction.[2]

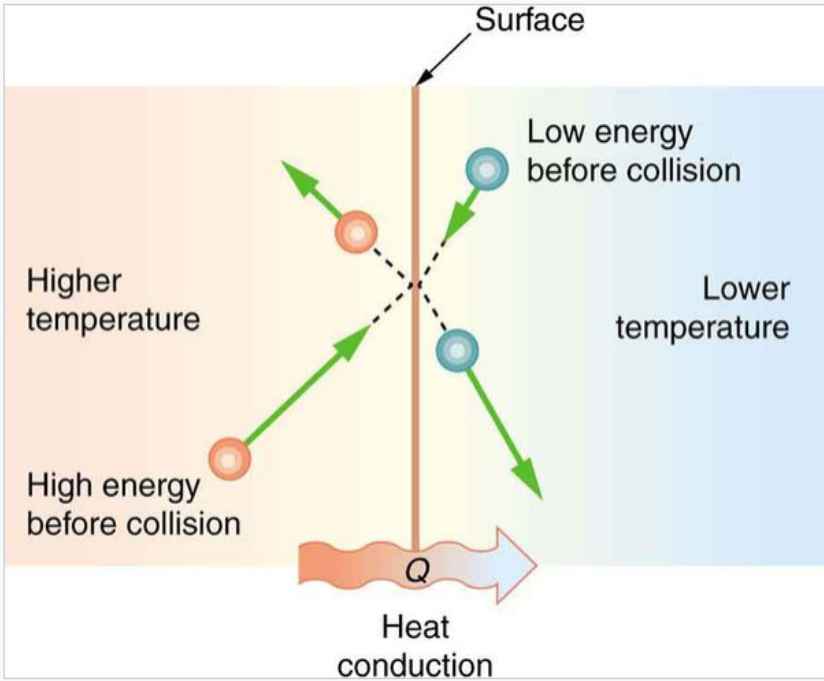
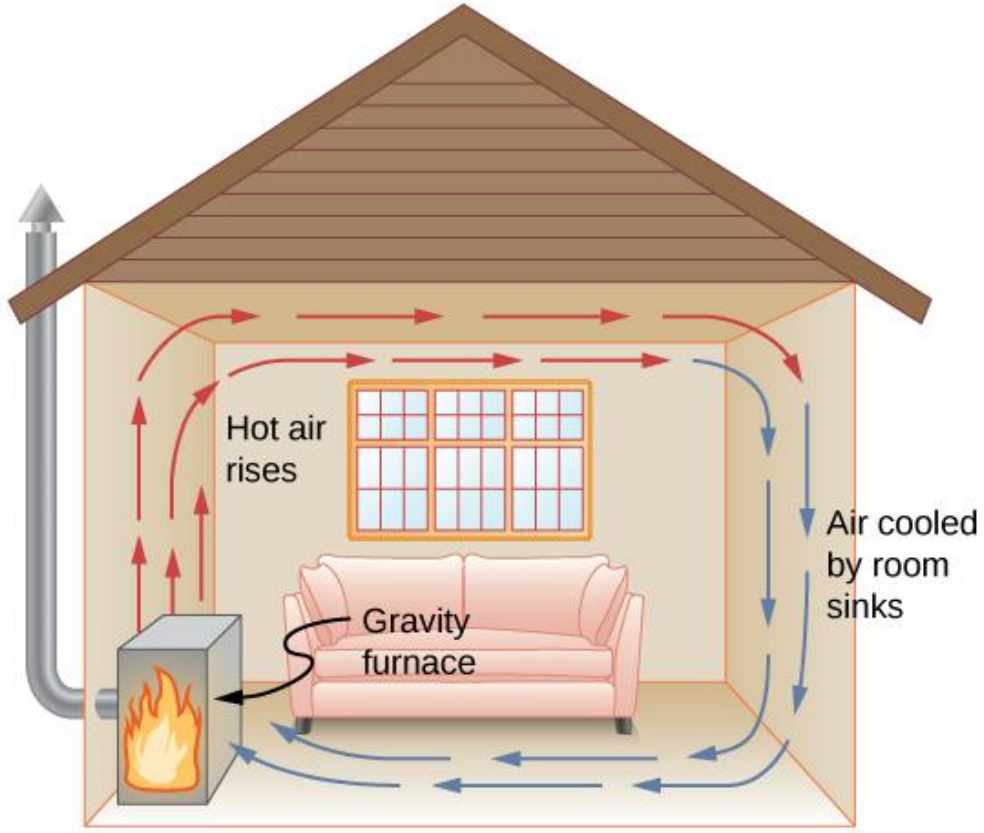


Figure 1. Heat transfers from a hot surface to a cold surface through thermal conduction.[1]

Thermal Conduction

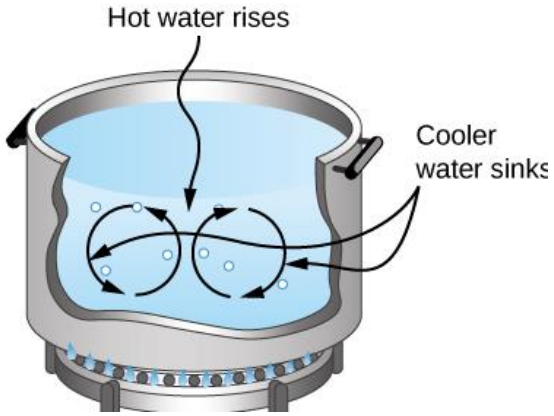
A region with greater thermal energy (heat) corresponds with greater molecular agitation. Thus when a hot object touches a cooler surface, the highly agitated molecules

Heat Convection



Air heated by a so-called gravity furnace expands and rises, forming a convective loop that transfers energy to other parts of the room. As the air is cooled at the ceiling and outside walls, it contracts, eventually becoming denser than room air and sinking to the floor. A properly designed heating system using natural convection , like this one, can heat a home quite efficiently.

In convection , thermal energy is carried by the large-scale flow of matter. It can be divided into two types. In forced convection , the flow is driven by fans, pumps, and the like. In free or natural convection , the flow is driven by buoyant forces: hot fluid rises and cold fluid sinks because density decreases as temperature increases. The house in the figure to the left is kept warm by natural convection, as is the pot of water on the stove



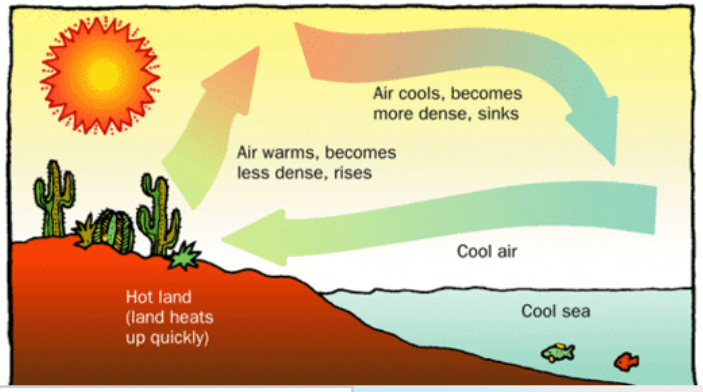
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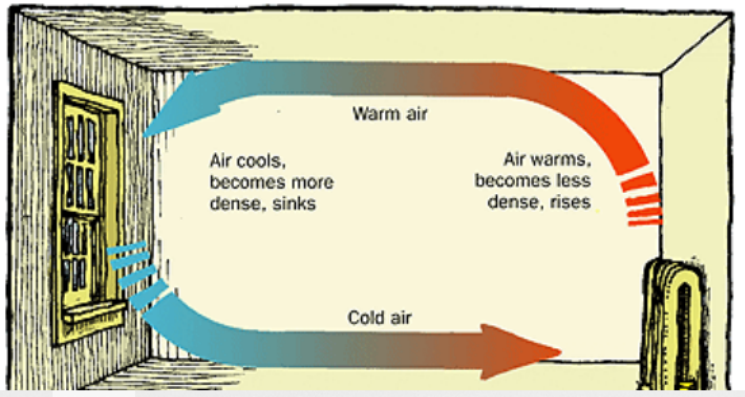
https://energyeducation.ca/encyclopedia/Convection

Convection

Convection is the motion of a fluid driven by temperature differences across that fluid. When a fluid is heated, the region in closest contact with the heat source becomes less dense due to increased kinetic energy in the particles. The portion of fluid that is less dense then rises, while the denser portion of fluid sinks. The process repeats itself because the less dense fluids cool down as they move away from their heat source, making them sink, while the denser fluids heat up as they near the heat source, making them rise. This creates convection currents.

Convection is one of the fundamental ways that heat is transferred. The others are thermal conduction,[1] radiant energy[1] and evapotranspiration.[2]



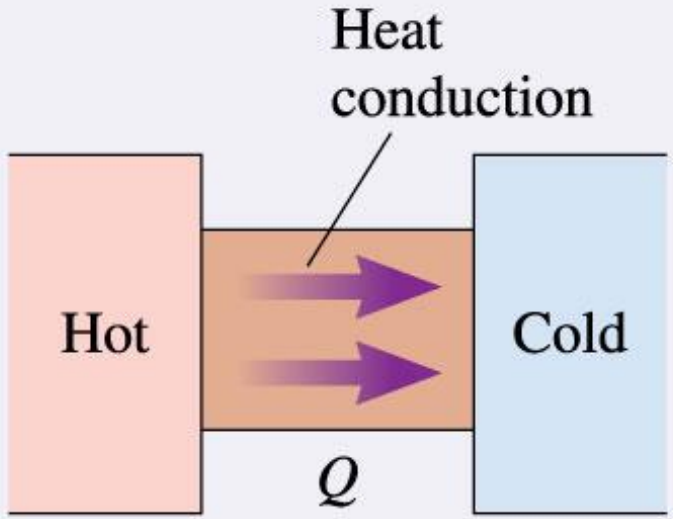


Heat Transfer

How is heat transferred?

Heat energy can be transferred between a system and its environment by

- Conduction
- Convection
- Radiation
- Evaporation



Heat: transferred thermal energy

- Our model of heat and temperature
- Types of heat transfer
- **Heating our homes, fenestration and building envelopes, HVAC**
- Heat pumps
- Solar and geothermal heating

https://www.weather.gov/jetstream/heat

https://energyeducation.ca/encyclopedia/Fenestration

ENERGY EDUCATION

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Fenestration

In other languages: Français

Fenestration refers to the openings in the building envelope, including the installation of windows, doors, and skylights. The inclusion of windows and other openings in the home are necessary as they improve the overall environment inside the home, however they do work to break the seal of the home, providing possible places for air, water, and cold air to enter the home. Thus, the number of openings included in a home must be taken into account, as well as the quality of the materials used to create these openings along with the placement.

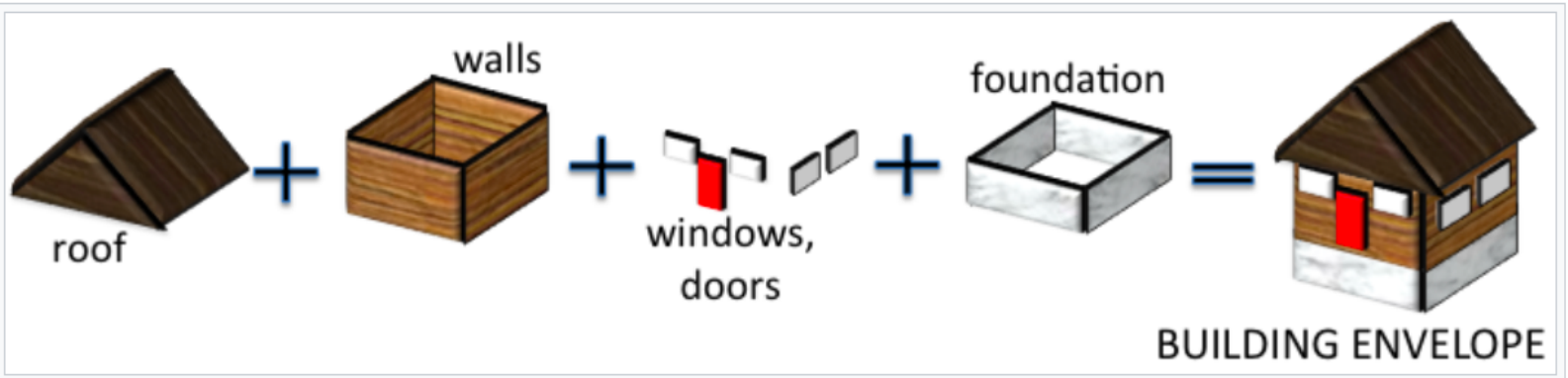


Figure 1 Windows, doors, and skylights are all vital components of the building envelope. The process of

Issues due to Fenestration

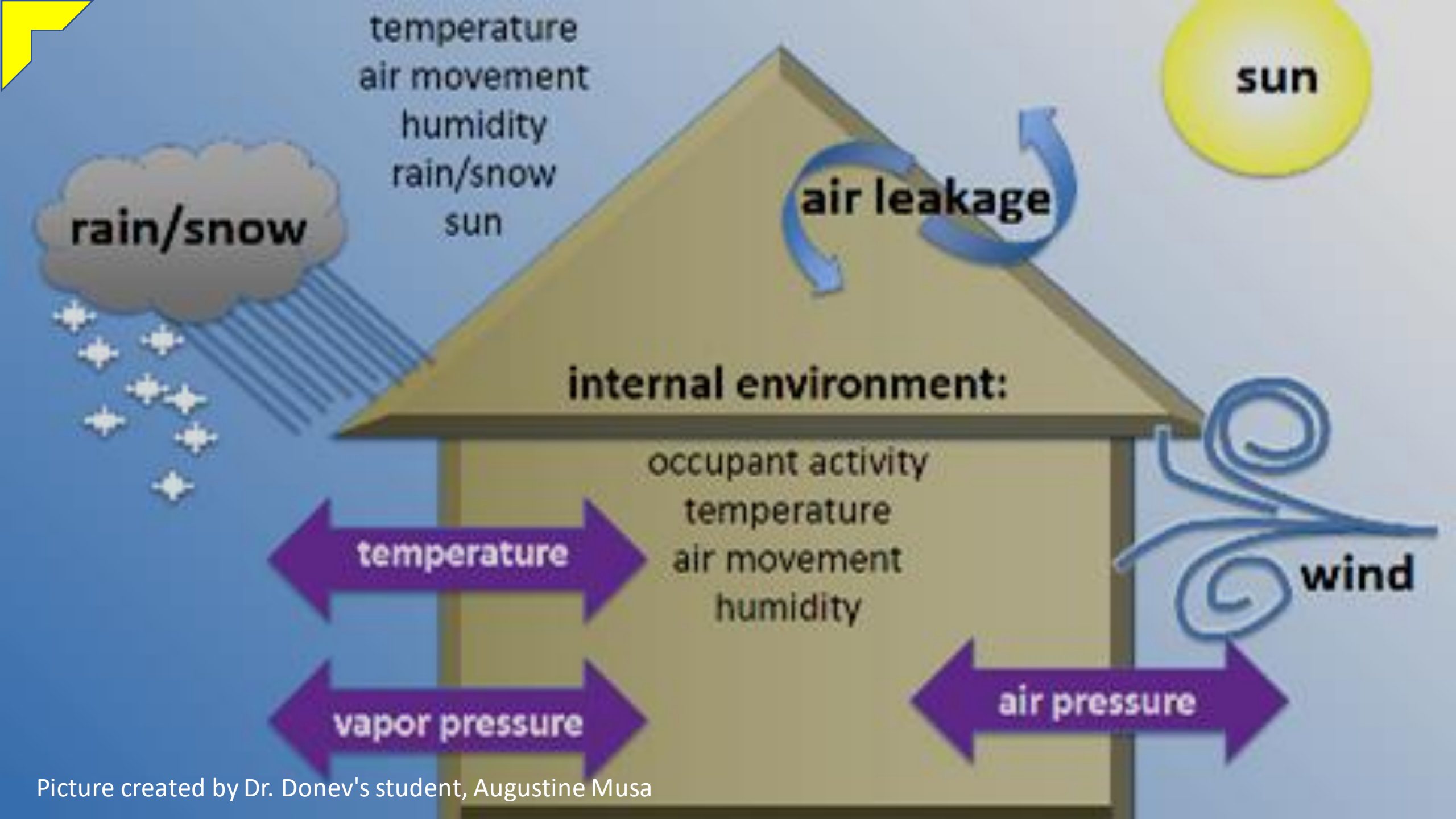
https://energyeducation.ca/encyclopedia/Fenestration

All fenestration products experience a degree of heat loss due to:[4]

- Radiation: heat energy is absorbed by the material of the door or window and radiates toward the cooler side.
- Conduction: heat energy moves through the solid materials that make up the frame or other parts of the window, door, or skylight.
- Convection: heat energy is transferred to the air between parts of the window or door.
- Air leakage: heat energy is transferred to air moving through seals or gaps in the door or window

The first issue in this arises due to improperly installed windows, doors, and skylights. When large drafts enter a home it can lead to overworked heating or air conditioning systems as outside air penetrates the building envelope, allowing untreated air to flow into the home.[5] A simple way to check for leaks such as these is to hold a candle or lit stick of incense around the frames of doors, windows or skylights. If the smoke swirls, it indicates a draft point.[6] Weatherstripping, caulking, and high-efficiency fenestration products may be used to increase the seal of the window or door and decrease the costs due to air leakage. As well, windows, doors, and skylights that let air in can also let water in. This leads to condensation and mold. Poorly sealed windows and doors can also let in noise and dust, negatively affecting air quality in the home.[5]

The second issue with including windows, doors, and other forms of fenestration is that simply including these products decreases the efficiency of the insulation in a home. By putting in a window of a door and removing part of the insulation in the wall of a home, the effective R-value of that wall is reduced. This leads to a reduced ability to resist the flow of heat within a home. To avoid this it is vital to ensure that quality insulation is used and installed



Picture created by Dr. Donev's student, Augustine Musa

Fenestration

fen·es·tra·tion

/ˌfenəˈstrāSHən/

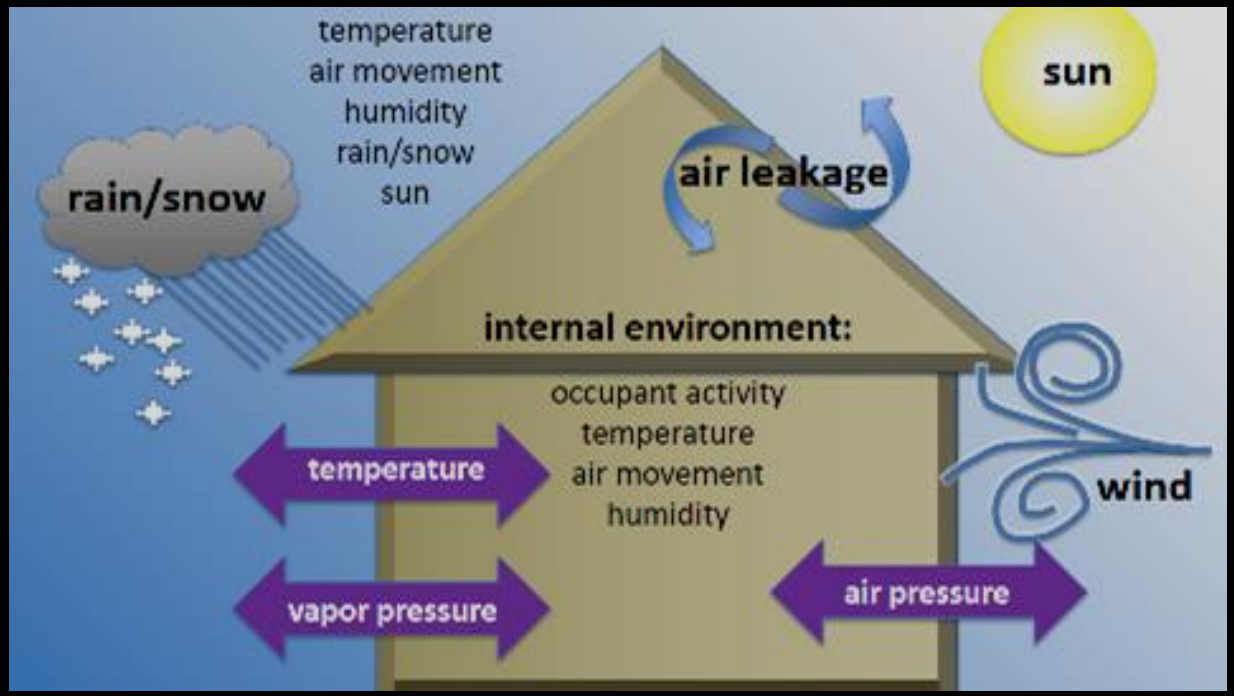
noun **ARCHITECTURE**

the arrangement of windows and doors on the elevations of a building.

the condition of being fenestrate.

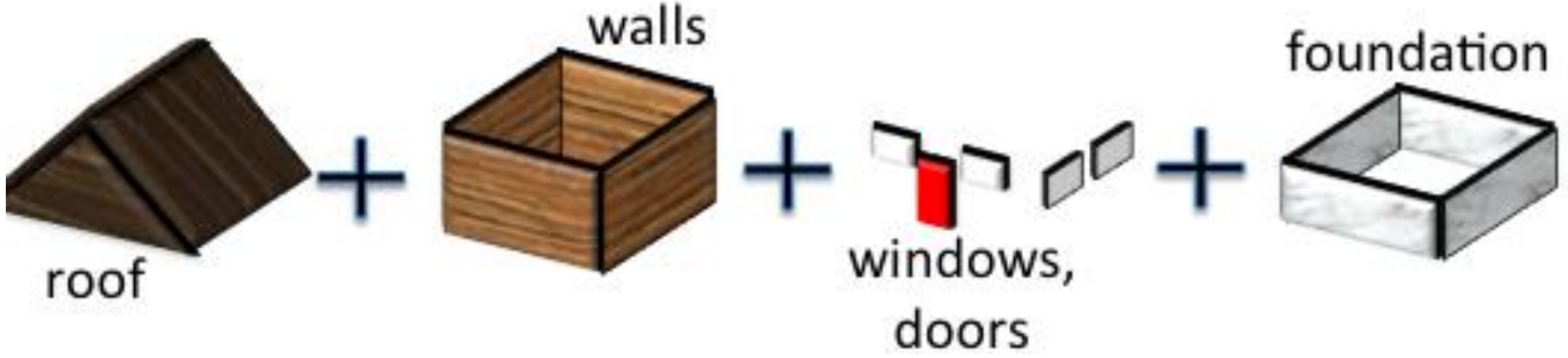
- **MEDICINE**
  a surgical operation in which a new opening is formed, especially in the bony labyrinth of the inner ear to treat certain types of deafness.

Definition found in Oxford Langugges
https://languages.oup.com/google-dictionary-en/



Picture created by Dr. Donev's student Augustine Musa

Building envelope and fenestration



Building envelope
(Fenestration, the holes)

=



Model: Houses are boxes with holes in them.

Picture created by Dr. Doven's student, Augustine Musa









Stop Air-leakage

Windows

- South and West:
  - Hard coat low-e coating add more heat to the home through solar gain than they lose.
- North and East:
  - soft-coat low-e coating and a low thermal conductivity



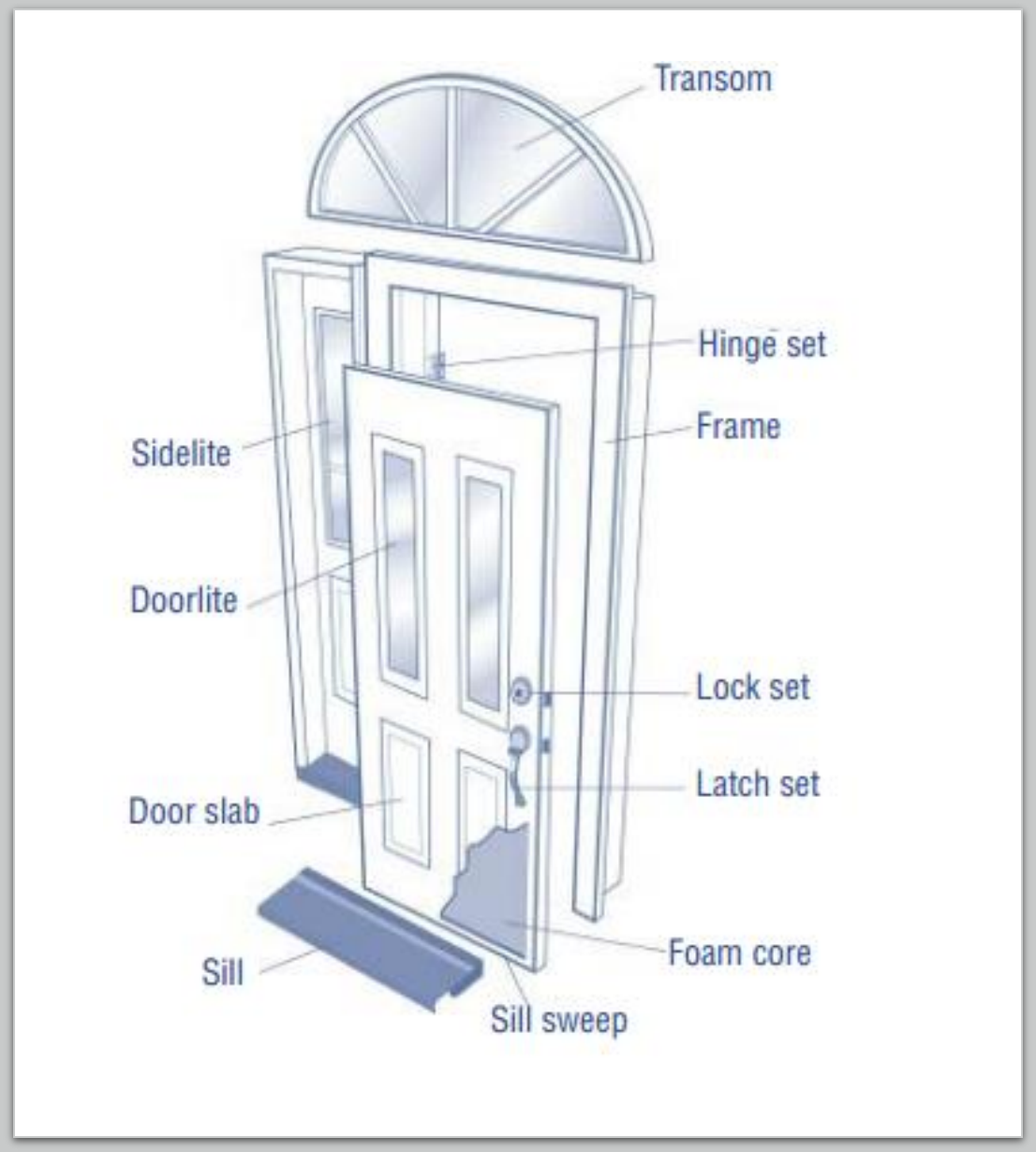
On the other side



- Solar gain on heating can overpower a room.
- NRCan recommends at least 10 m^2 of floor space for every 1 m^2 of fenestration

Doors

- Out of prevailing winds (leeward side)
- Windbreaks: a porches, vestibules
- Weather-stripping in good condition
- Small blanket or towel on bottom blocks draft

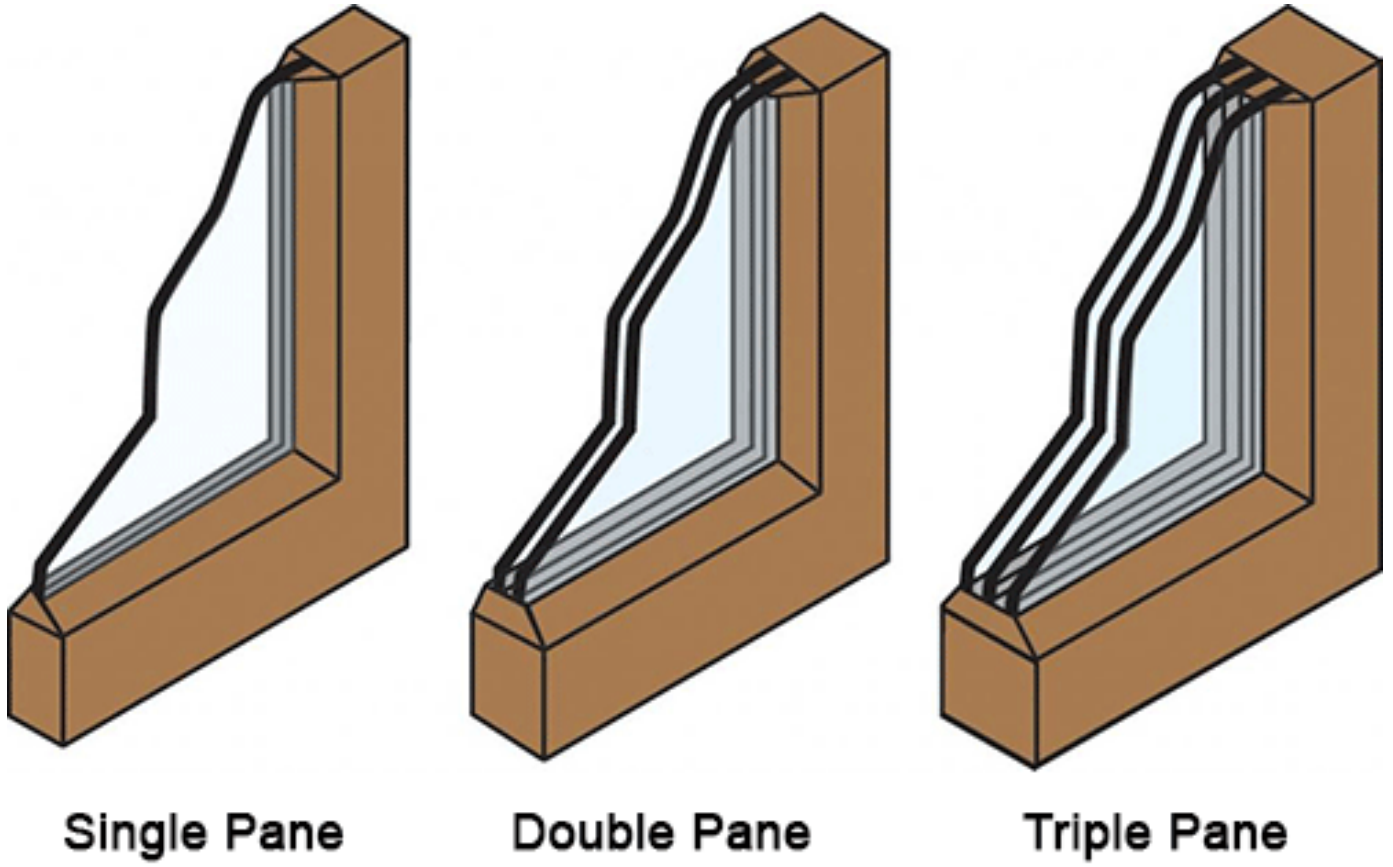


Skylights

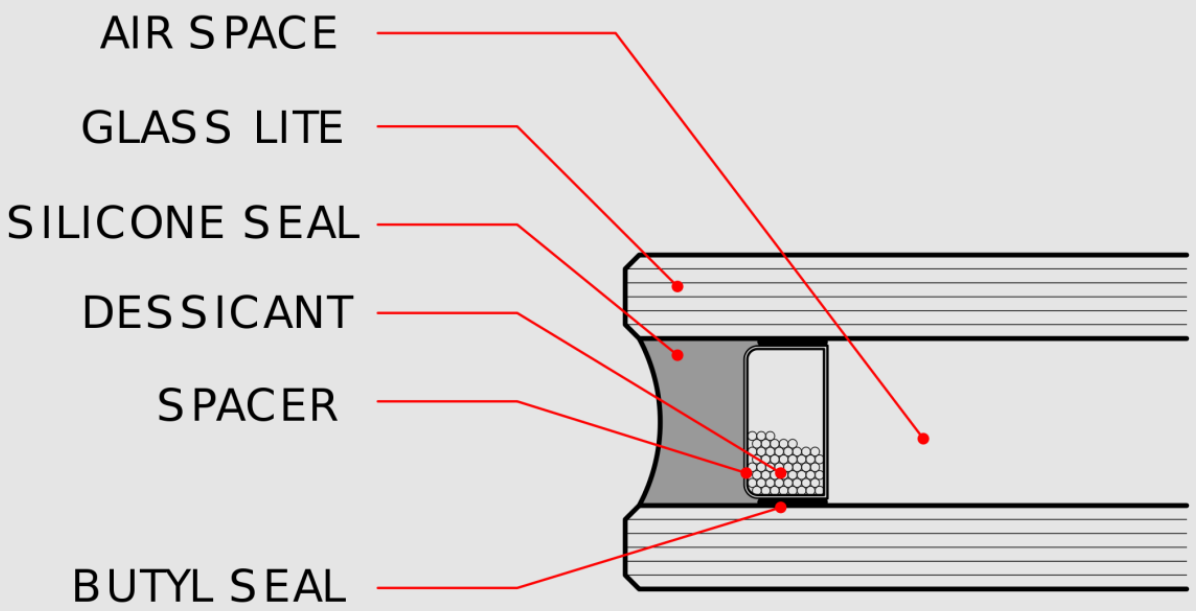
- On South facing roof (or west if need be)
- Weatherstripping and e-coating
- Not in high humidity, (bathroom near a shower or over a kitchen sink.



Glazing



Insulating Glass Units

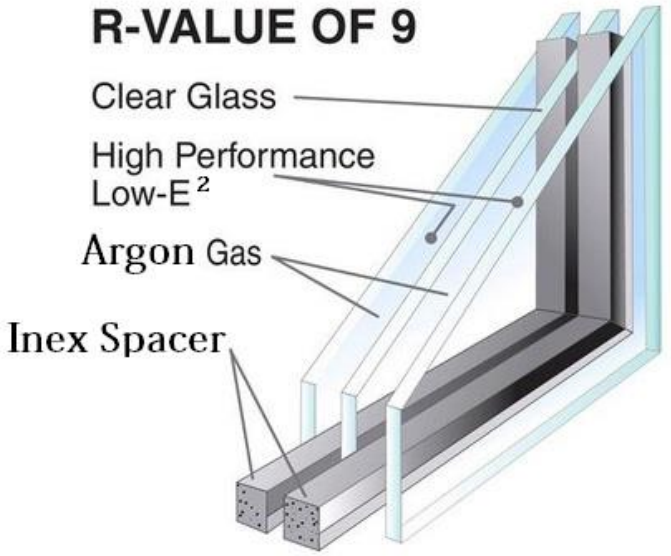


EDGE OF A TYPICAL IGU

- Windows: where we lose most of our heat.
- Double Paned windows much better

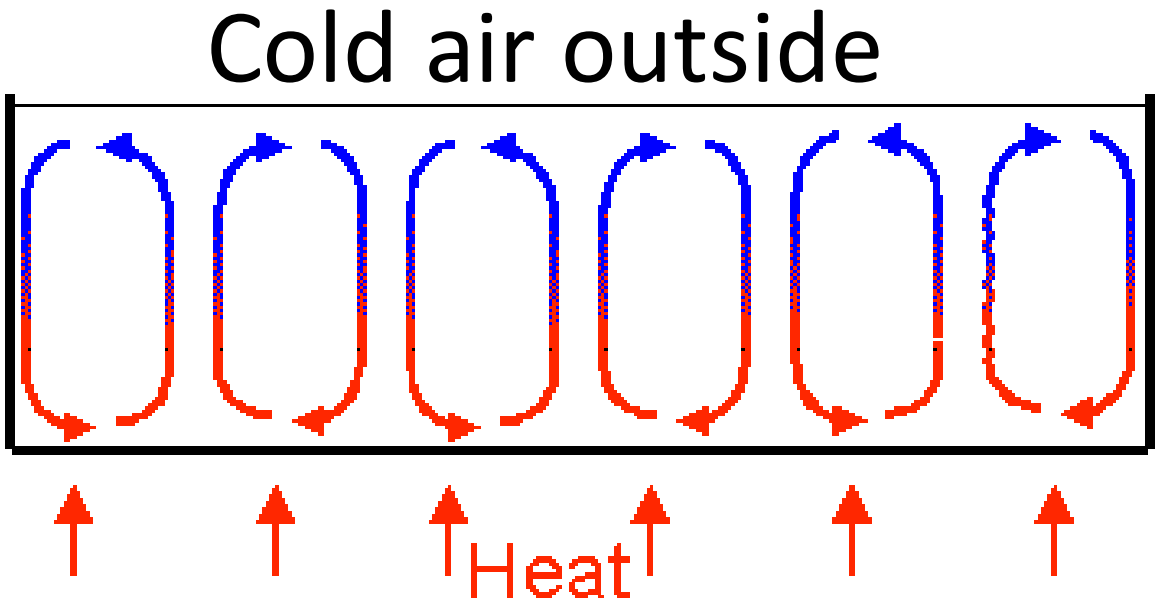
Triple paned windows

- Insulate more.
- BUT often a better places to focus on
- Low emissivity to reduce radiation losses.

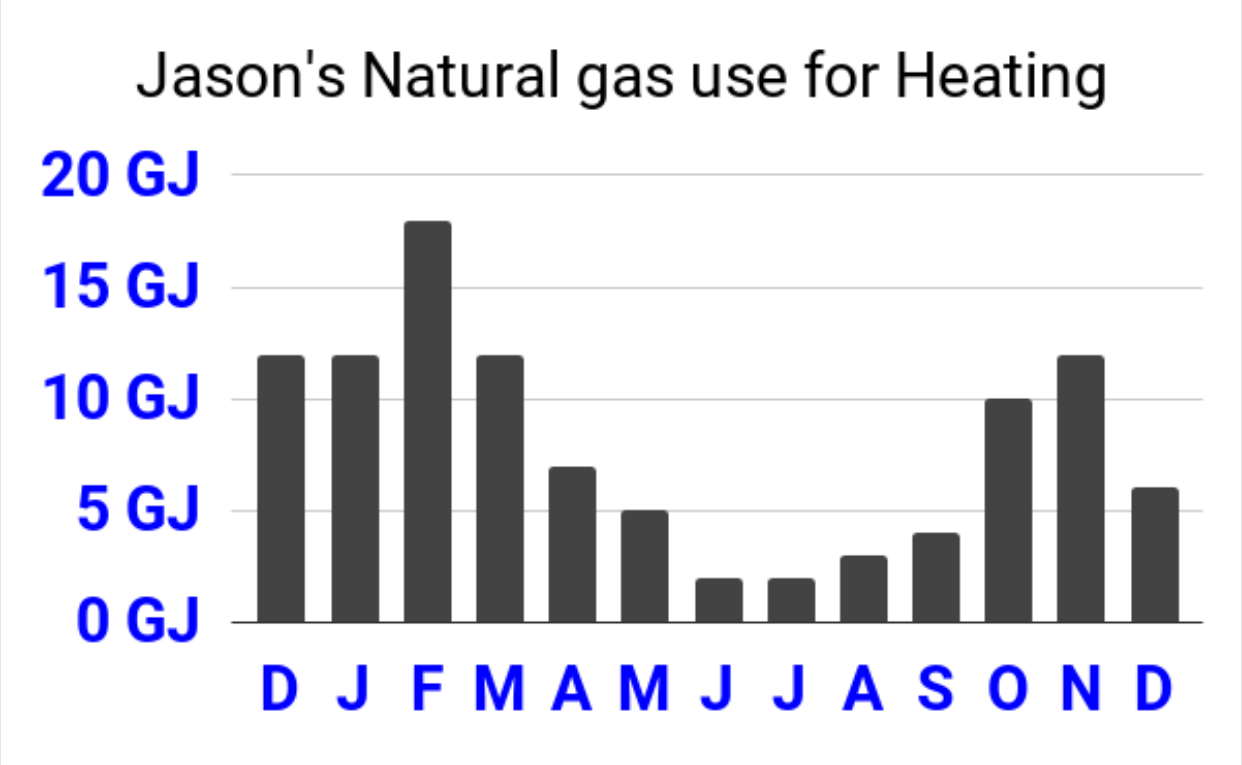


Convection

- Convection currents in windows carry most of the heat.
- Thin space to stop convection.



Other heat in the house; Sun Leaks from doors, windows, etc.



- Heat in our homes

Reading assignment for next class: https://energyeducation.ca/encyclopedia/Building_envelope

Topic of Wednesday's Lecture: Heating our homes

PHYS 371 Introduction to Energy

LECTURE 13: THERMAL ENERGY – **MOVING HEAT**

WEDNESDAY, OCTOBER 6, 2021

Course Information - Communication Guidelines

Course Information - Communication Guidelines

Item/Issue	*Method of communication*
Discussion about topics	Piazza, TopHat
Questions about the homework, technical difficulties uploading homework, questions about the format of the exams	Piazza, TopHat, stop by office hours, TAs
Questions about the concepts	Stop by office hours, Instructor/TAs
Issues with marking, grades	Students help, TAs; if unresolved, office hours, Instructor
Urgent and/or important personal issues (prolong absentees, illness, missing an exam, etc.)	Email or stop by office hours, Instructor

Email sample/template:

*Subject: **PHYS 317** – (2/3 word issue description) [1]*

Hello Dr, Professor [2] Last-Name [3],

OPTIONAL line that recognizes our common humanity [4].

I'm in your Class Name, Section Number that meets on This Day [5].

This is the IMPORTANT ISSUE I have or NEED HELP with [6]. This is the question I have about the issue [7]. This is the action I would like you to take [8].

Signing off with a Thank You is always a good idea [9]
Favorite Student's first and last name[10]

Course Information - Contact Information

Course Information - Contact Information

Instructor: Dr. Laura Mazzino

Email: laura.mazzino@ucalgary.ca (Please insert PHYS371 in subject line!)

Phone: +1 (403) 220-8648

Office: Science B 533

Hours: Monday 14:00-15:00 (via zoom), Tuesday 10:30-11:30 (via zoom), Thursday 13:30-15:00 (via zoom)

Join Zoom Meeting

https://ucalgary.zoom.us/j/91215878528

Meeting ID: 912 1587 8528
Passcode: 604667

Teaching assistants

Travis Gartner

Email: travis.gartner@ucalgary.ca (Please insert PHYS371 in subject line!)

Hours: Thursday 10-11am

Join Zoom Meeting:

https://ucalgary.zoom.us/j/91904882038

Meeting ID: 919 0488 2038
Passcode: 441381

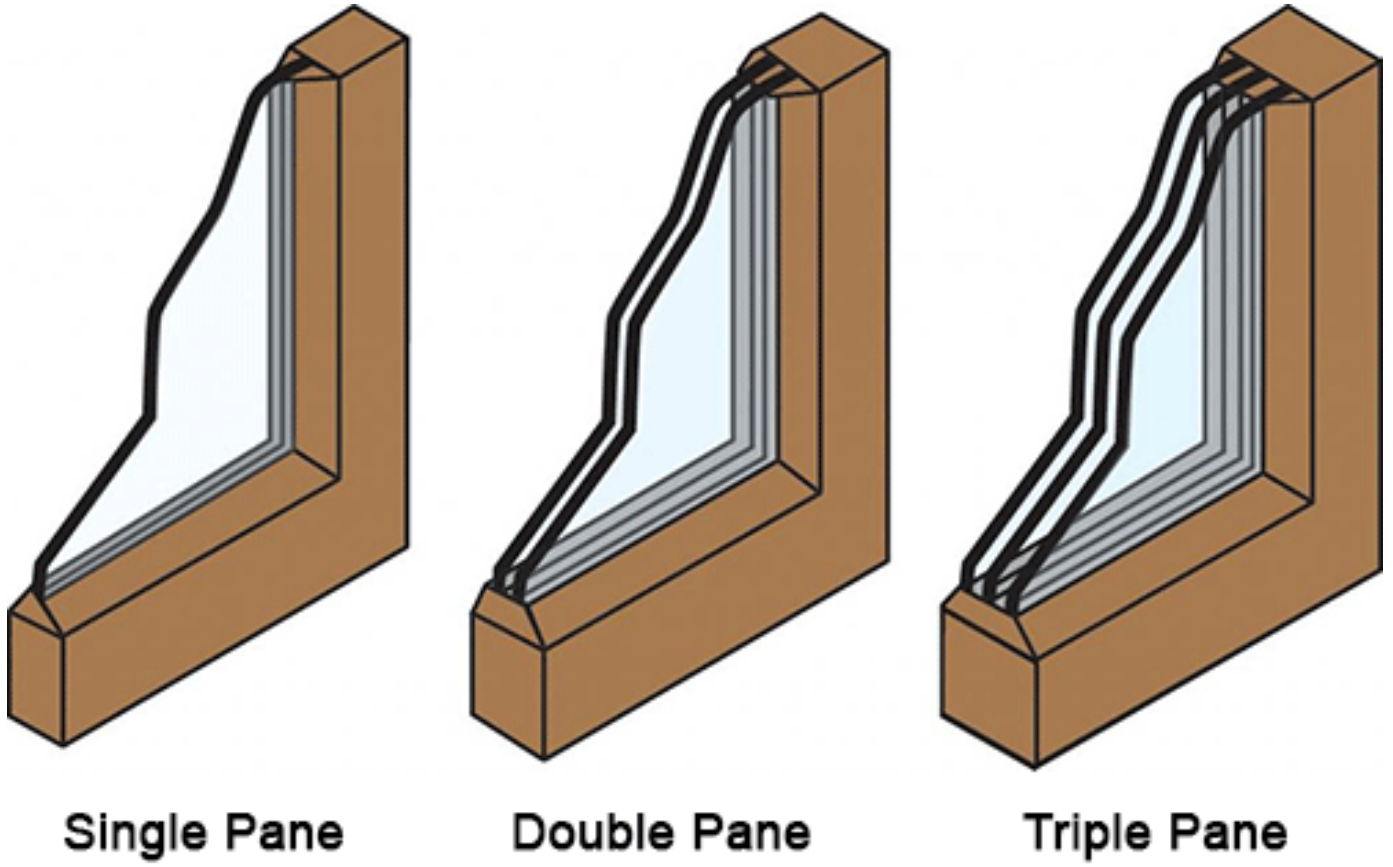
Finley Rogers

Email: finley.rogers@ucalgary.ca (Please insert PHYS371 in subject line!)

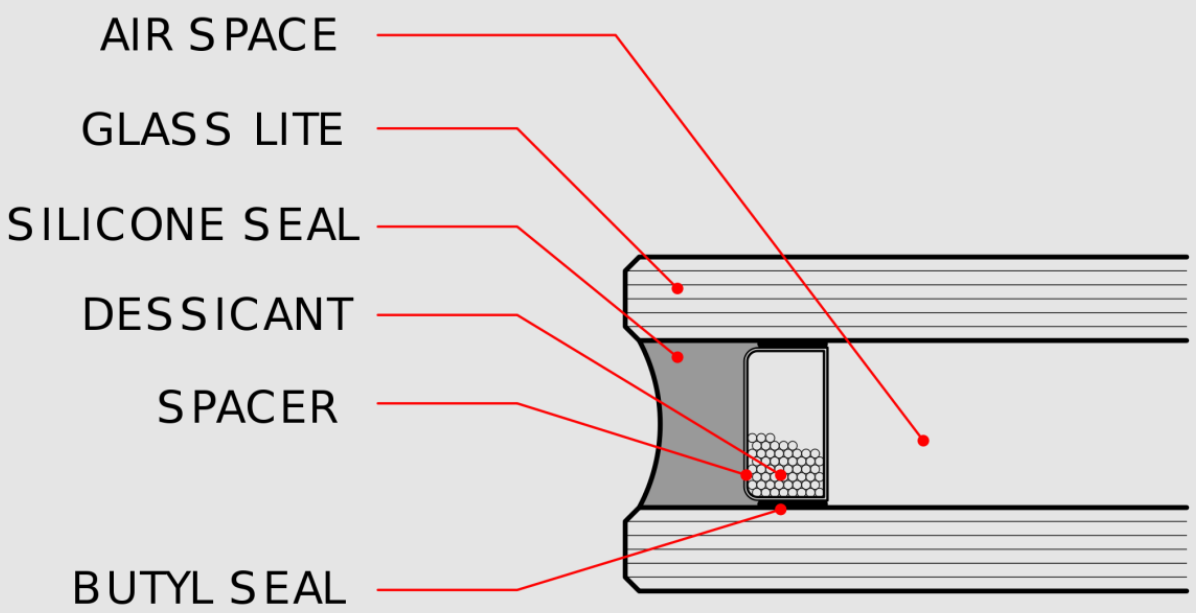
Hours: Tue 4pm-5pm

Join Zoom Meeting

Glazing



Insulating Glass Units



EDGE OF A TYPICAL IGU

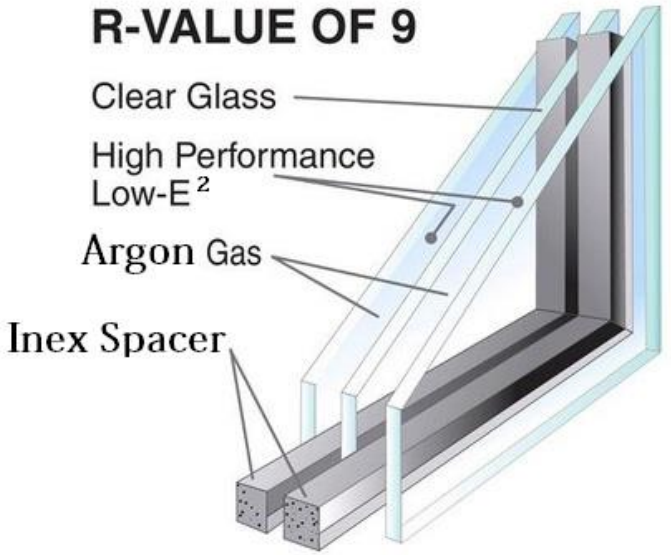
https://energyeducation.ca/encyclopedia/Home_temperature_control

- Windows: where we lose most of our heat.
- Double Paned windows much better

Triple paned windows

- Insulate more.
- BUT often a better places to focus on
- Low emissivity to reduce radiation losses.

https://energyeducation.ca/encyclopedia/R-value



R-value

https://energyeducation.ca/encyclopedia/R-value

In other languages: Français

The **R-value** of insulation is a value that is used to measure how well a specific type of insulation can resist heat flow. The higher the R-value, the more effective the material is at preventing heat transfer.[2] R-value is short for **Resistance value**, and is closely related to the metric unit of RSI. Windows also have a specific R-value associated with how well they keep heat in (although the heat that comes from sunlight coming through the window is not included in R-values, it's an important part of the net effect of having a window in a particular wall). R-value is also related to U-value (which is 1/R-value) and thermal conductivity which is a property of a material that says how well it conducts heat.



Figure 1. Polyisocyanurate insulation, this type of insulation is similar to polyurethane but has a higher R-value.[1]

Different insulating materials each have their own unique R-value per unit length. The thicker the material the more it resists heat

https://energyeducation.ca/encyclopedia/R-value

Although effective, looking at R-value alone isn't enough to determine how well an insulation will work. Since heat moves by conduction, convection, radiation, and air infiltration, all of these must be accounted for to truly know how well any one insulation will work. R-value measures only conduction, and thus doesn't provide the whole picture.[4] As well, R-value doesn't take into account individual factors such as wind, humidity, and temperature changes which can cause air flow and leakages in the insulation of the building.[4] These factors change how well a specific type of insulation works, effectively changing it's R-Value, but this is very hard to measure.[5]

Calculating R-value

Mathematically, R-value is calculating from a measuring heat flow across a surface where each side is at a particular temperature:[4]

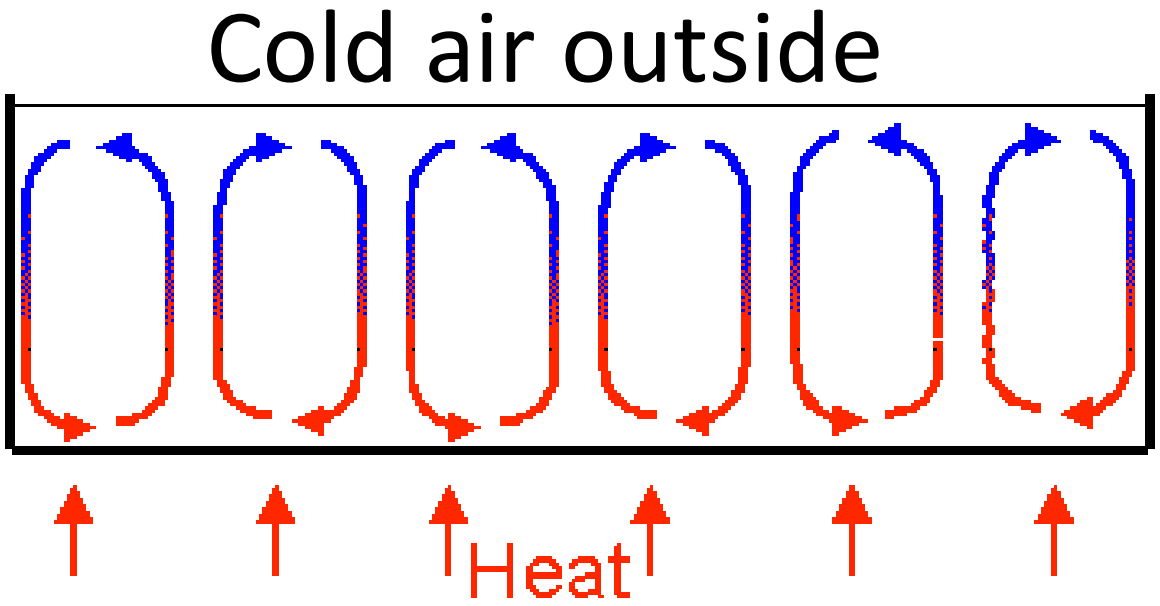
$$R - Value = \frac{\Delta T \times Area \times Time}{HeatLoss}$$

- ΔT is the temperature difference inside and outside the house in °F (or °C for RSI)
- $Area$ is the area of the wall (or ceiling) that's being insulated in ft ^{2} (or m^2 for RSI)
- $Time$ is how long the measurement took place in seconds (same in RSI)
- $HeatLoss$ is how much heat is lost through the wall in BTU (J in RSI)

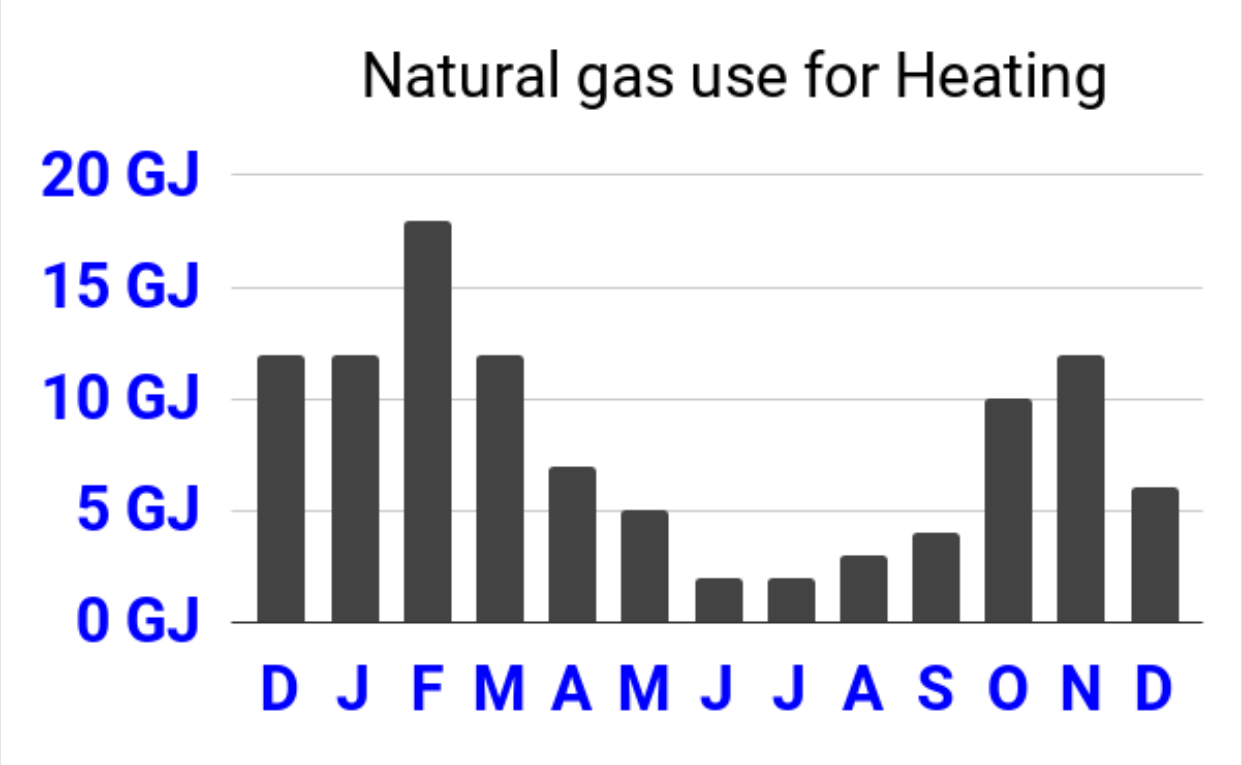
To convert from an RSI value to an R-value multiply by 6. If one insulation material is put on top of another insulation material, the R-values just add. For a helpful online R-value calculator from Ekotrope, click here.

Convection

- Convection currents in windows carry most of the heat.
- Thin space to stop convection.



Other heat in the house; Sun Leaks from doors, windows, etc.



- Heat in our homes

Heating degree day (HDD) is a measurement designed to quantify the demand for energy needed to heat a building. HDD is derived from measurements of outside air temperature.

Heating degree days today

Model: Take base temperature as 18°C (for Canada)
1 heating degree day=day when average temperature in that day was 17° (deviating of 1°C from the base temperature 18°C)

How to calculate/count ***Heating Degree Days quantity*** for a given day
HDD= # days in a year when temp is below 18°C
*(18-average temp on that day)

Heating degree day (HDD) is a measurement designed to quantify the demand for energy needed to heat a building. HDD is derived from measurements of outside air temperature.

Heating degree days today

How to calculate/count ***Heating Degree Days quantity*** for a given day
HDD= # days in a year when temp is below 18°C
*(18-average temp on that day)

Example: Today, Wed Oct 6, 2021, the average temperature in Calgary is 7°C
HDD for today = 1*(18-7)=11
The number of HDD for today is 11

Model: Take base temperature as 18°C (for Canada)
1 heating degree day=day when average temperature in that day was 17°
(deviating of 1°C from the base temperature 18°C)

Heating degree day (HDD) is a measurement designed to quantify the demand for energy needed to heat a building. HDD is derived from measurements of outside air temperature.

Heating degree days today

Calculate the quantity HDD for today for Calgary, Place your answer in TopHapt discussion

Adding all the temperatures for October 6, 2021 gives a total of 173; divided by 24 hours, gives an average temp of 7.2. To calculate HDD= 18-7=11

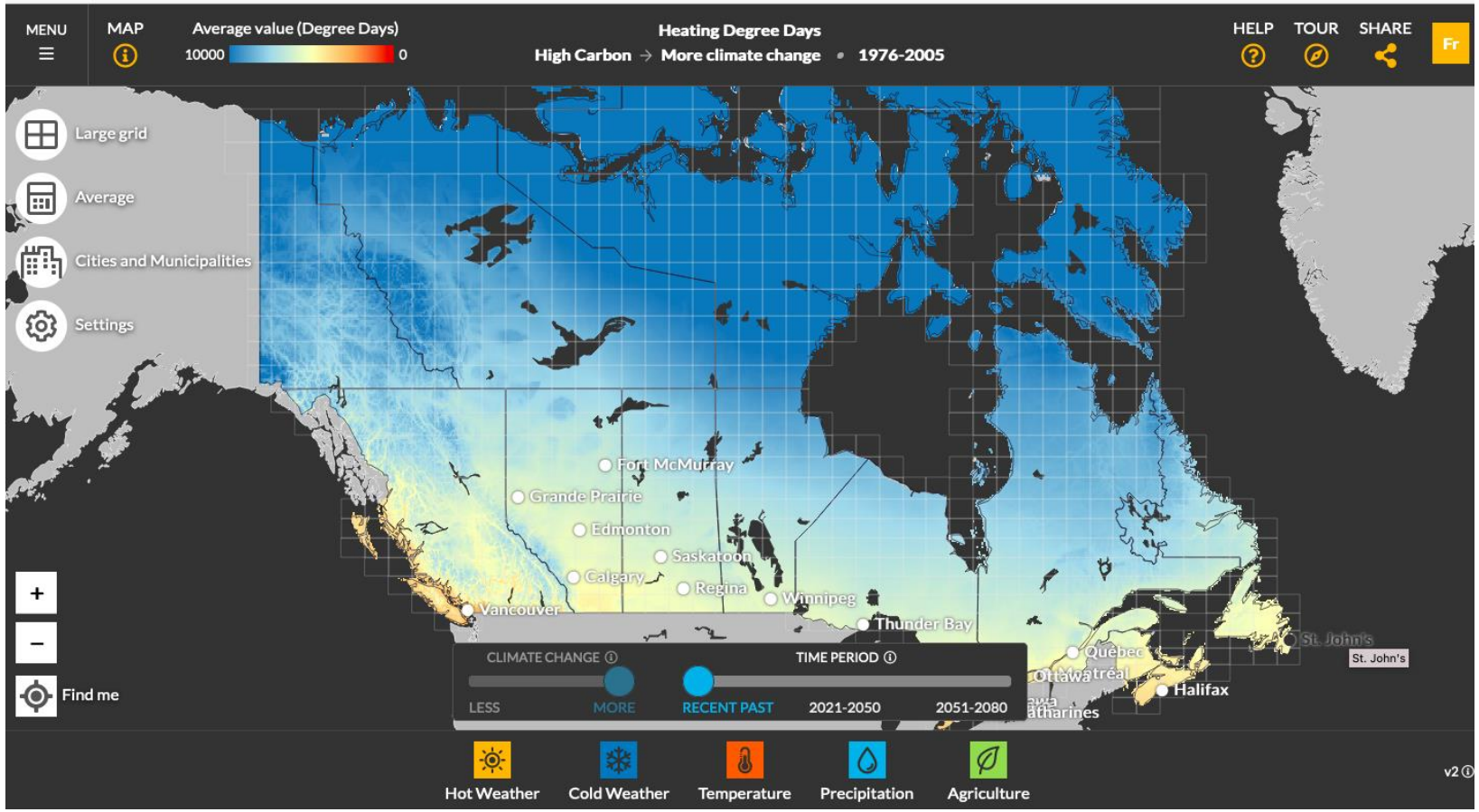
Hourly Forecast - Calgary

No Alerts in effect

Date/Time (MDT)	Temp. (°C)	Weather Conditions	Likelihood of precip †	Wind (km/h)
06 October 2021				
07:00	5	Mainly cloudy	Nil	S 15
08:00	7	Mainly cloudy	Nil	S 15
09:00	9	Mainly cloudy	Nil	W 10
10:00	10	Mainly cloudy	Nil	W 10
11:00	12	Mainly cloudy	Nil	W 10
12:00	13	Mainly cloudy	Nil	N 20 gust 40
13:00	14	Mainly cloudy	Nil	N 20 gust 40
14:00	15	Mainly cloudy	Nil	N 20 gust 40
15:00	16	Mainly cloudy	Nil	N 20 gust 40
16:00	14	Chance of showers	Low	N 20 gust 40
17:00	13	Chance of showers	Low	N 20 gust 40
18:00	11	Chance of showers	Low	N 20 gust 40
19:00	9	Chance of showers	Low	N 20 gust 40
20:00	8	Chance of showers	Low	N 20 gust 40
21:00	6	Chance of showers	Low	NW 10
22:00	6	Chance of showers	Low	NW 10
23:00	5	Chance of showers	Low	NW 10
07 October 2021				
00:00	5	Clear	Nil	NW 10

Model: Take base temperature as 18°C
1 heating degree day=day when temperature was 17° (deviating from 18°C)

Heating degree days today

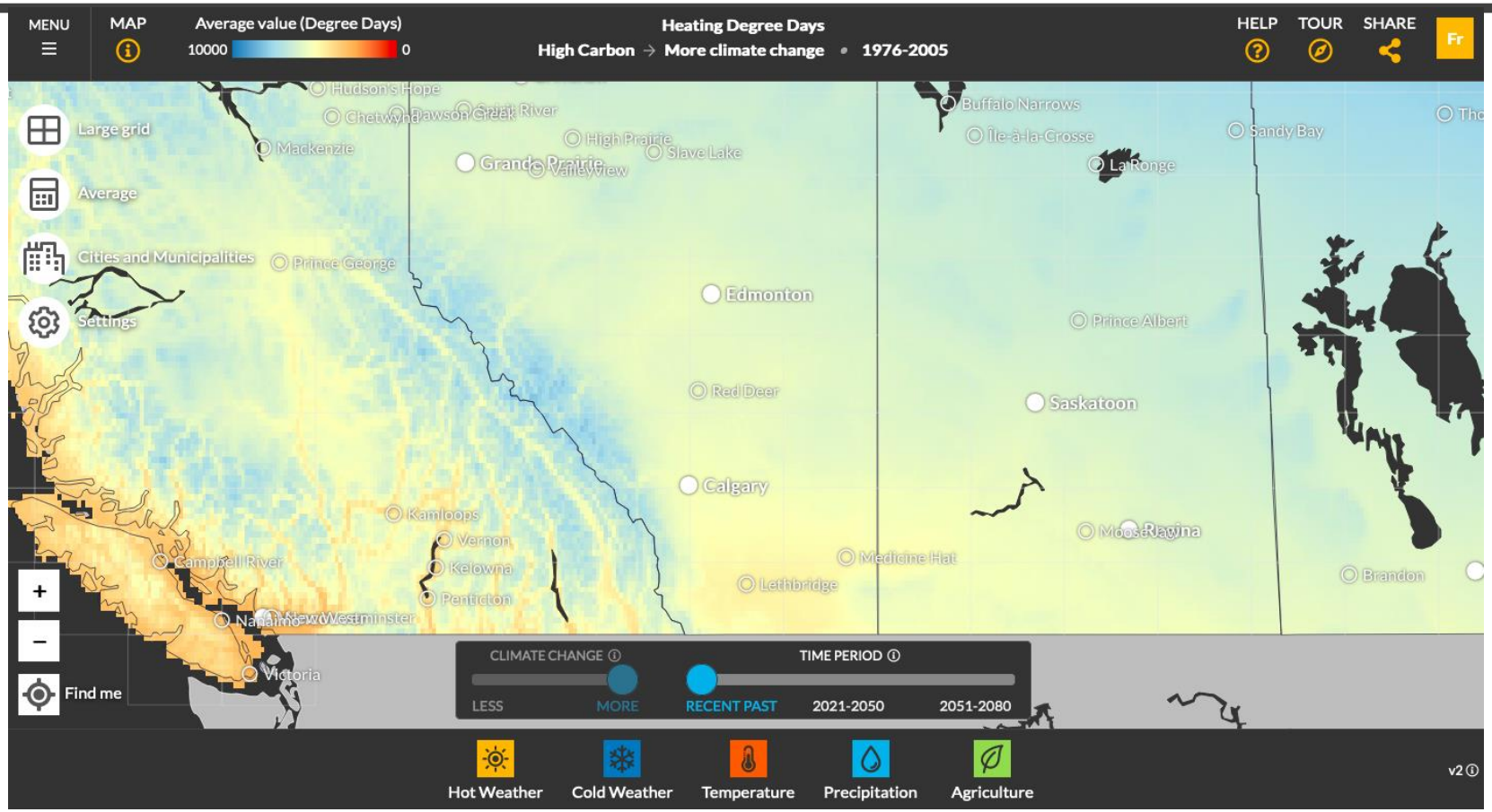


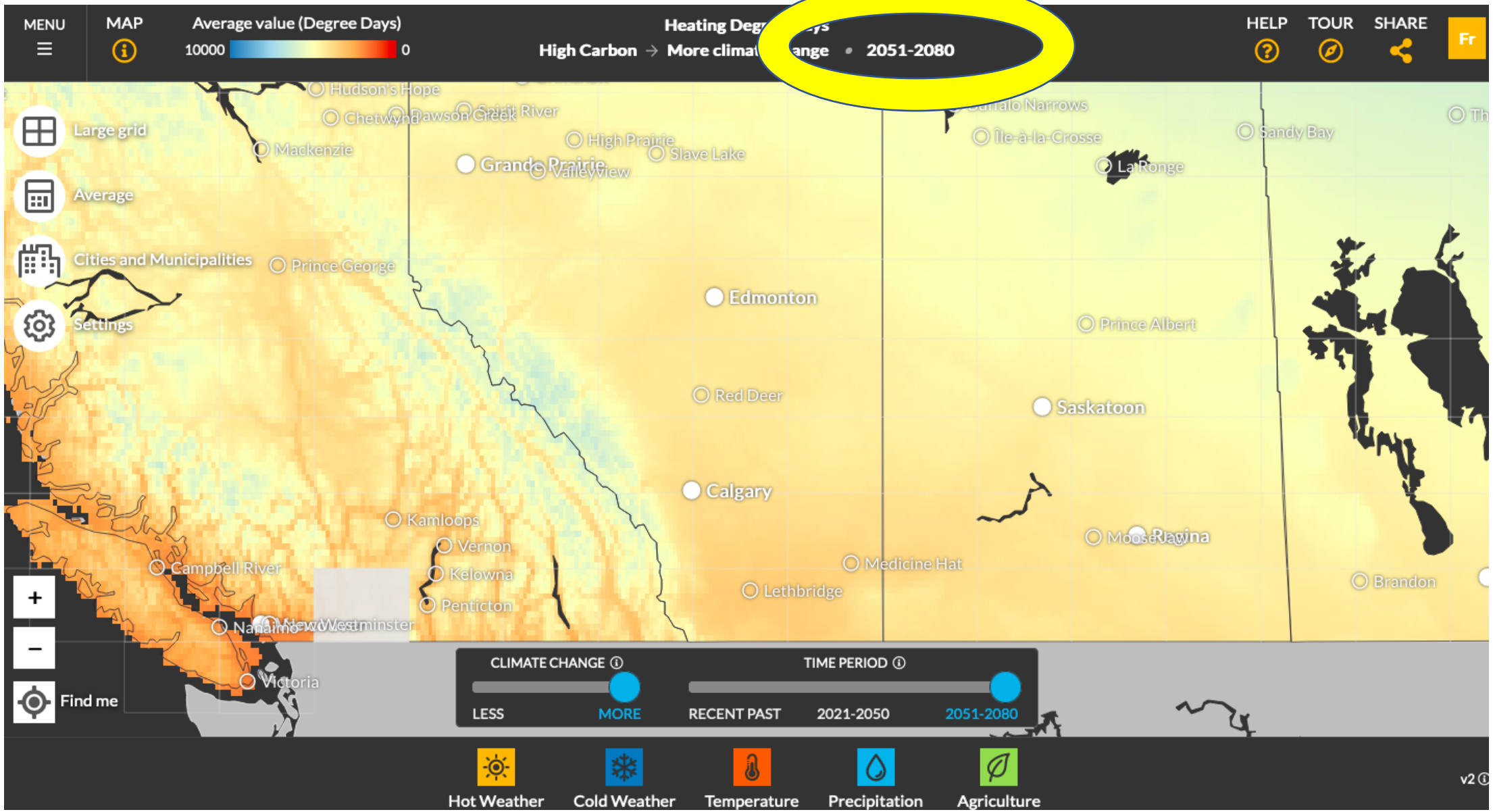
Remember!
How to calculate/count Heating Degree Days
HDD= # days in a year when temp is below 18°C
*(18-average temp on that day)

https://climateatlas.ca/map/canada/

Locally, today

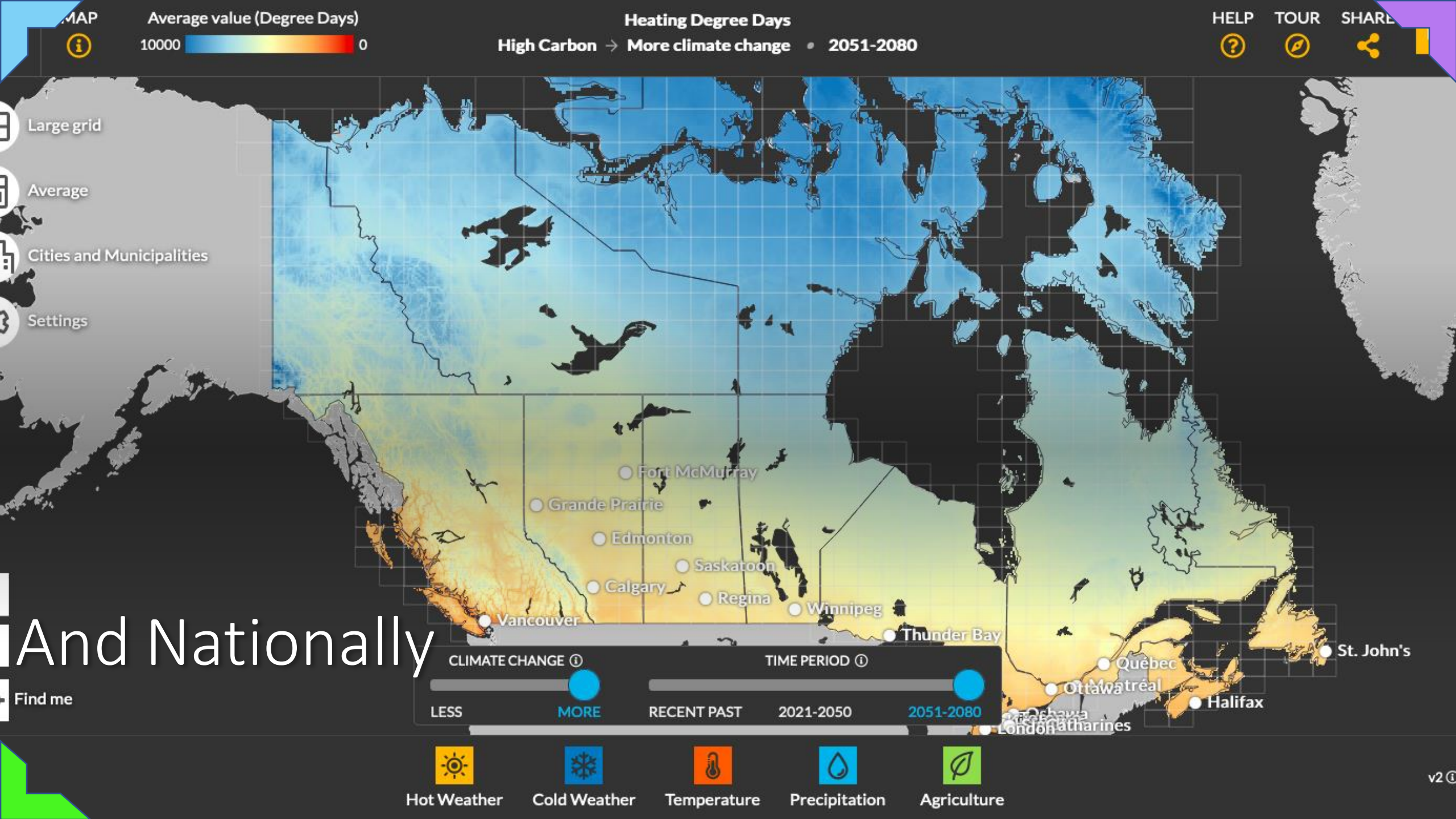
Calgary
2005= 5,110 HDD
2050=3,870 HDD





Heating degree days will reduce

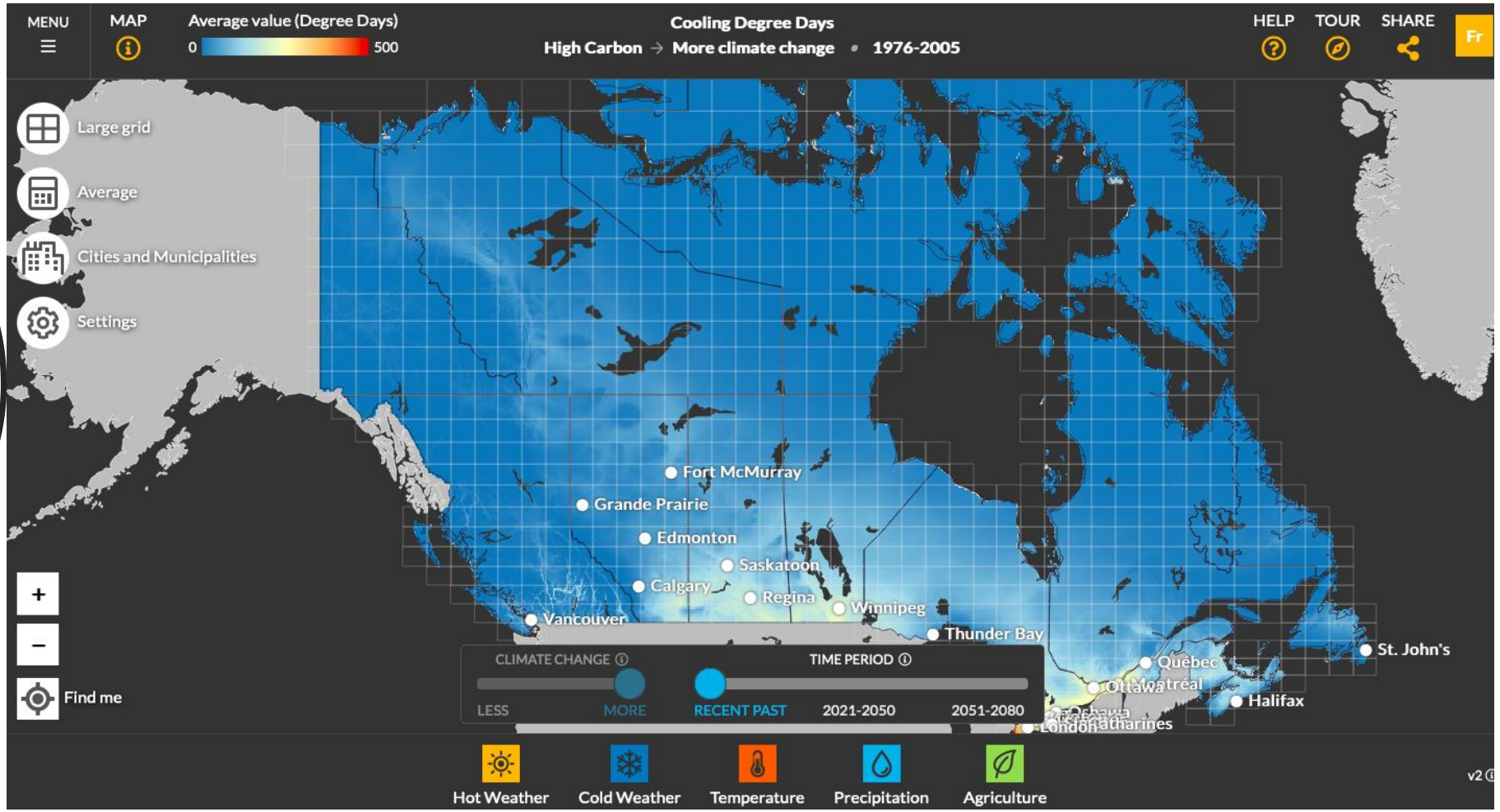
Calgary
2005= 5,110 HDD
2050=3,870 HDD



And Nationally

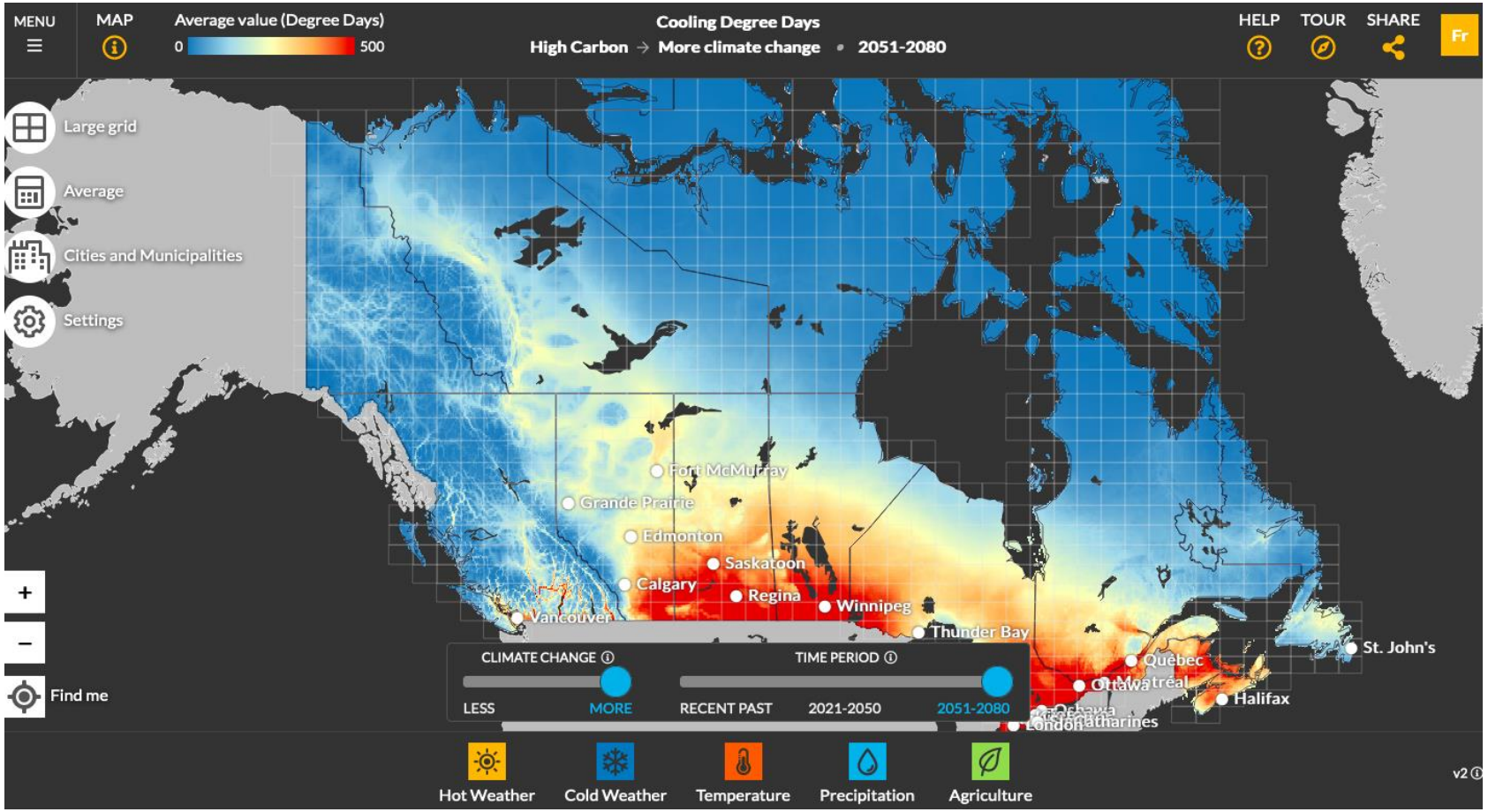
Model: Take base temperature as 18°C
1 cooling degree day=day when temperature was 19° (deviating from 18°C)
How to calculate/count Cooling Degree Days :
CDD= # days in a year when temp is below 18°C*(average temp on that day-18)

Canada has very few cooling degree days right now

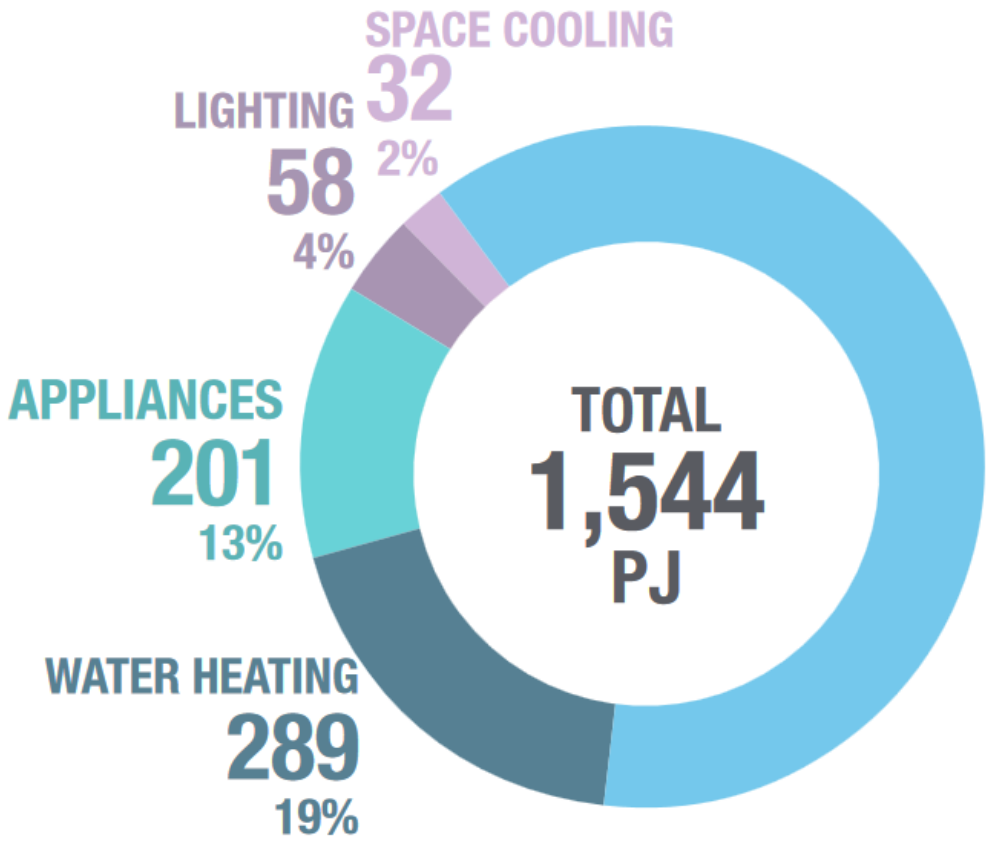


https://climateatlas.ca/map/canada/

Climate change drives that up



Residential Energy use in Canada



petajoule

The joule is the standard unit of energy in general scientific applications. One joule is the equivalent of one watt of power radiated or dissipated for one second. One petajoule is **1015 joules (1 million billion)** or 278 gigawatt hours.

https://www.energy.gov.au › sites › default › files › 2016-...

One petajoule (PJ) explained - | energy.gov.au

https://energyeducation.ca/encyclopedia/Heater

http://extraconversion.com/energy/petajoules

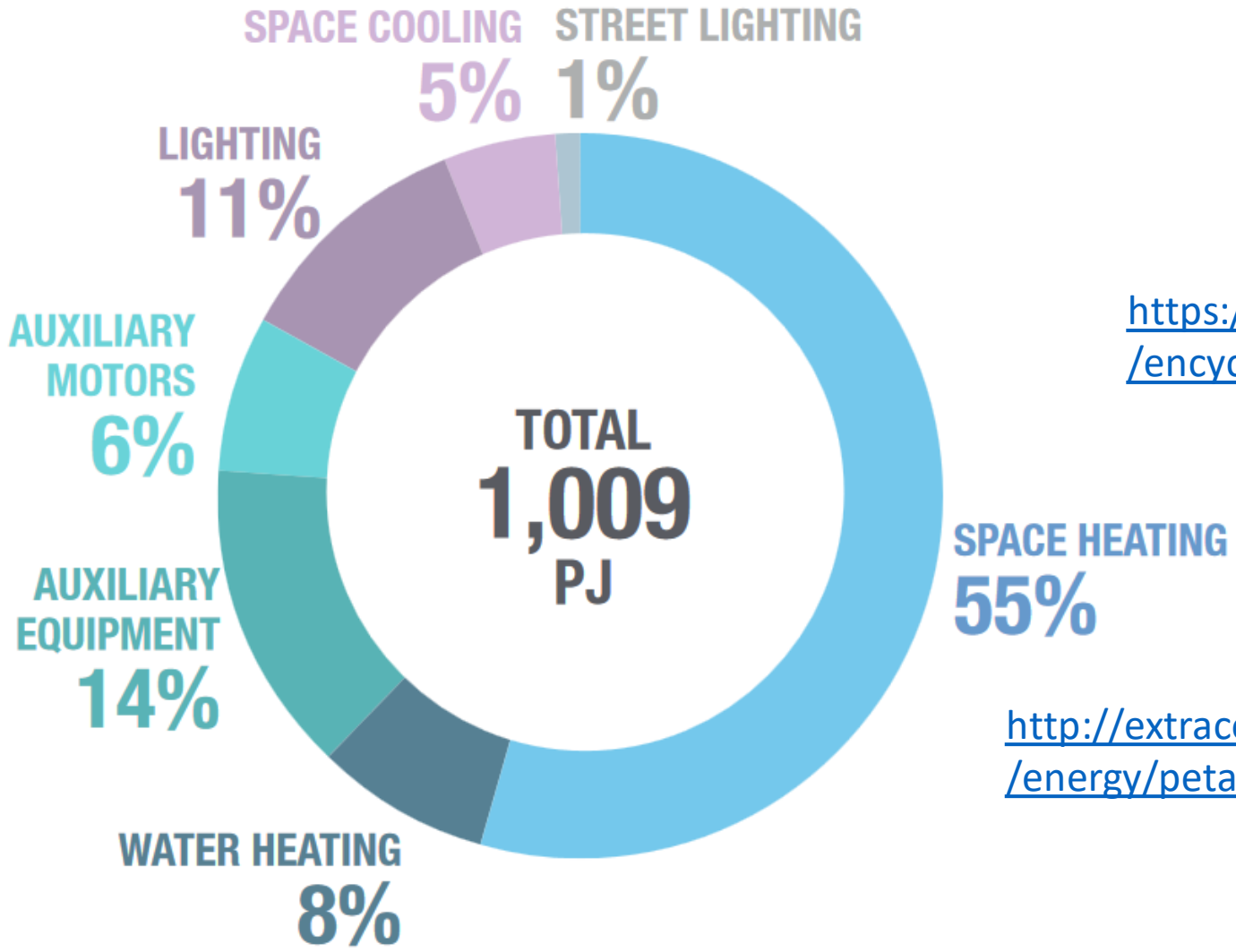
A petajoule is **a quadrillion (one followed by 15 zeros — a million billion) of the little devils**. A terajoule is a trillion of them, a gigajoule is one billion joules, and a megajoule is a mere one million of them. Sep. 28, 2017

https://www.news.com.au › economy › news-story

Petajoules: Explanation of the bewildering terms Malcolm ...

Canada Avg Space heating is ~3 x electricity

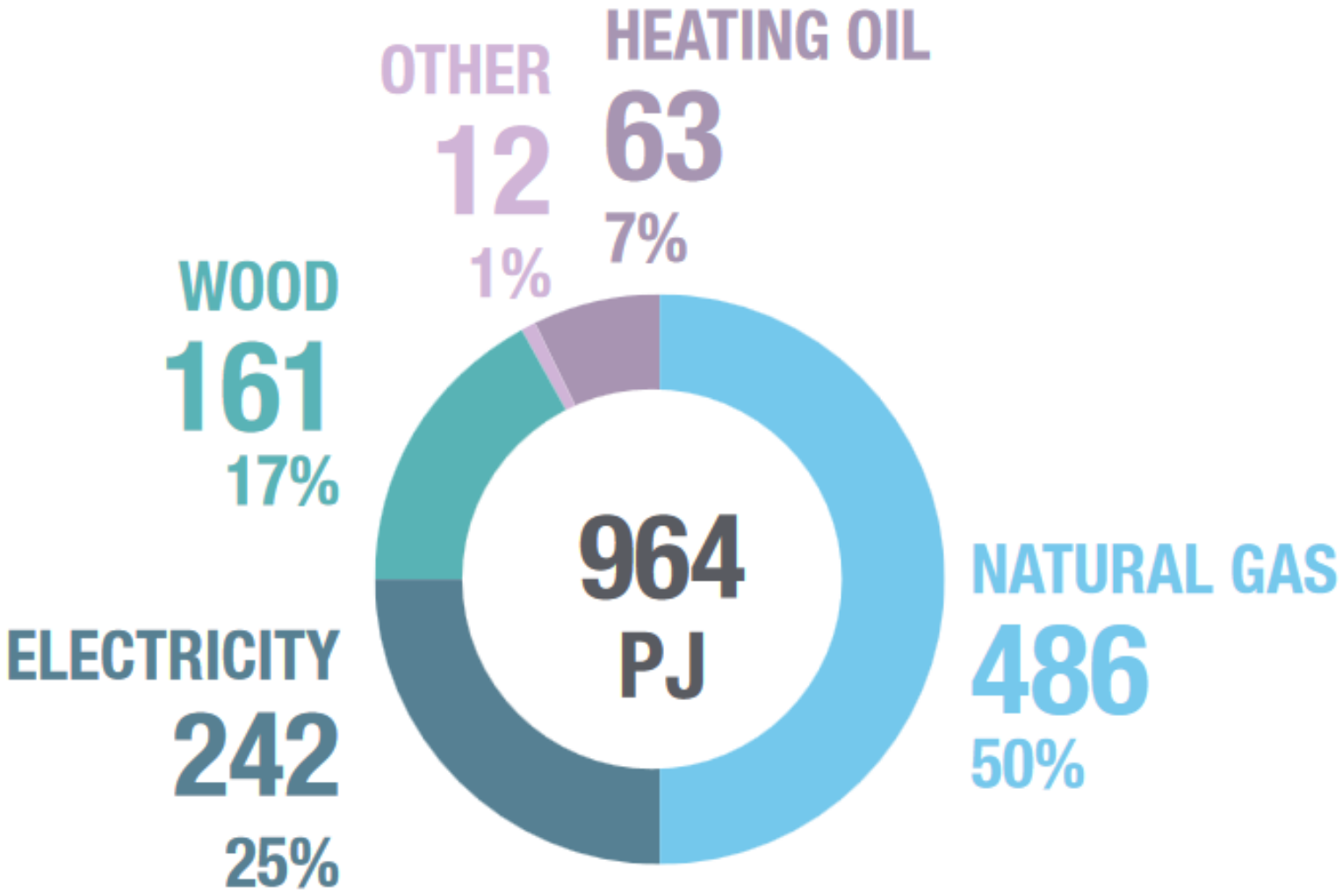
Commercial Energy Use



https://energyeducation.ca/encyclopedia/Heater

http://extraconversion.com/energy/petajoules

SPACE-HEATING ENERGY USE (PJ), 2015



- LIST OF LINKS MENTIONED IN THIS LECTURE (ENERGYEDUCATION PAGES AND OTHER SOURCES) TO READ, EXPLORE AND TO ADD TO YOUR REFLECTIVE WRITING:

https://energyeducation.ca/encyclopedia/Home_temperature_control

https://energyeducation.ca/encyclopedia/R-value

https://climateatlas.ca/map/canada/

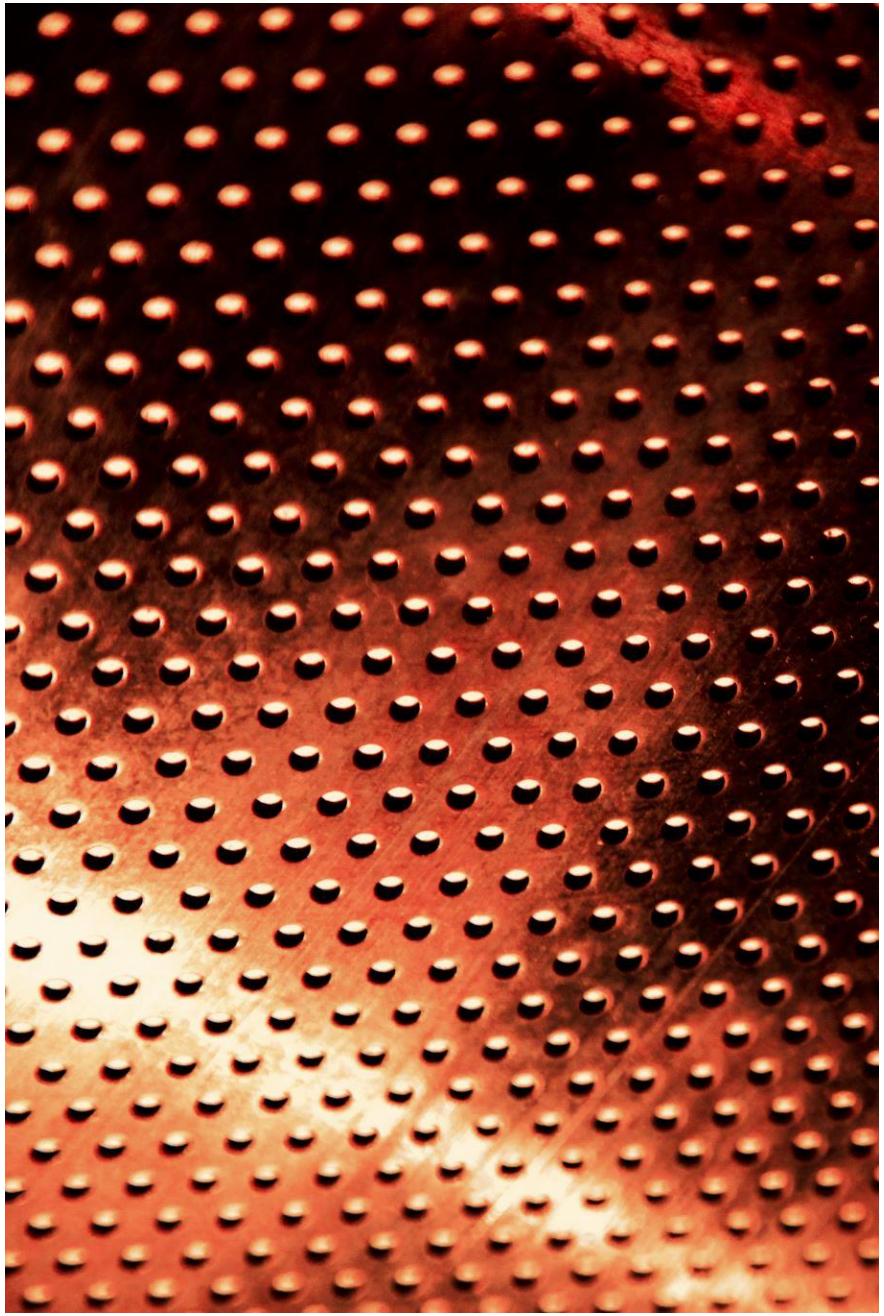
https://energyeducation.ca/encyclopedia/Heater

http://extraconversion.com/energy/petajoules

NEXT CLASS:

HVAC

- Makes the inside of the building envelope pleasant
- Heating Ventilation Air-Conditioning
  - Furnaces
  - Ducts
  - Vents
  - Fans
  - AC
  - Humidifiers





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PHYS 371 Introduction to Energy

LECTURE 14: THERMAL ENERGY – **MOVING HEAT**

WEDNESDAY, OCTOBER 13, 2021

Sunday, October 10 World Mental Health Day 2021

HTTPS://WELLNESSTOGETHER.CA

HTTPS://WWW.UCALGARY.CA/WELLNESS-SERVICES/SERVICES/MENTAL-HEALTH-SERVICES

HTTPS://UCALGARY.CA/PODCASTS/WE-CAN-ANSWER/EPISODE-4-MENTAL-HEALTH-2020

HTTPS://THEGAUNTLET.CA/2021/09/06/FROSH-2021-MENTAL-HEALTH-ON-CAMPUS/



Mindfulness refers to a mental state of focusing on the present moment. Pexels/Oluremi Adebayo

Aug. 31, 2021

Mindfulness meditation in brief daily doses can reduce negative mental health impact of COVID-19

How 10 minutes a day of app-guided meditation can make a positive difference.

Calgary community in general.

risk of harm, contact the Student at Risk Team.

Why contact the Student at Risk Team?

If you're concerned about a student, and think they might be at risk of harming them self or others, let the Student at Risk Team know. We can help by:

- Making sure the student receives necessary support.
- Preventing the situation from escalating.
- Providing a multi-disciplinary approach to the student's situation.

Training requests

Our team is happy to facilitate group training or consultations if you want to learn more about recognizing or supporting a student at risk.

Request a training session

Responding with care

Recognizing signs of distress and responding with care and concern can help students resolve issues interfering with their personal and academic lives. Contact us if you think a student is at risk.

Referral required:

Brief individual counselling

Using a brief model, individual counselling aims to help you address concerns through connection with helpful resources and short-term, goal-focused support.

Learn more about counselling

Physician/psychiatry

We offer psychiatric consultations and treatment for UCalgary students using a short–term model (usually up to six sessions). Referrals are only made by a community-based or Student Wellness Services physician.

Learn more

Student at Risk Team

If you know of a student who may be at risk of harming them self or others, the Student at Risk Team can help. If you call us after hours or are experiencing a current mental health crisis, you can access 24/7 mental health support.

After-hours mental health support

Student at Risk Team



University of Calgary
2500 University Drive NW
Calgary Alberta T2N 1N4

Direct access services

Peer listening

Come visit with a trained student volunteer who is ready to listen and talk with you about your concerns. Peer listeners are knowledgeable about on- and off-campus resources.

Learn more about peer listening »

Self-help resources

Access videos, learning modules, online information, apps, and more that provide mental health information and strategies to help you make positive changes to your health and wellbeing. Available any time of day!

Access Self-help resources »

Workshops

Student Wellness Services offers a variety of workshops that cover various mental health topics.

View our current offerings »

Mental health educational groups

These multi-session, ongoing groups provide support, mental health information, and strategies to promote your well-being.

Learn more about group programs

One-at-a-time counselling

Get faster access to support when you need it most. Through single session counselling, you can explore concerns, gain insights, and co-create some strategies you can leave the appointment with. Many find that one session of counselling meets their needs, but if you feel something more is needed, you can discuss this with the counsellor, and further supports on or off campus will also be explored. You can access single session counselling as many times as you need.

With appointments available from Monday to Friday, you'll usually be able to book a 75-minute appointment within a week.

Coordinated care

Our team of Student Support Advisors (Registered Social Workers and a Registered Nurse) are here to help you with any issues keeping you from personal or academic success, using a coordinated care approach.

The purpose of coordinated care is to help you reach your optimum level of wellness through practical problem solving, resource navigation, and linking & liaising with campus and community resources. Coordinated care can occur concurrently with individual counselling.

With appointments available from Monday to Friday, you'll usually be able to book a 60-minute appointment within a week.

Learn more about Coordinated care

Mental Health Services

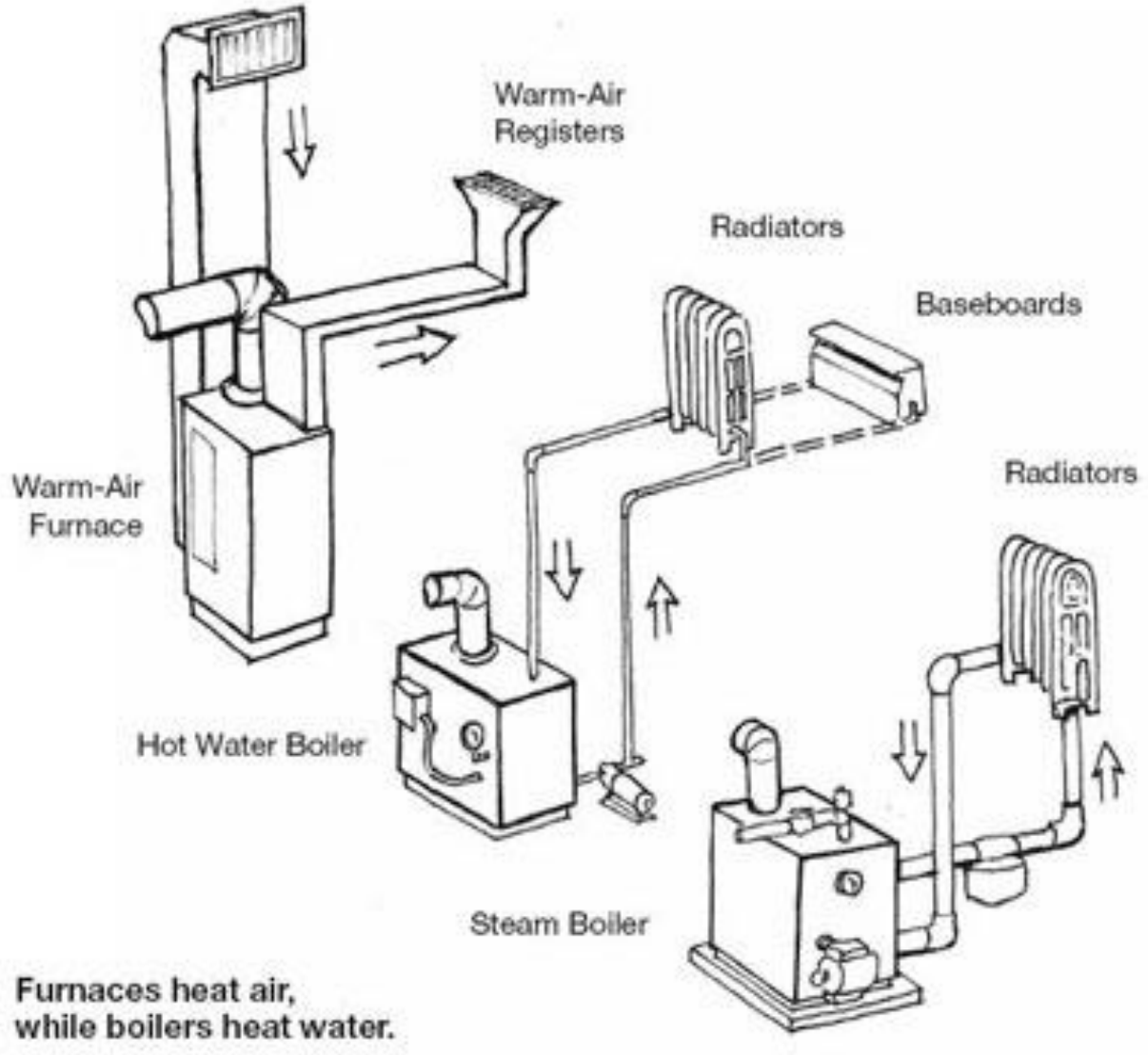
Seeking mental health support and improving your understanding of mental health can have a positive impact on your wellbeing, and help you succeed on your academic journey.

If you need after-hours mental health support or are experiencing a current mental health crisis, you can access 24/7 support.

HVAC

- Makes the inside of the building envelope pleasant
- Heating Ventilation Air-Conditioning
  - Furnaces
  - Ducts
  - Vents
  - Fans
  - AC
  - Humidifiers

Furnaces heat air Boilers heat water/steam

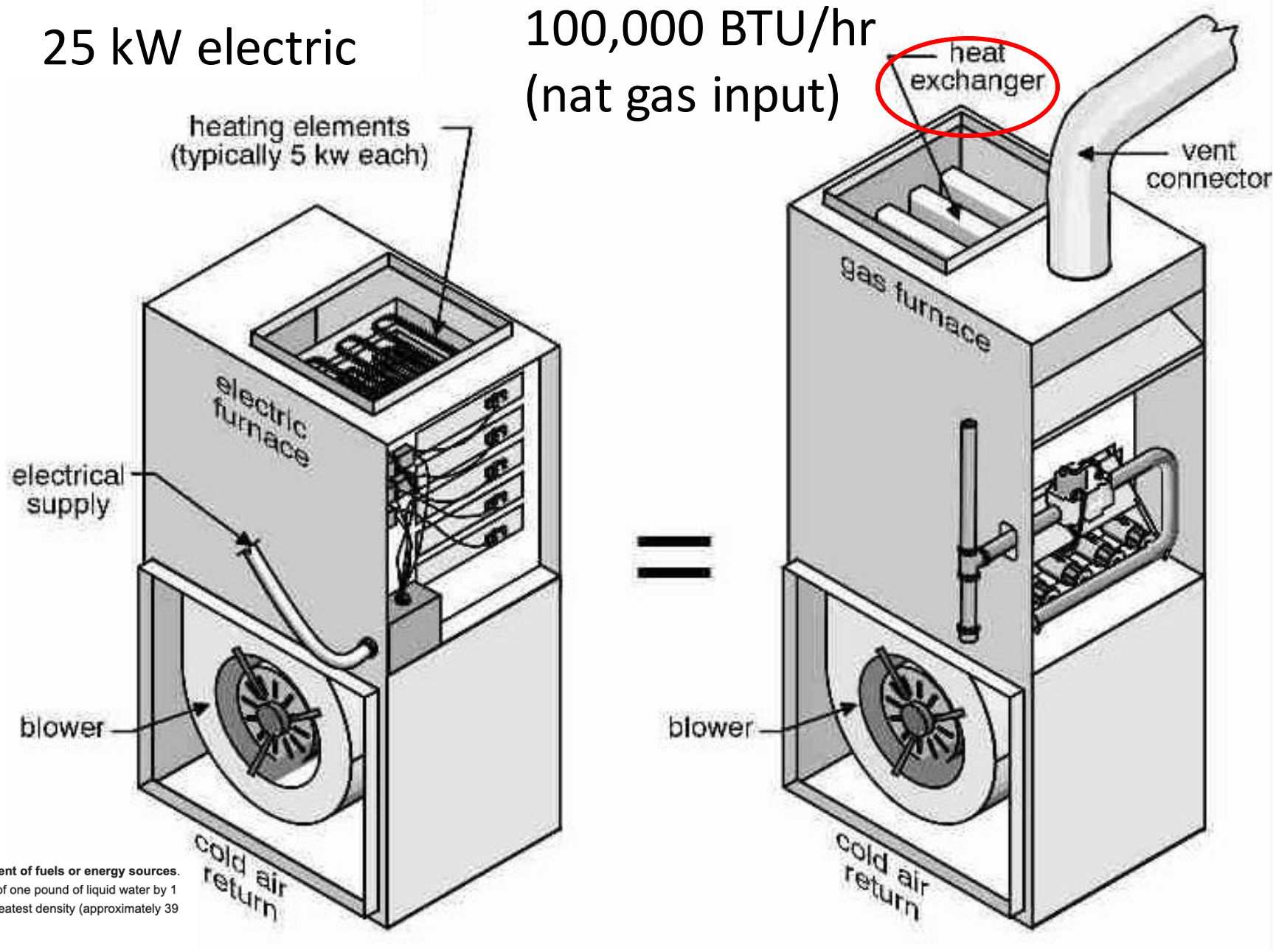


Furnaces heat air, while boilers heat water.

Hot fluids move through house

25 kW electric

100,000 BTU/hr
(nat gas input)



A British thermal unit (Btu) is **a measure of the heat content of fuels or energy sources**. It is the quantity of heat required to raise the temperature of one pound of liquid water by 1 degree Fahrenheit at the temperature that water has its greatest density (approximately 39 degrees Fahrenheit). May 13, 2021

https://www.eia.gov › units-and-calculators › british-ther...

British thermal units (Btu) - U.S. Energy Information ... - EIA

British thermal unit https://energyeducation.ca/encyclopedia/British_thermal_unit

(Redirected from BTU)

British thermal units, or BTUs, are a unit of energy. It is the amount of energy required to heat a pound of water by one degree Fahrenheit at one atm.

The BTU is defined as 251.9958 calories, and due to the calorie having many different accepted values, so does the BTU. These different values of the BTU include:[1]

thermochemical Btu	1 Btu = 1054.35 J
59 °F (15 °C) Btu	1 Btu = 1054.80 J
International Table Btu	1 Btu = 1055.06 J
mean Btu	1 Btu = 1055.87 J

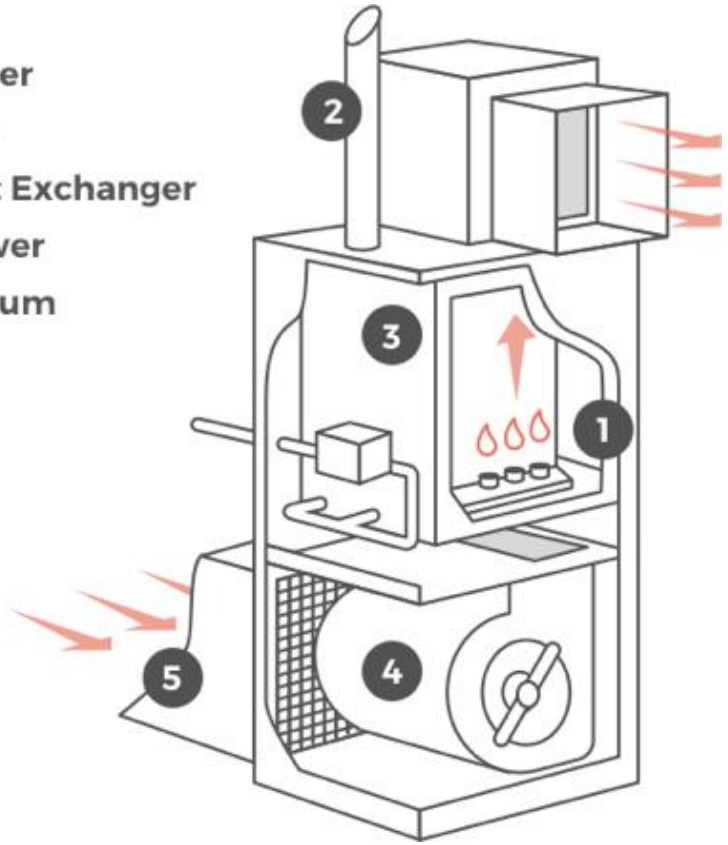
The International Table BTU is the value that is most commonly accepted in most modern energy publications,[2] so

chart Highlight All Match Case Match Diacritics Whole Words 1 of 1 match Reached end of page, continued from top

Natural gas furnaces

Forced air, needs a fan

1. Burner
2. Flue
3. Heat Exchanger
4. Blower
5. Plenum





Natural gas furnaces $\eta \approx$ 80-97%



Efficiency https://energyeducation.ca/encyclopedia/Efficiency

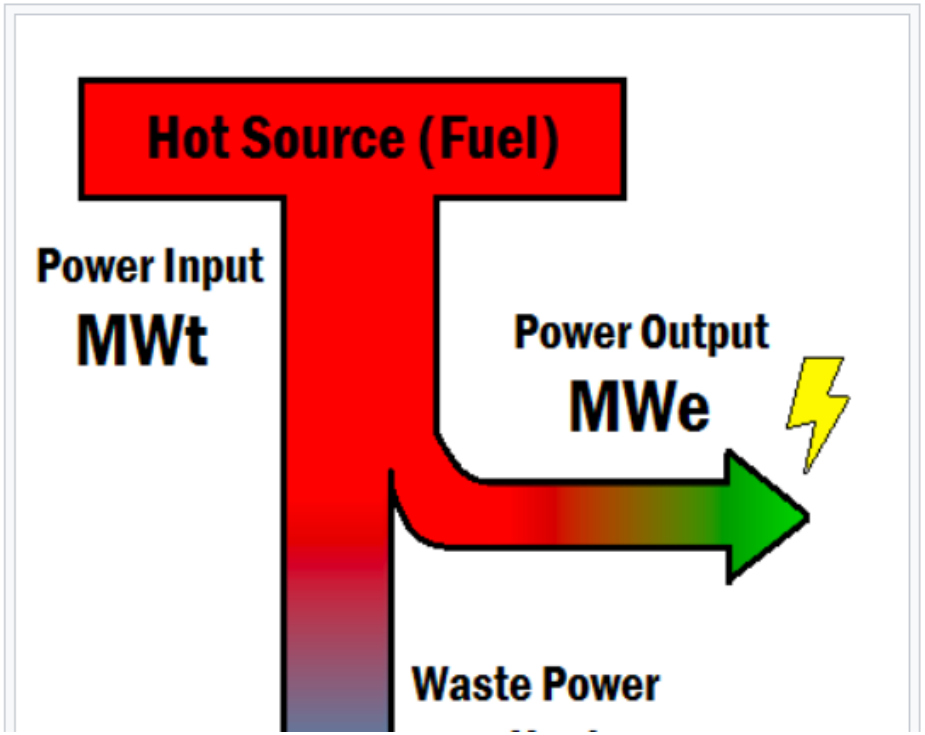
In other languages: Español Français

A word can have multiple and ambiguous meanings in everyday language but they have precise meanings in science. **Efficiency** in [illegible] mparison of the energy output to the energy input in a given system. It is defined as [illegible] the input energy, given by the equation:

$$Efficiency = \frac{E_{out}}{E_{in}} \times 100\%$$

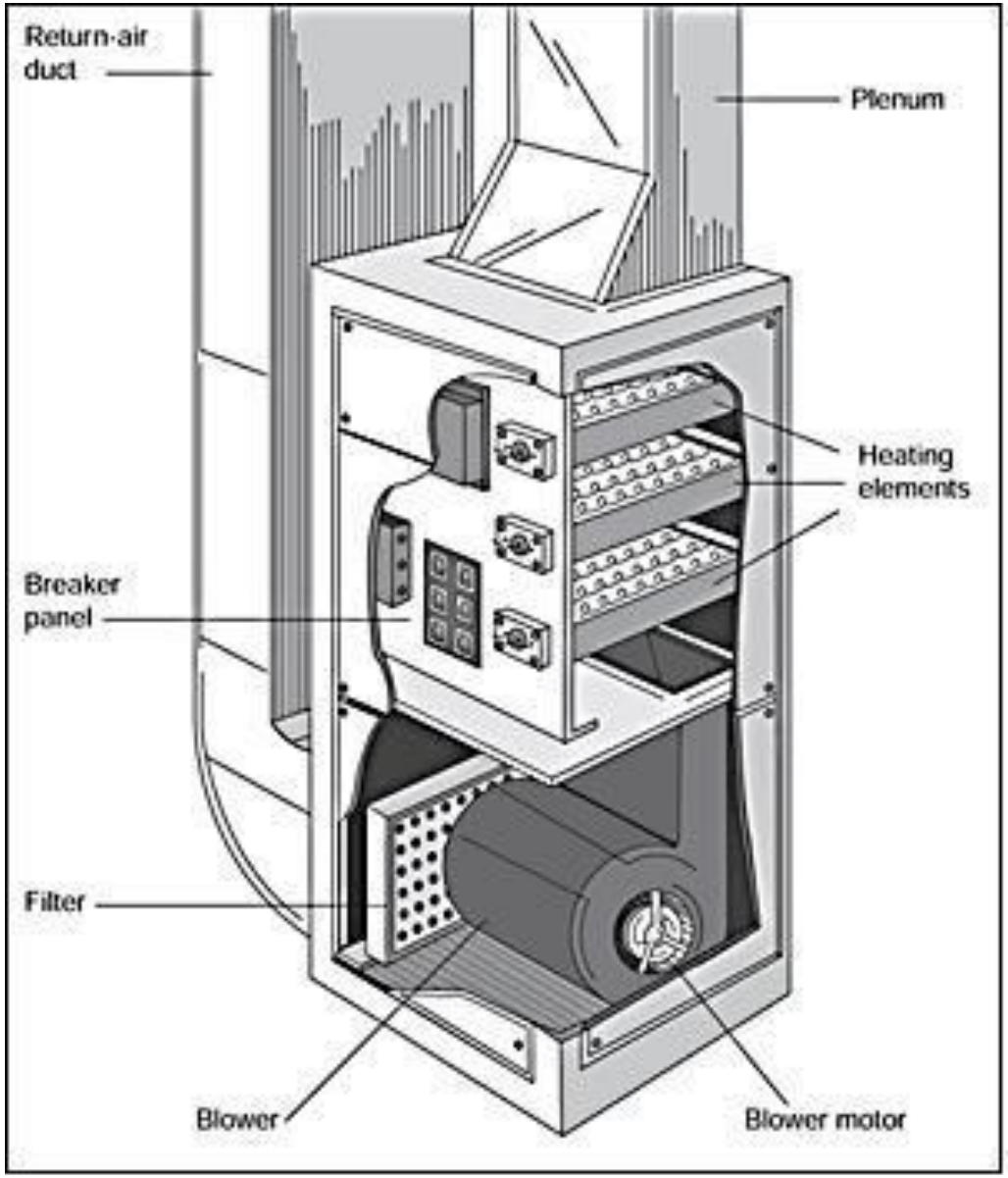
This equation is commonly used in order to represent energy in the form of heat or power.

"Efficiency" is often confused with "effectiveness", and the two should be recognized as distinct from one another when



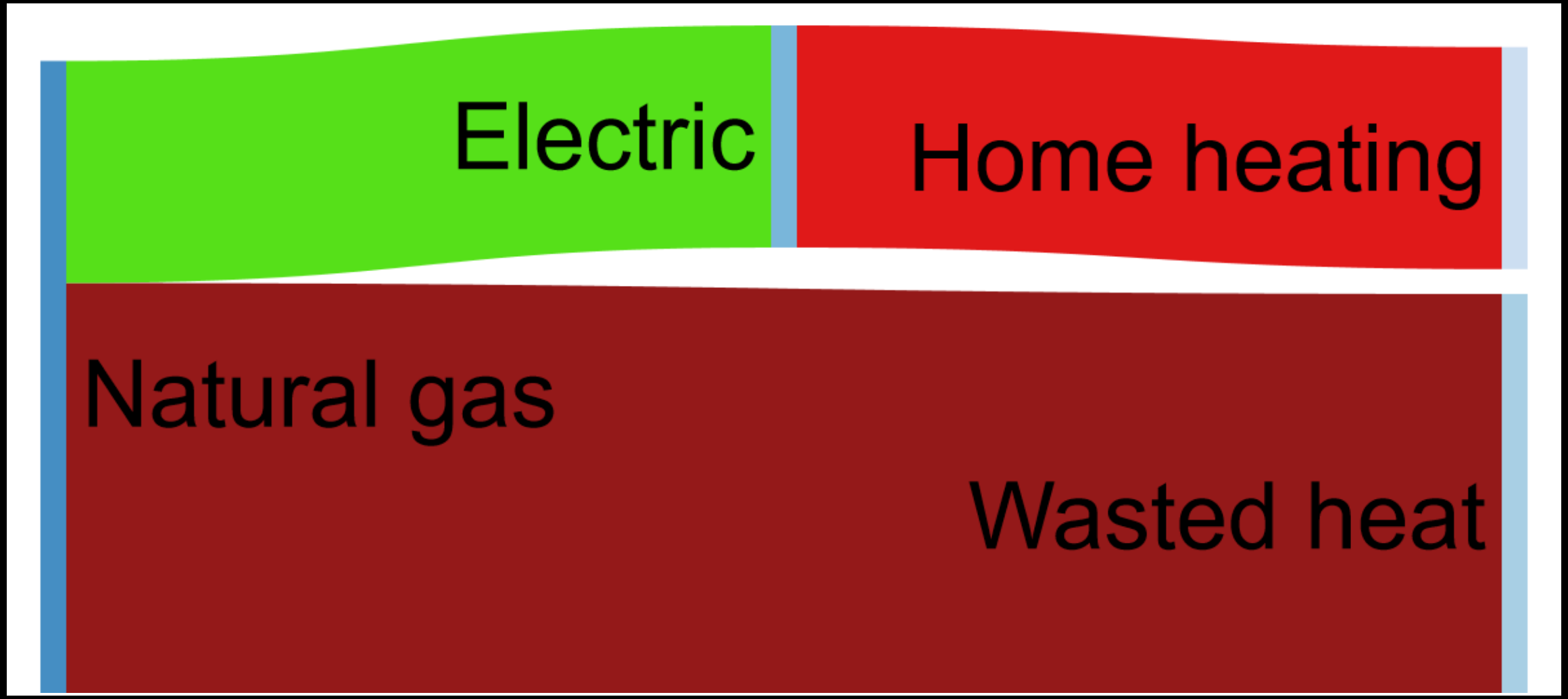
Electric furnace

- No heat exchanger
- No waste gas

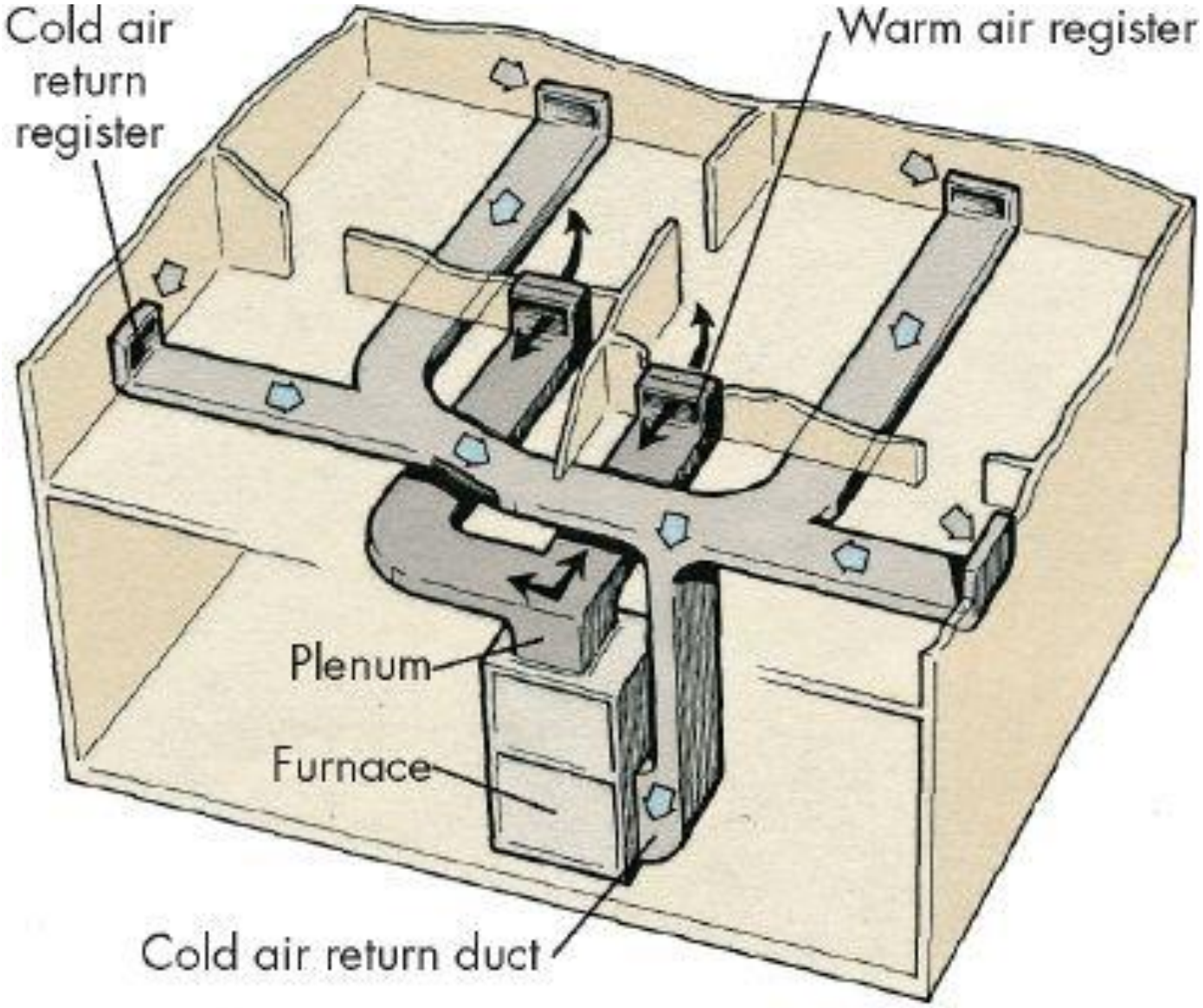


Electric furnaces $\eta \approx 100\%$

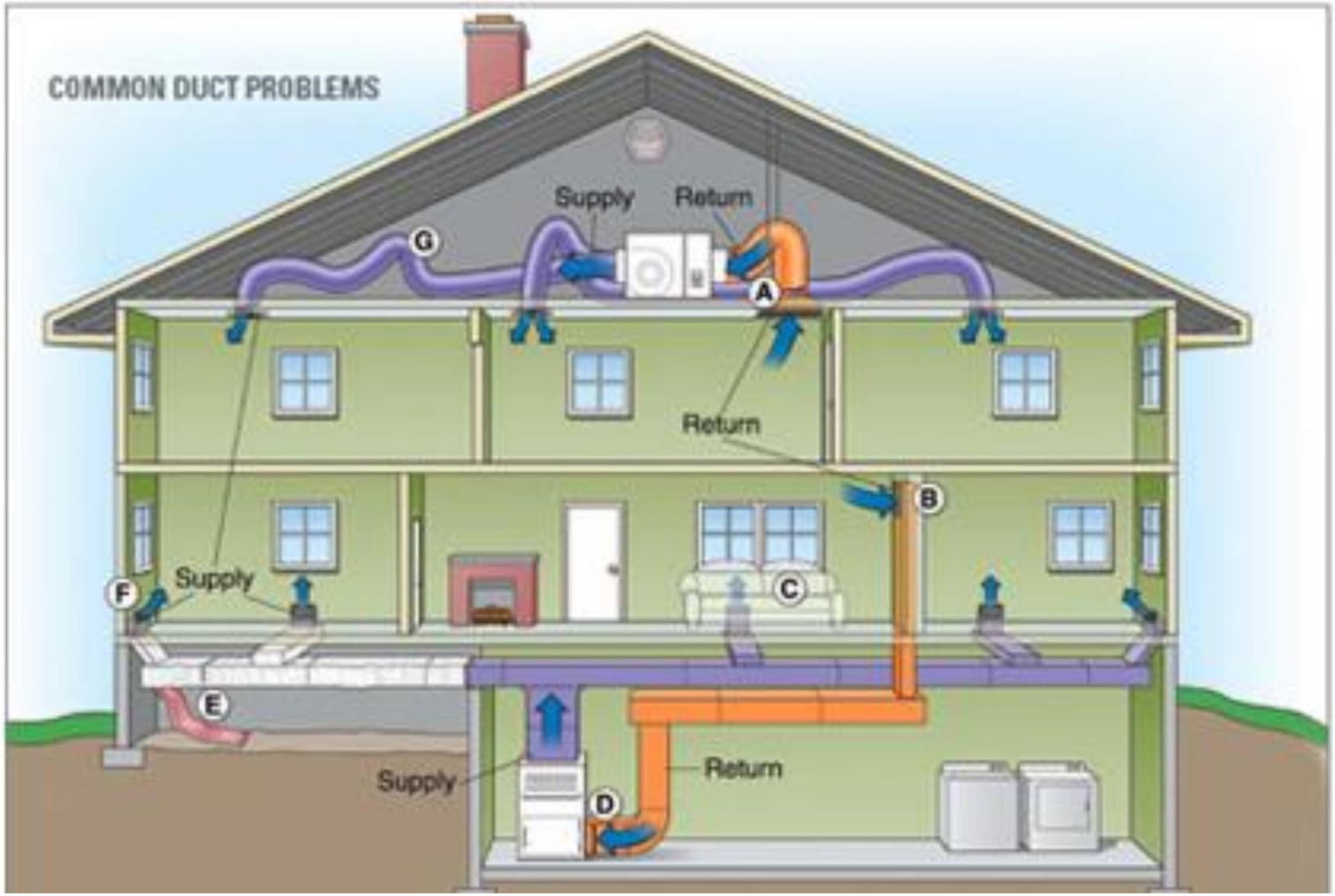




But only ~33% efficient at making electricity!


Cold air return register
Warm air register
Plenum
Furnace
Cold air return duct

In a house

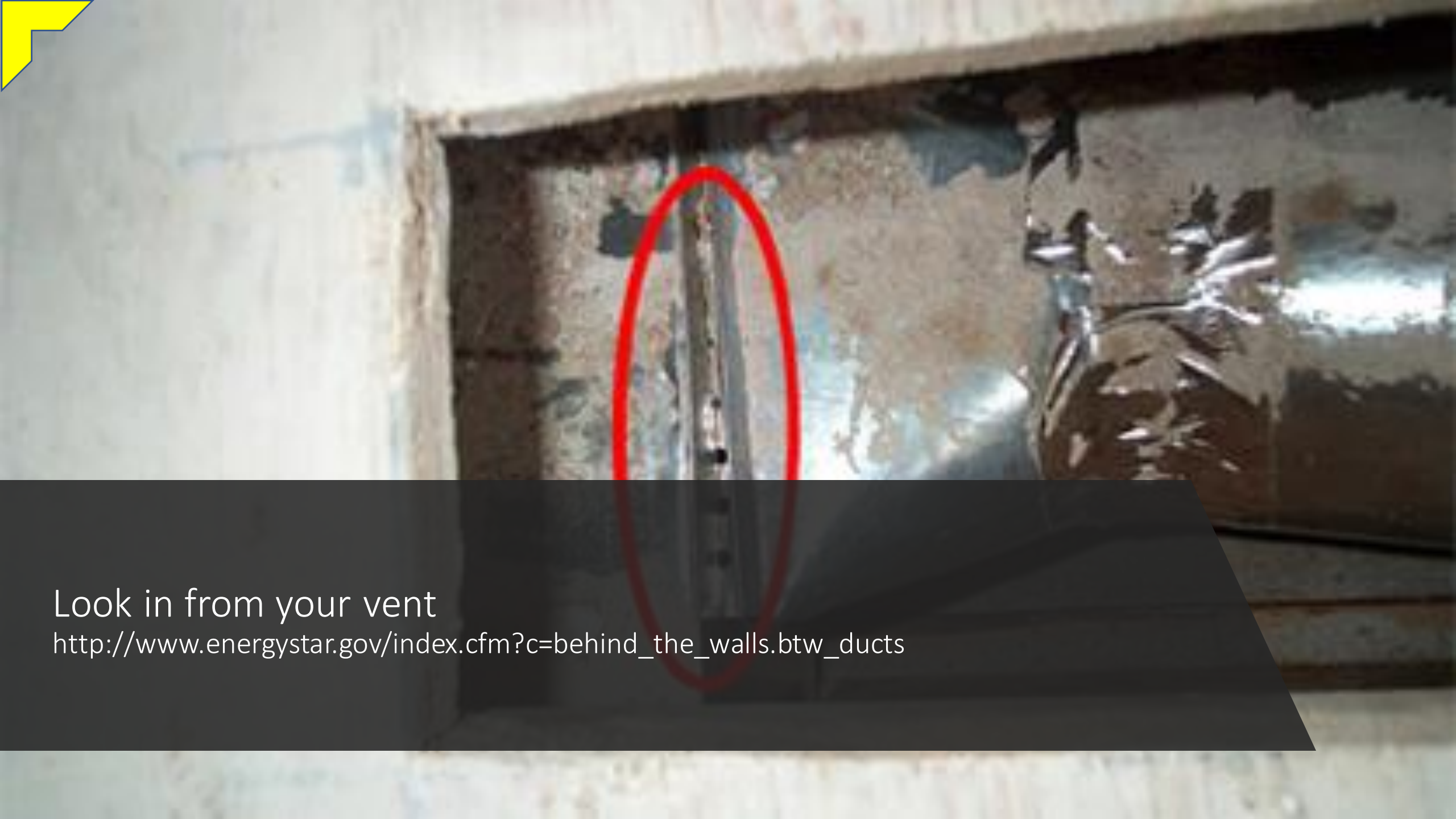


http://www.energystar.gov/index.cfm?c=behind_the_walls.btw_ducts





Ducts can leak



Look in from your vent

http://www.energystar.gov/index.cfm?c=behind_the_walls.btw_ducts

Heater vents



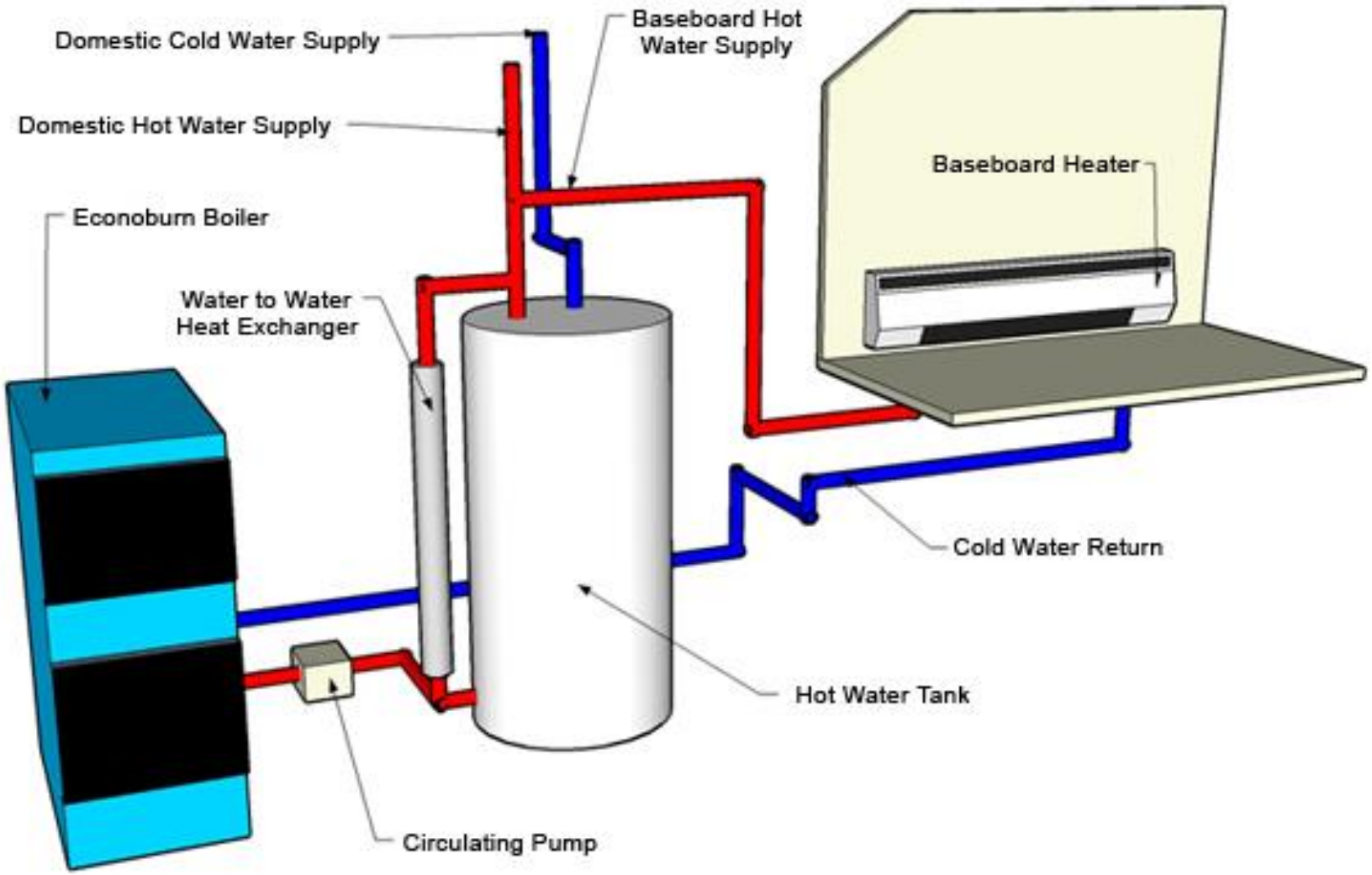
https://energyeducation.ca/encyclopedia/Heating_registers_and_vents

- Vents: usually by windows and doors.
- Heat inputs are present to try to keep the room temperature consistent.

Vents should warm in front of curtains, not behind



http://tales.indulgedfurries.com/?p=3258


Domestic Cold Water Supply
Baseboard Hot Water Supply
Domestic Hot Water Supply
Baseboard Heater
Econoburn Boiler
Water to Water Heat Exchanger
Cold Water Return
Hot Water Tank
Circulating Pump

Midterm 1

Manage Quizzes › View Statistics

View Statistics

Include exempted users in stats

User Stats | Question Stats

User Statistics

Score Dis

Percenta

Clas

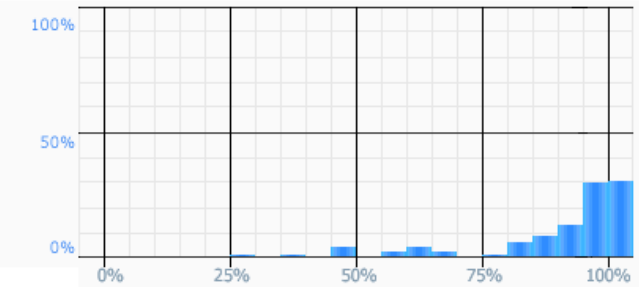
The C

Question Statistics

Export to CSV | Export to Excel

Score Distribution:

Percentage of Questions



Average Grade

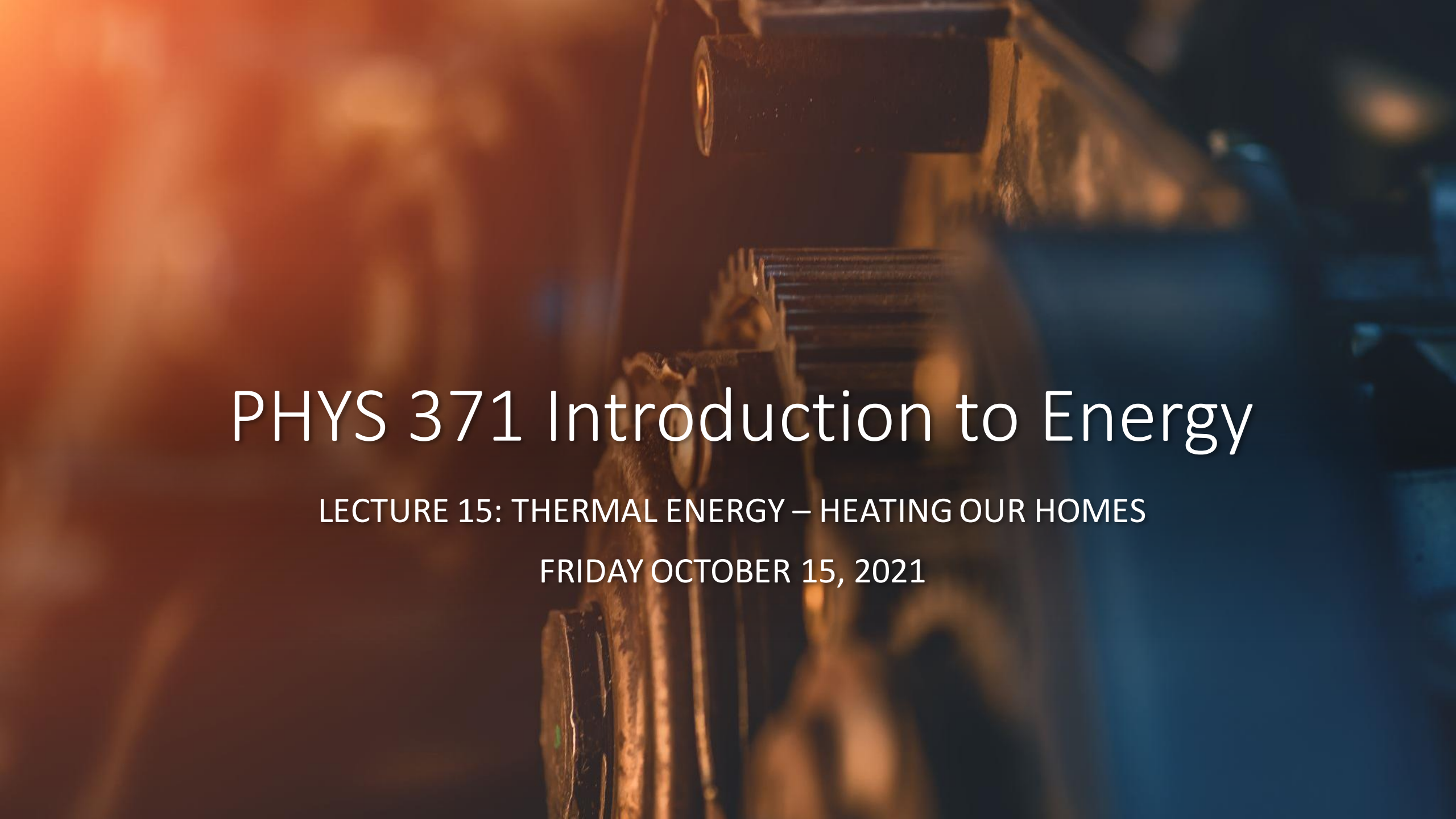
Class Average: 92.18 % (Std Dev = 6.61 %)

The Class Average is calculated on first attempts flagged as graded.

What do the statistics on this page mean?

Question	Average Grade	Standard Deviation	Discrimination Index	Point Biserial

Very high average (92.18% average, **85% of the students received an A- or higher mark**).



PHYS 371 Introduction to Energy

LECTURE 15: THERMAL ENERGY – HEATING OUR HOMES

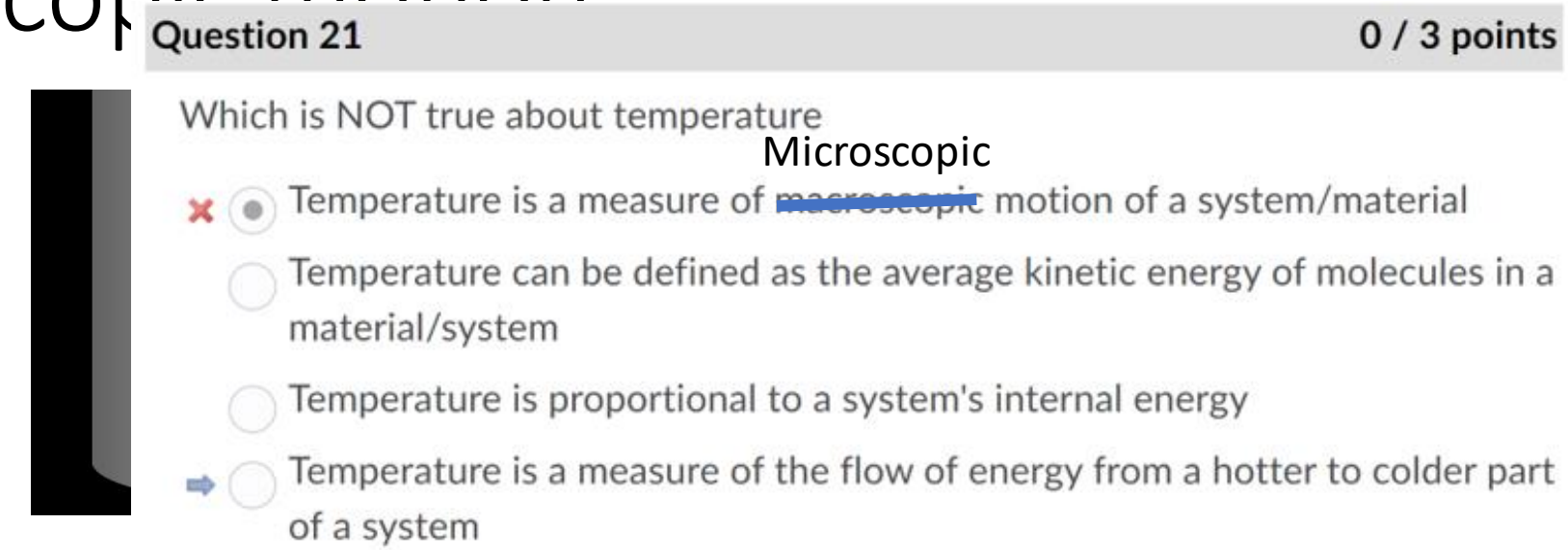
FRIDAY OCTOBER 15, 2021

Tophat question roman aqueduct

- **The water atop Niagara Falls has potential energy despite if there is a dam built around it or not. Potential energy relates to height (position in general with respect of a field, but in this class, we simplify height from ground). Hydroelectric power harvests kinetic energy of the water, this is why the turbines are located at the bottom of the dam and not atop!**

Relative and absolute temperature

Model: Temperature is a measure of microscopic motion



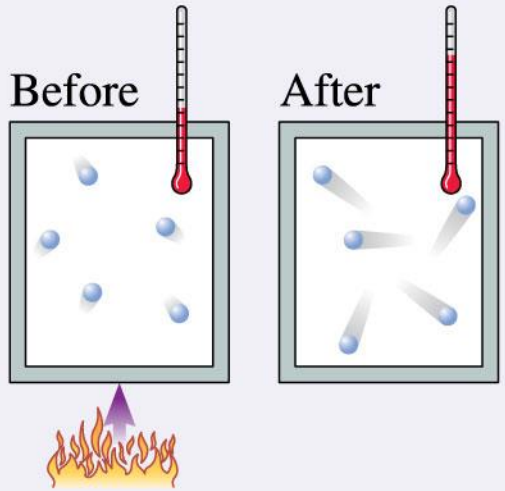
Temperature = measurement of internal energy

Heat = Flow of thermal energy from hotter to colder

Temperature

What is temperature?

You're familiar with temperature, but what does it actually measure? We'll start with the simple idea that temperature measures "hotness" and "coldness," but we'll come to recognize that temperature measures a system's thermal energy. We'll study the well-known fact that objects expand or contract when the temperature changes.



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Temp is a MACROSCOPIC property of an object.

Temp is proportional to the internal (a.k.a. thermal) energy of an object.

Temperature is derived from the average of the MICROSCOPIC kinetic and rotational kinetic energy of the molecular or atomic particles in a system. Monoatomic and diatomic ideal gases have different degrees of freedom (sum of rotation and translation degrees of freedom).

When you measure temperature, you measure the temperature of a MACROSCOPIC object, you do not measure the 'temperature of an atom'. You also do not measure the microscopic kinetic energy of a particle for each particle in your system to average them out. You make assumptions and you solve for the average.

See:
https://phys.libretexts.org/Bookshelves/University_Physics/Book%3A_University_Physics_(OpenStax)/Book%3A_University_Physics_II_-_Thermodynamics_Electricity_and_Magnetism_(OpenStax)/02%3A_The_Kinetic_Theory_of_Gases/2.03%3A_Pressure_Temperature_and_RMS_Speed

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Microscopic properties

Why are macroscopic properties important?

Physicists, chemists, biologists, and engineers all work with matter at the macroscopic level. Everything from basic science to engineering design depends on knowing how materials respond when they are heated, compressed, melted, or otherwise changed by factors in their environment. Changing states of matter underlie devices ranging from car engines to power plants to spacecraft.

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Temperature

- What is **temperature**?
- Temperature is related to how much *thermal energy* is in a system.
- For now, in a very practical sense, temperature is what we measure with a thermometer!



- In a glass-tube thermometer, such as the ones shown, a small volume of liquid expands or contracts when placed in contact with a “hot” or “cold” object.
- The object’s temperature is determined by the length of the column of liquid.

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Units of absolute Temperature

The SI unit for absolute temperature is

A. Celsius.
B. Fahrenheit.
C. Kelvin.
D. Newton.
E. Rankine.

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Units of absolute temperature

The SI unit for absolute temperature is

A. Celsius.

B. Fahrenheit.

✔ **C. Kelvin.**

D. Newton.

E. Rankine.

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Temperature Scales

- The *Celsius* temperature scale is defined by setting $T_C = 0$ for the freezing point of pure water, and $T_C = 100$ for the boiling point.
- The *Kelvin* temperature scale has the same unit size as Celsius, with the zero point at absolute zero. The conversion from the Celsius scale to the Kelvin scale is

$$T_K = T_C + 273$$

- The *Fahrenheit* scale, still widely used in the United States, is defined by its relation to the Celsius scale, as follows:

$$T_F = \frac{9}{5} T_C + 32°$$

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Heat, Temperature, and Thermal Energy

- **Thermal energy** E_{th} is an energy of the system due to the motion of its atoms and molecules.
- **Heat** Q is energy transferred between the system and the environment as they interact.
- **Temperature** T is a state variable that quantifies the "hotness" or "coldness" of a system.



- A temperature difference is required in order for heat to be transferred between the system and the environment.

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Internal energy (thermal energy) and heat

Heat transfer is the movement of energy from one place or material to another as a result of a difference in temperature

- Internal (thermal) energy: average of the total mechanical energy of all the molecules or entities in the system, at the MICROSCOPIC level
- Heat: energy transferred due to a temperature difference

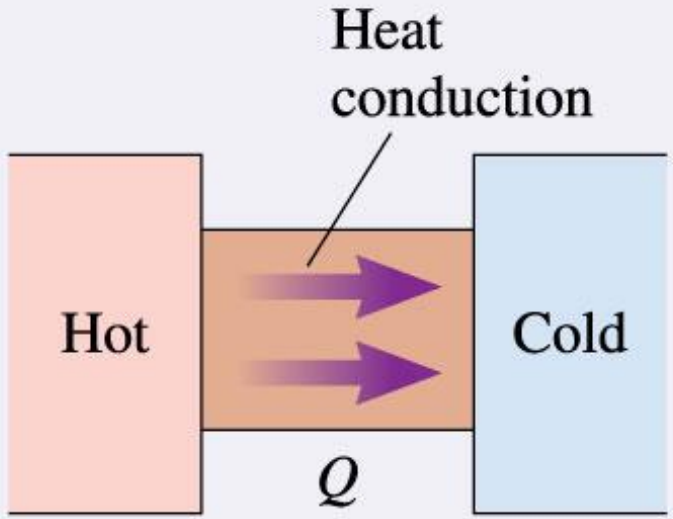
Heat Transfer, Specific Heat, and Calorimetry. (2020, November 5). Retrieved September 28, 2021, from https://phys.libretexts.org/@go/page/4347

Heat Transfer

How is heat transferred?

Heat energy can be transferred between a system and its environment by

- Conduction
- Convection
- Radiation
- Evaporation



Joule's most famous experiment

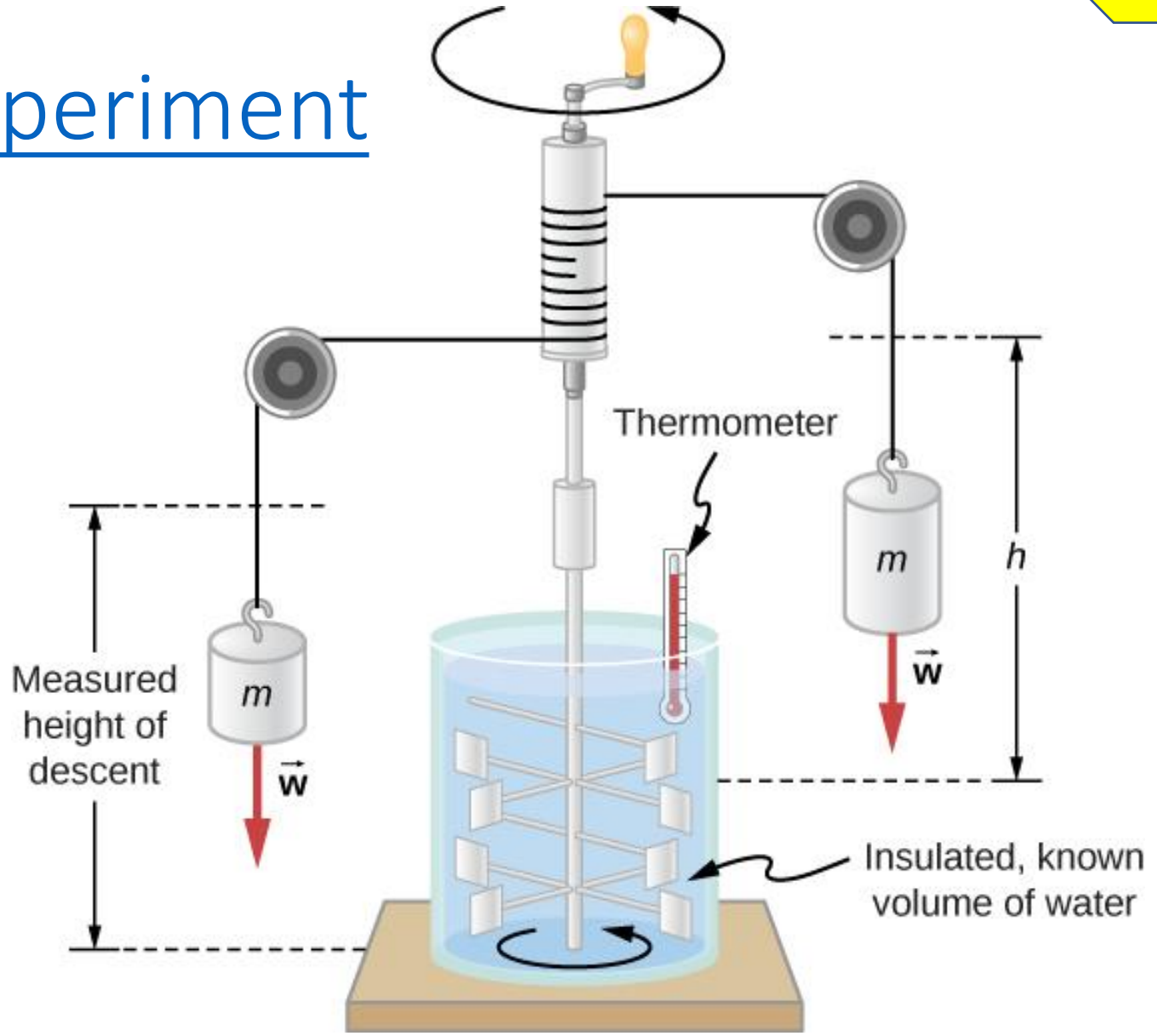
Joule's experiment established the equivalence of heat and work. As the masses descended, they caused the paddles to do work, $W = mgh$, on the water. The result was a temperature increase, ΔT, measured by the thermometer. Joule found that ΔT was proportional to **W** and thus determined the mechanical equivalent of heat

.

$$1.000kcal = 4{,}186J.$$

$$Q = mc\Delta T$$

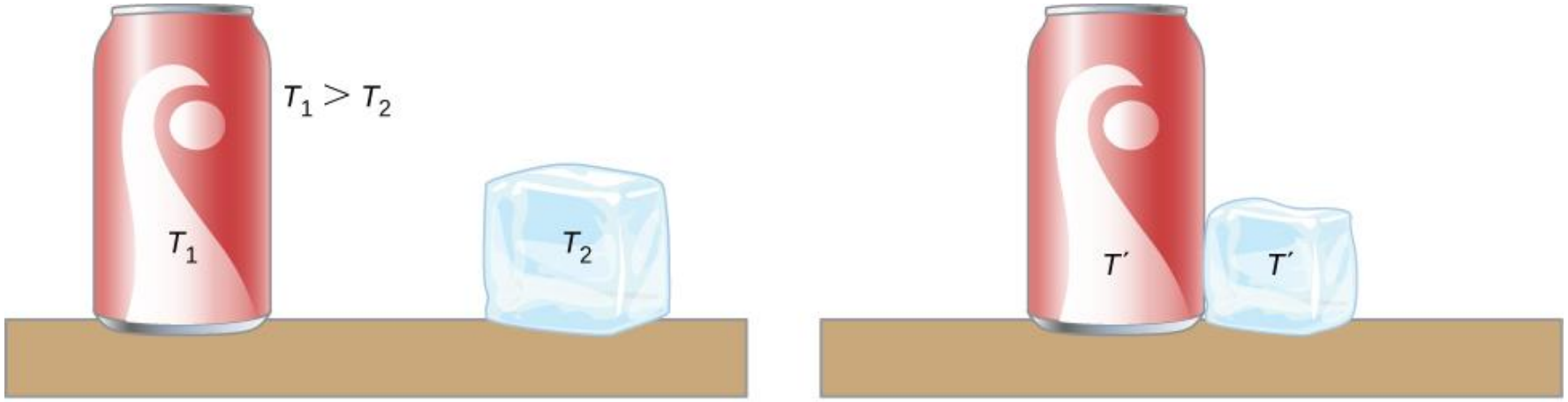
where Q is the symbol for heat transfer ("quantity of heat"), **m** is the mass of the substance, and ΔT is the change in temperature. The symbol **c** stands for the **specific heat** (also called "**specific heat capacity**") and depends on the material and phase.



Heat Transfer, Specific Heat, and Calorimetry. (2020, November 5). Retrieved September 28, 2021, from https://phys.libretexts.org/@go/page/4347

Temperature and internal energy

A thermal system has **internal energy** (also called **thermal energy)**, which is the sum of the mechanical energies of its molecules. A system's internal energy is proportional to its temperature.



(a) Here, the soft drink has a higher temperature than the ice, so they are not in thermal equilibrium. (b) When the soft drink and ice are allowed to interact, heat is transferred from the drink to the ice due to the difference in temperatures until they reach the same temperature, T', achieving equilibrium. In fact, since the soft drink and ice are both in contact with the surrounding air and the bench, the ultimate equilibrium temperature will be the same as that of the surroundings.

THERMAL ENERGY

ENERGY EDUCATION

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Thermal energy

In other languages: Français

The **thermal energy** of an object is the energy contained in the motion and vibration of its molecules. Thermal energy is measured through temperature.

The energy contained in the small motions of the object's molecules can be broken up into a combination of microscopic kinetic energy and potential energy. The total energy of an object is equal to:

$$E_T = E_K + E_P$$

- E_T is the total energy in an object.
- E_K is the kinetic energy of an object.
- E_P is the potential energy of an object.

Temperature is a direct measurement of thermal energy, meaning that the hotter an object is, the more thermal energy it has. Heat is a measure of how much thermal energy is transferred between two systems.

It is easy to turn mechanical energy into thermal energy, for example using friction. It's also possible to turn thermal energy into mechanical energy by using a heat engine, but there will always be waste heat with this method.

Specific heat

https://energyeducation.ca/encyclopedia/Thermal_energy

CONDUCTION

Example: Molecules transferring energy by bumping

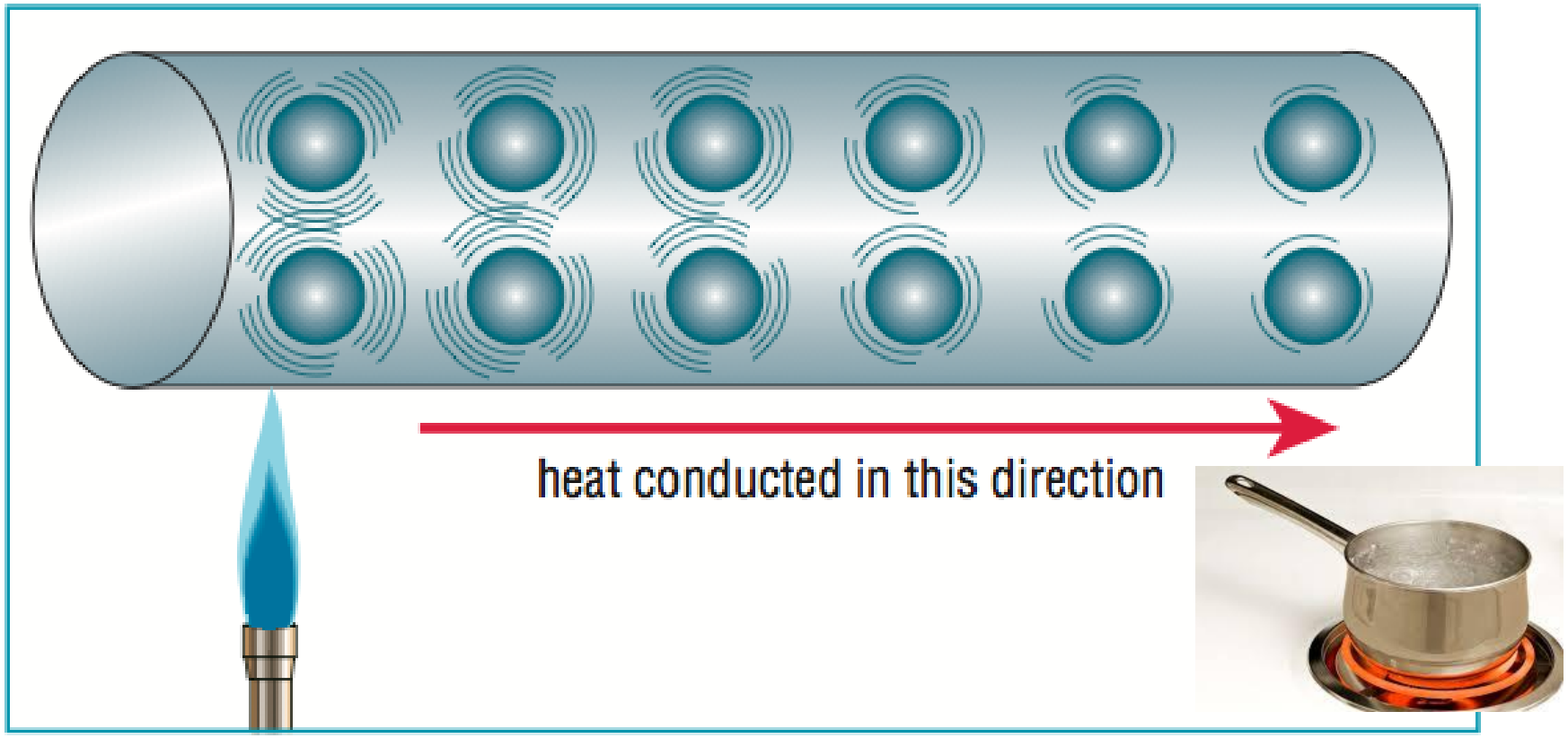
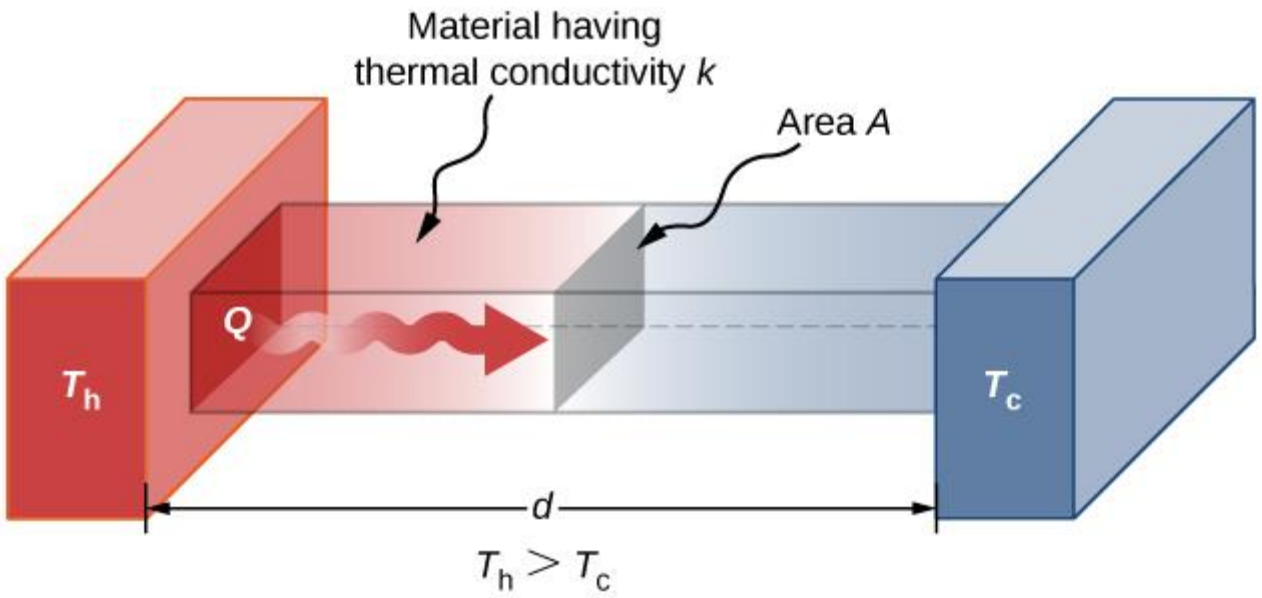


Fig 6.2.3 Conduction—vibrations pass along from particle to particle away from the heat source.

Heat Conduction



Heat conduction occurs through any material, represented here by a rectangular bar, whether window glass or walrus blubber.

$$P = \frac{kA(T_h - T_c)}{d}$$

where P is the power or rate of heat transfer in watts or in kilocalories per second, A and d are its surface area and thickness, as shown in the figure, Th−Tc is the temperature difference across the slab, and k is the thermal conductivity of the material.

Mechanisms of Heat Transfer. (2020, November 5). Retrieved September 30, 2021, from https://phys.libretexts.org/@go/page/4349

Conduction equation

$$\frac{Q}{\Delta t} = k\frac{A(T_h - T_c)}{d}$$

$\frac{Q}{\Delta t}$ Heating power in Watts

k is the thermal conductivity $\frac{\mathrm{W}}{\mathrm{m \cdot K}}$

A Surface area in m^2.

d is the length the heat travels

T_h & T_c Temperature of Hot and cold sides

https://energyeducation.ca/encyclopedia/Thermal_conduction#cite_note-1

Thermal conduction

Thermal conduction is the diffusion of thermal energy (heat) within one material or between materials in contact. The higher temperature object has molecules with more kinetic energy; collisions between molecules distributions this kinetic energy until an object has the same thermal energy throughout. *Conduction is the main mode of heat transfer between or inside solid materials*. Conduction allows gas and electric stoves heat up pans. Buildings lose much of their heat by conduction, the pockets of air in insulation prevents this loss by stopping conduction.[2]

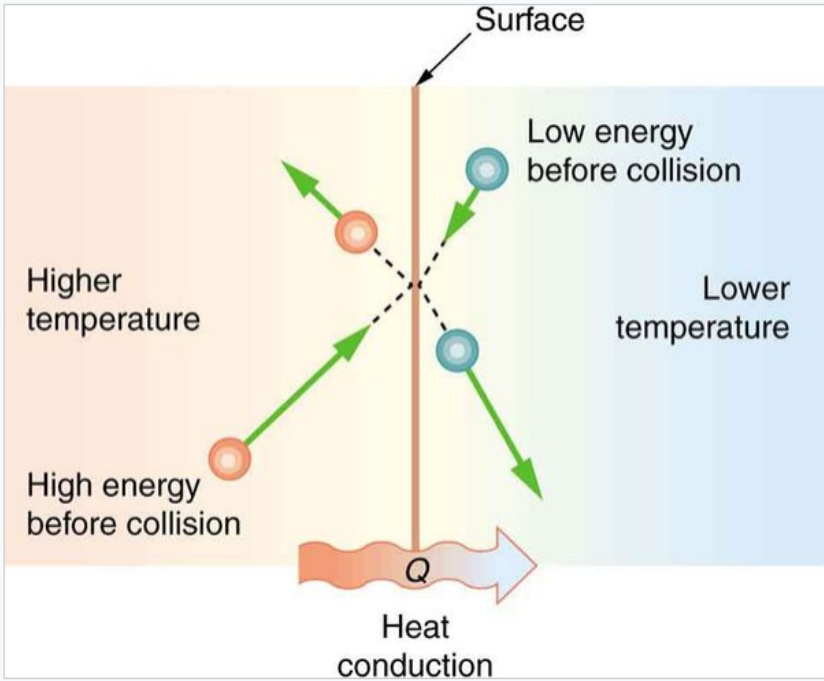


Figure 1. Heat transfers from a hot surface to a cold surface through thermal conduction.[1]

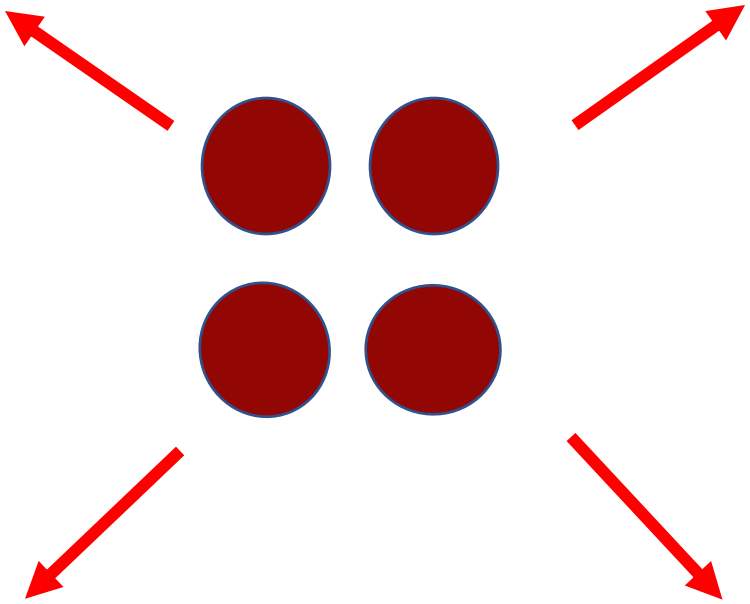
Thermal Conduction

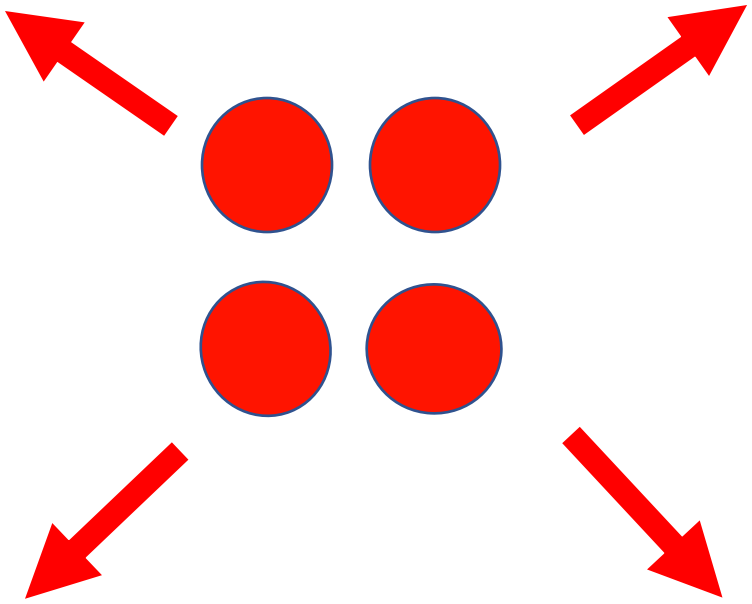
A region with greater thermal energy (heat) corresponds with greater molecular agitation. Thus when a hot object touches a cooler surface, the highly agitated molecules

Radiation

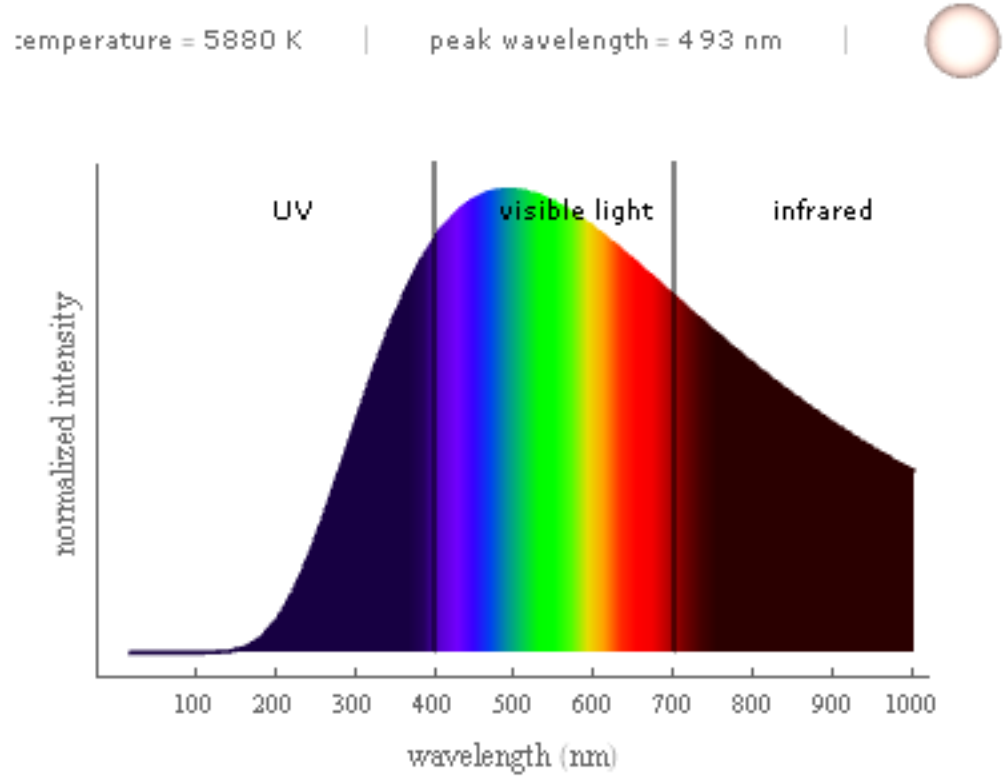
Molecule wiggle create electromagnetic radiation





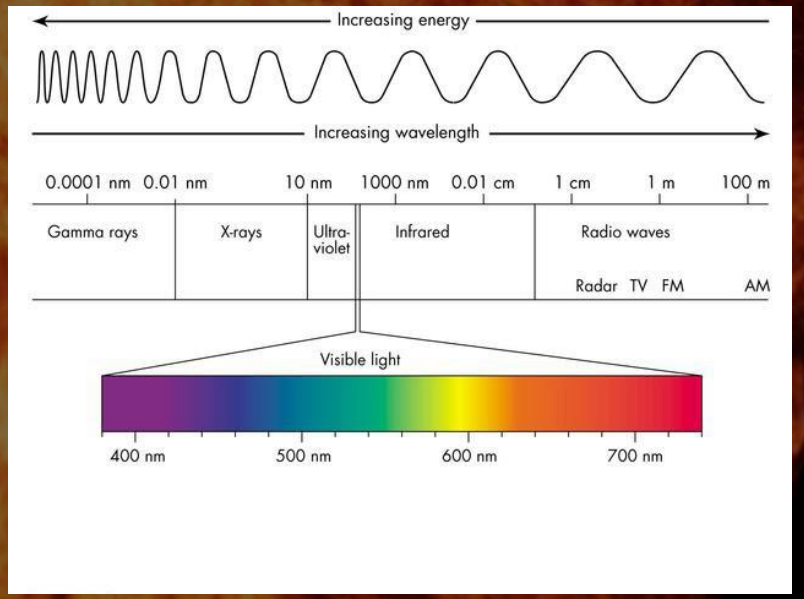


Blackbody radiation, no special wavelength given off



The hot body emits electromagnetic waves that are absorbed by other body.
No medium is required for electromagnetic waves to propagate.
Different names are used for electromagnetic waves of different wavelengths: radio waves, microwaves , infrared radiation , visible light , ultraviolet radiation , X-rays, and gamma rays.

Radiation



A shorter wavelength (or higher frequency) corresponds to a higher energy. Because more heat is radiated at higher temperatures, higher temperatures produce more intensity at every wavelength but especially at shorter wavelengths.

Image Source: https://sites.google.com/a/coe.edu/principles-of-structural-chemistry/relationship-between-light-and-matter/electromagnetic-spectrum

Thermal Radiation

https://energyeducation.ca/encyclopedia/Radiation

Thermal radiation is one type of electromagnetic radiation that is talked about in great detail. In terms of heat transfer, radiation is the emission of thermal energy in the form of infrared waves.[6] Generally, thermal radiation and infrared waves are referred to simply as "heat". Since heat is carried by electromagnetic waves, it does not need a physical medium to transfer it. Instead it radiates through space - this is how the Earth is heated by the Sun despite space being a vacuum.[7]

All objects at normal temperature emit thermal radiation; however it is not visible to the naked eye. Infrared cameras are able to pick up this invisible radiation and digitally convert it into a visible image (such as the one shown in Figure 4). Sometimes this radiant heat is visible. For example, a candle radiates heat. It also gives out visible light, which corresponds with the temperature of the flame. The flame burns hottest at the wick, and gives off blue or white light as it is on the higher end of the visible light spectrum. Surrounding the wick, the flame is yellow and then red in appearance, which is at the lower end of the visible light spectrum. The region surrounding the flame gives off no light as it emits infrared waves, but feels warm to the touch.

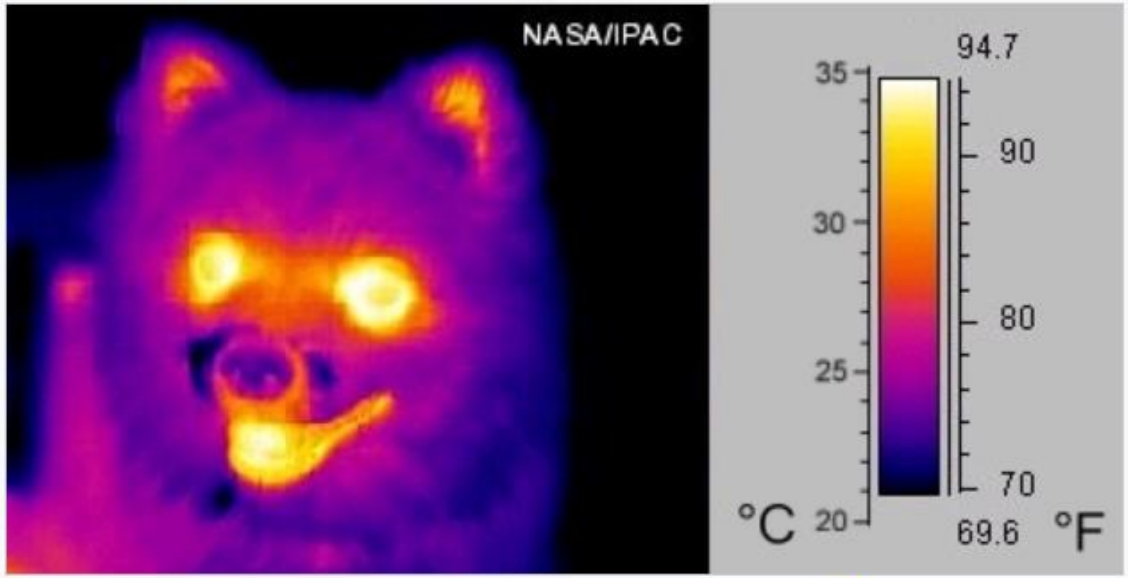


Figure 4. A dog as seen in the infrared spectrum.[8]

Radiation and Power

The rate of heat transfer by emitted radiation (Radiation Power) is directly proportional to the Temperature to the fourth!

$$P \propto T^4$$

The proportionality to the **fourth power** of the absolute temperature is a remarkably strong temperature dependence. It allows the detection of even small temperature variations.

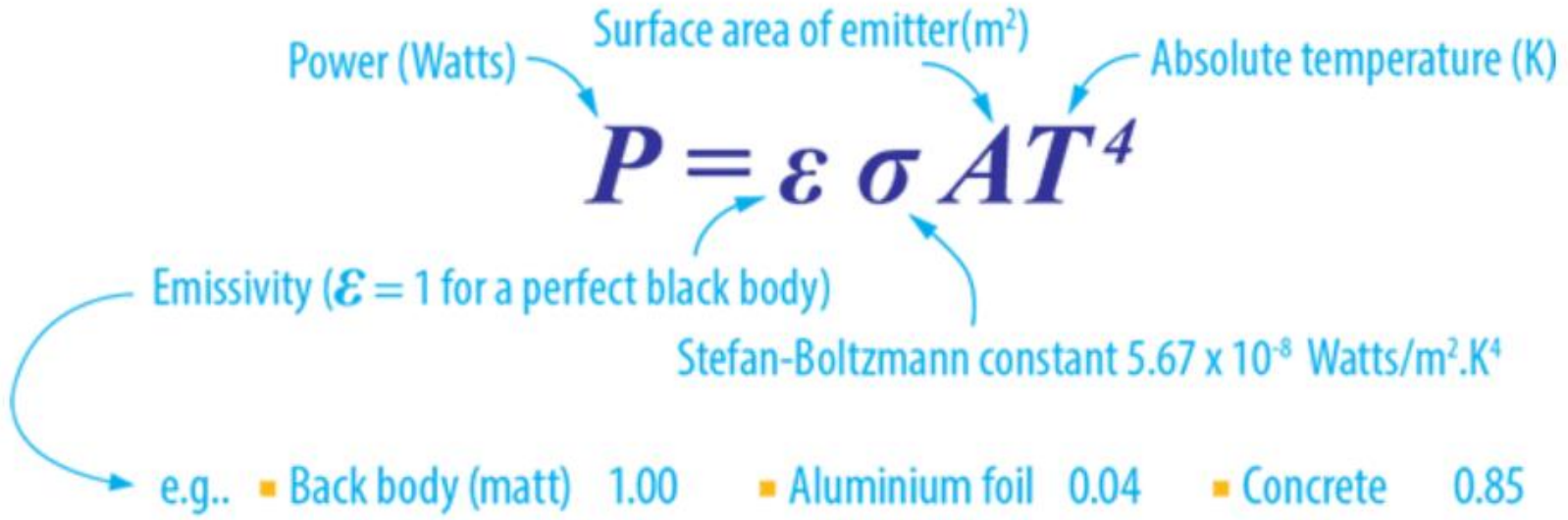
Radiation and Power

The rate of heat transfer by emitted radiation is described by the **Stefan-Boltzmann law of radiation**

$$P = \sigma A e T^4,$$

where $\sigma = 5.67 \times 10^{-8}\, J/s \cdot m^2 \cdot K^4$

is the Stefan-Boltzmann constant, a combination of fundamental constants of nature; **A** is the surface area of the object; e is emissivity; and **T** is its temperature in Kelvins.



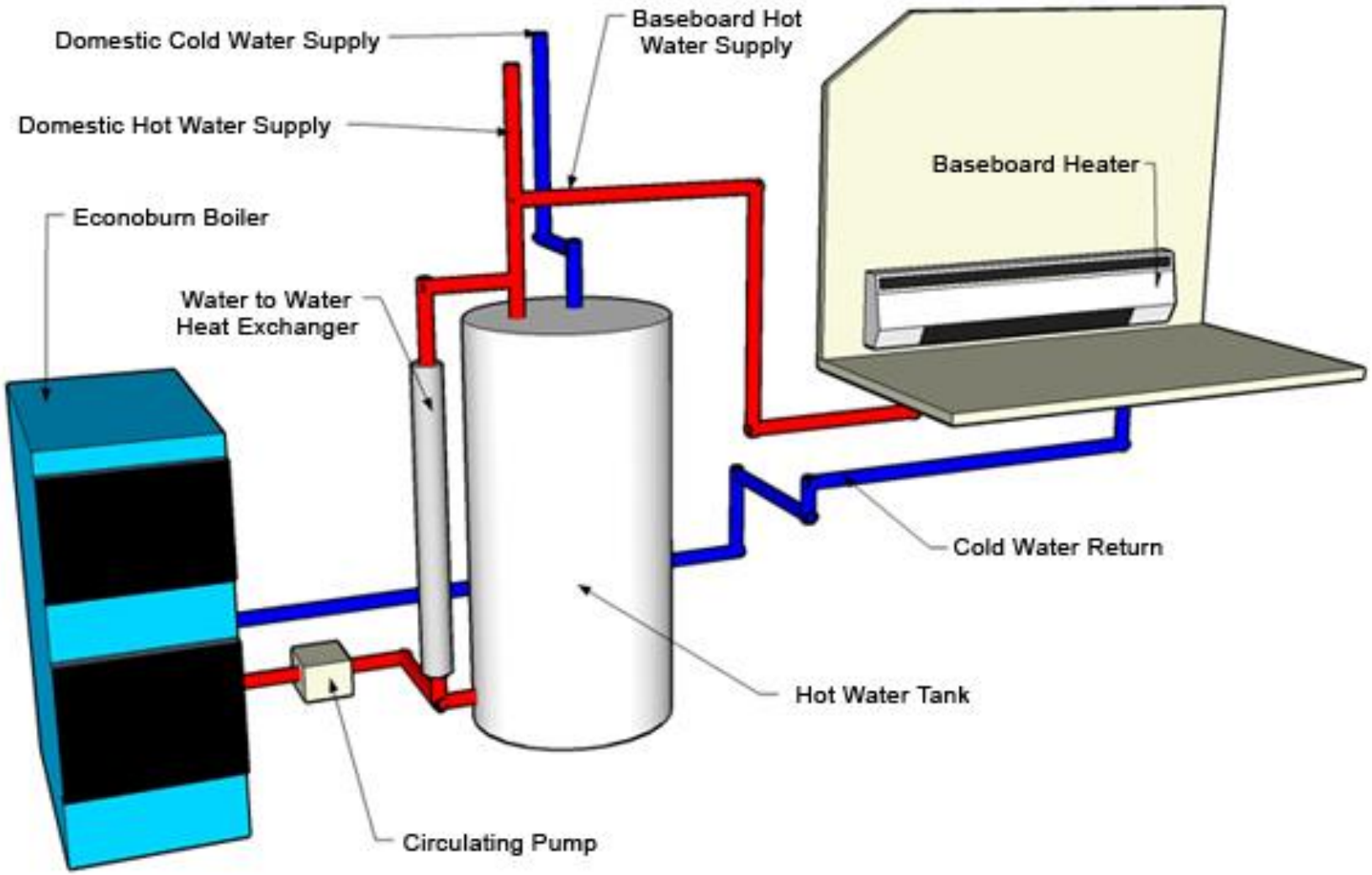
https://www.ceramicx.com/information/support/why-infrared-laws-of-infrared-heating/

Chapter 4 Lectures

- **Our model of heat and temperature**
- **Types of heat transfer**
- **Heating our homes, HVAC, fenestration and building envelopes**

Next week:

- Solar and geothermal heating
- Heat pumps


Domestic Cold Water Supply
Baseboard Hot Water Supply
Domestic Hot Water Supply
Baseboard Heater
Econoburn Boiler
Water to Water Heat Exchanger
Cold Water Return
Hot Water Tank
Circulating Pump

PHYS 371 Introduction to Energy

LECTURE 17: THERMAL ENERGY – **MOVING HEAT**

WEDNESDAY, OCTOBER 20, 2021

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Chapter 4

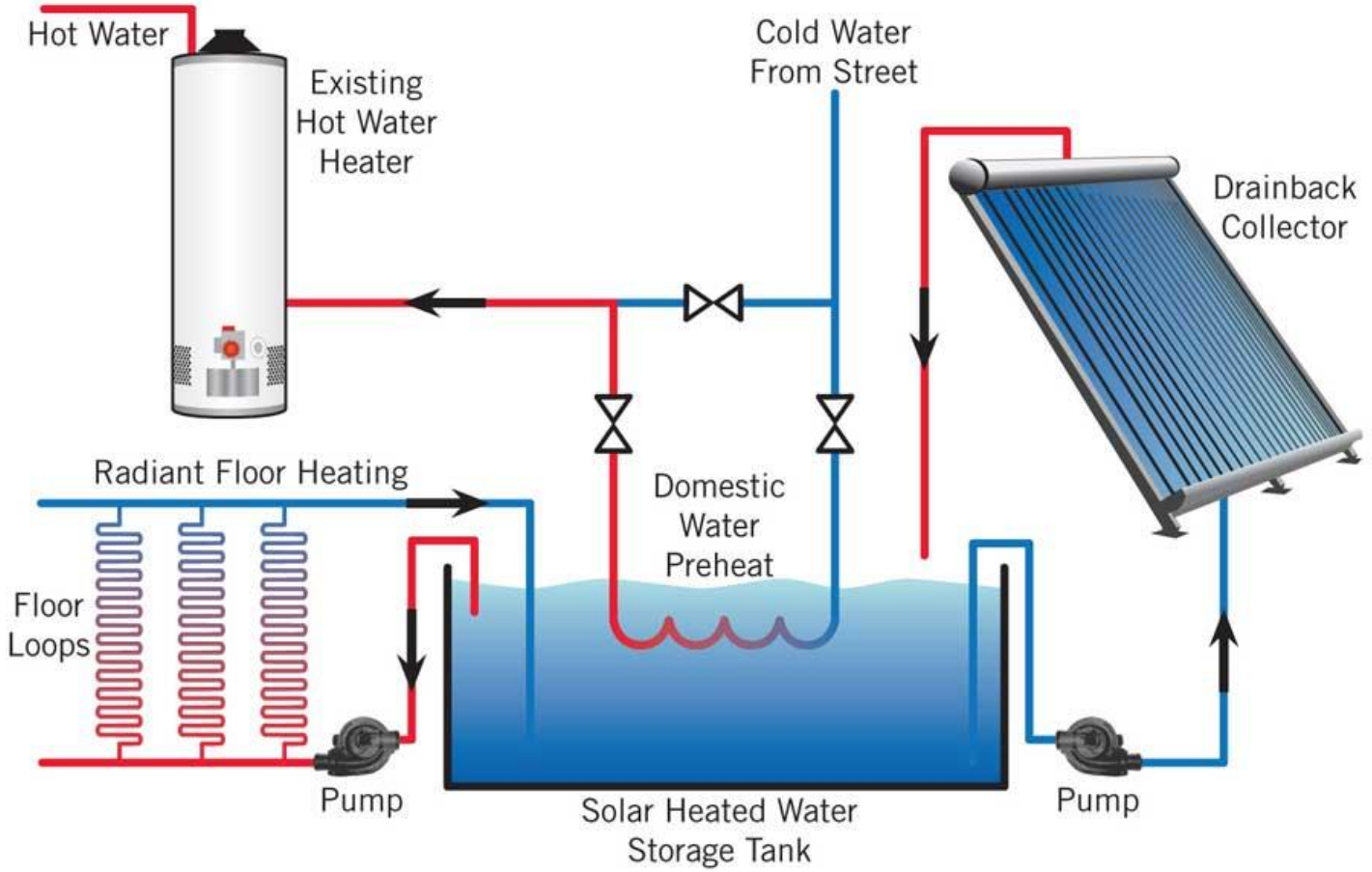
- **Our model of heat and temperature**
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Next week:

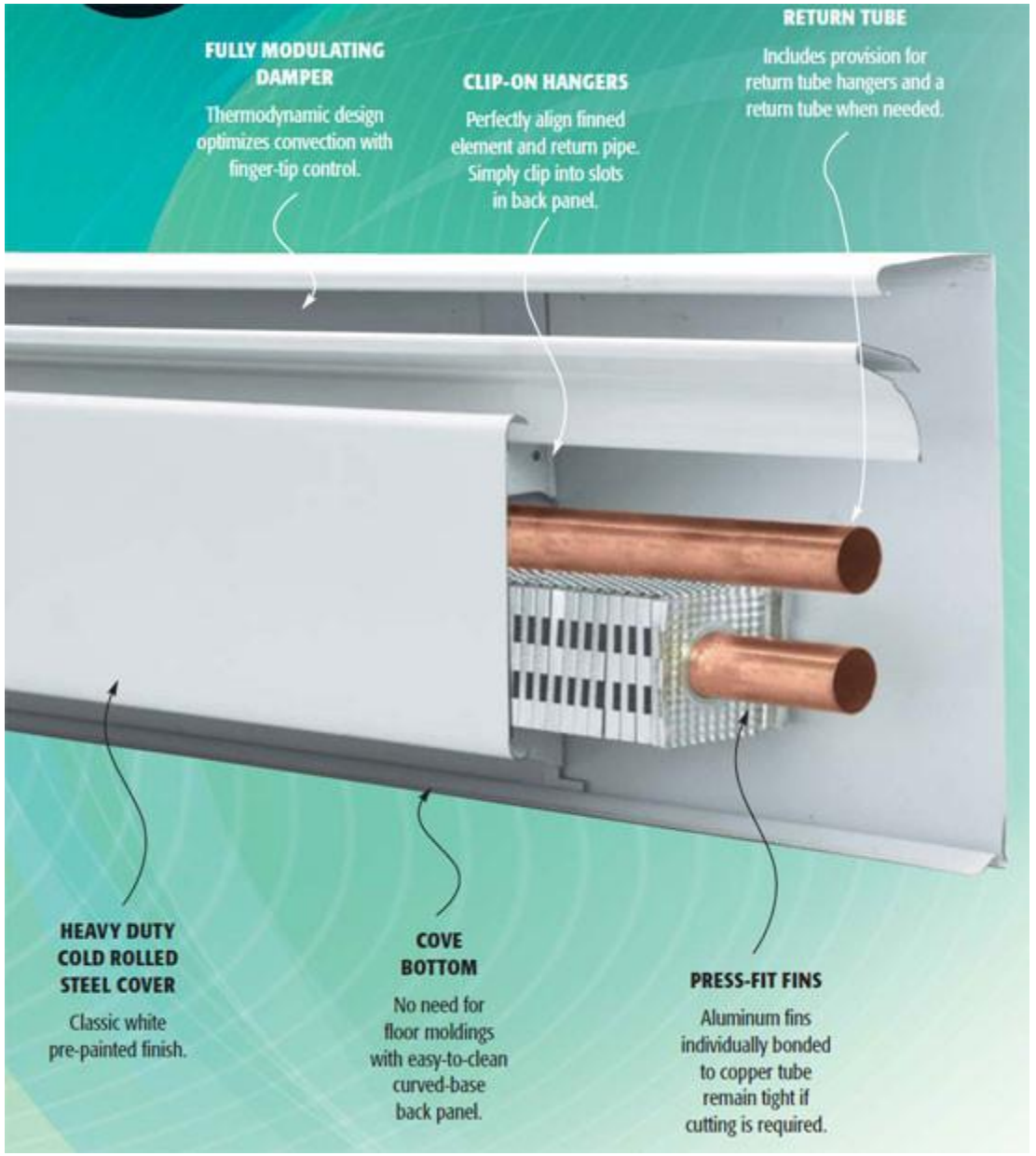
- Solar and geothermal heating
- Heat pumps

https://energyeducation.ca/encyclopedia/Energy_Education:Chapter_4

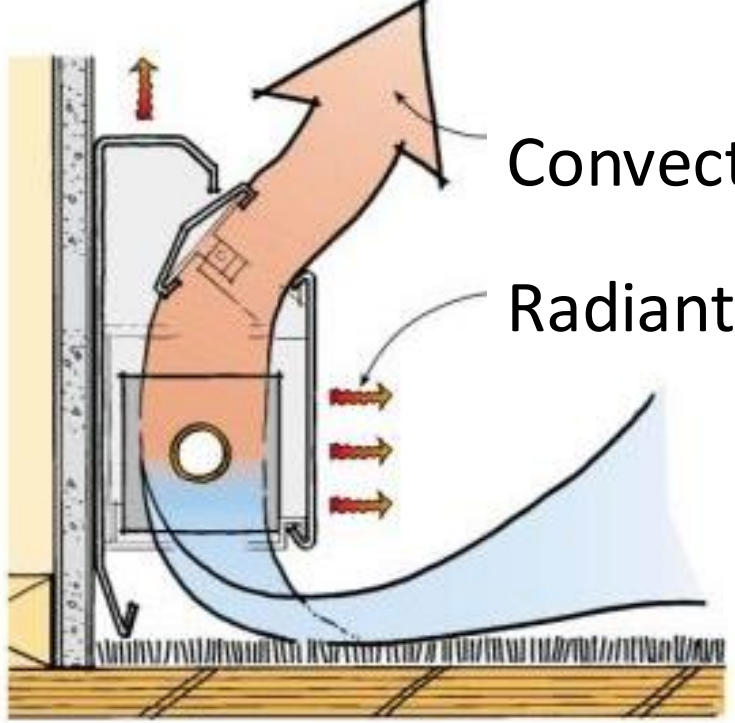
Add solar!


Hot Water
Existing
Hot Water
Heater
Cold Water
From Street
Drainback
Collector
Radiant Floor Heating
Domestic
Water
Preheat
Floor
Loops
Pump
Solar Heated Water
Storage Tank
Pump

Hydronic baseboard heaters

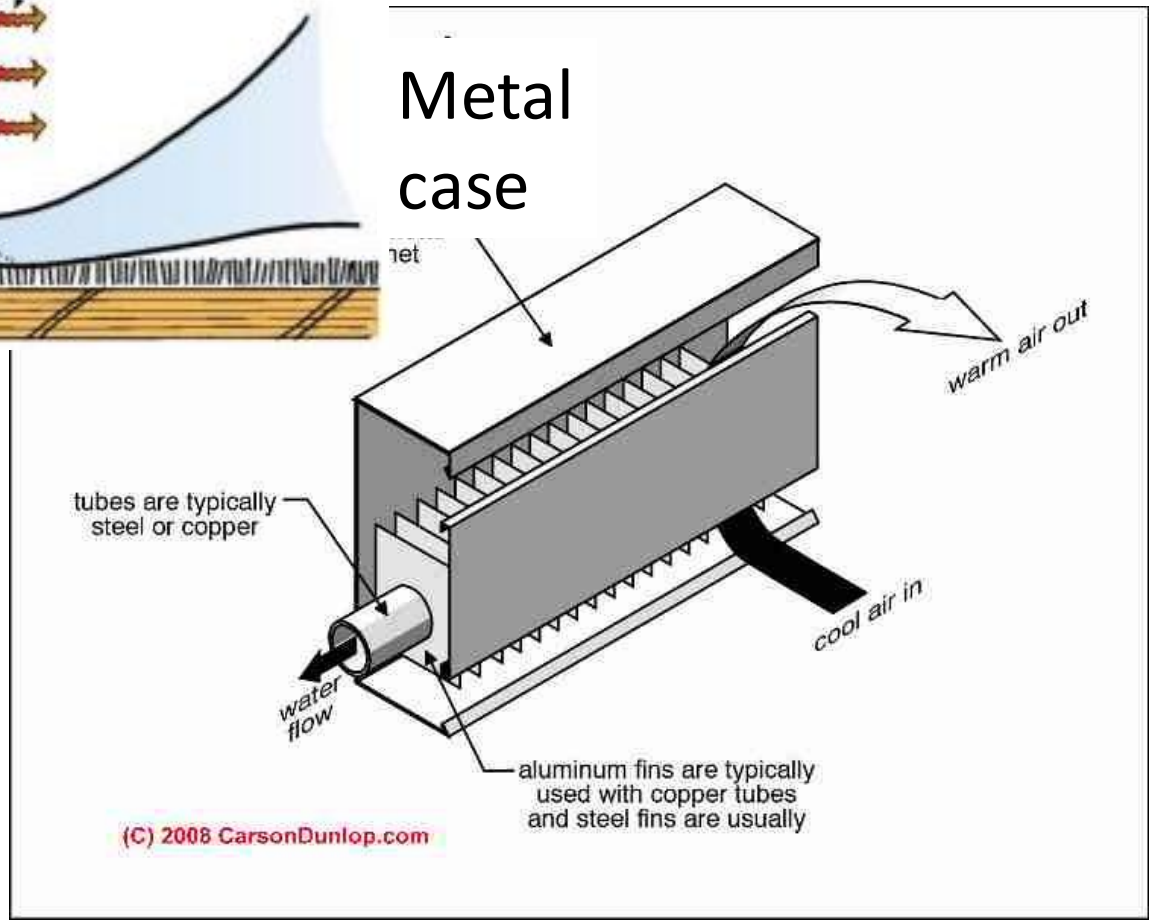


Baseboard heater



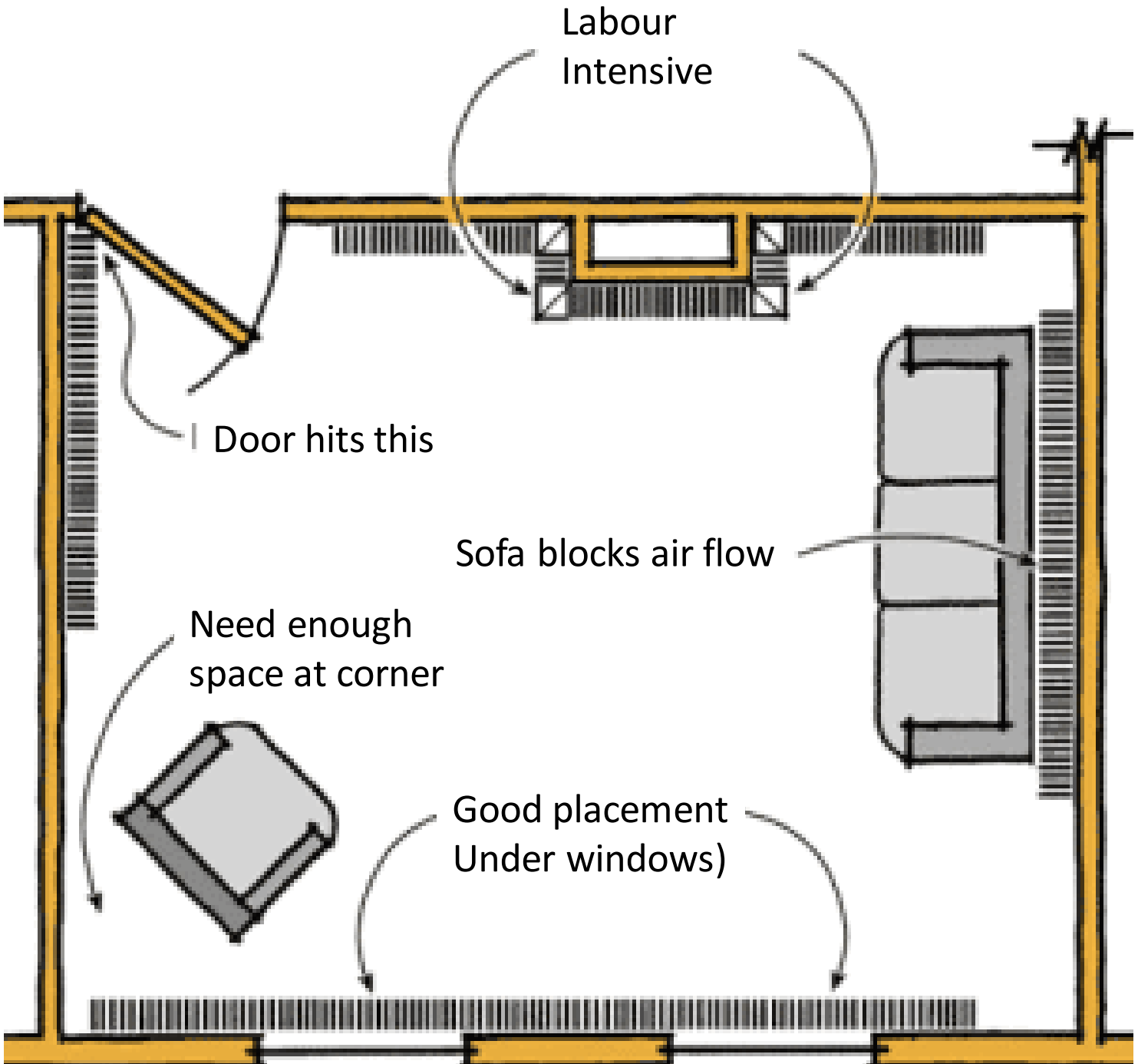
Convective heat

Radiant heat

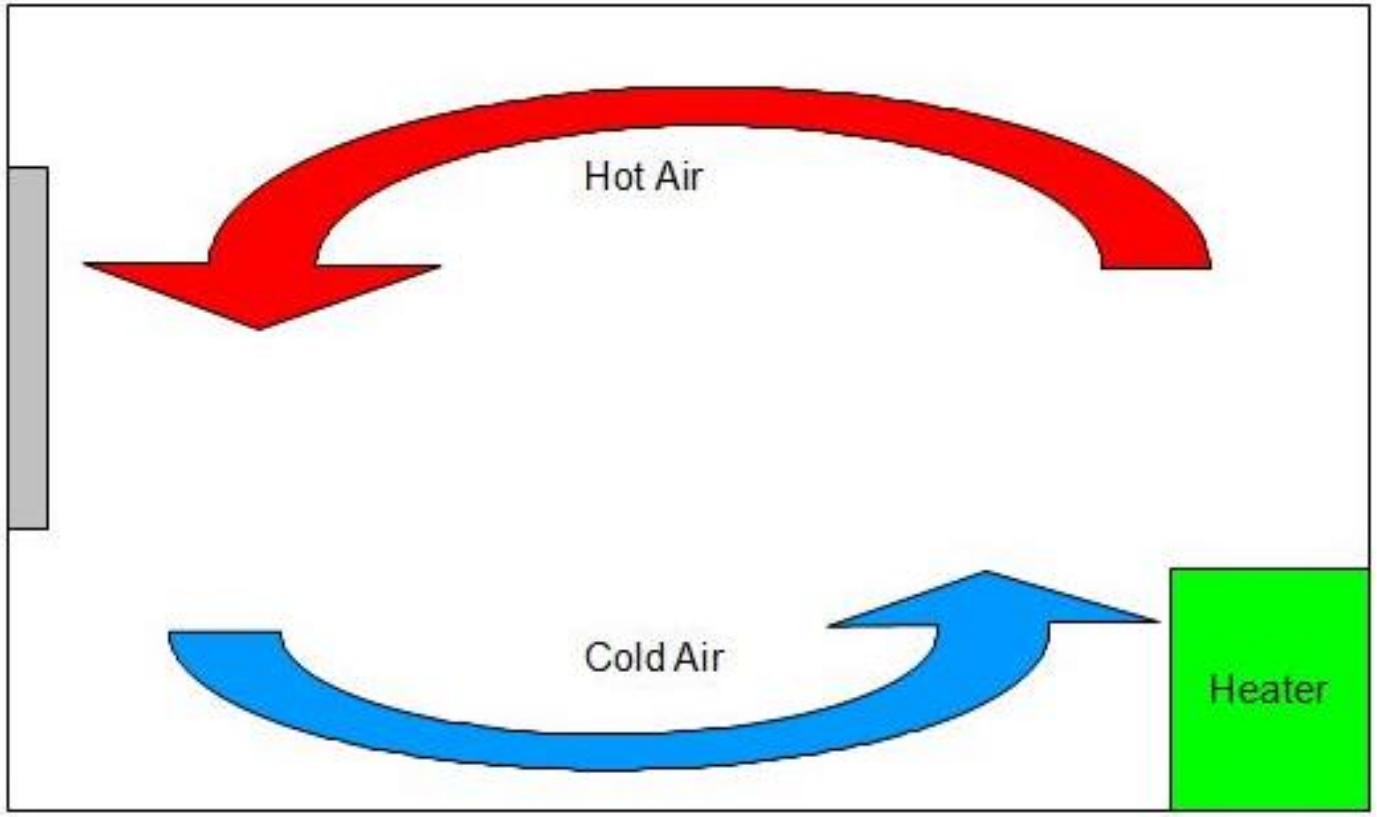


Electric Baseboard heaters



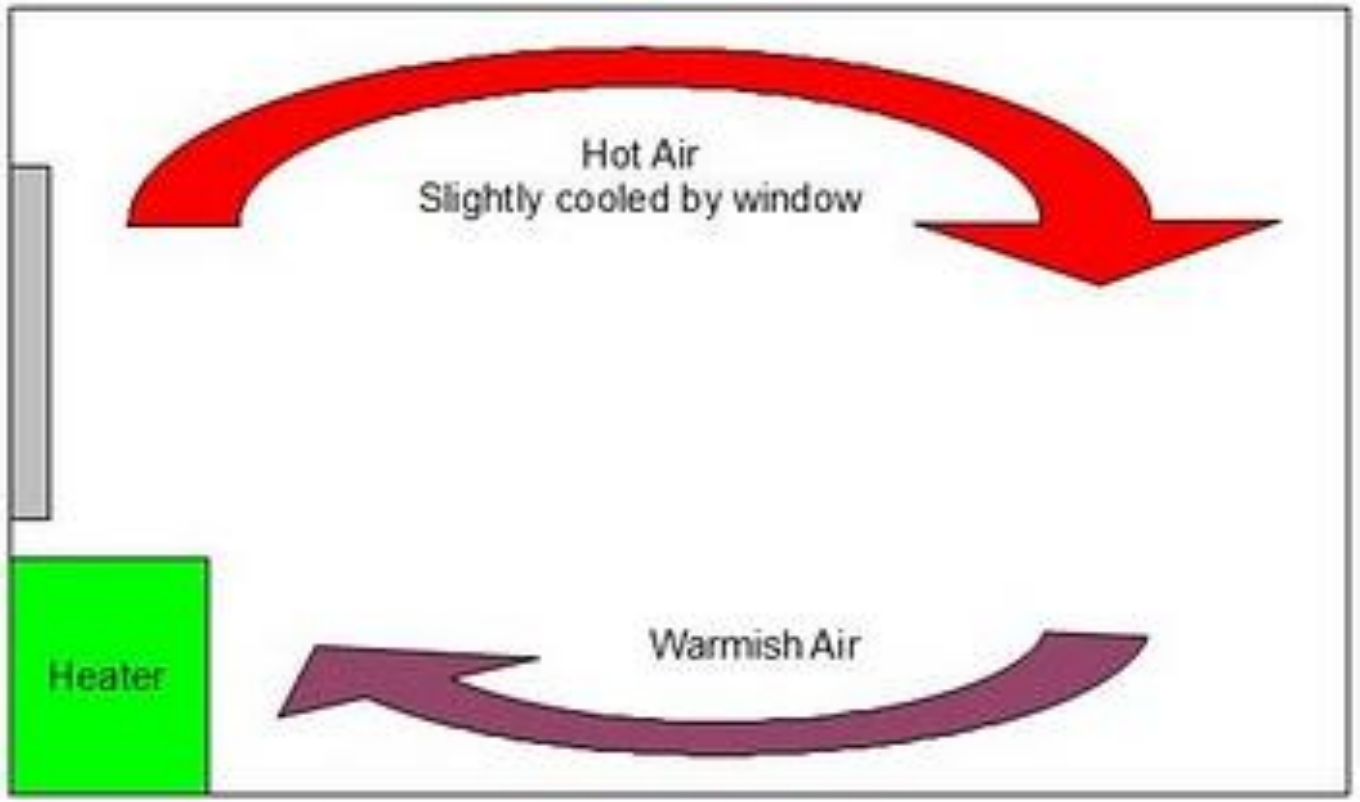

Labour
Intensive
Door hits this
Sofa blocks air flow
Need enough
space at corner
Good placement
Under windows)

Heater far away, doesn't help



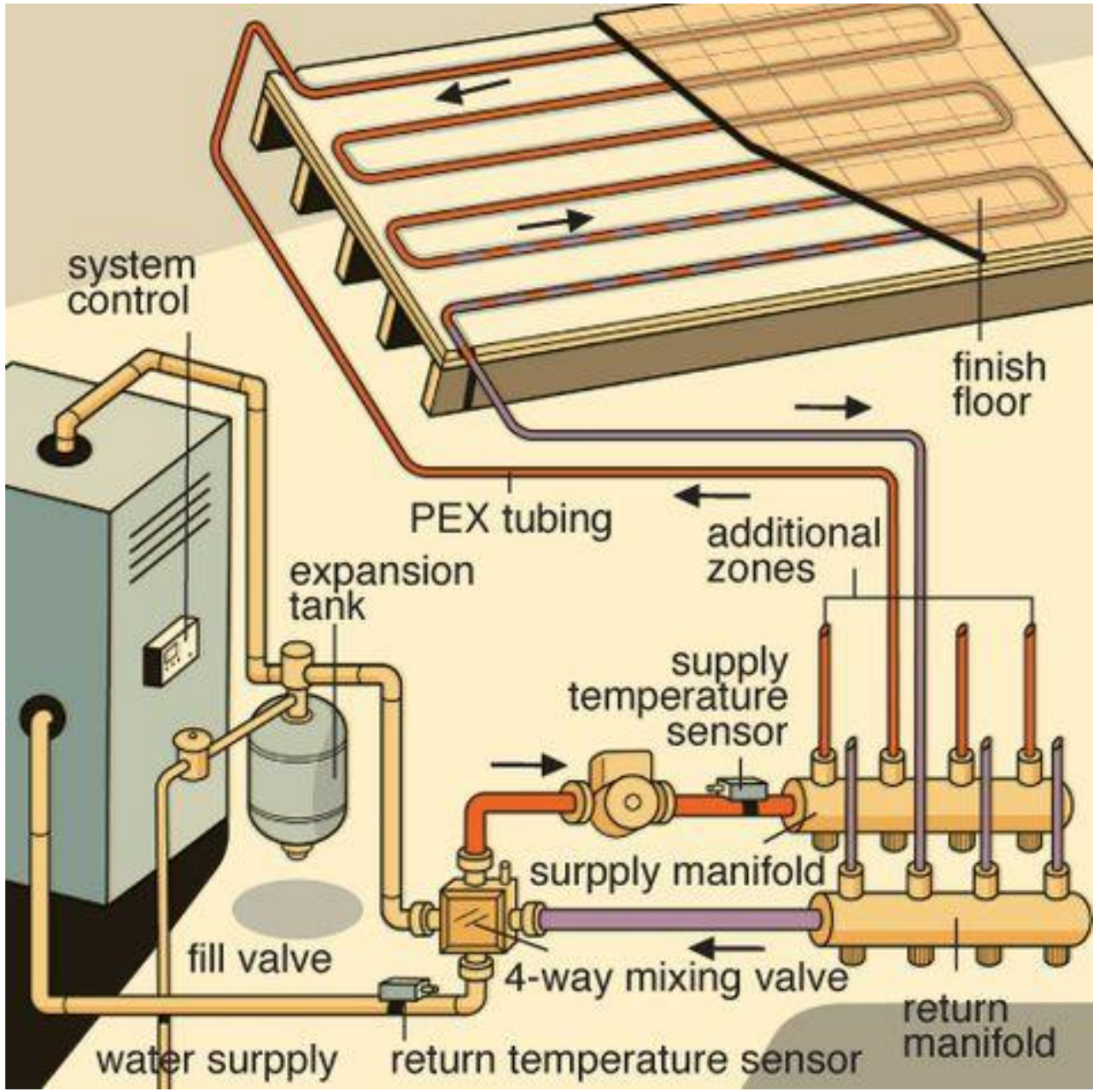
http://latentvalue.blogspot.ca/2010/11/how-heater-manufacturers-can-improve.html

Right kind of circulation



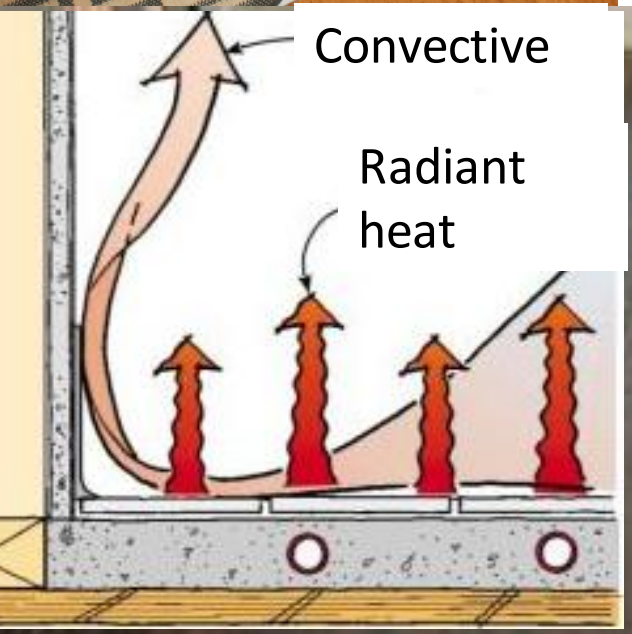
http://latentvalue.blogspot.ca/2010/11/how-heater-manufacturers-can-improve.html

Hydronic radiant heating





Electric radiant heating



Electric coil

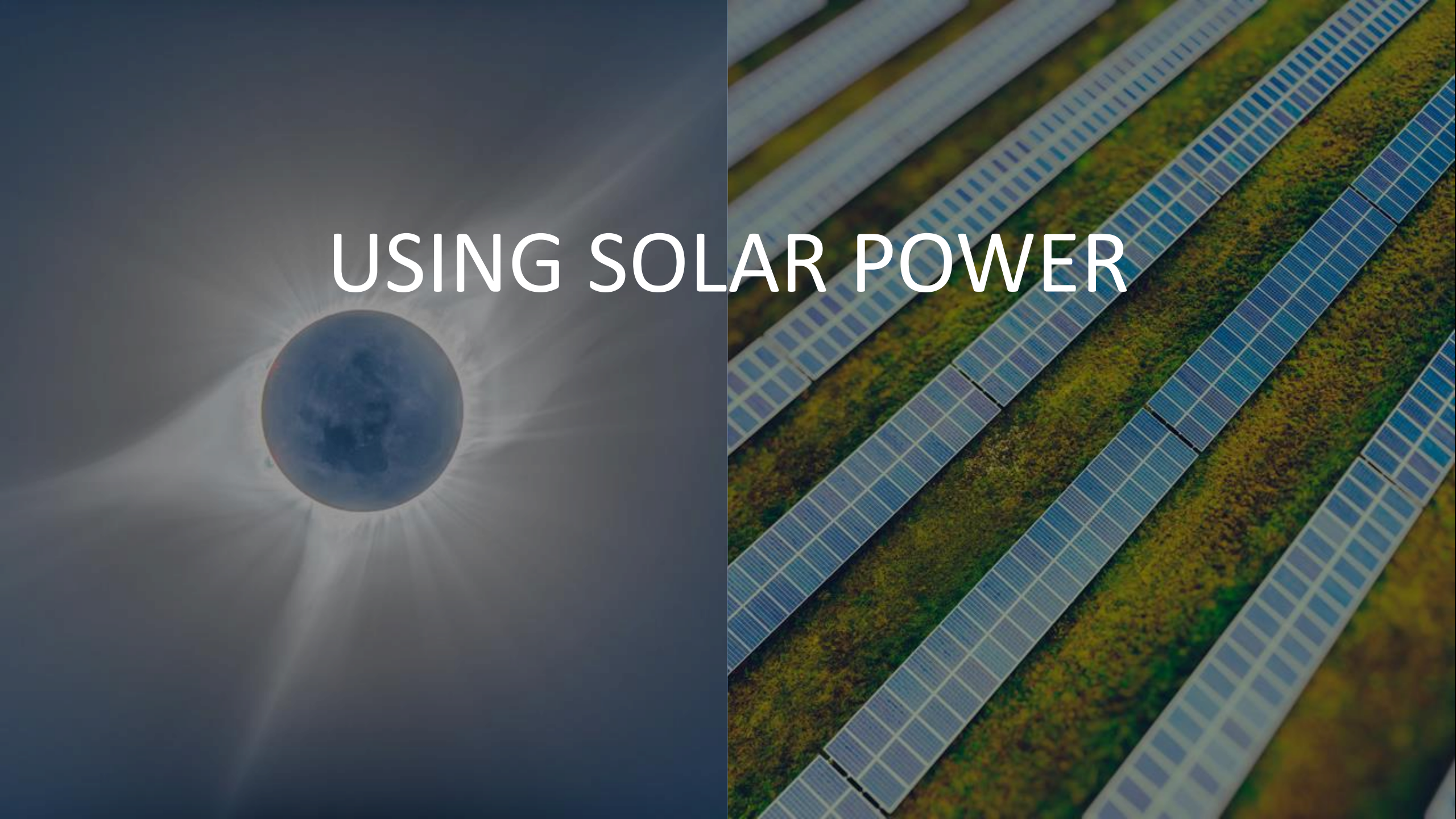
Aluminum panels

A note on thermostats

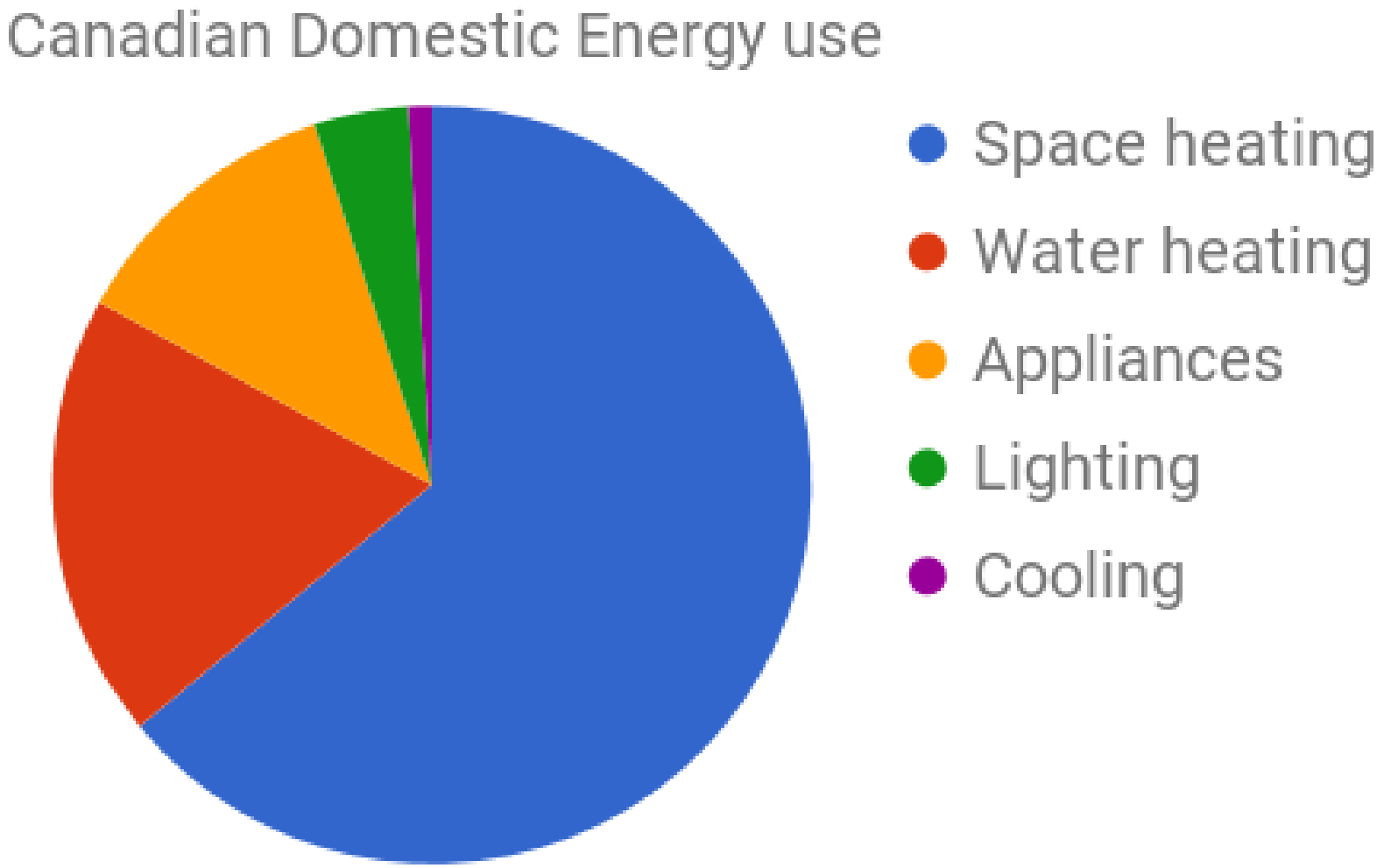
- Far from fenestration, heater vents & radiators
- Measure <u>average</u> temperature of house.
- Programmable can save money

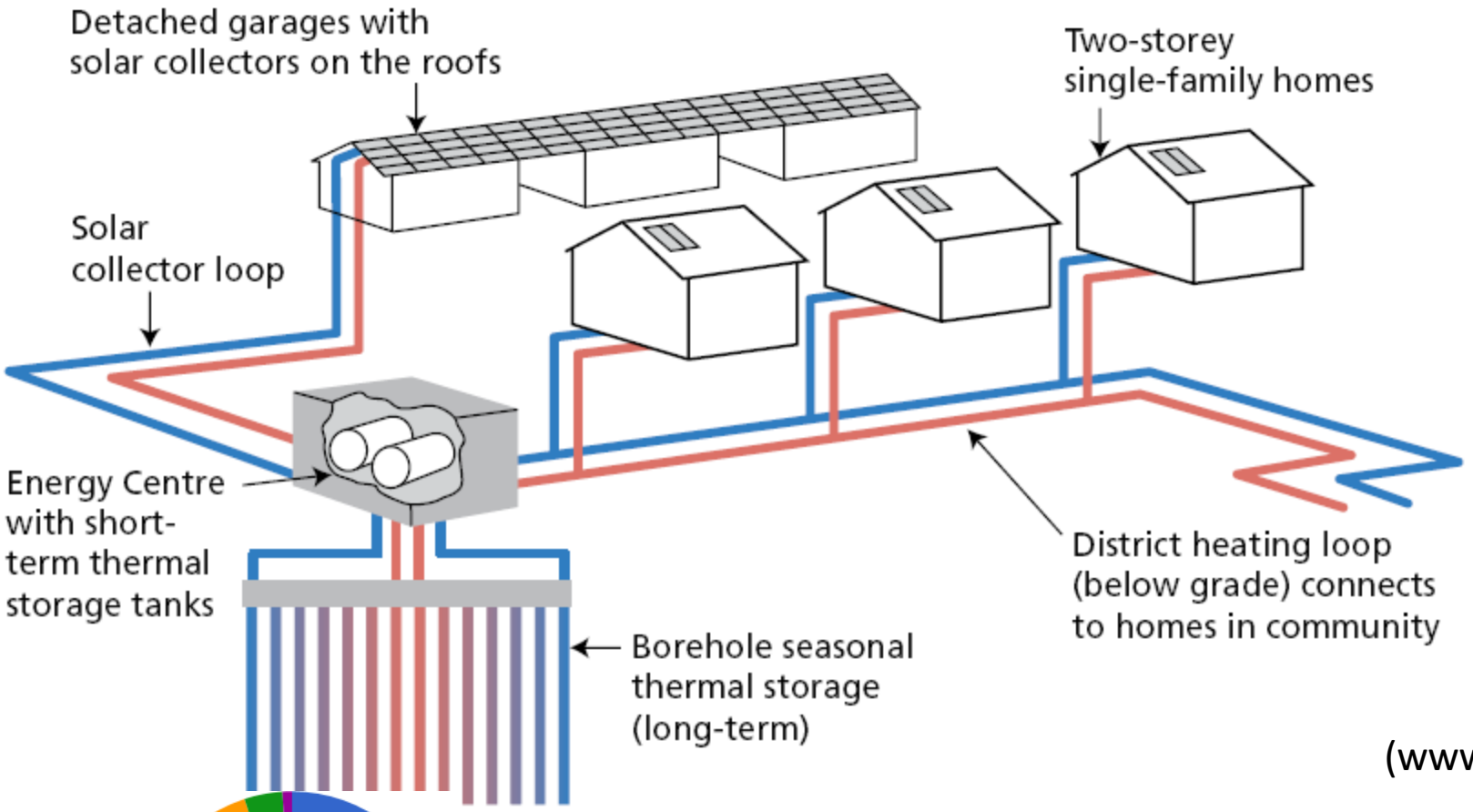


USING SOLAR POWER

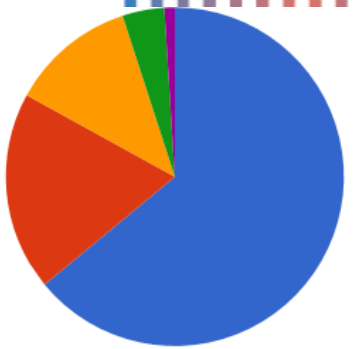


What energy service should we prioritize making solar powered?





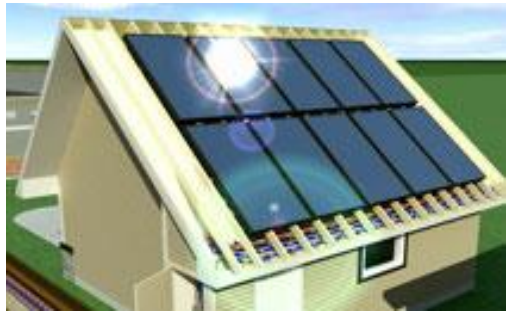
(www.dlsc.ca/DLSC_Brochure_e.pdf)



Space heating

Drake Landing, Okotoks, AB

Turn sunlight to heat



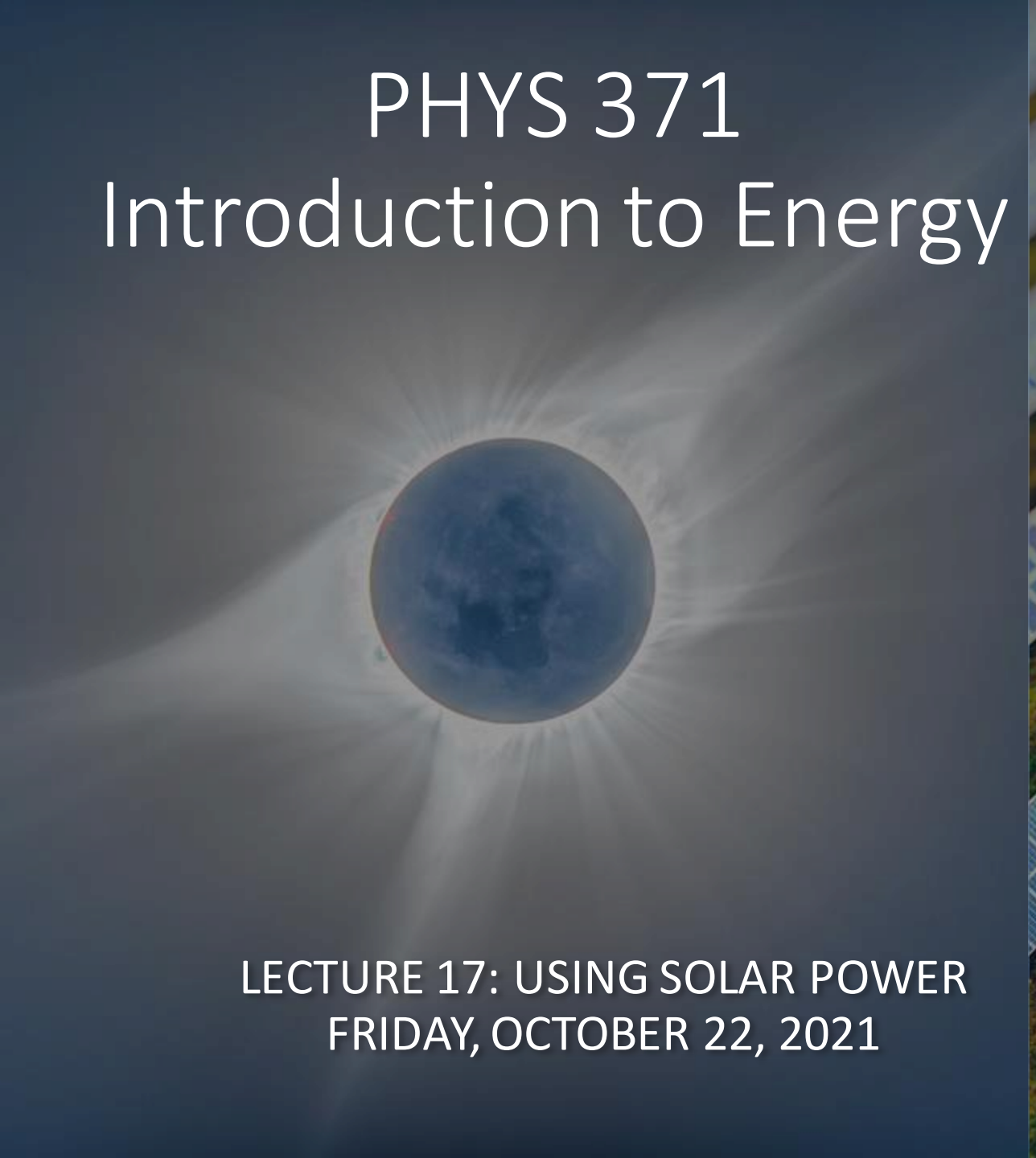
Solar glass
(lets lots of light through)

Back Insulation

Sheet absorbs sunlight
Copper tubing carries propylene glycol antifreeze to transfer heat

Metal frame

PHYS 371
Introduction to Energy





LECTURE 17: USING SOLAR POWER
FRIDAY, OCTOBER 22, 2021

Territorial acknowledgement



Important considerations

Diversity
Inclusive environment
Safety: Physical and Mental Health



	A+	A
Minimum % Required	95 %	90 %
Class Participation (Attendance/Tophat/Discussions)		
Reflective Writing (ePortfolio)		
Assignments (8 assignments, weekly)		
Midterm 1		
Midterm 2		
Final Examination		

A note about Grace and Courtesy in this course

"*When doing the task on finding the rate of heat transfer through the steel slab, I get an answer that fits none of the answer alternatives. This happens when I change the temperature into Kelvin, which should produce the correct solution, however, if I solve for the temperature in celsius I get an answer that fits with one of the alternatives. Are you guys sure you didn't mess up when making this task? When looking at the units alone, it's clear that we should be working with Kelvin and not Celsius.*" Student in Trouble

We are NOT *'guys'*
You shall call me Dr. Mazzino
You shall call TAs by their names, Finley, Andre, Travis
Call ***US*** 'Educational team"

We do not 'mess up' when making a task.
This statement is highly disrespectful

Another issue
Chat in Zoom

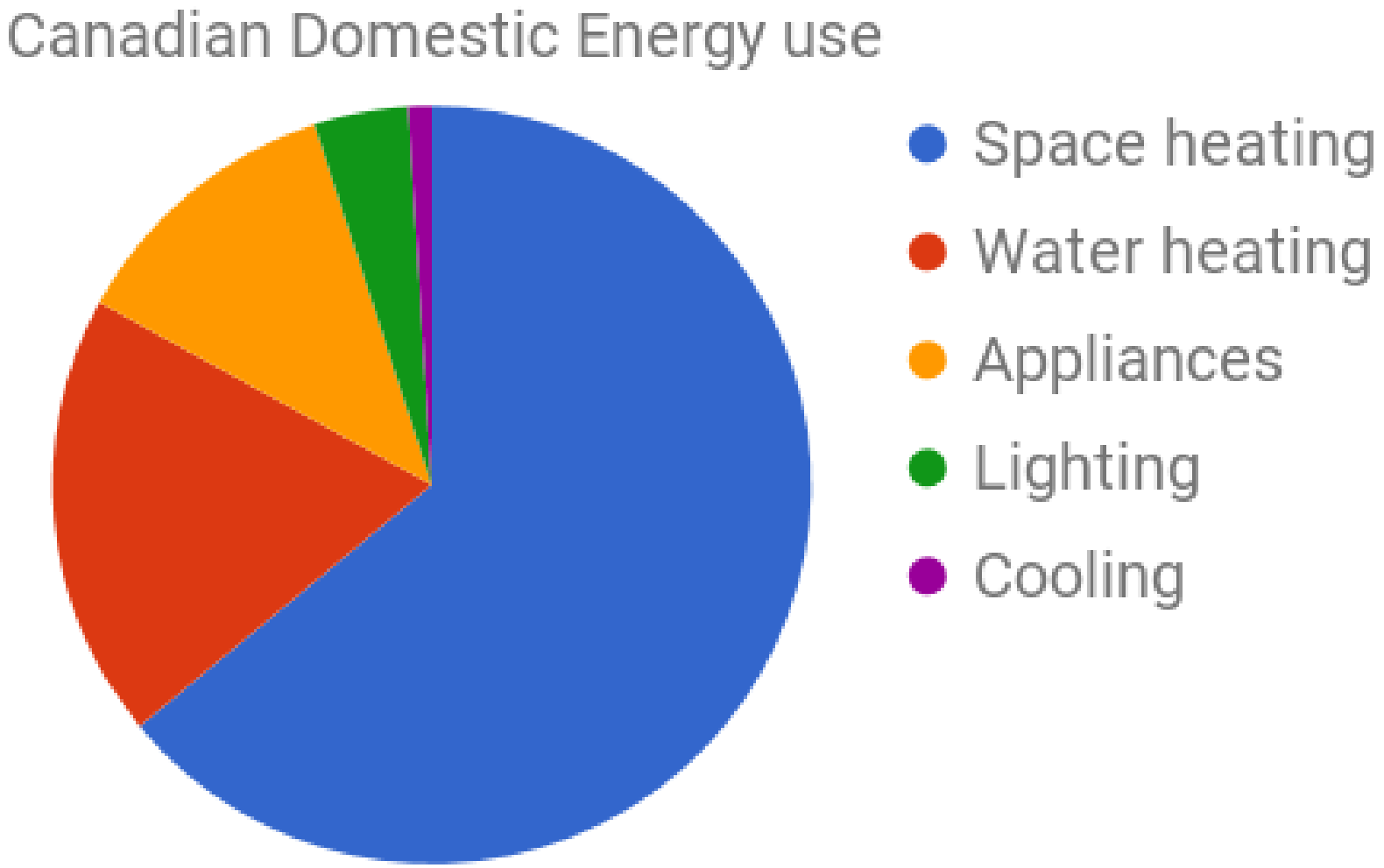
Chat in zoom is ONLY to

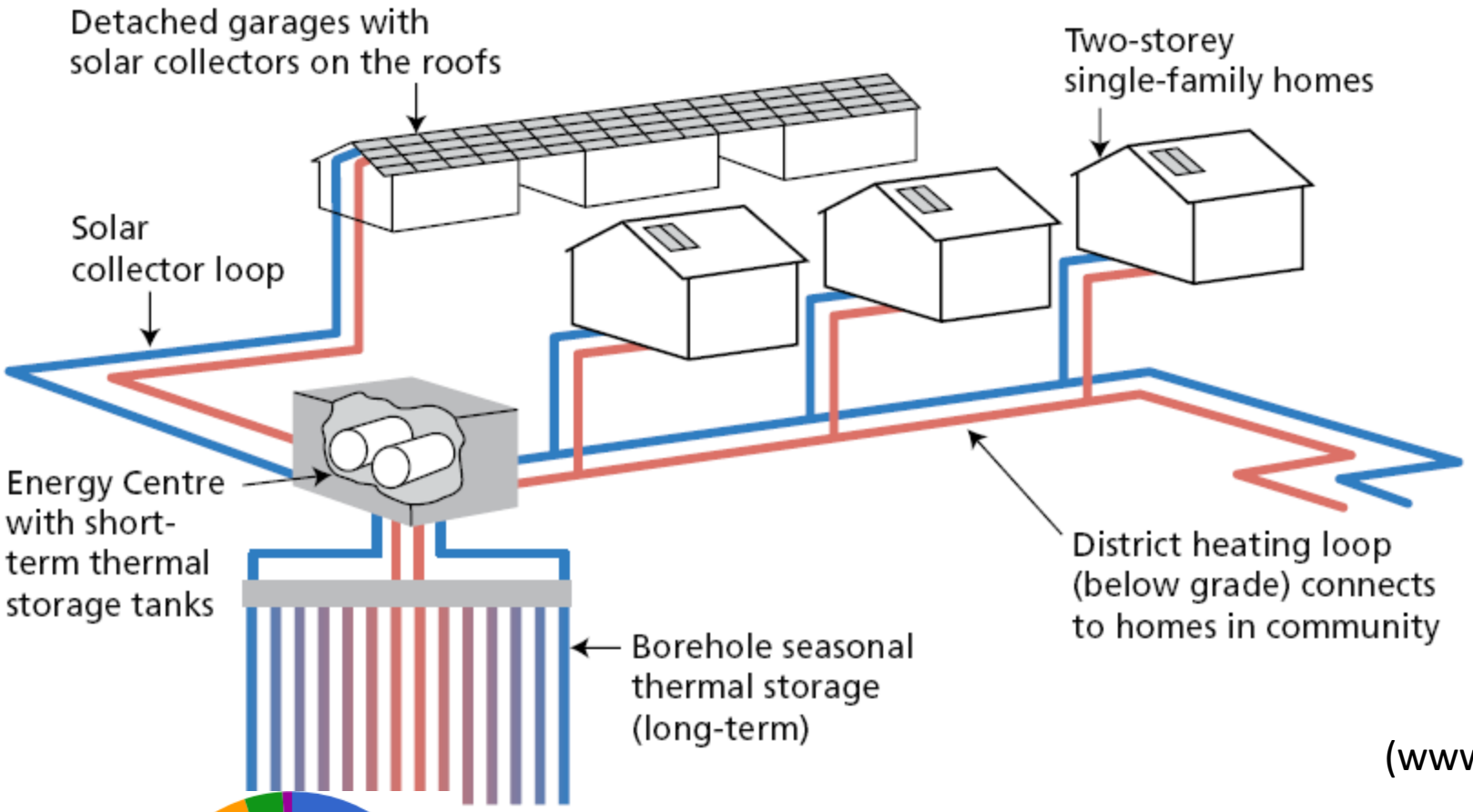
- Ask questions during lecture
- Participate to give an oral answer
- Ask to clarify a concept
- Ask to clarify an assignment, due date, format, content
- Ask about logistics about the course

Jokes that are offensive to the diversity of the class (racial comments, comments about LGTBQ, comments about color of skin, comments against diversity, comments against cultural diversity) WILL NOT BE TOLERATED. THE UNIVERSITY OF CALGARY is an INCLUSIVE COMMUNITY WHERE EVERYONE SHALL FEEL SAFE AND WELCOMED.

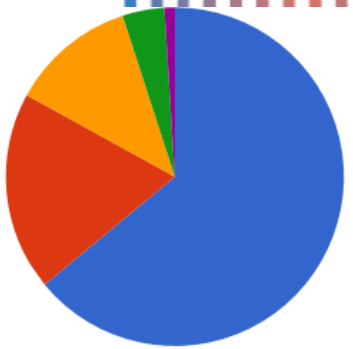
I AM VERY PASSIONATE ABOUT EQUITY, INCLUSION AND DIVERSITY. I AM PASSIONATE ABOUT STUDENT'S HEALTH (BOTH MENTAL AND PHYSICAL)

What energy service should we prioritize making solar powered?





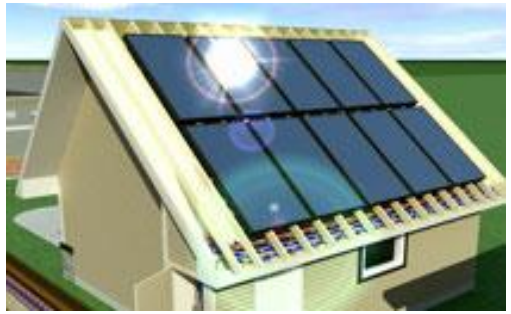
(www.dlsc.ca/DLSC_Brochure_e.pdf)



Space heating

Drake Landing, Okotoks, AB

Turn sunlight to heat



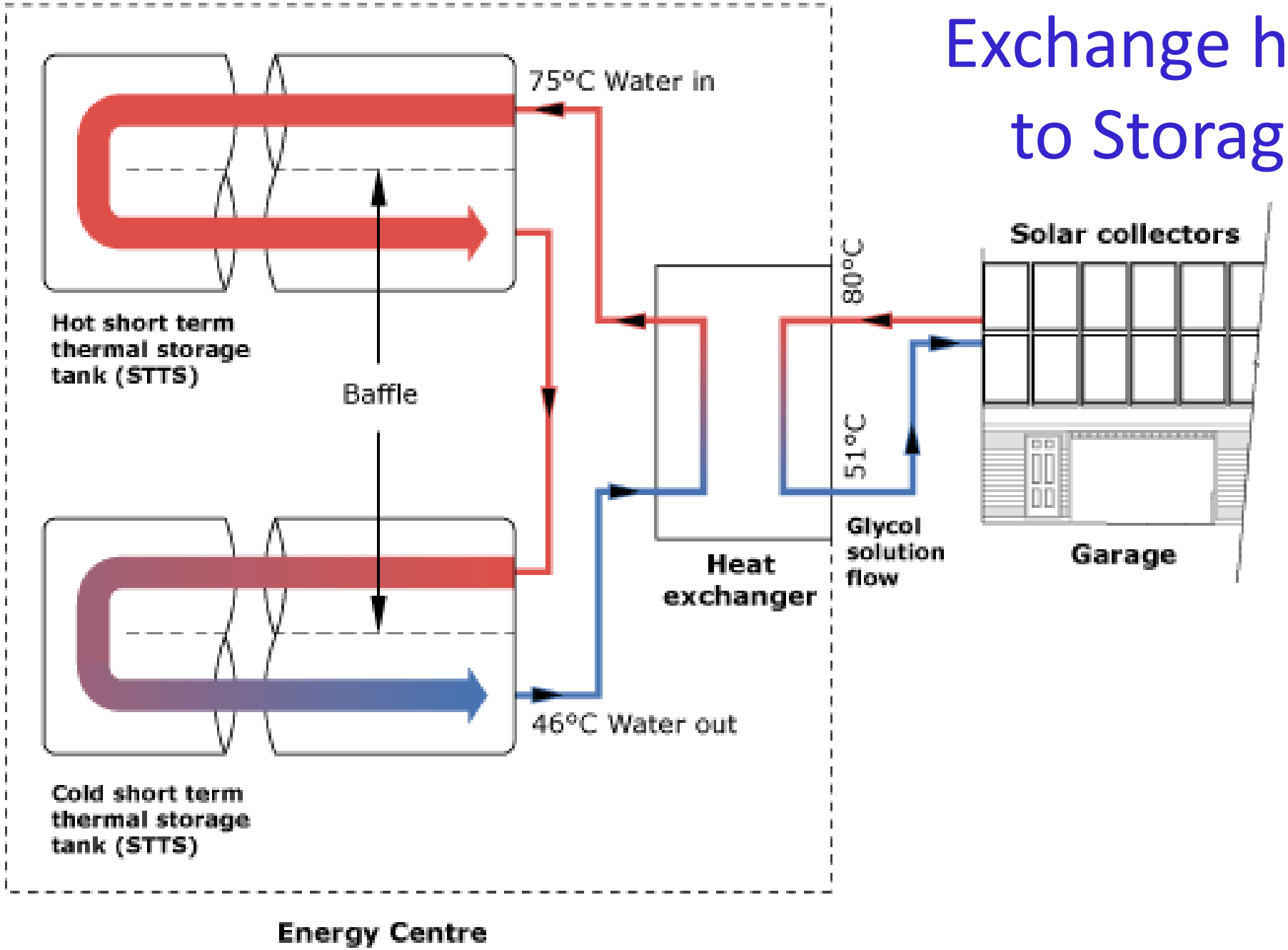
Solar glass
(lets lots of light through)

Back Insulation

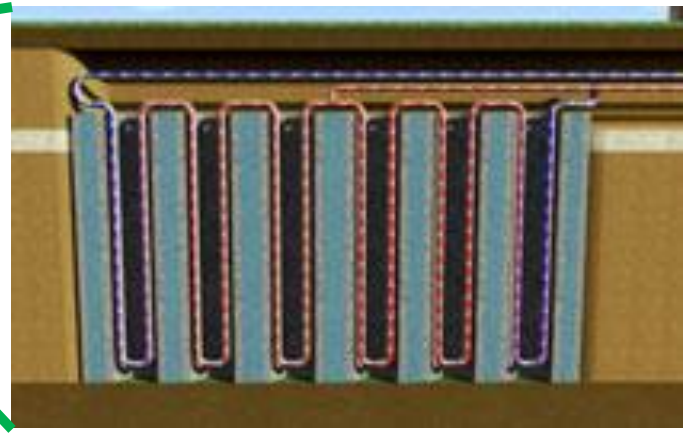
Sheet absorbs sunlight
Copper tubing carries propylene glycol antifreeze to transfer heat

Metal frame

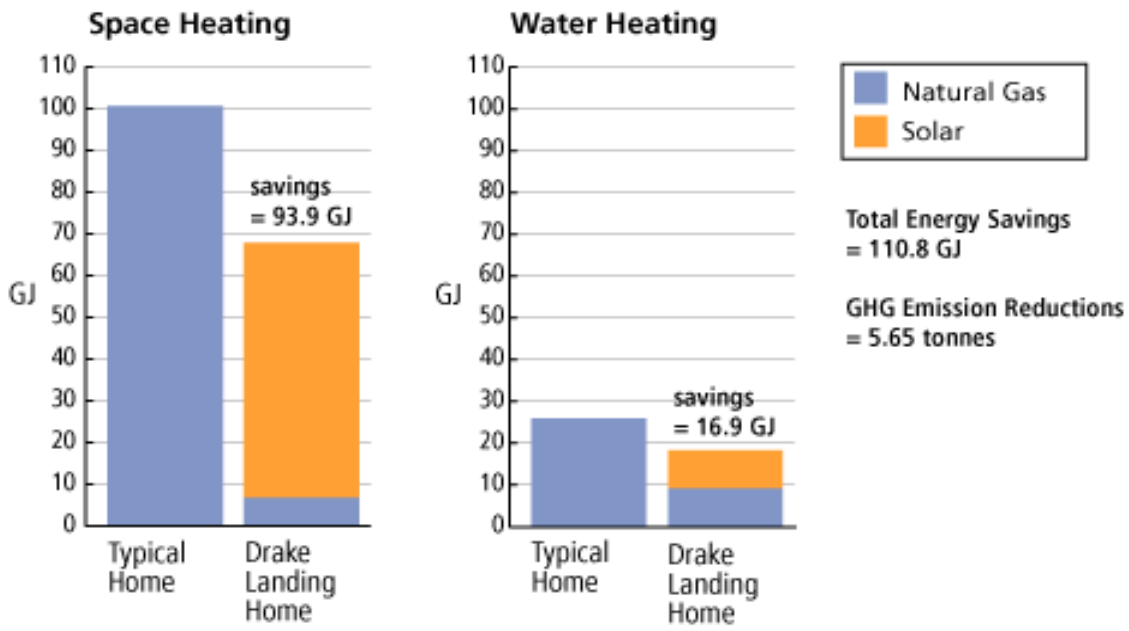
Exchange heat to Storage

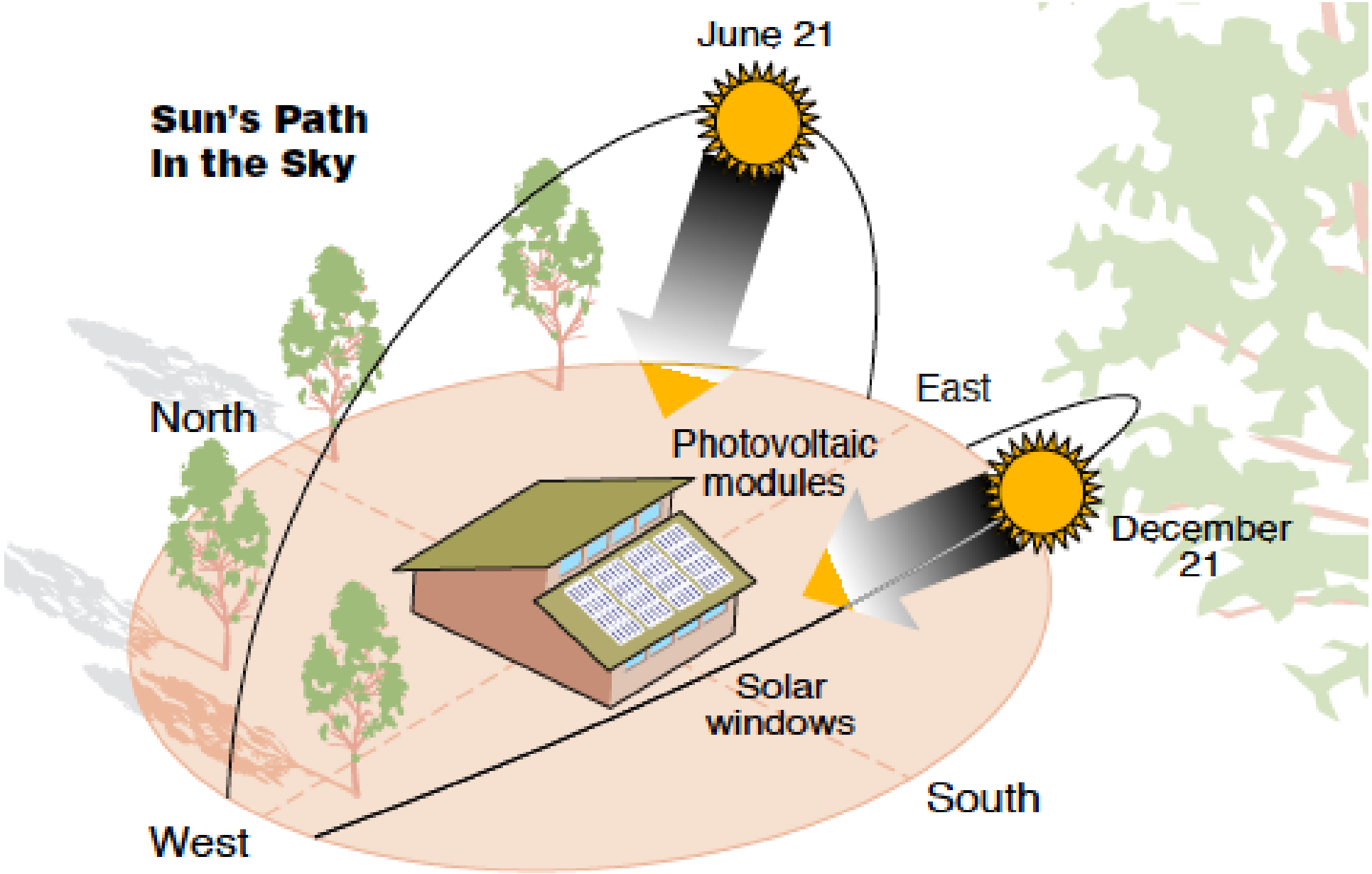




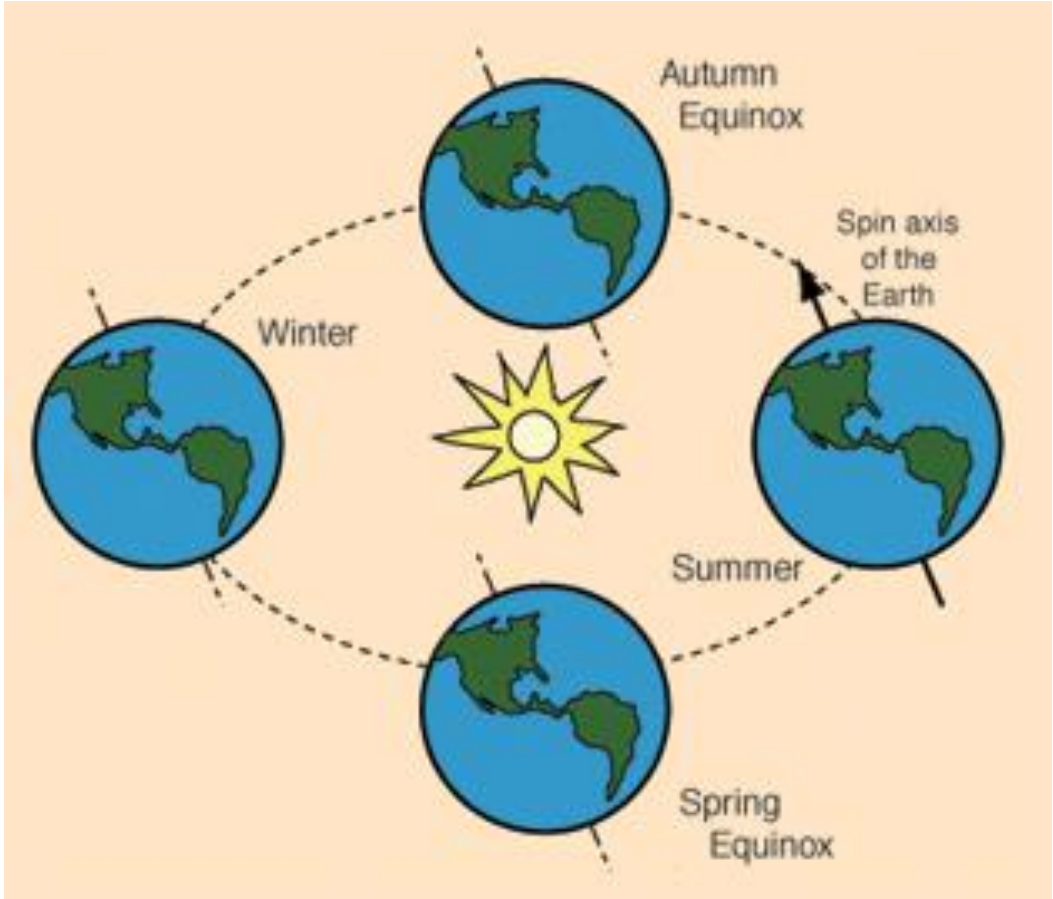


52 houses
Reducing Nat gas
–94% heating
–60% hot water




Sun's Path
In the Sky
June 21
East
North
Photovoltaic
modules
December
21
Solar
windows
South
West

Axial tilt is the reason for the seasons!

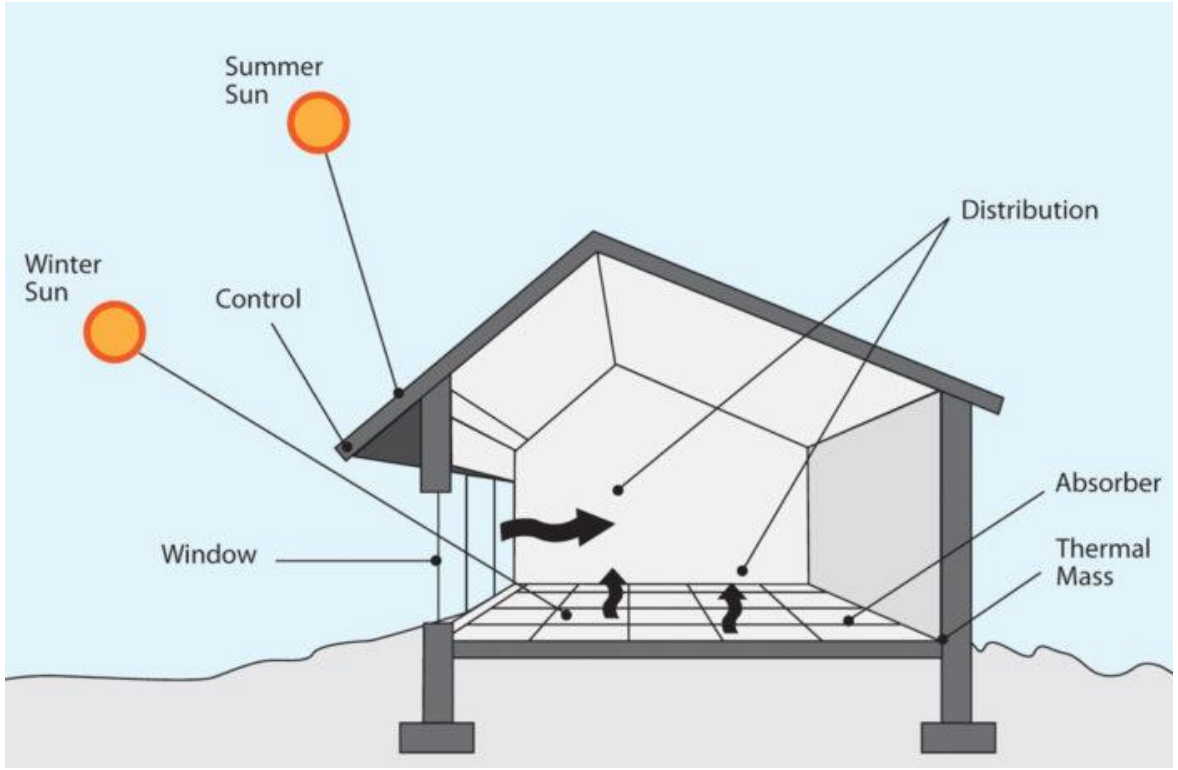


Shape of roof passive solar

Overhangs on buildings controls sun:

- Blocks summer sun
- Passes winter sun

Can be fixed, solid or moveable





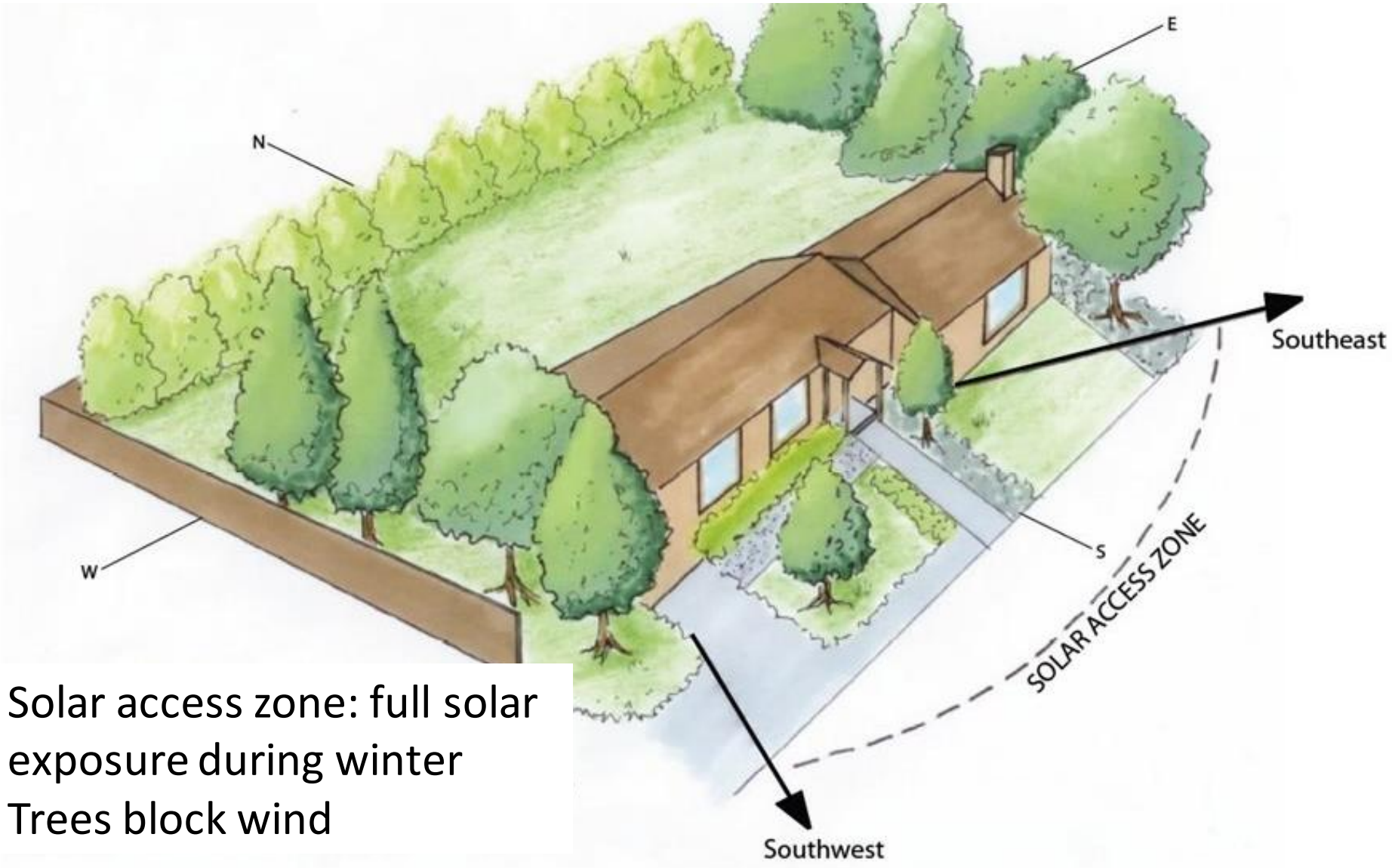






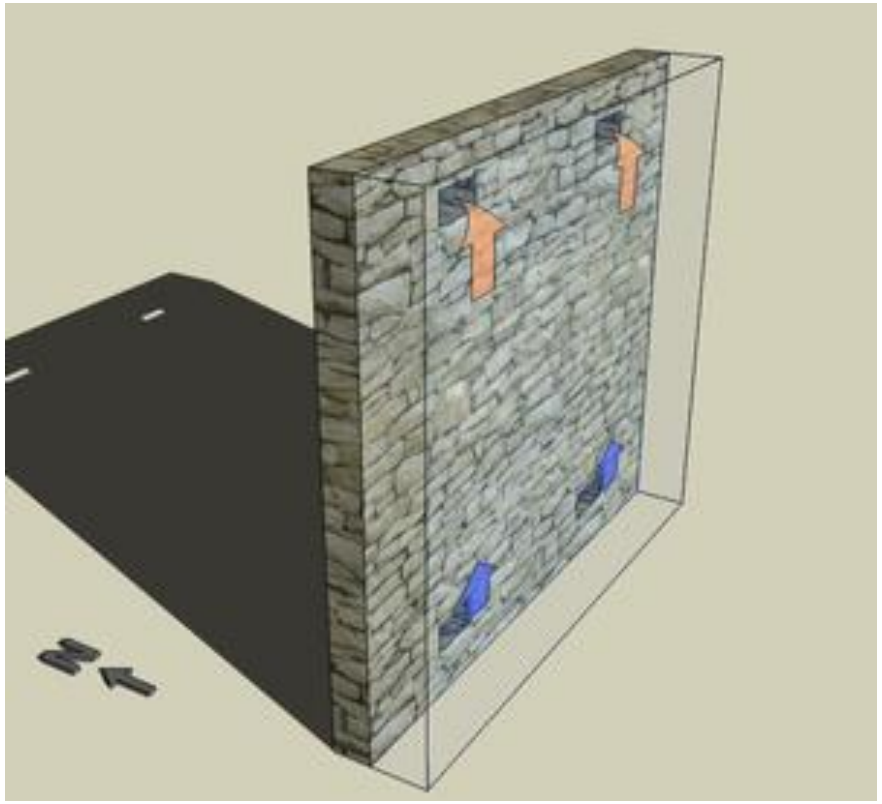
Deciduous trees:
Block sun in summer
Let light through in winter

Want windows on south side of house



Solar access zone: full solar exposure during winter
Trees block wind

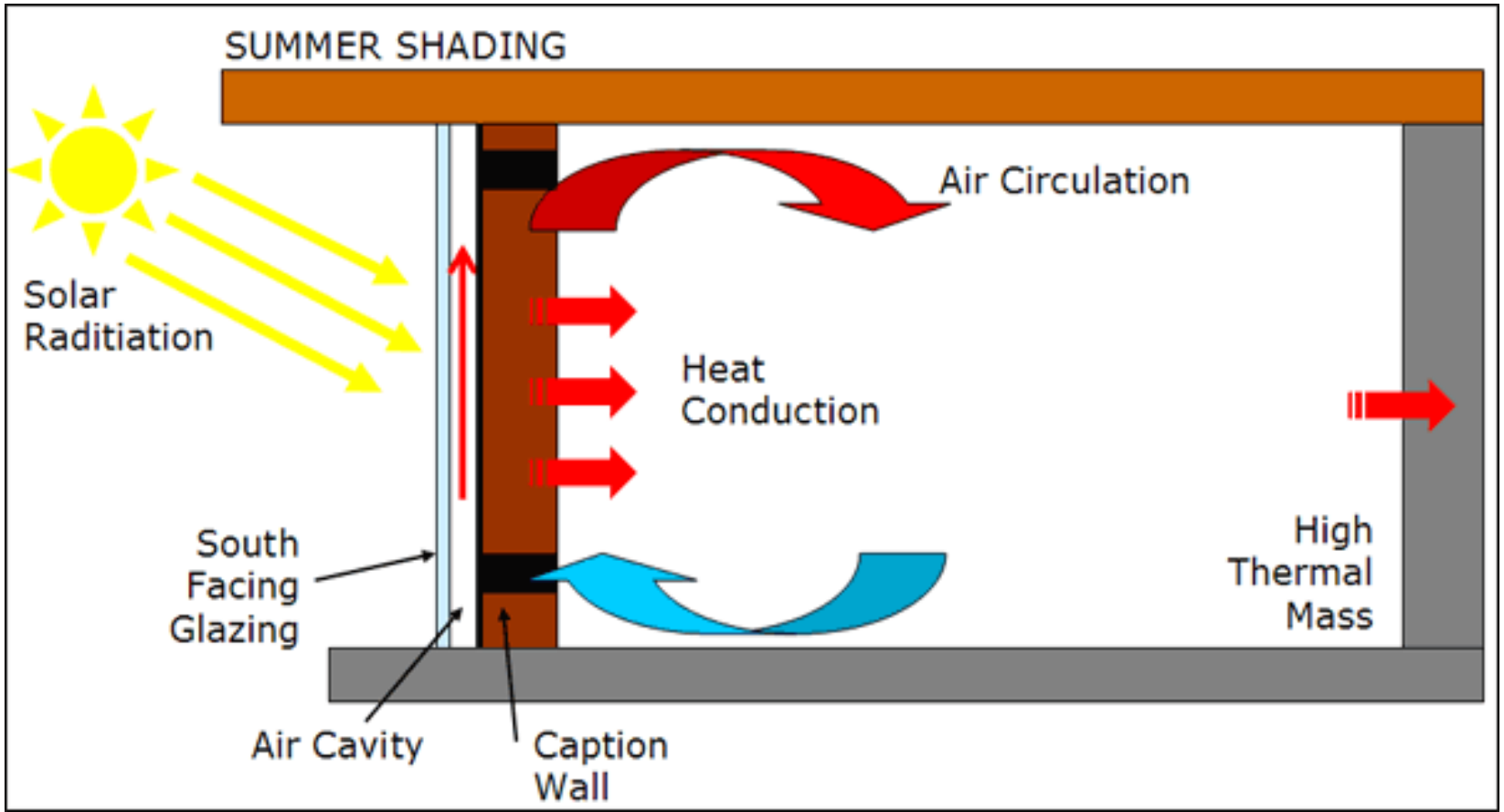




Trombe Wall:
Glass lets most light through,
provides some insulation (not as much as a wall though

Trombe walls

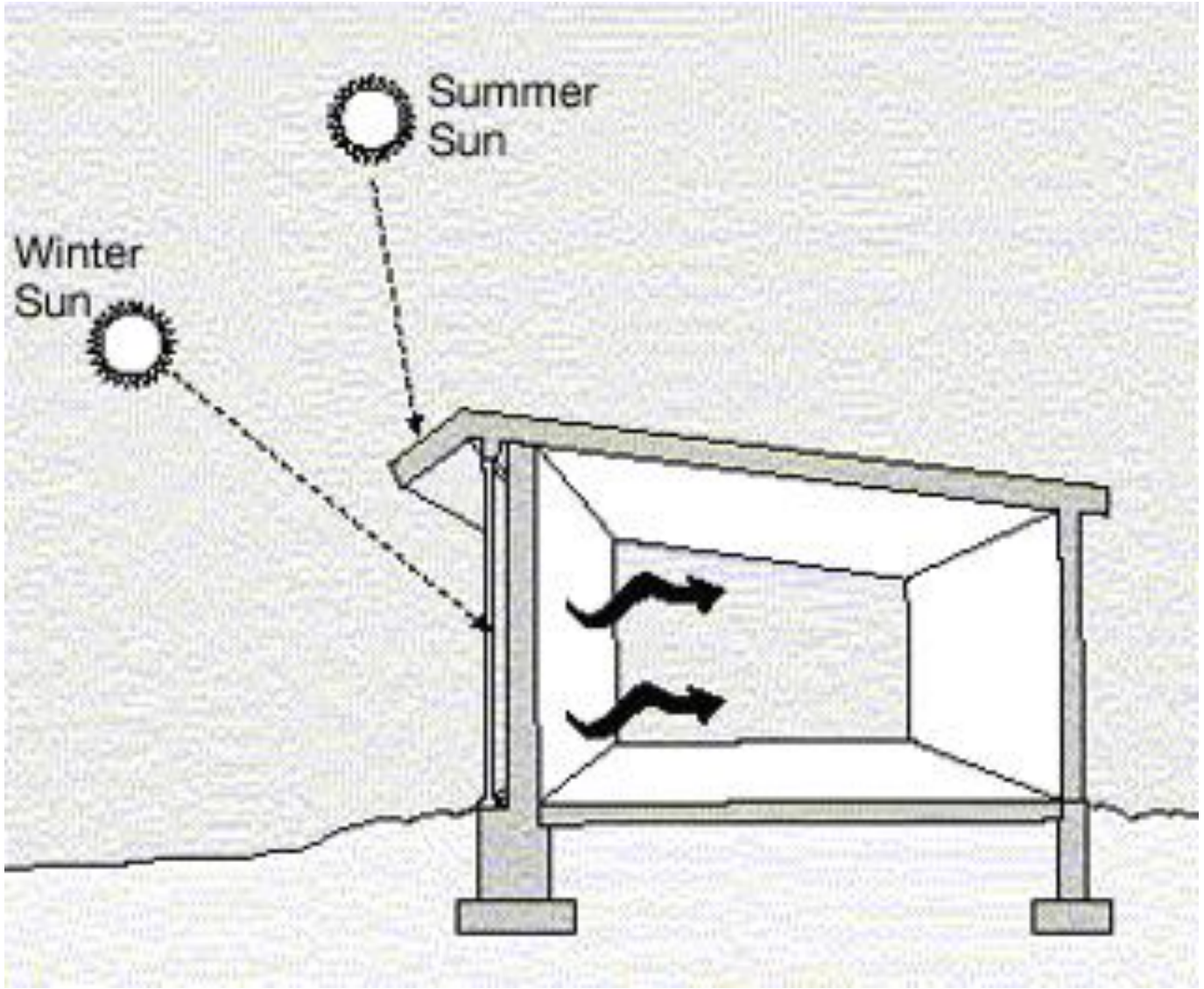
- A south facing (in Calgary) wall covered with glass.
- Small holes make for air circulation by convection.

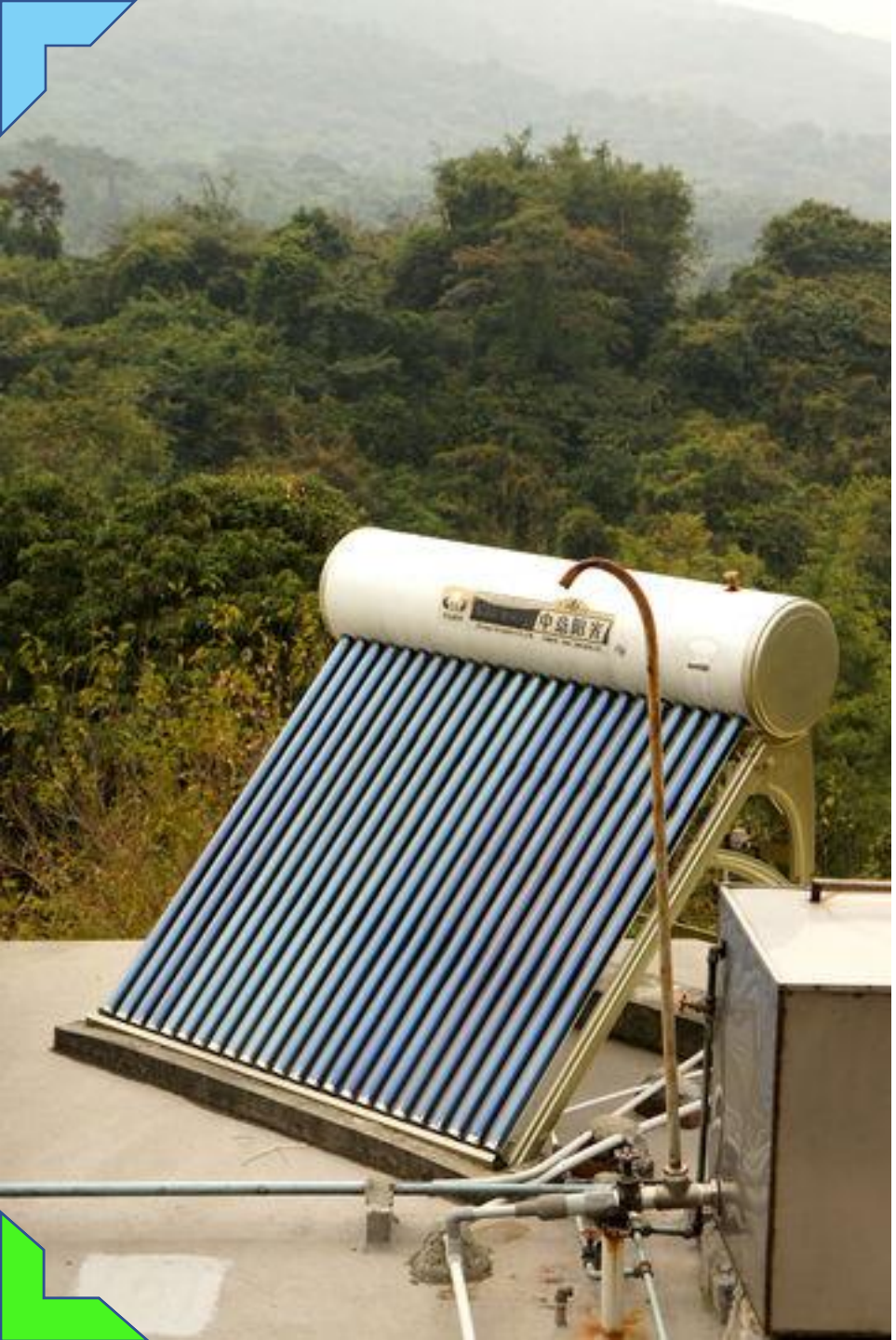


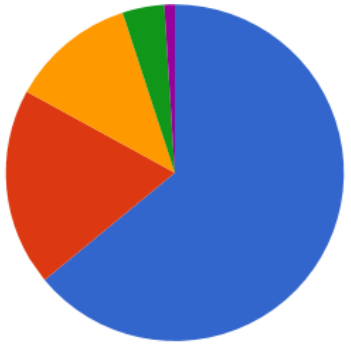
From http://www.dwls.org

Trombe walls

- In warmer climates than Calgary you want warm in the winter, cool in summer.
- An overhang shades the Trombe Wall from the sun in summer.

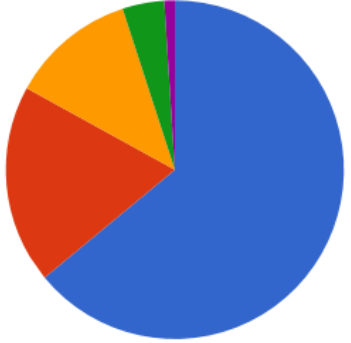


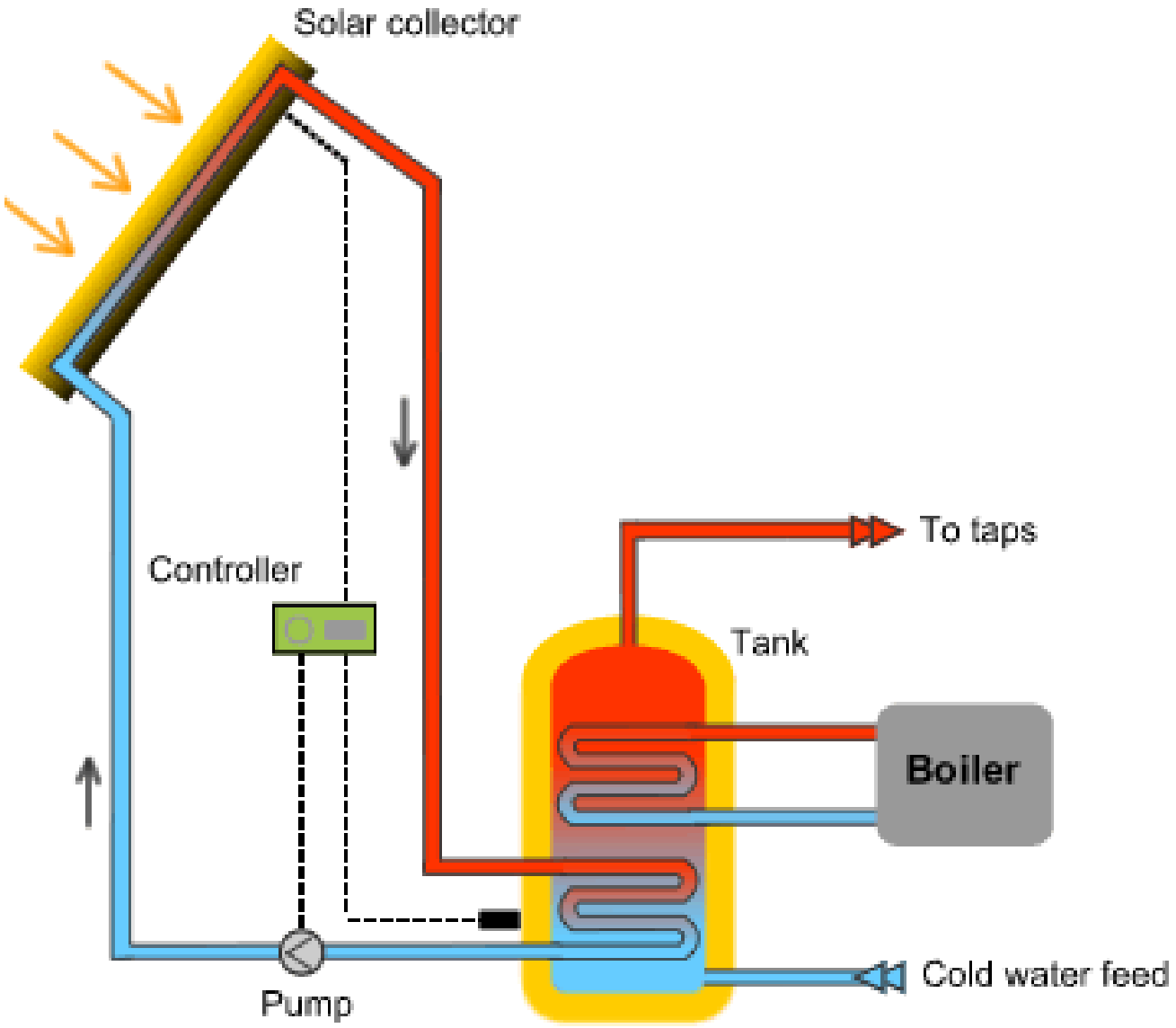




Solar water heating

Supplemental, rather than providing all hot water



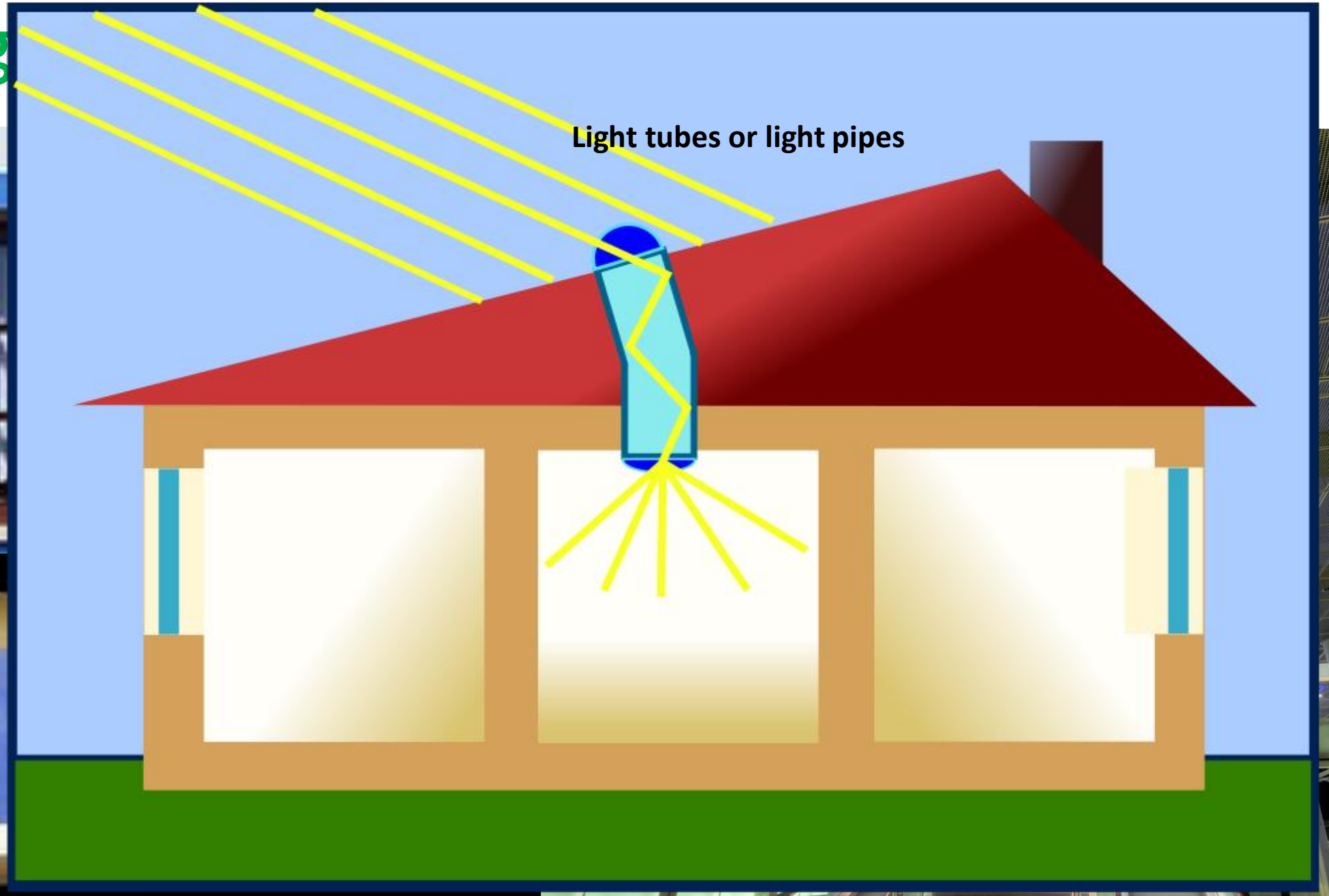

Solar collector
Controller
To taps
Tank
Boiler
Pump
Cold water feed

Heat water

Lig

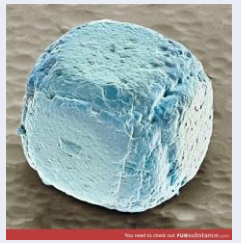








A note to Micro vs. Macro (for midterm 2)

Observable or variable	Type
Volume	Macro
Pressure	Macro
Temperature	Macro
Velocity	It depends! Is the object the size of a molecule/atom? Yes? Micro (quantity is measured by indirect methods) Is the object the size of a grain of salt/sand? Macro (quantity is measured by direct methods) 
Kinetic Energy	It depends! Is the object the size of a molecule/atom? Yes? Micro Is the object the size of a grain of salt/sand? Macro
Mass	It depends! Is the object the size of a molecule/atom? Yes? Micro Is the object the size of a grain of salt/sand? Macro

Macroscopic- *large enough* to be seen or observed by the unaided eye.
Microscopic- *too small* to be seen or observed by the unaided eye

About temperature (for midterm 2 and final)

"Temperature is not directly proportional to internal energy since temperature measures only the kinetic energy part of the internal energy, so two objects with the same temperature do not in general have the same internal energy"

http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/temper.html

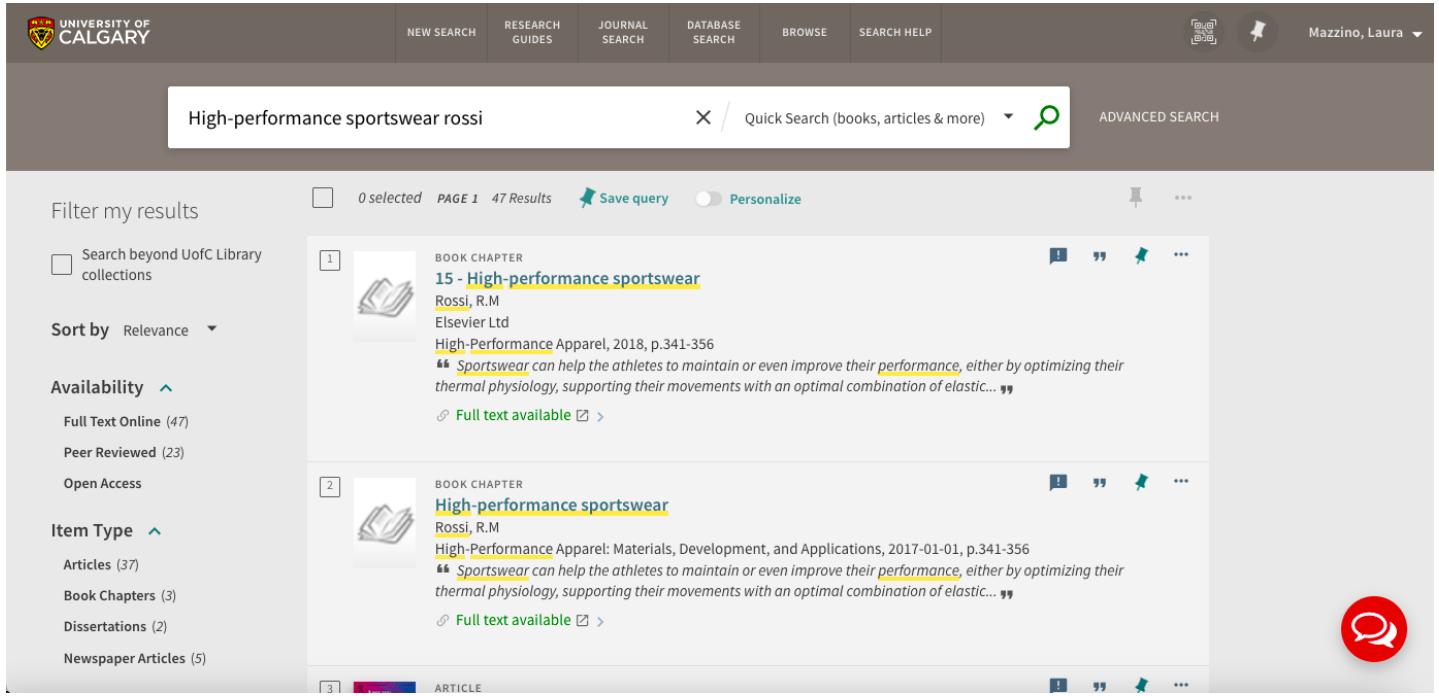
Further reading for your own benefit (concepts and calculations in these pages that were not covered during class **WILL NOT** be part of the questions in exams):

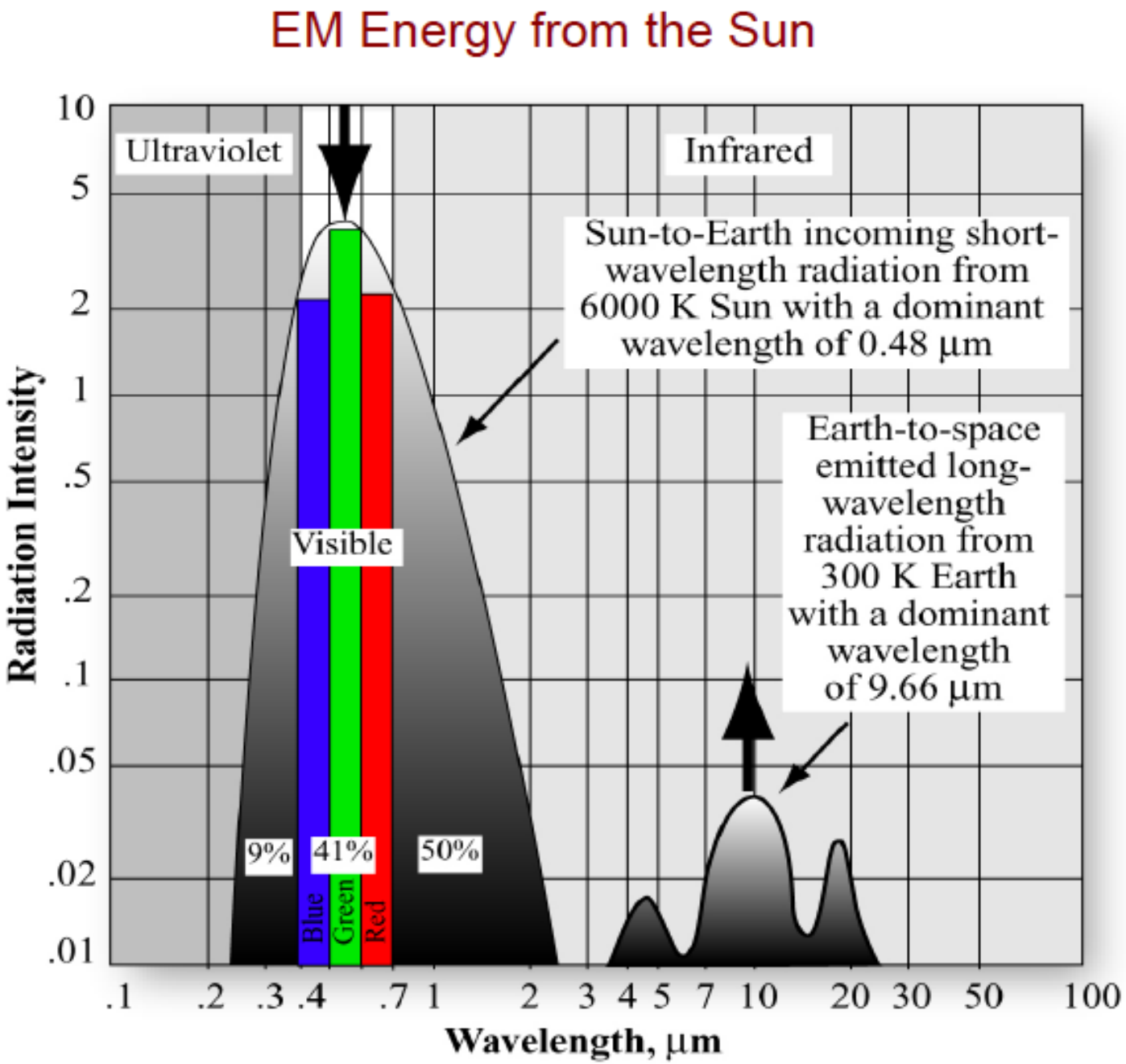
- https://physics.info/temperature/
- https://www.wired.com/story/temperature-is-not-what-you-think-it-is/
- https://www.physicsclassroom.com/class/thermalP/Lesson-1/Temperature-and-Thermometers

About thermal radiation

"Thermal radiation is emitted by all matter with temperatures above the absolute zero and is transferred in the form of electromagnetic waves." Rossi, R. (2018). 15 - High-performance sportswear. In *High-Performance Apparel* (pp. 341-356). Elsevier.

Also see
https://physics.info/radiation/





Electromagnetic radiation emitted by the Sun:

9% Ultraviolet

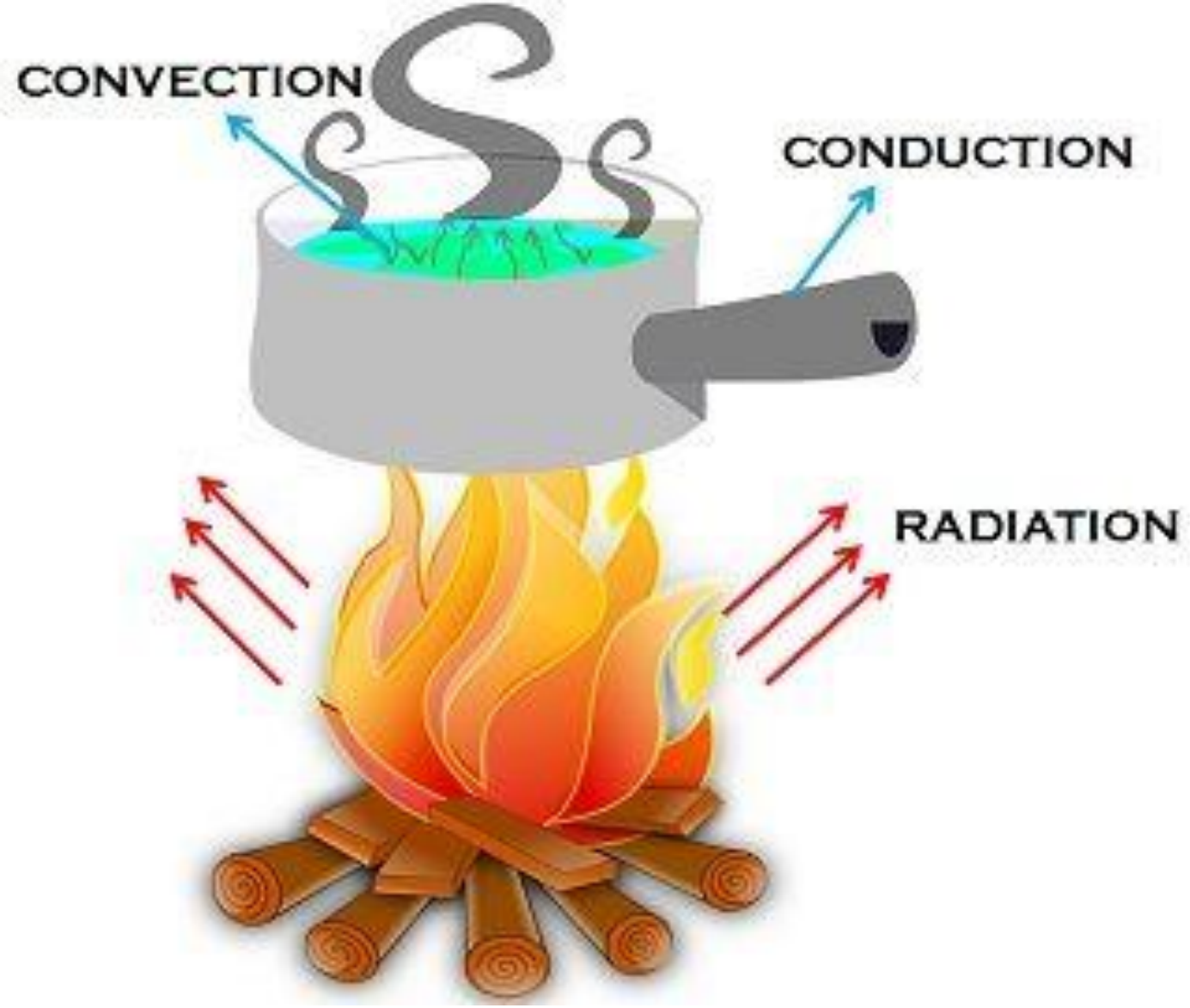
41% Visible light

50% Infrared

Earth profile is in the Infrared range

Source: The University of California, San Diego – Satellite Geodesy

https://topex.ucsd.edu/rs/thermal.pdf



"Convection is heat transfer by mass motion of a fluid such as air or water when the heated fluid is caused to move away from the source of heat, carrying energy with it." http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/heatra.html#c1

"Conduction is heat transfer by means of molecular agitation within a material without any motion of the material as a whole." (same webpage)

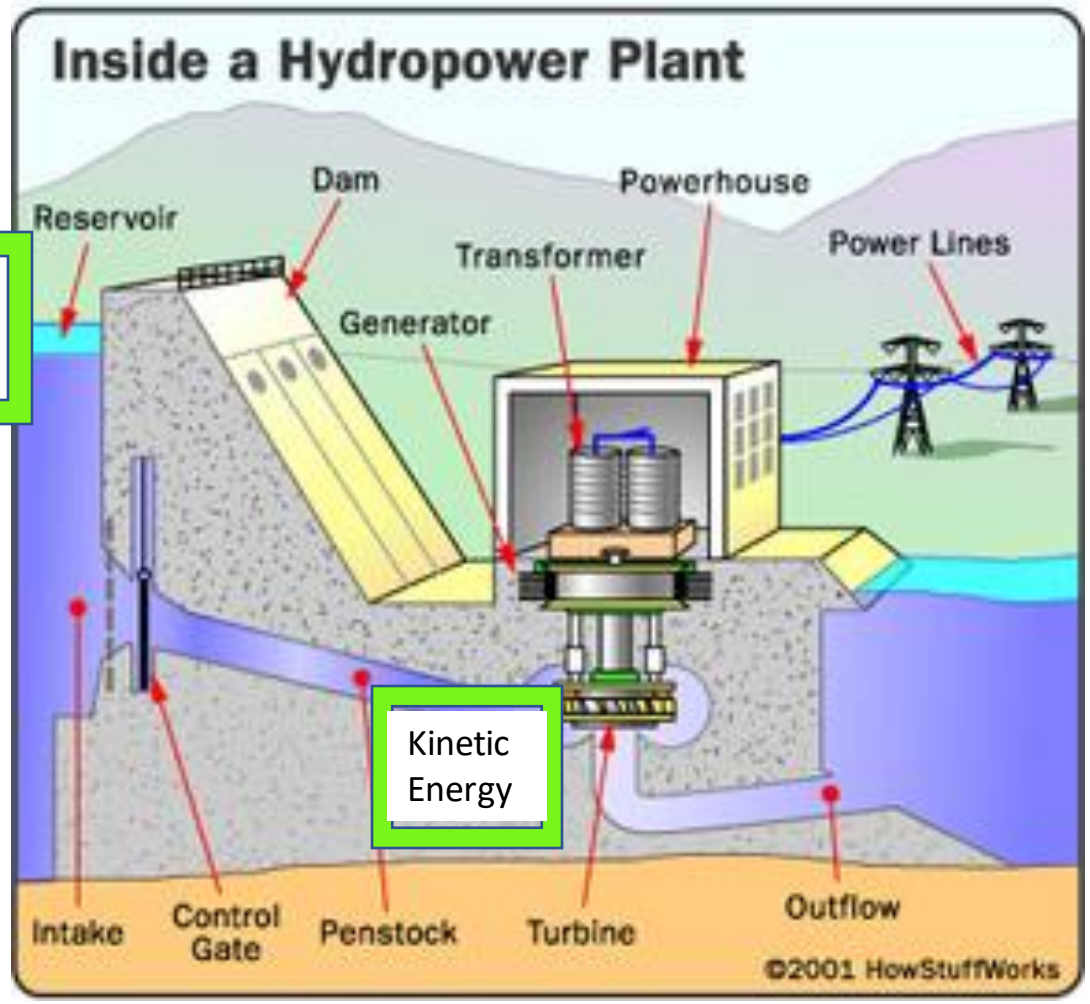
BASIS FOR COMPARISON	CONDUCTION	CONVECTION	RADIATION
Meaning	Conduction is a process in which transfer of heat takes place between objects by direct contact.	Convection refers to the form of heat transfer in which energy transition occurs within the fluid.	Radition alludes to the mechanism in which heat is transmitted without any physical contact between objects.
Represent	How heat travels between objects in direct contact.	How heat passes through fluids.	How heat flows through empty spaces.
Cause	Due to temperature difference.	Due to density difference.	Occurs from all objects, at temperature greater than 0 K.
Occurence	Occurs in solids, through molecular collisions.	Occurs in fluids, by actual flow of matter.	Occurs at a distance and does not heats the intervening substance.

"Heat transfer by **radiation** occurs when microwaves, infrared radiation, visible light, or another form of electromagnetic radiation is emitted or absorbed. " https://pressbooks.bccampus.ca/introductorygeneralphysics2phys1207/chapter/14-4-heat-transfer-methods/

https://keydifferences.com/difference-between-conduction-convection-and-radiation.html

Generating electricity

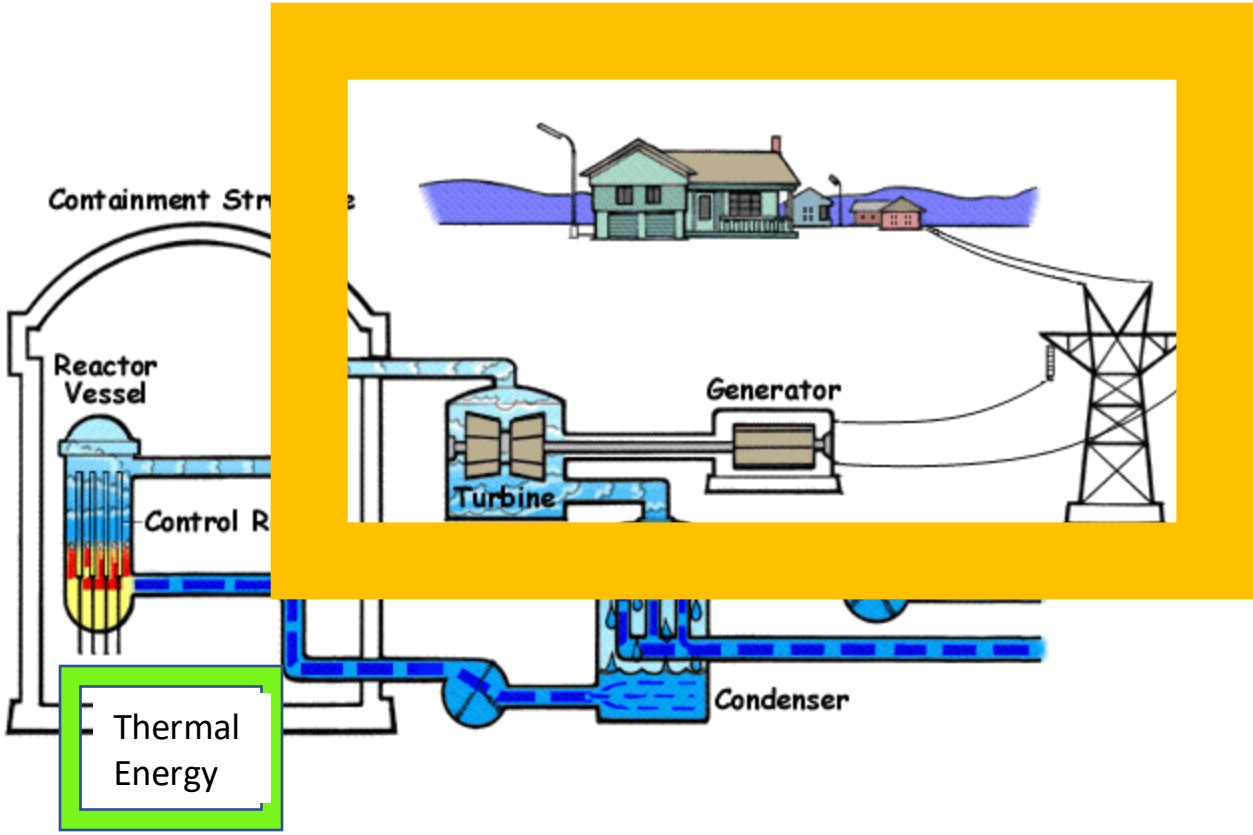
https://energyeducation.ca/encyclopedia/Power_plant



Potential Energy

Kinetic Energy

Hydro, tidal, wind

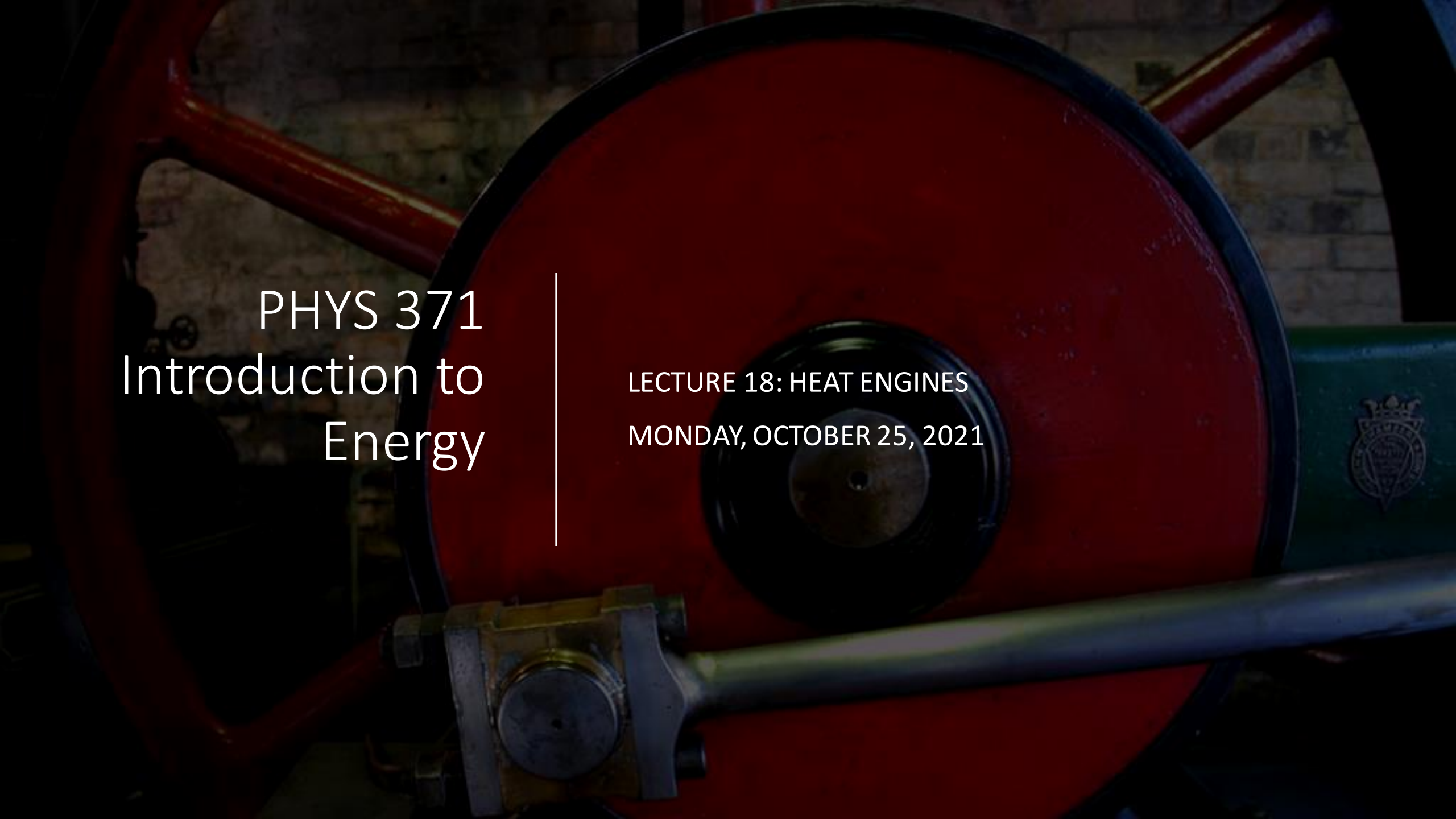


Thermal Energy

https://energyeducation.ca/encyclopedia/Heat_engine

Heat and steam moves the turbine.
Examples: Natural gas power plant (natural gas), Nuclear Power Plants (uranium), coal-fired power plants (Coal) and solar thermal power plants (using heat to produce steam).

"The exception is solar power plants, which use photovoltaic cells (instead of a turbine) to generate this electricity."



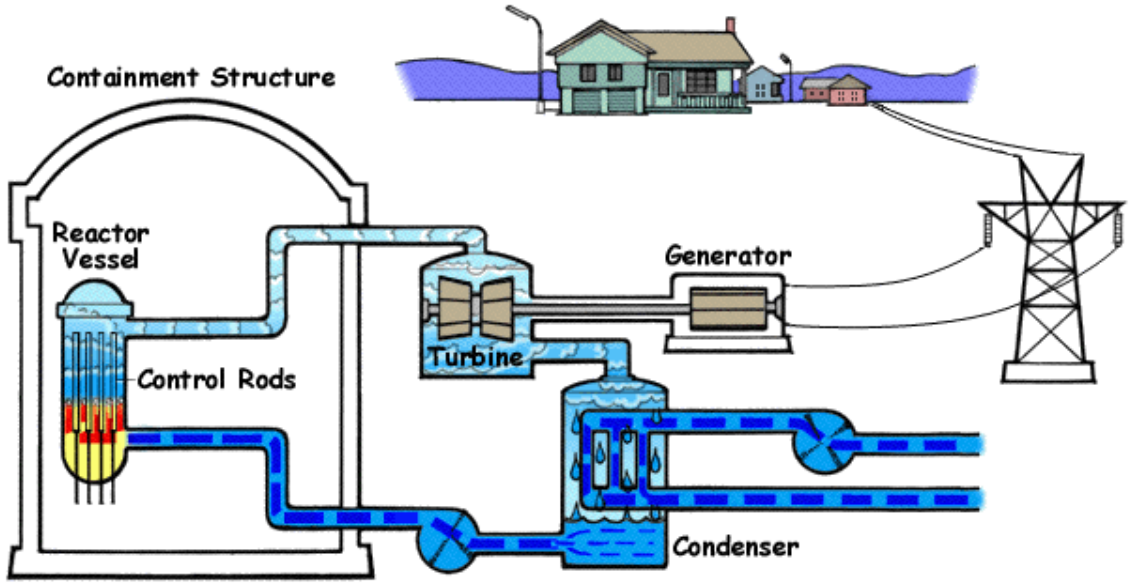
PHYS 371 Introduction to Energy

LECTURE 18: HEAT ENGINES

MONDAY, OCTOBER 25, 2021

Overview – This week

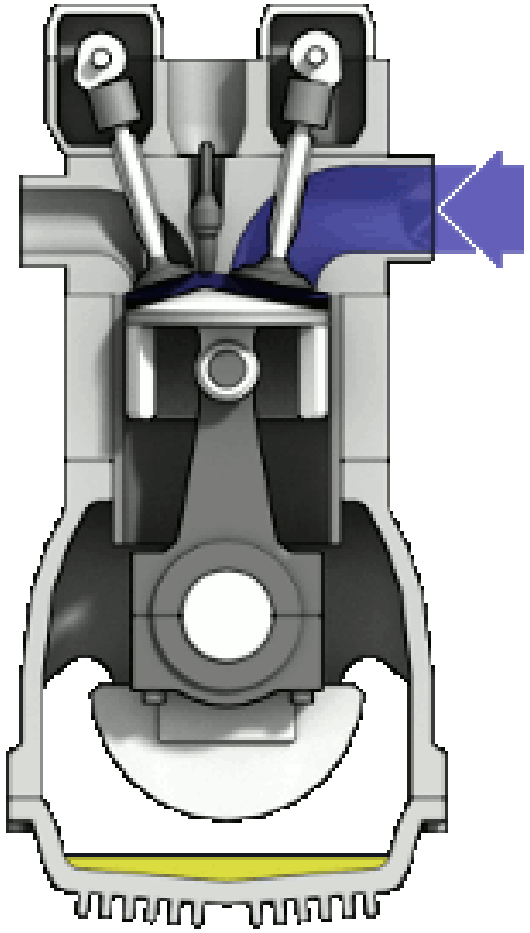
- ❑ Fluids. Machine for motion. Turbines
- ❑ Heat engines
- ❑ Efficiency
- ❑ Cogeneration
- ❑ (maybe) Refrigerators



- Next Week:
- Electricity. Electricity production. Power plants

Heat engines

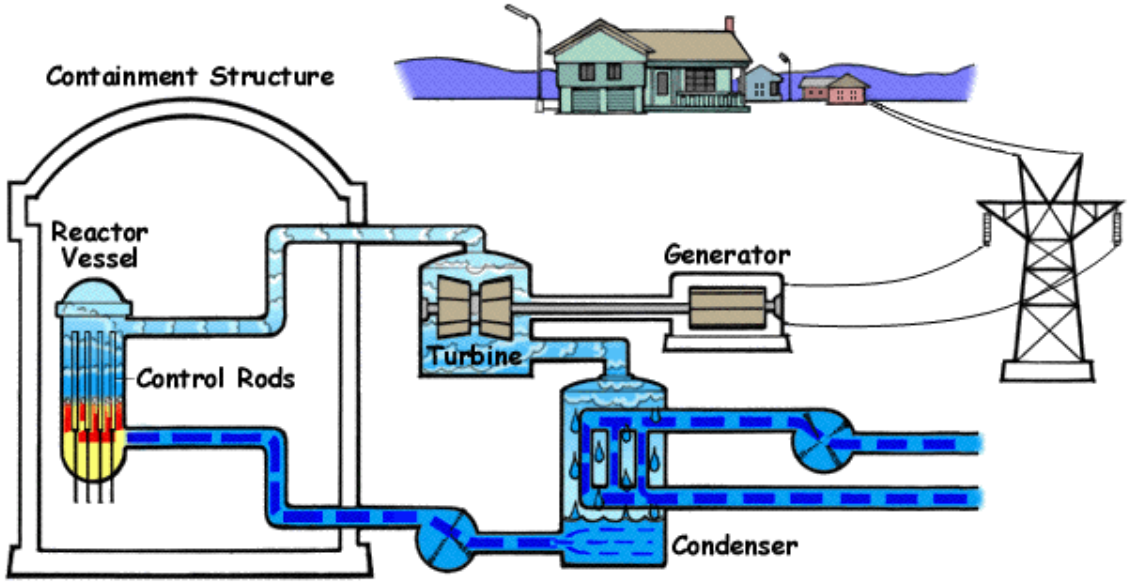
1



Run:

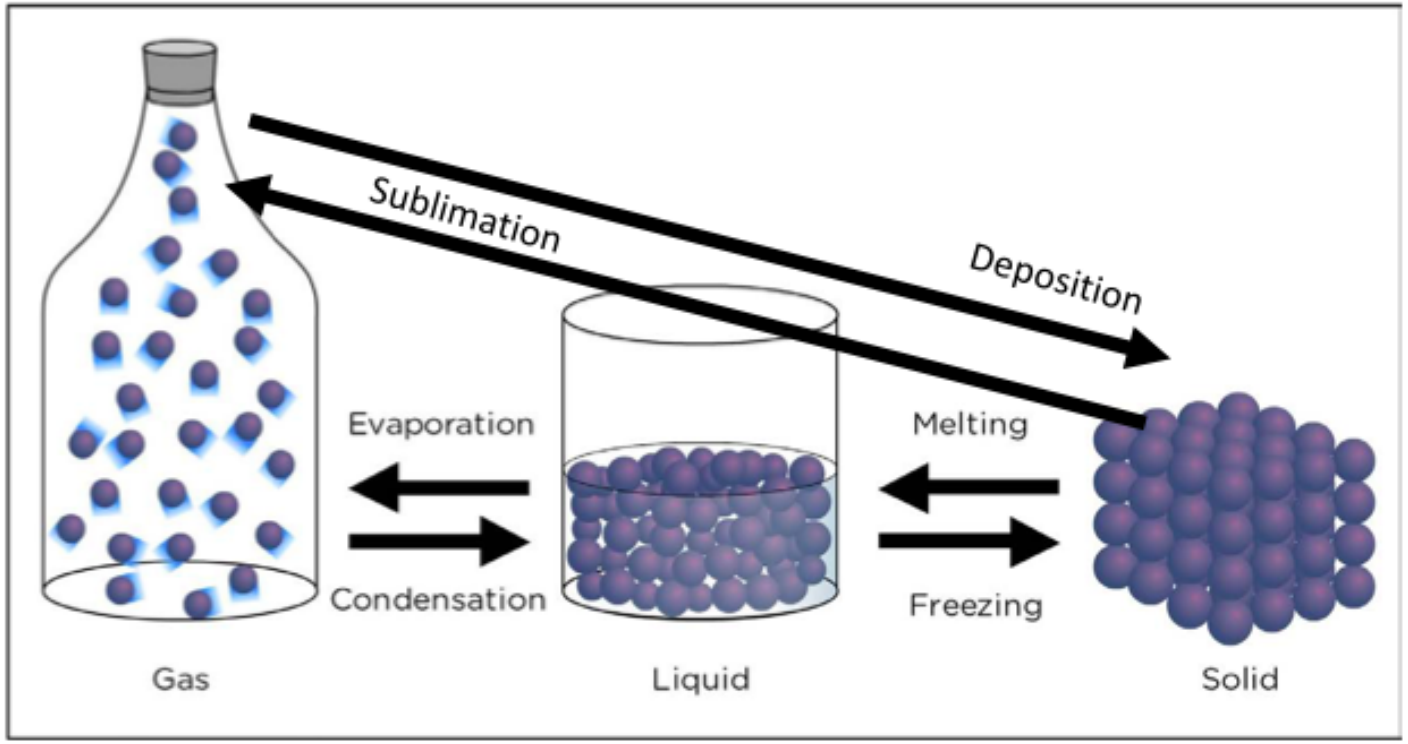
Power plants (most types)

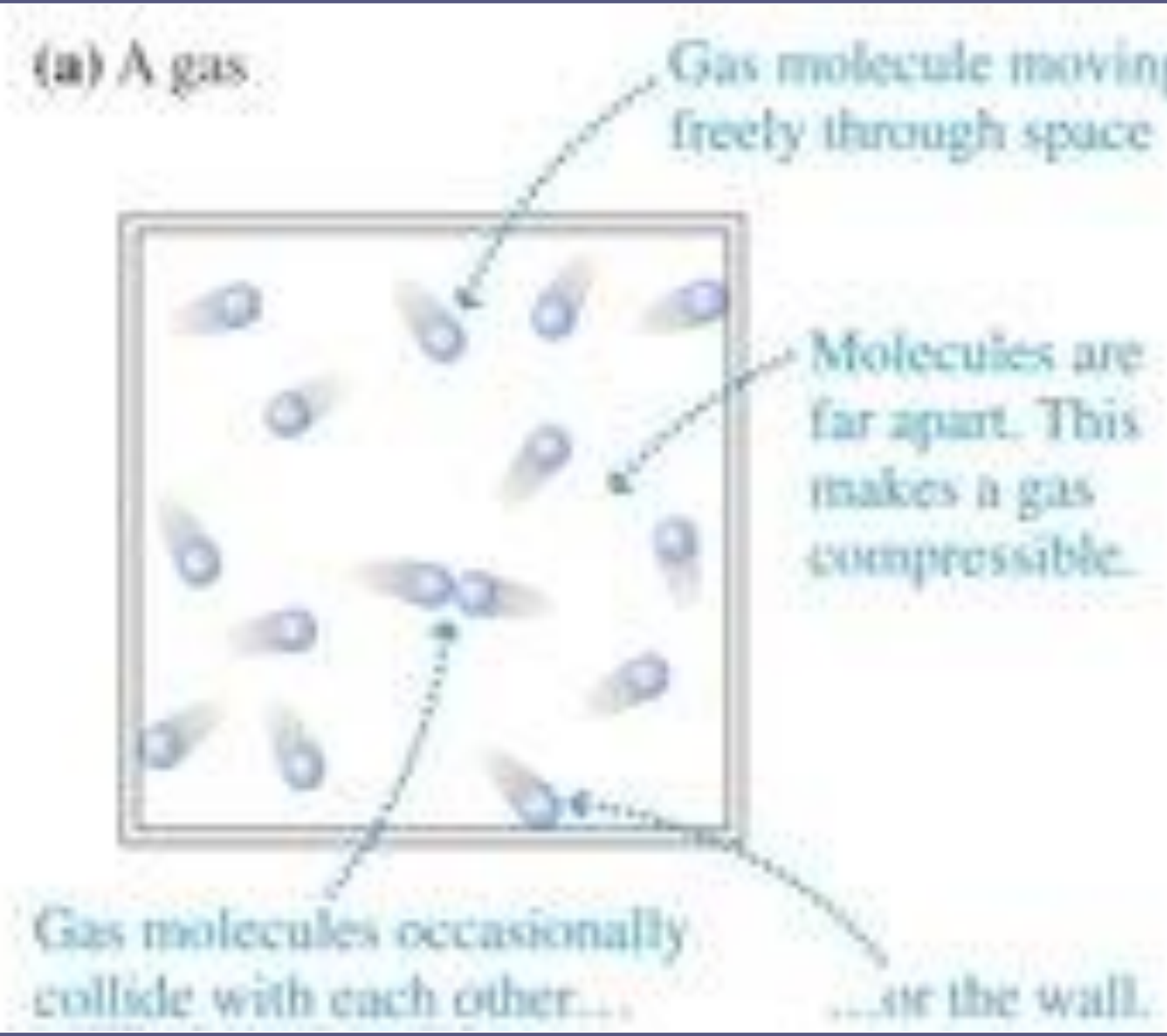
Cars, planes, boats, submarines



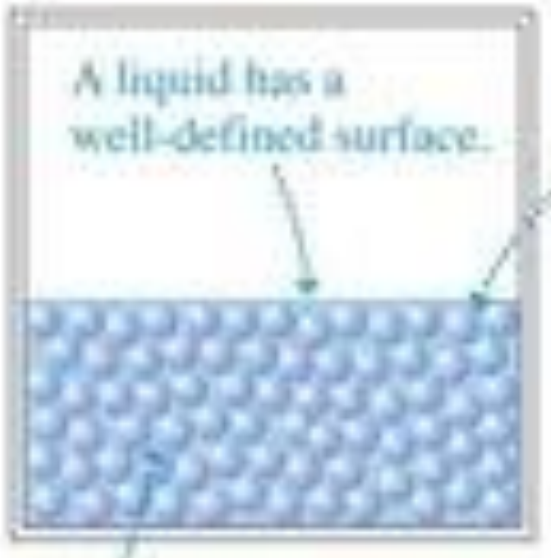
Model: Sheer forces on matter:

- Maintains shear forces – solids
- Deformation resolves – fluids




(a) A gas
Gas molecule moving freely through space
Molecules are far apart. This makes a gas compressible.
Gas molecules occasionally collide with each other...
...or the wall.

(b) A liquid

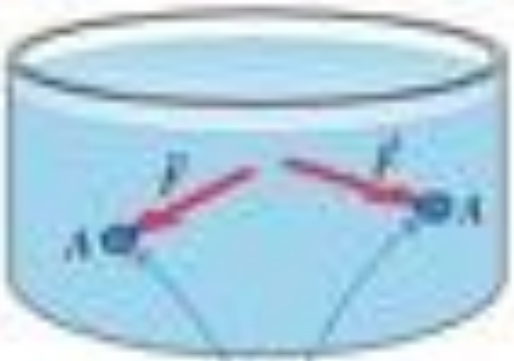

A liquid has a well-defined surface.
Molecules are about as close together as they can get. This makes a liquid incompressible.
Molecules have weak bonds between them, keeping them close together. But the molecules can slide around each other, allowing the liquid to flow and conform to the shape of its container.

Fluids exert force:

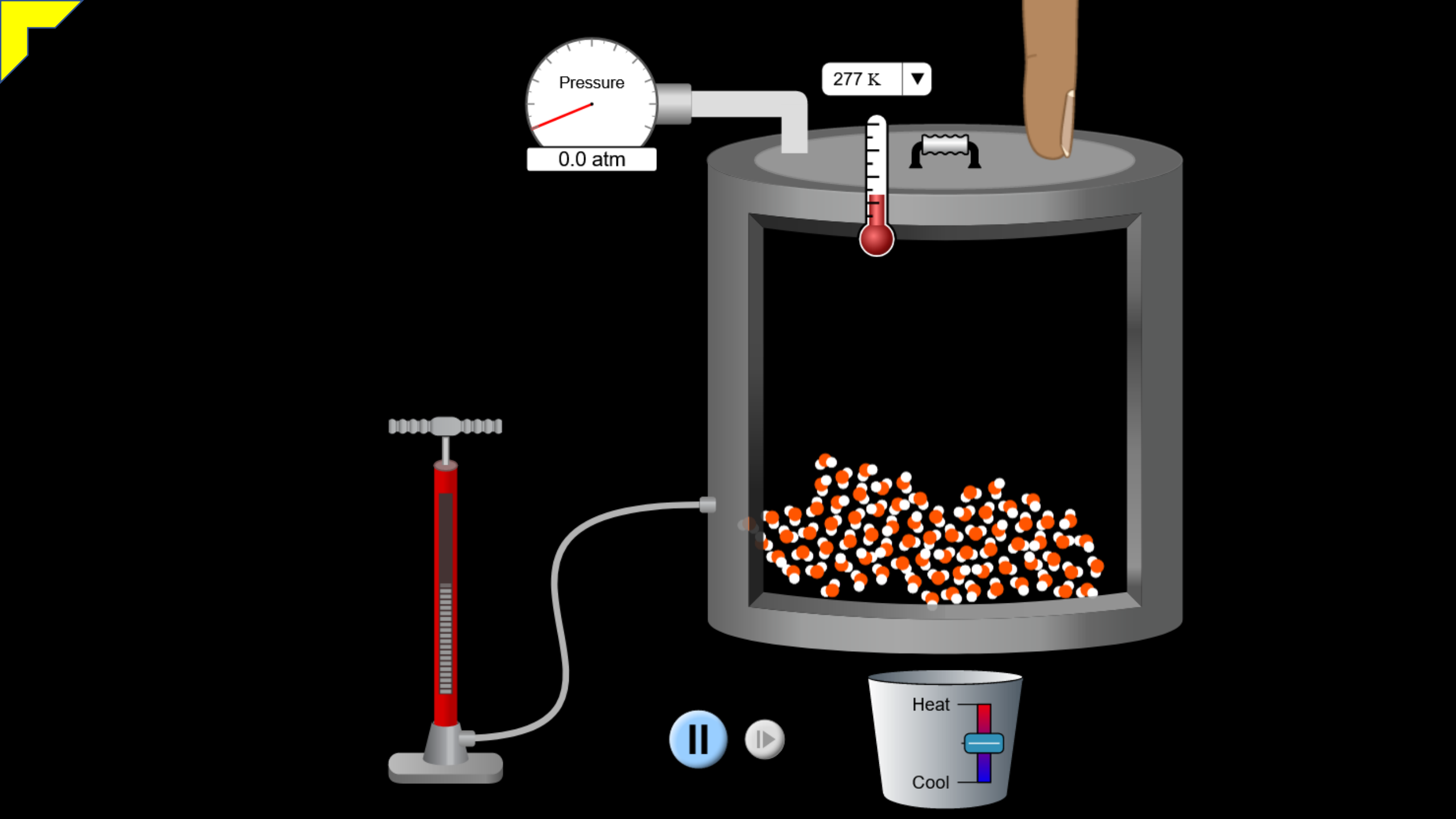
Pressure: ratio of force to area on which force is exerted.

$$p = \frac{F}{A}$$

Units: 1 pascal = 1 Pa = 1 N/m^2.



The fluid pushes with


Pressure
0.0 atm
277 K
Heat
Cool

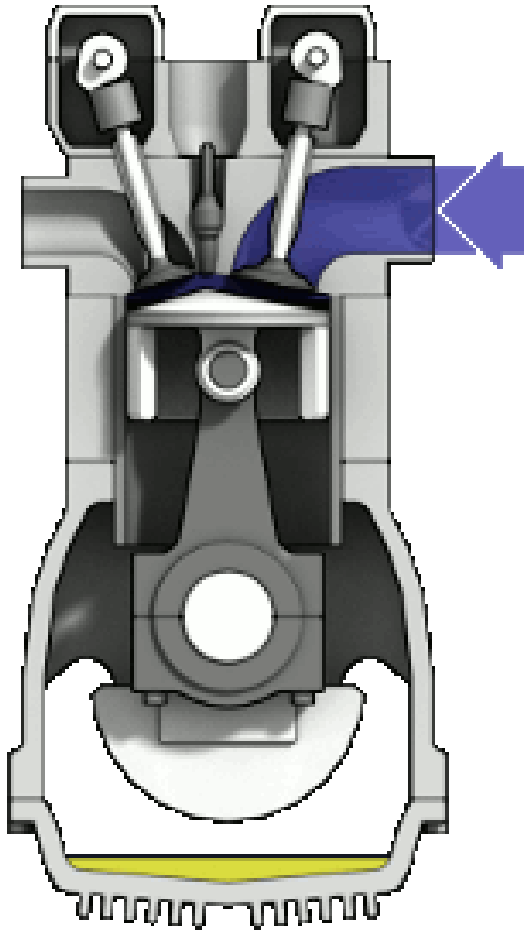


PHYS 371
Introduction to Energy

- LECTURE 19: HEAT ENGINES - TURBINES
- WEDNESDAY, OCTOBER 27, 2021

Heat engines

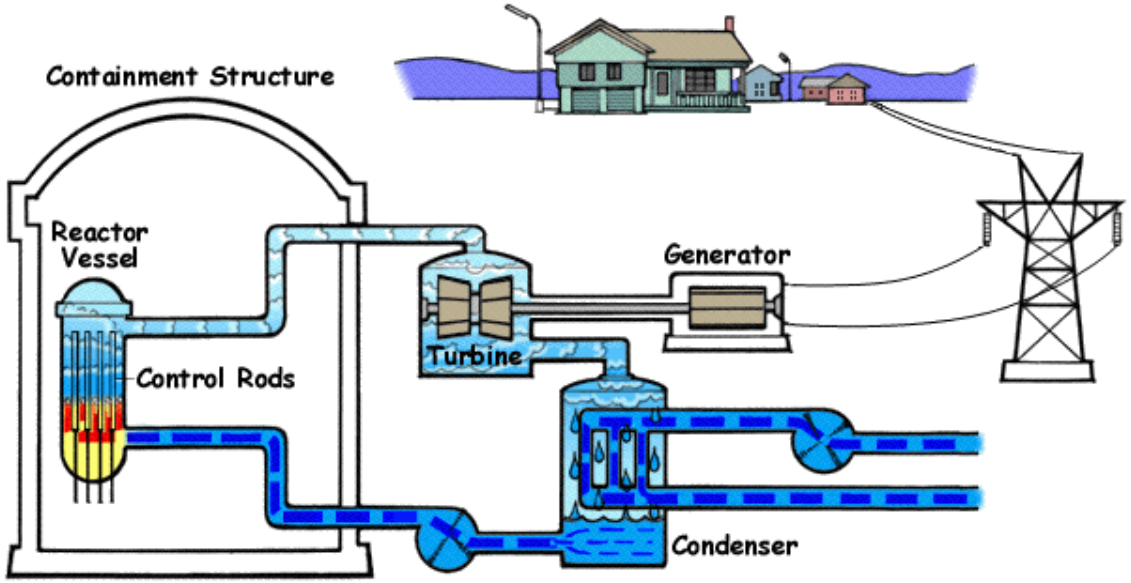
1



Run:

Power plants (most types)

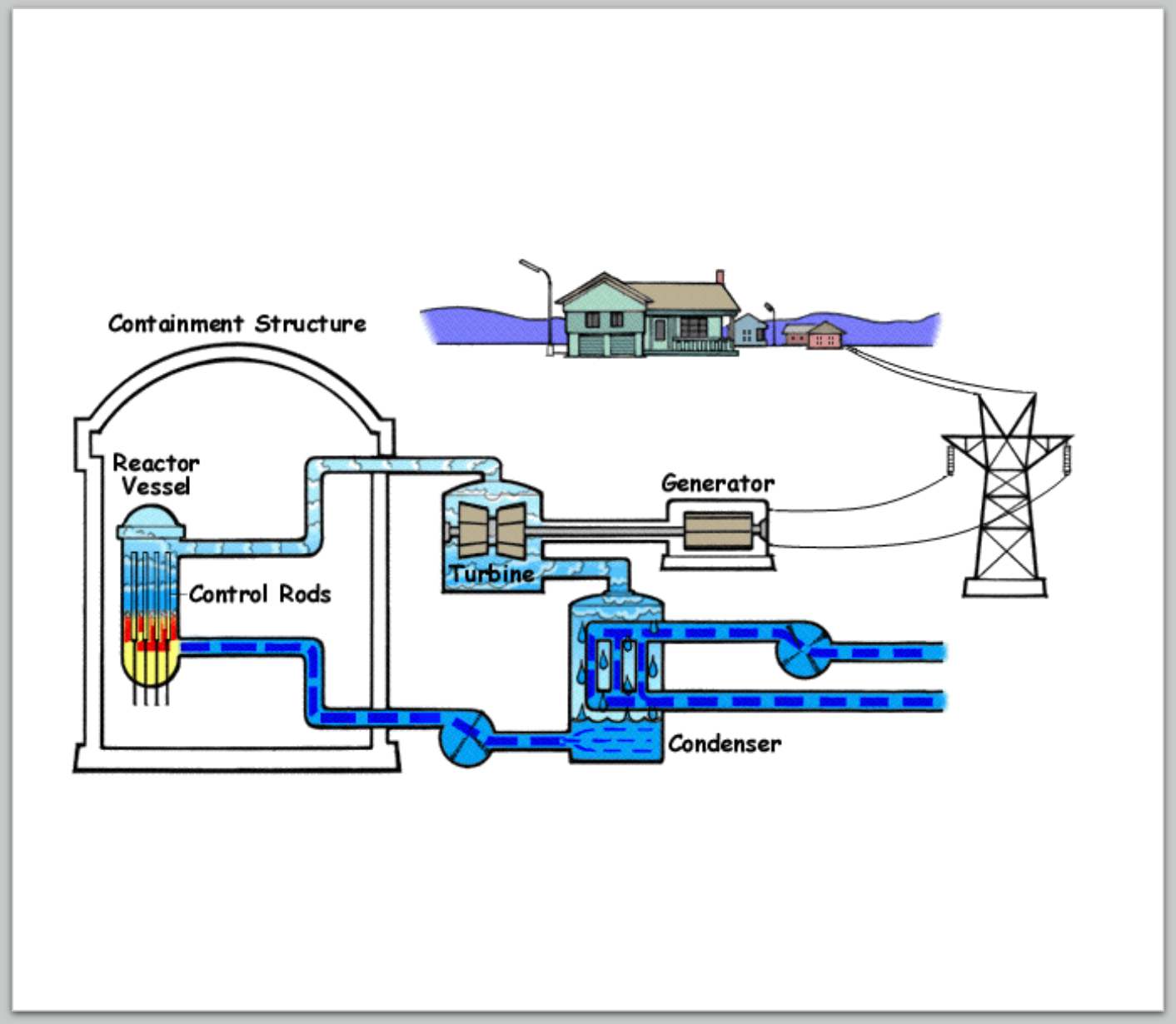
Cars, planes, boats, submarines



Overview – This week

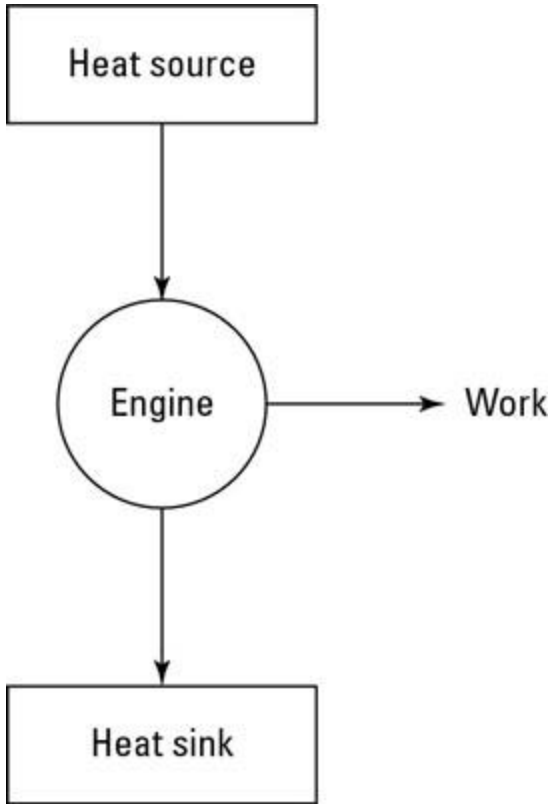
- ❑ **Fluids.** Machine for motion. Turbines
- ❑ Heat engines
- ❑ Efficiency
- ❑ Cogeneration
- ❑ (maybe) Refrigerators

- Next Week:
- Electricity. Electricity production. Power plants



Heat Engine

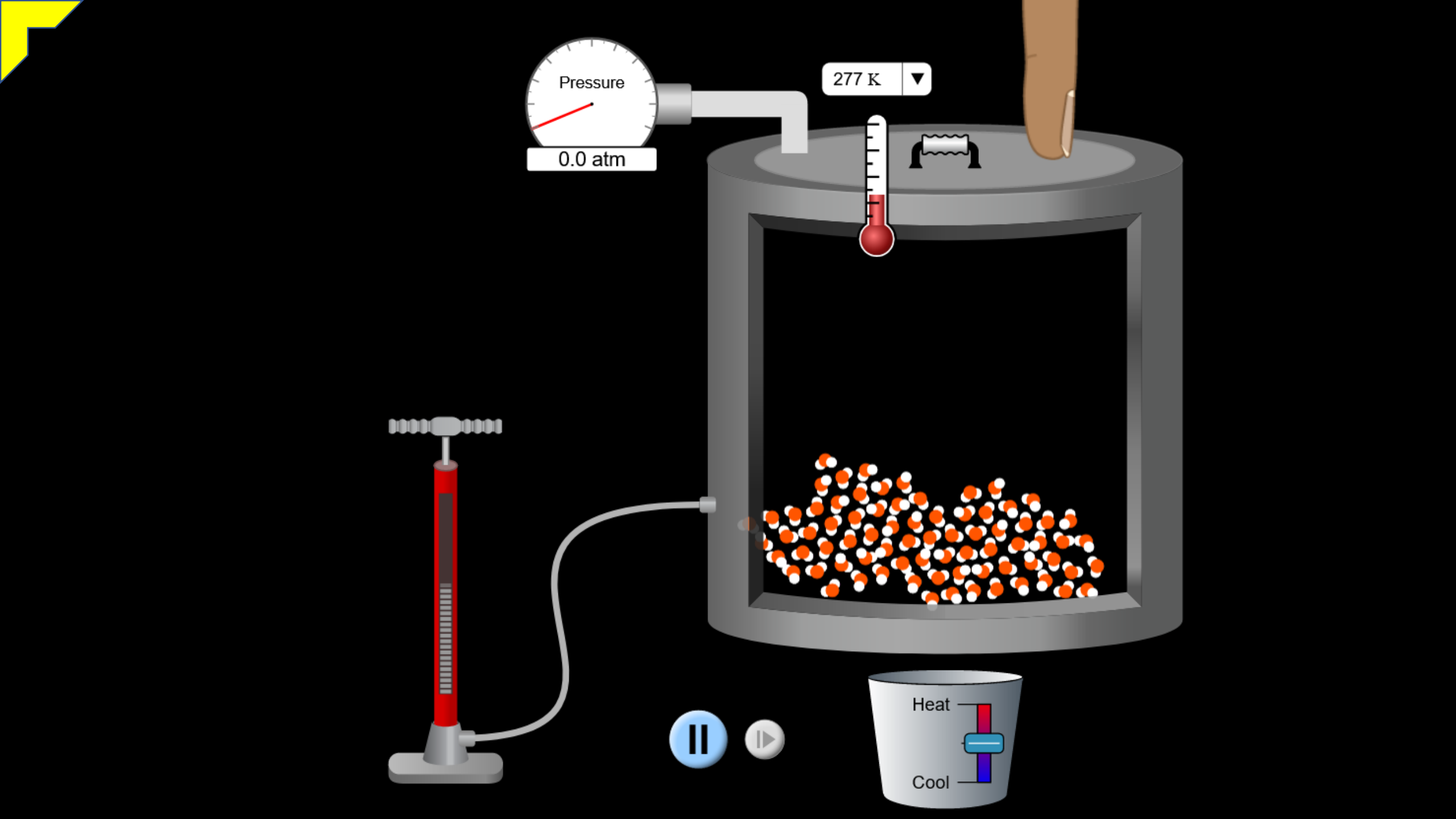
A heat engine turns heat into work.



Engines that rely on a heat source to do work are called *heat engines*.

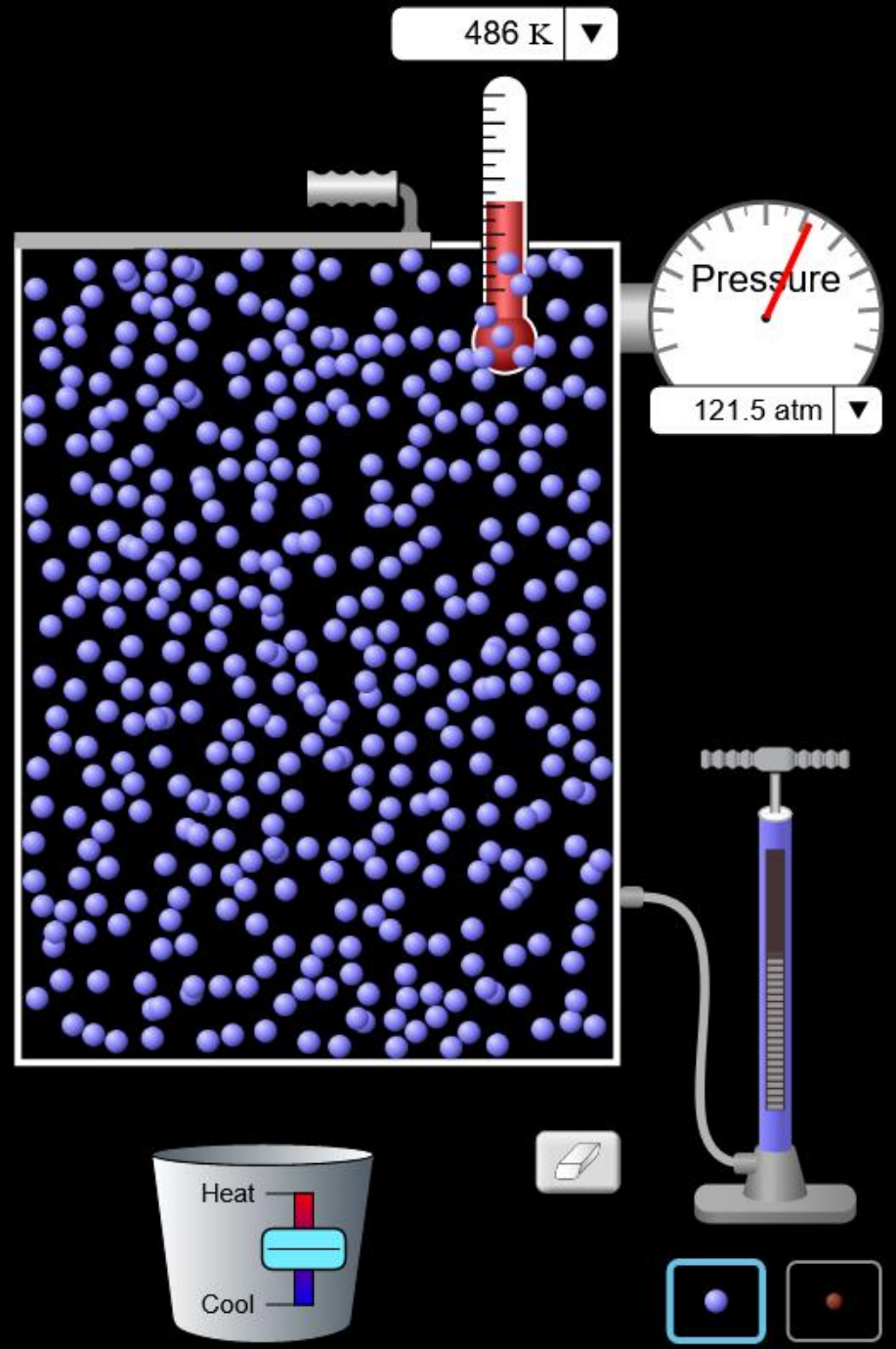
A ***heat source*** provides heat to the engine, which does ***work***. The waste heat left over goes to a ***heat sink***.

We will discuss all this at the end of this lecture and on Friday, once we have learned all the required background information and knowledge needed

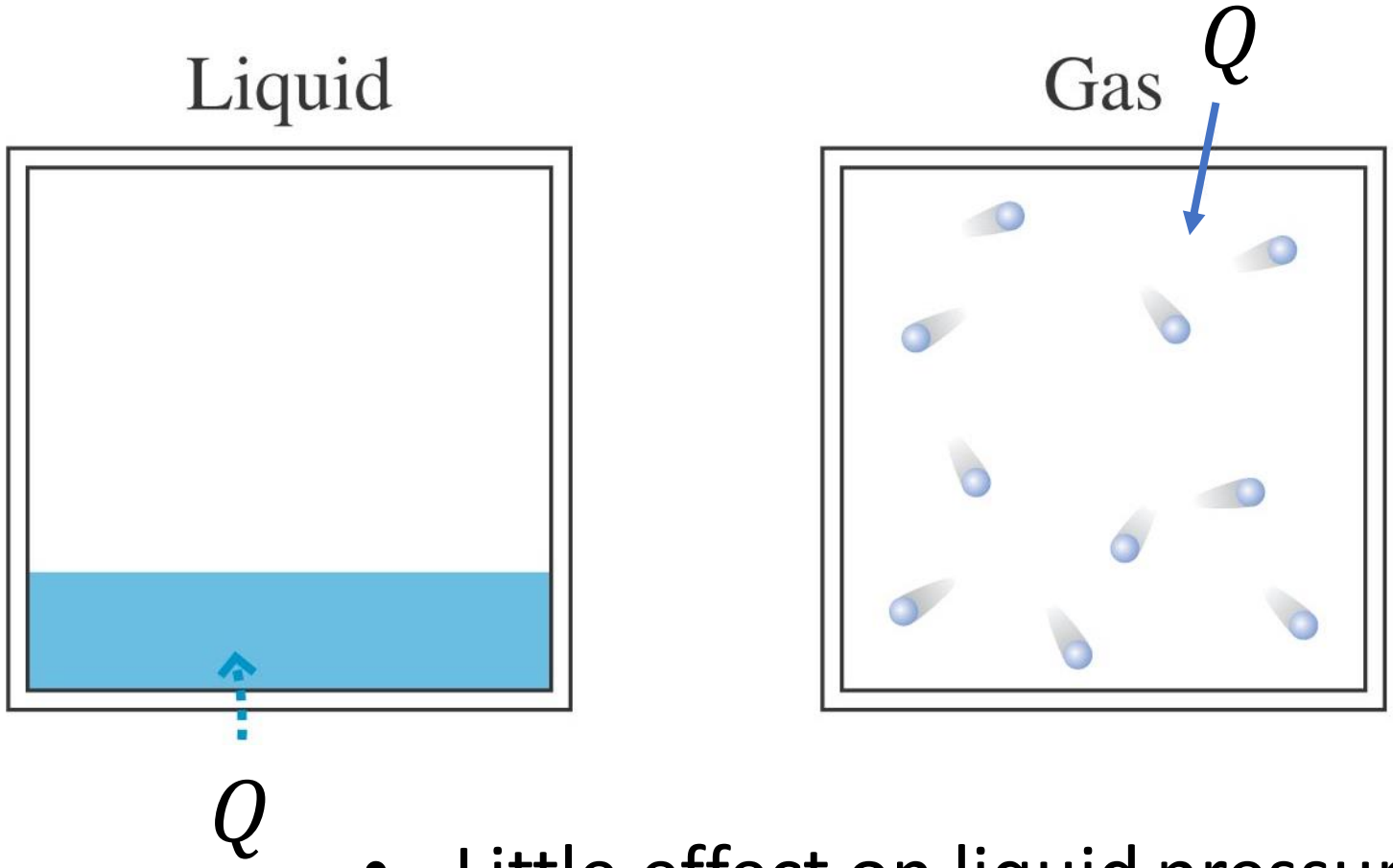

Pressure
0.0 atm
277 K
Heat
Cool

Q_{in}

Container changes size (constant p)

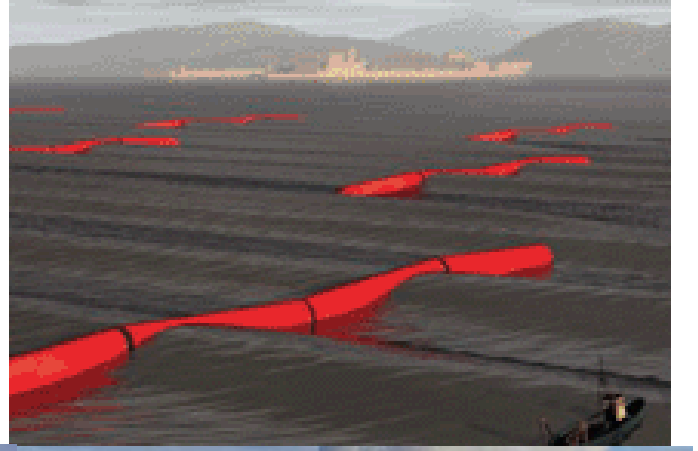


Q in → More molecular motion



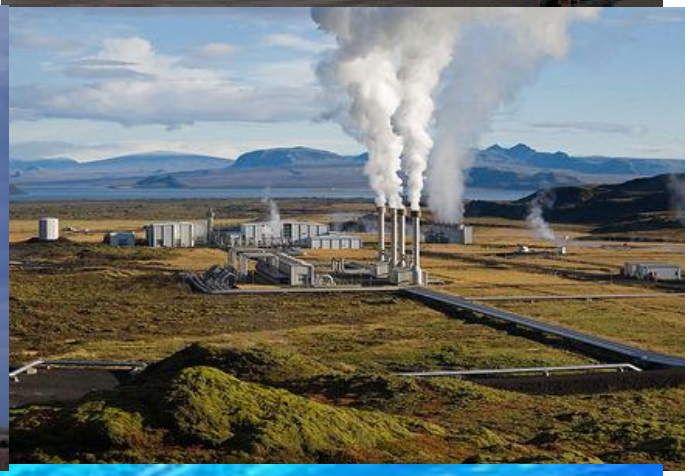
- Little effect on liquid pressure
- Increases gas pressure

Flows often are fluids and use fluids





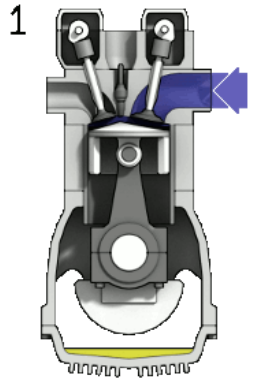




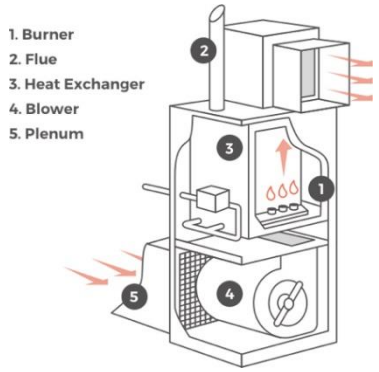


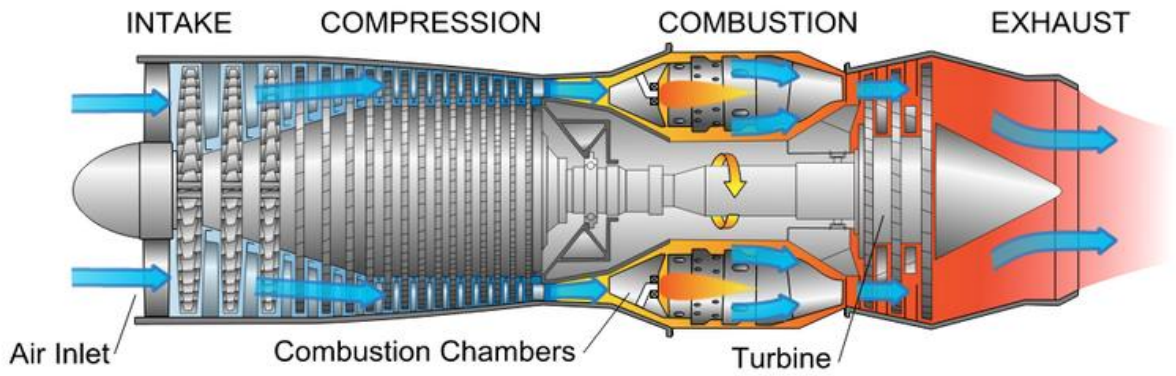


Fuels use fluids as well









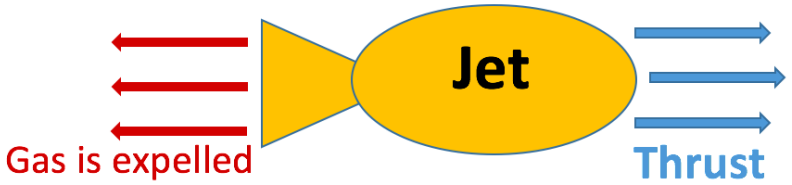






Model:

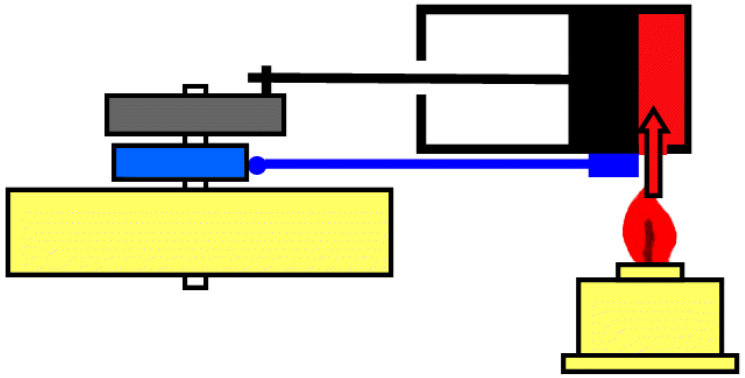
3 types of motion;
3 types of machine to create motion from fluid



Translation – Jet

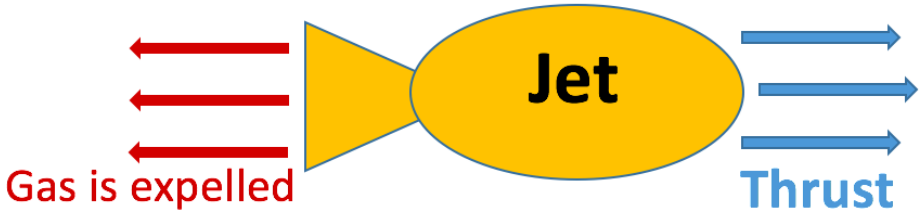


Rotation – Turbine

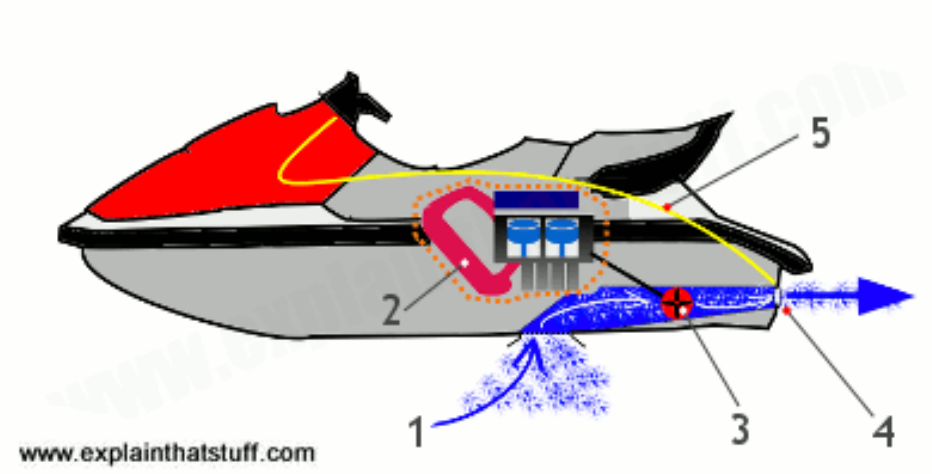


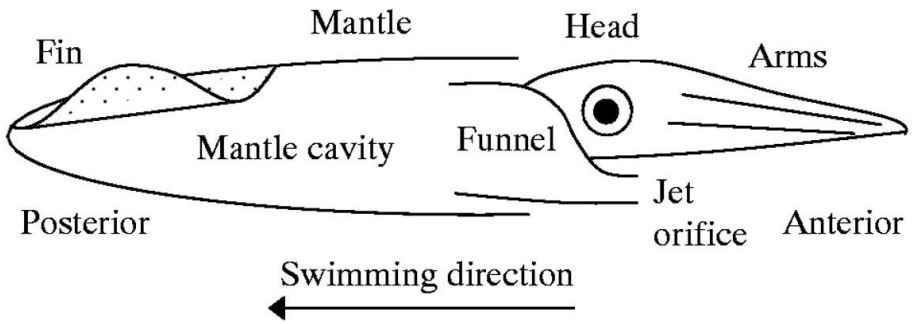
Reciprocating – Piston

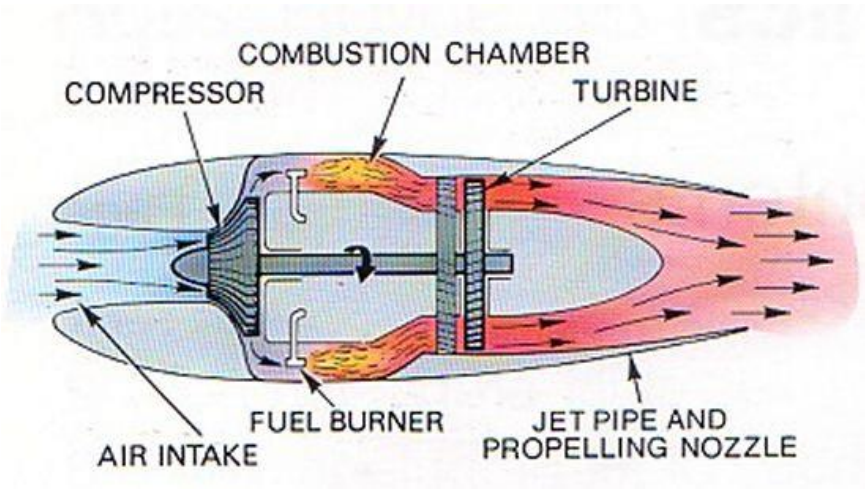
Jet


Jet
Gas is expelled
Thrust

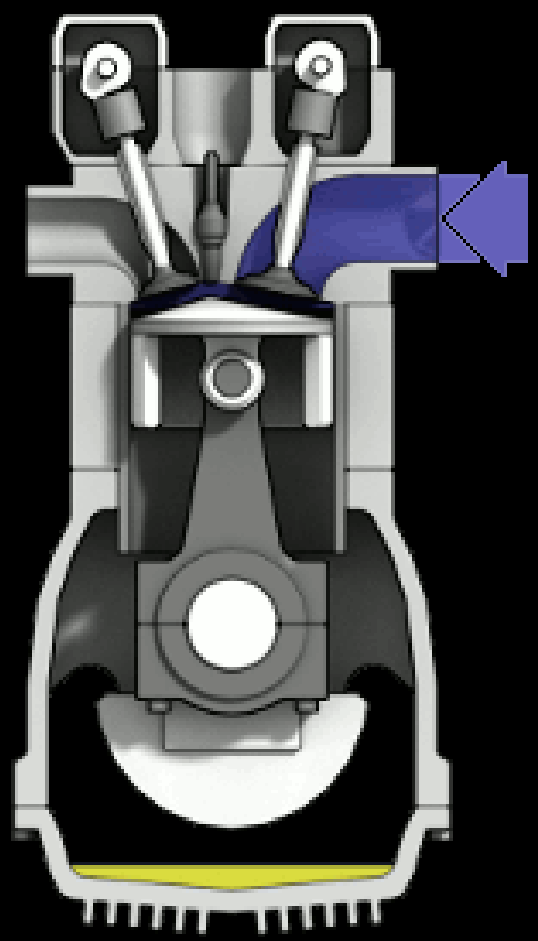


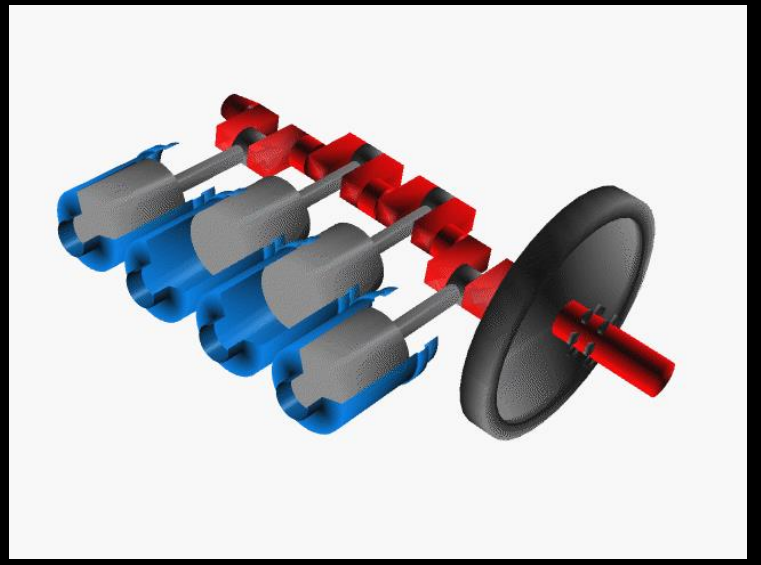

5
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www.explainthatstuff.com

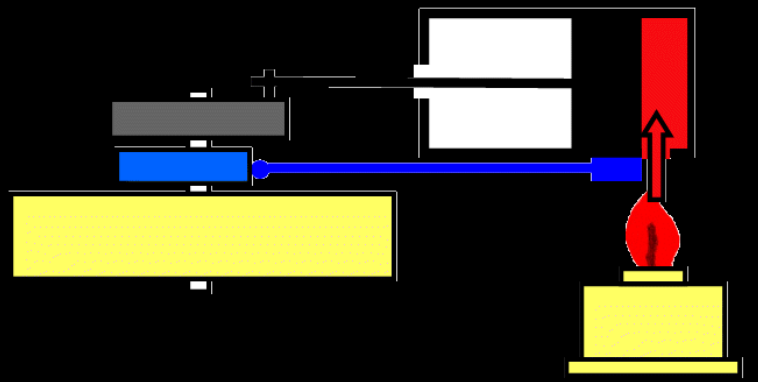

Fin
Mantle
Head
Arms
Mantle cavity
Funnel
Jet
orifice
Posterior
Anterior
Swimming direction


COMBUSTION CHAMBER
COMPRESSOR
TURBINE
FUEL BURNER
JET PIPE AND
PROPELLING NOZZLE
AIR INTAKE

Piston – reciprocating motion

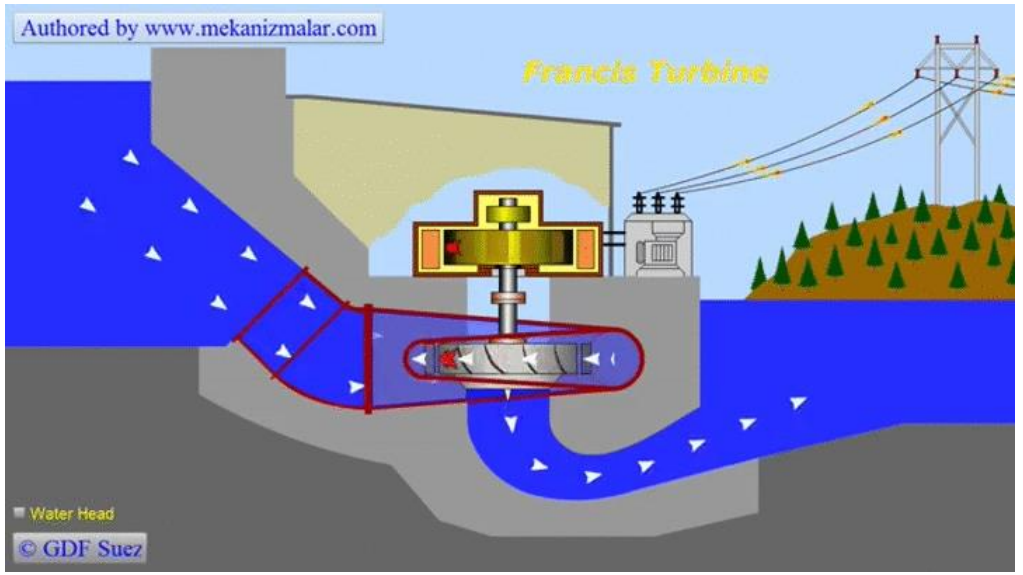


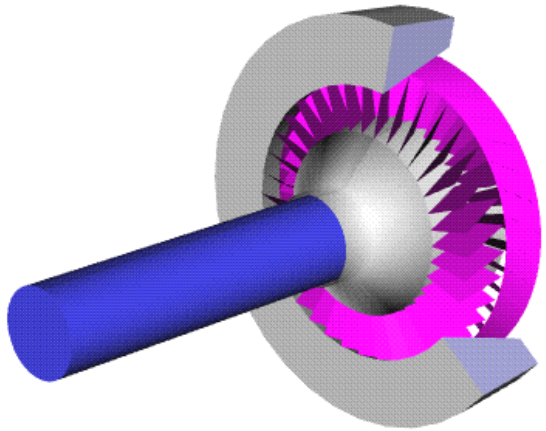




Model: Machine converting fluid energy into shaft work - Turbine



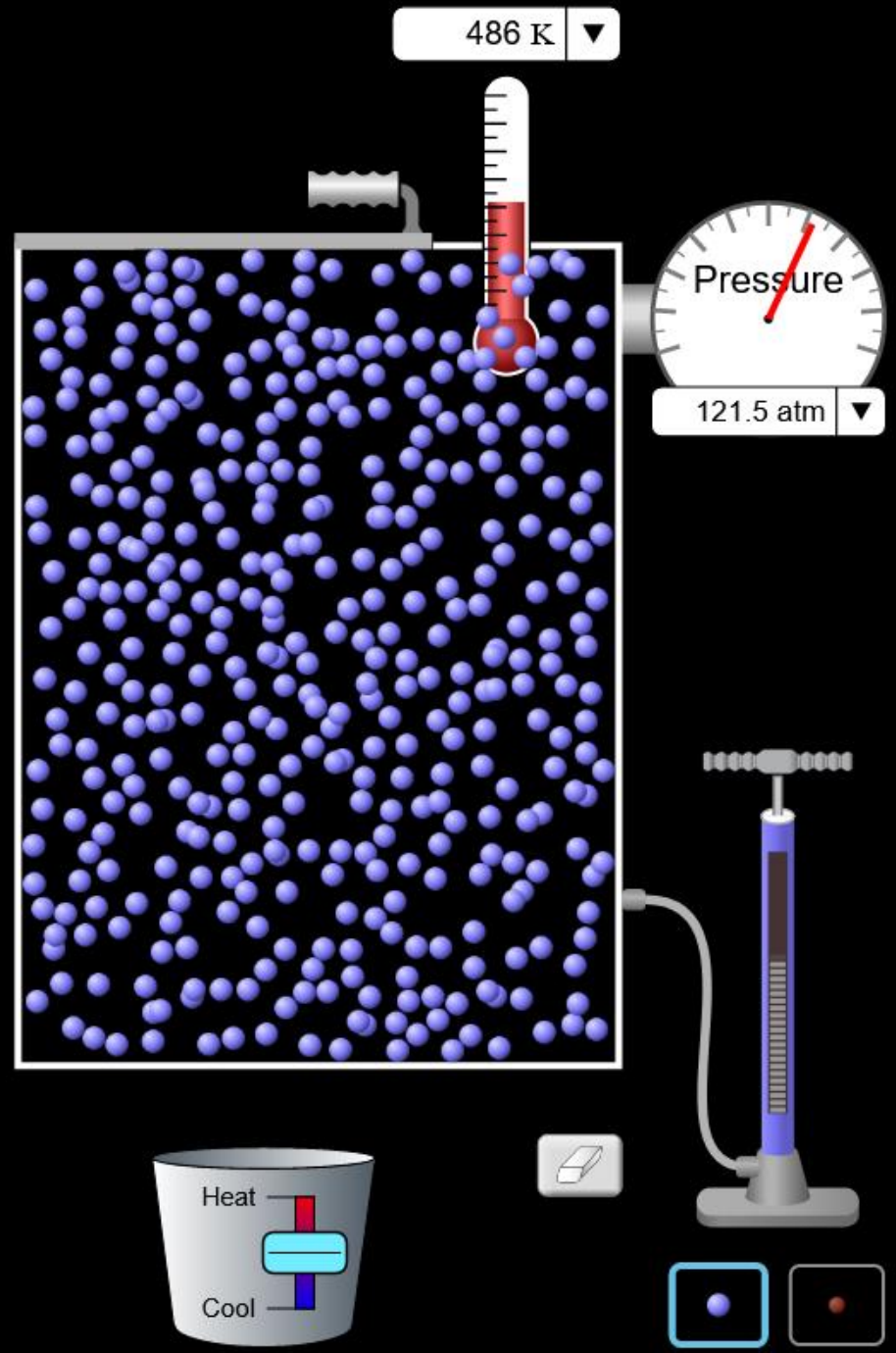


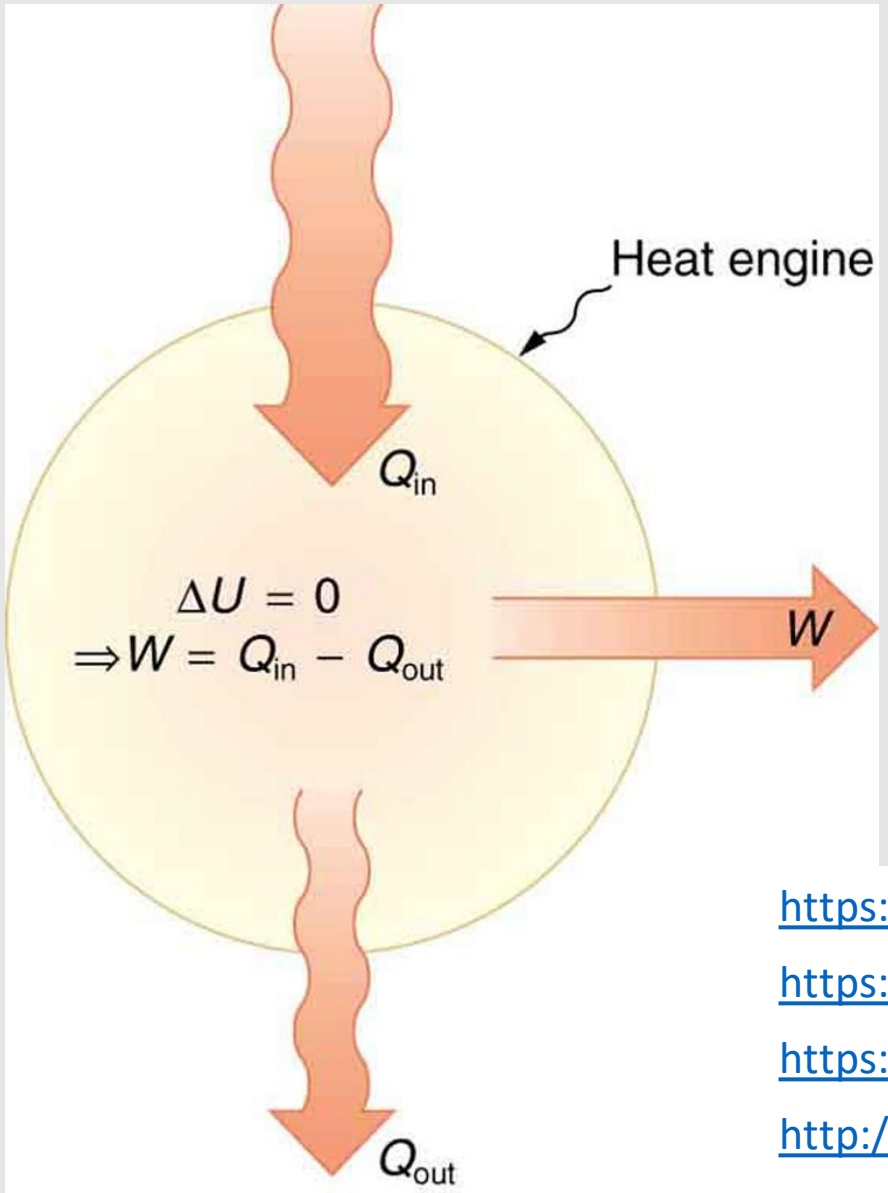




Q_{in}

Increase p and/or V





HEAT ENGINE

U= Internal (thermal) energy
ΔU= CHANGE in the internal energy
W= Work out (work done by engine)
Q_{in}= Heat in (heat source)
Q_{out}= Heat out (heat sink)

https://energyeducation.ca/encyclopedia/Energy_Education:Chapter_5

https://energyeducation.ca/encyclopedia/Engine

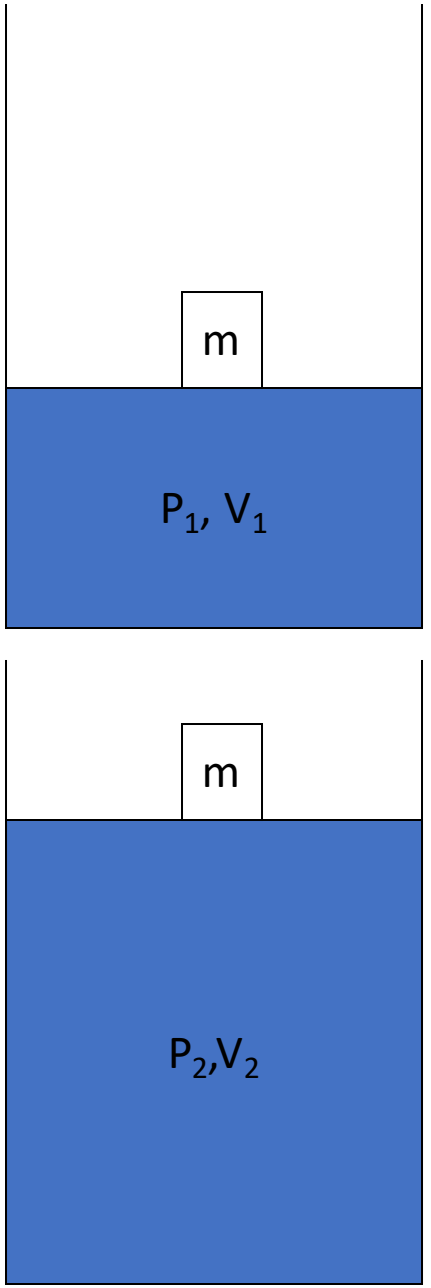
https://energyeducation.ca/encyclopedia/External_heat_engine

http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/heaeng.html

https://galileo.phys.virginia.edu/classes/152.mf1i.spring02/CarnotEngine.htm

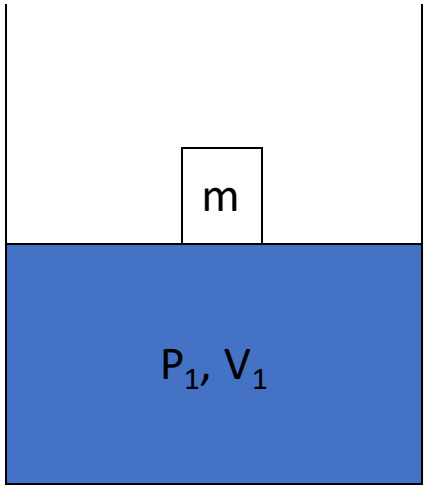
Pistons

- Place a mass on the top of a container held at a pressure and volume
- Make the gas expand
- Gas pushes the mass up.

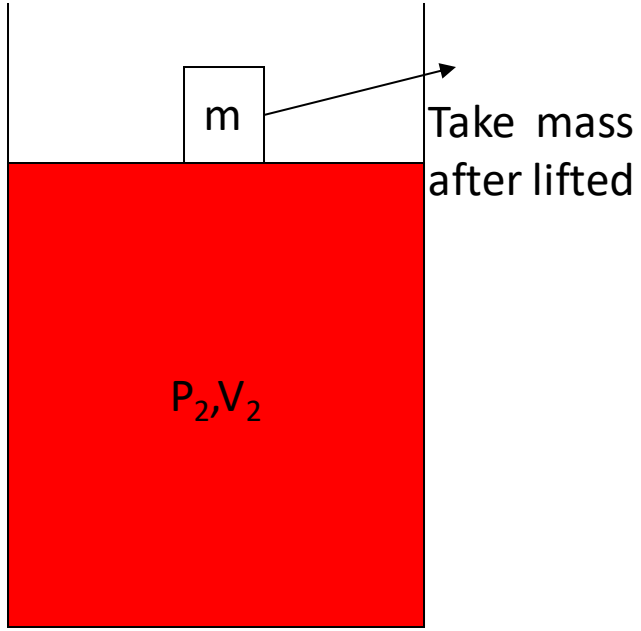


Source of heat

- Find a source of heat, to expand the gas.
- Piston pushes some distance.
- Getting work out of a gas.

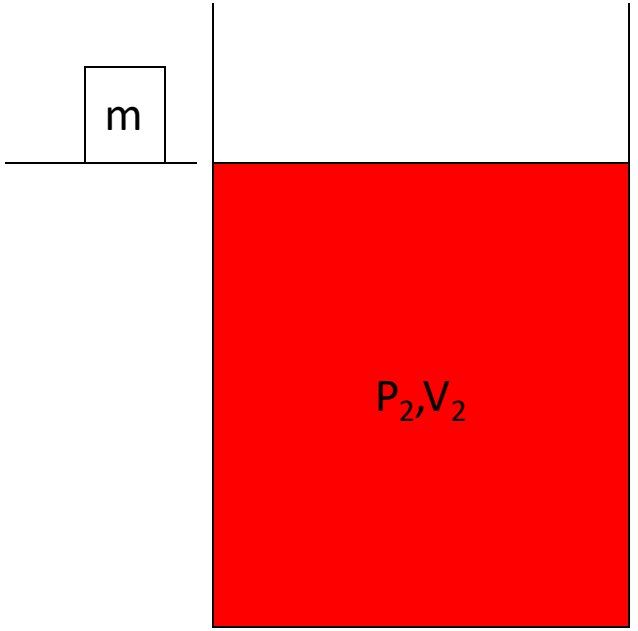


Heat into the system



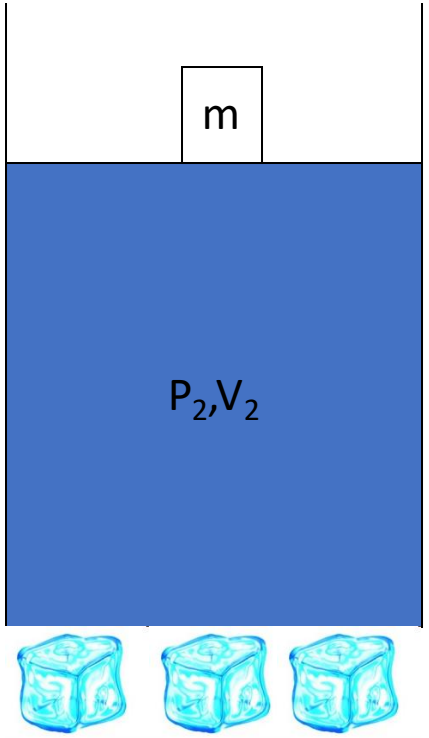
Only works once?

- Gas expanded: got the work out.
- Took off the mass.
- We want to repeat the process



Take heat out!

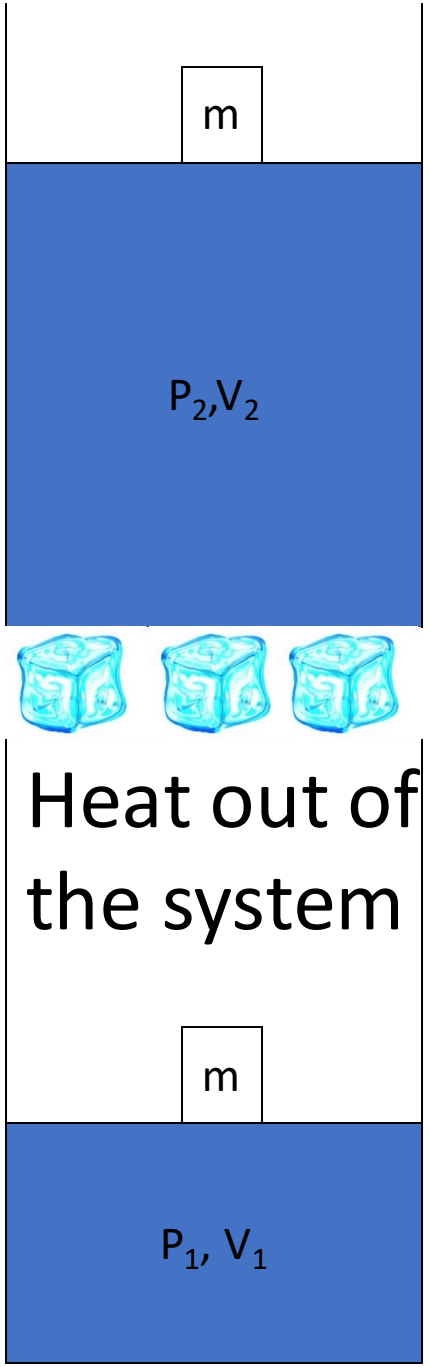
- Removing heat contracts the gas reduce V (and usually p too)



Heat out of the system

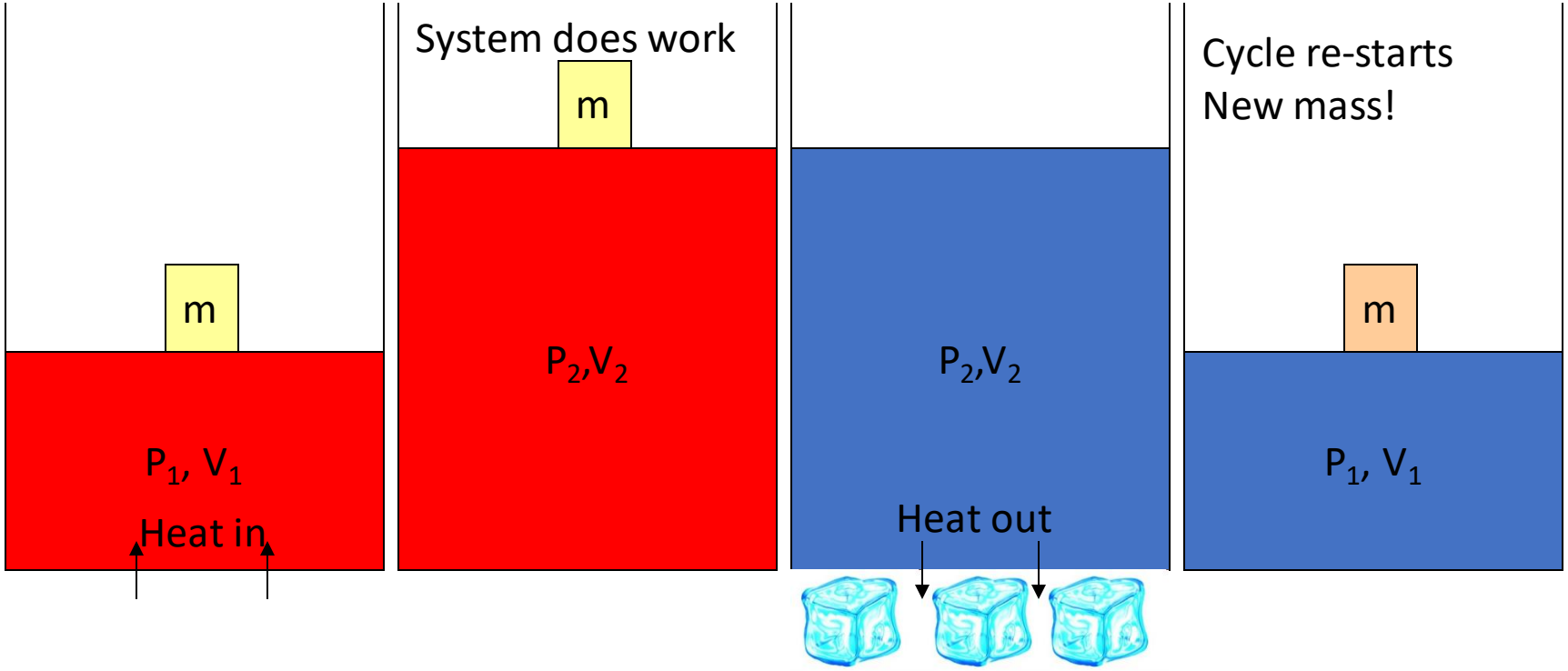
A cycle

- Back to where we started.
- Repeat as desired.



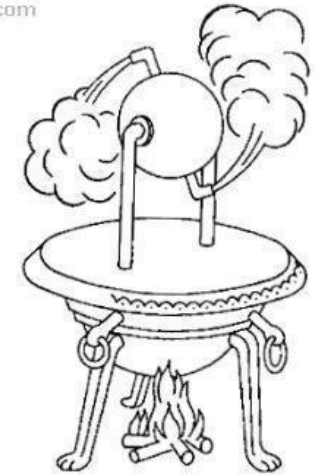
The concept of a heat engine

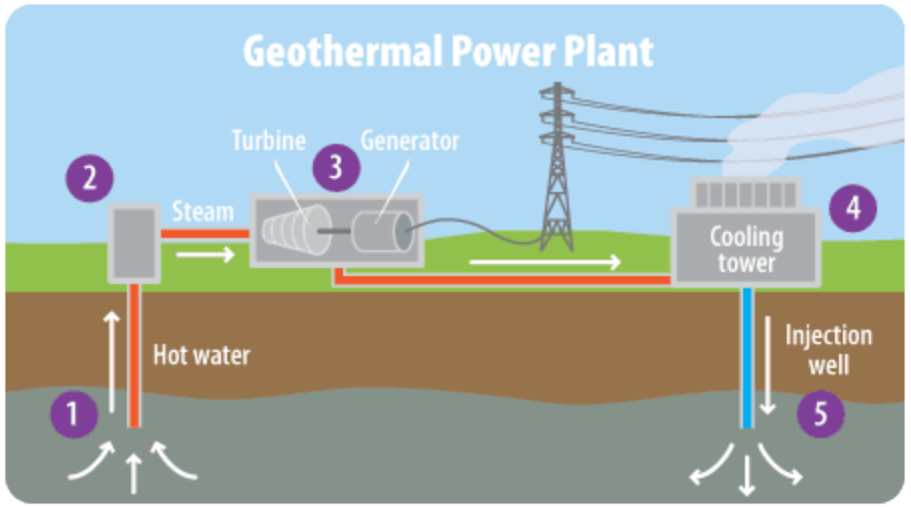
- Some heat is converted to useful work (but not all).
- Basically, any heat source will work

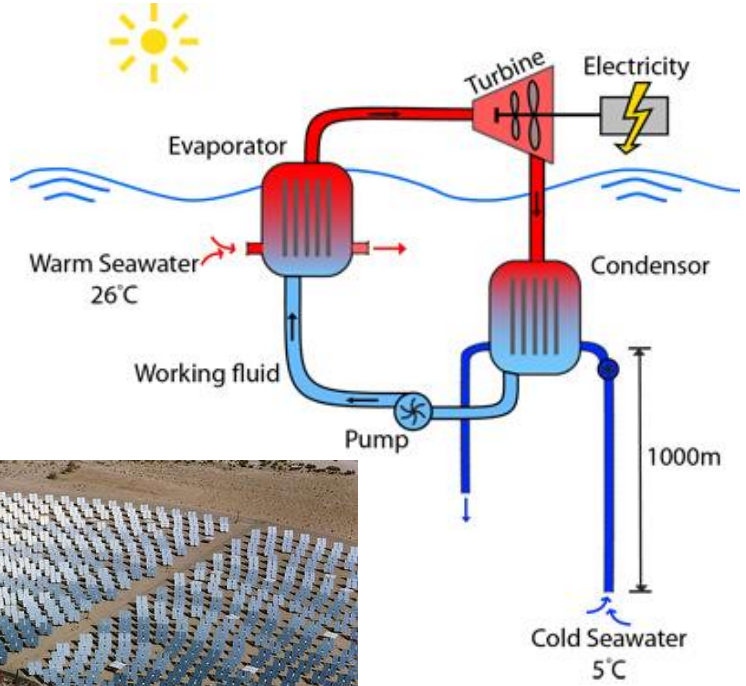


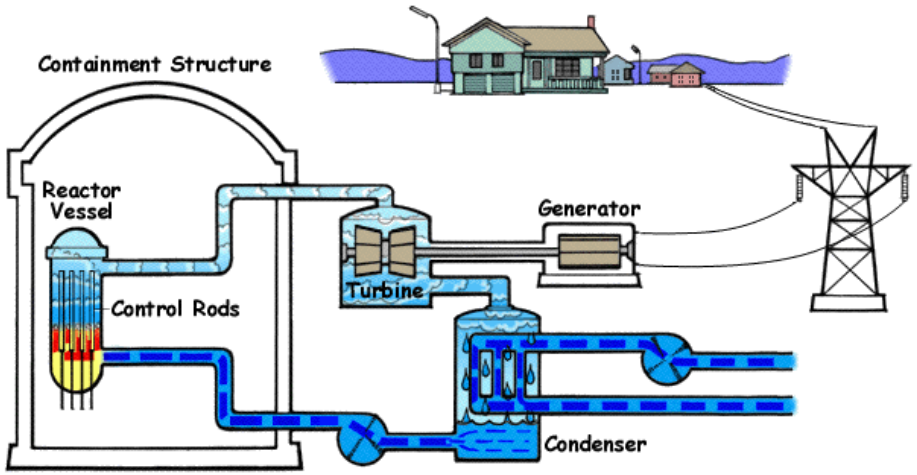
Heat outside engine: External heat engine





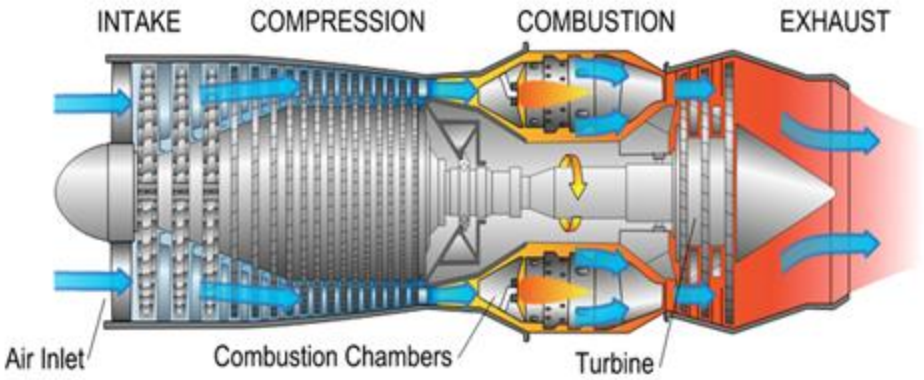


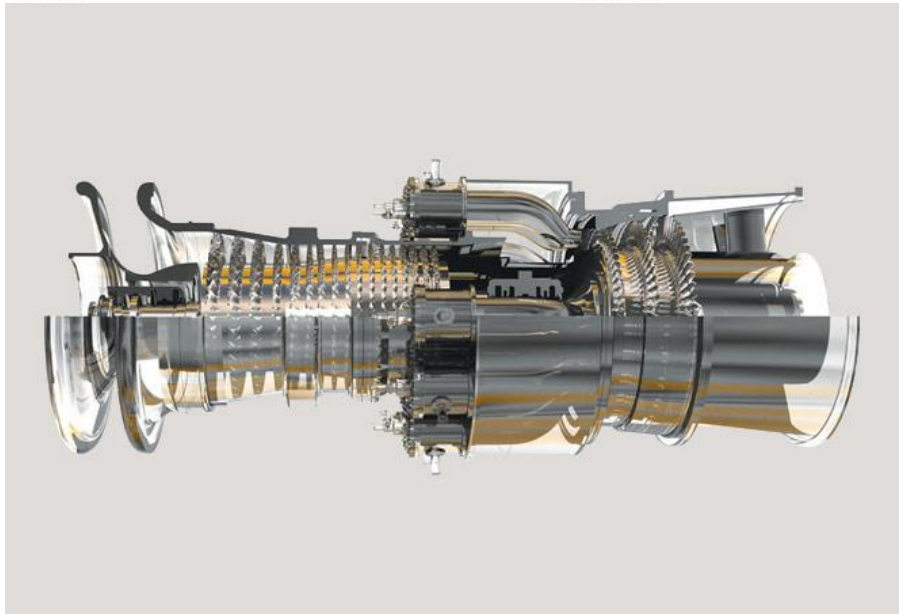


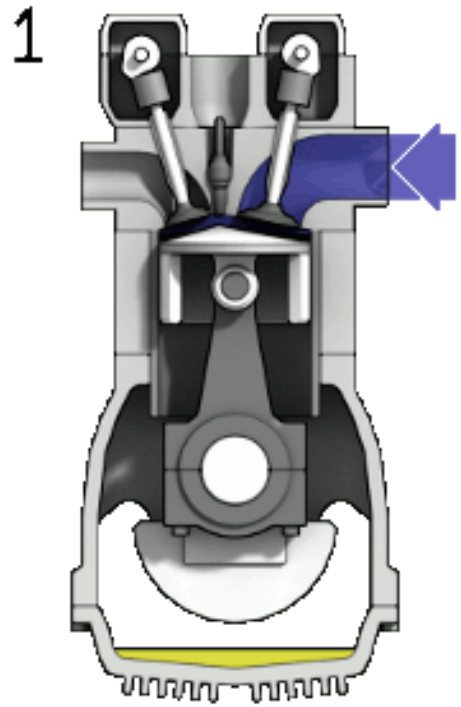


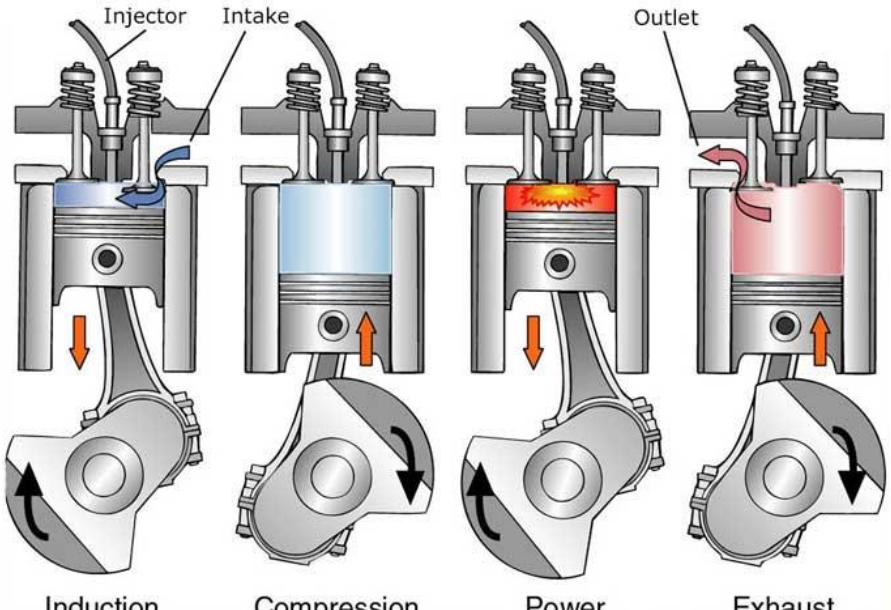


Heat from inside:
Internal combustion engine

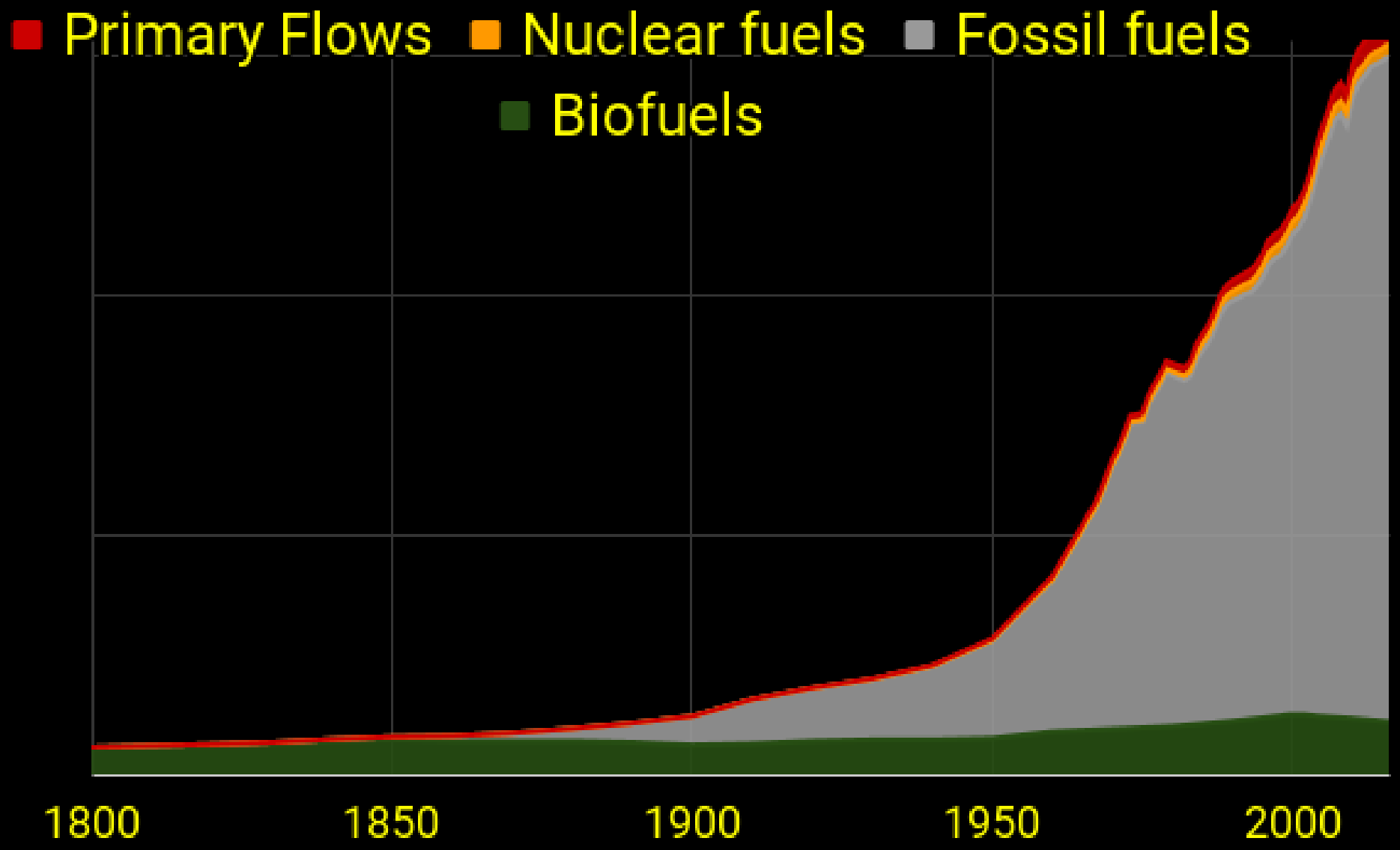




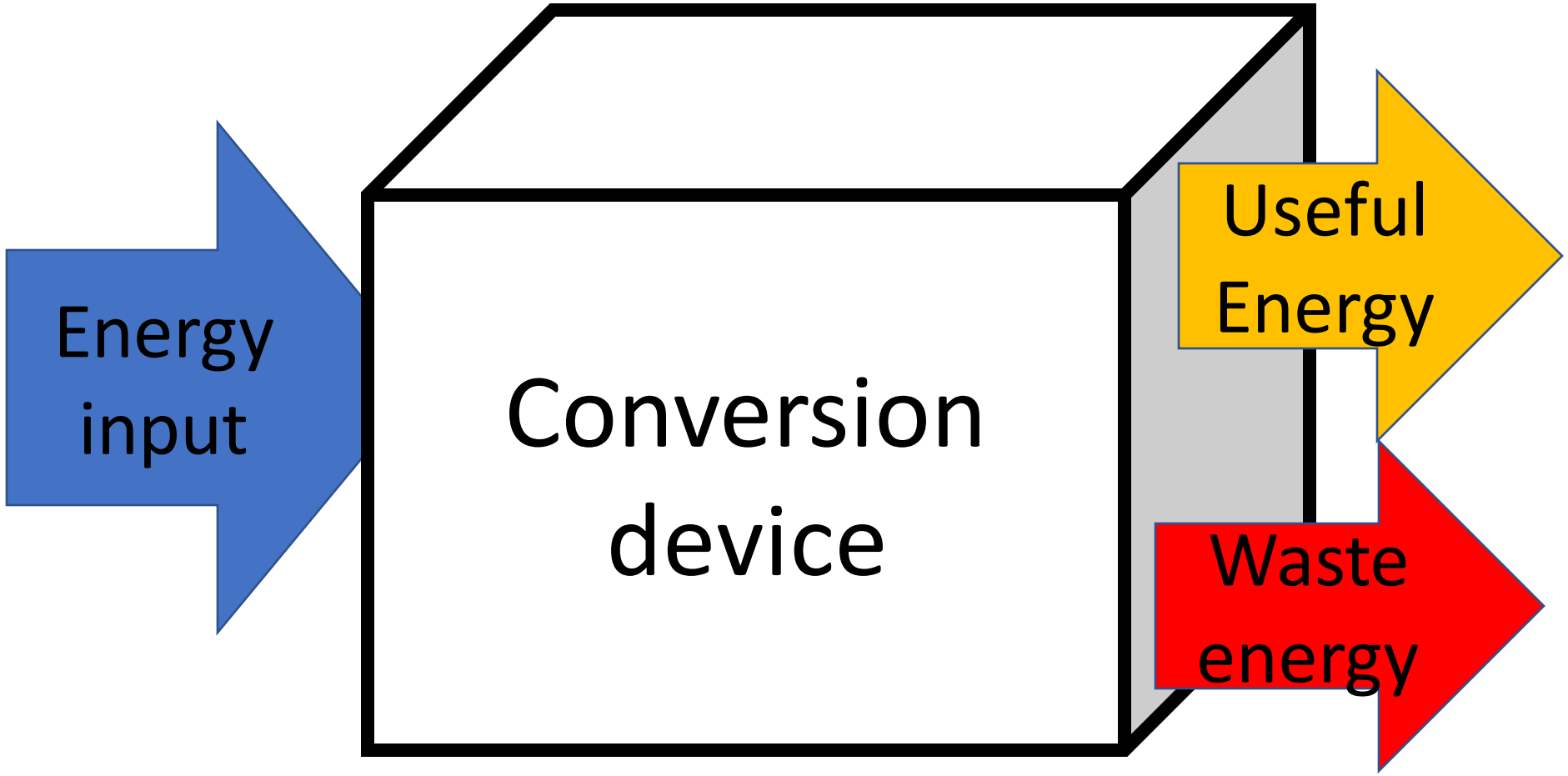




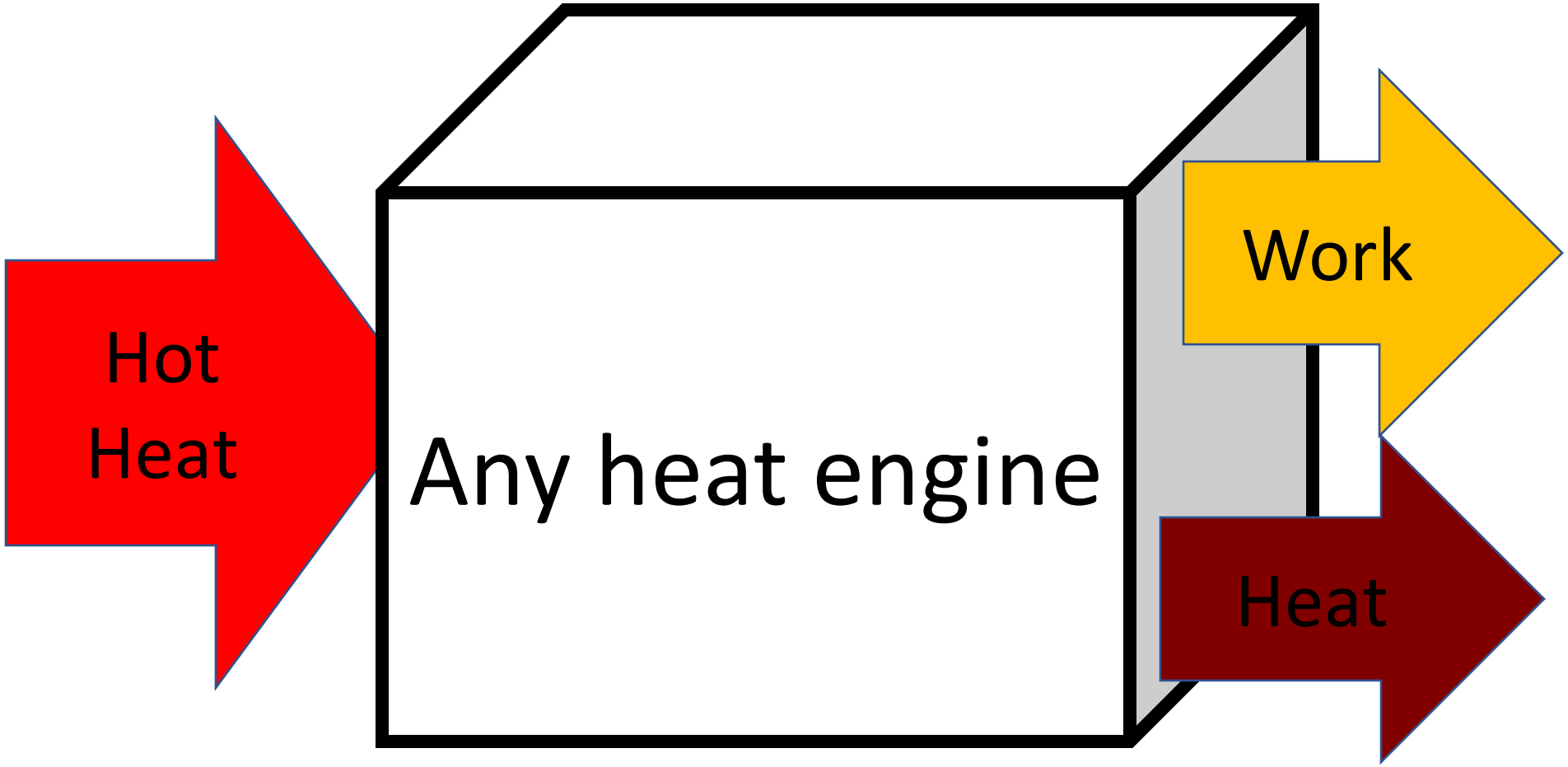
Heat engines are everywhere



Model: Efficiency quantifies useful fraction of energy

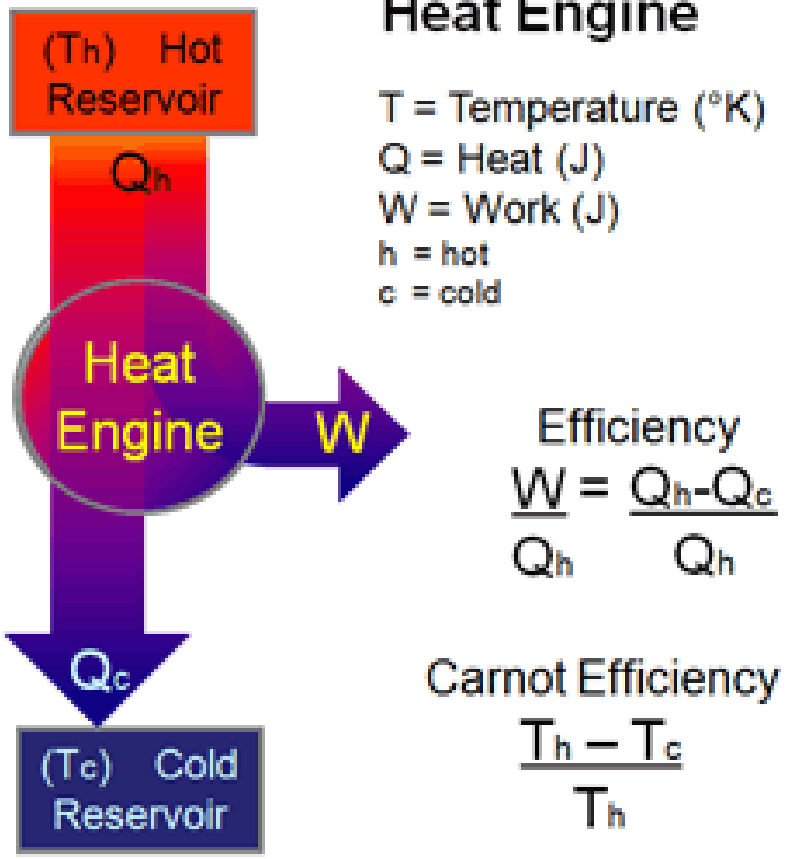


Work efficiency η_W: fraction of heat turned into work in a heat engine.



HEAT ENGINE

https://energyeducation.ca/encyclopedia/Carnot_efficiency



Heat Engine

T = Temperature (°K)
Q = Heat (J)
W = Work (J)
h = hot
c = cold

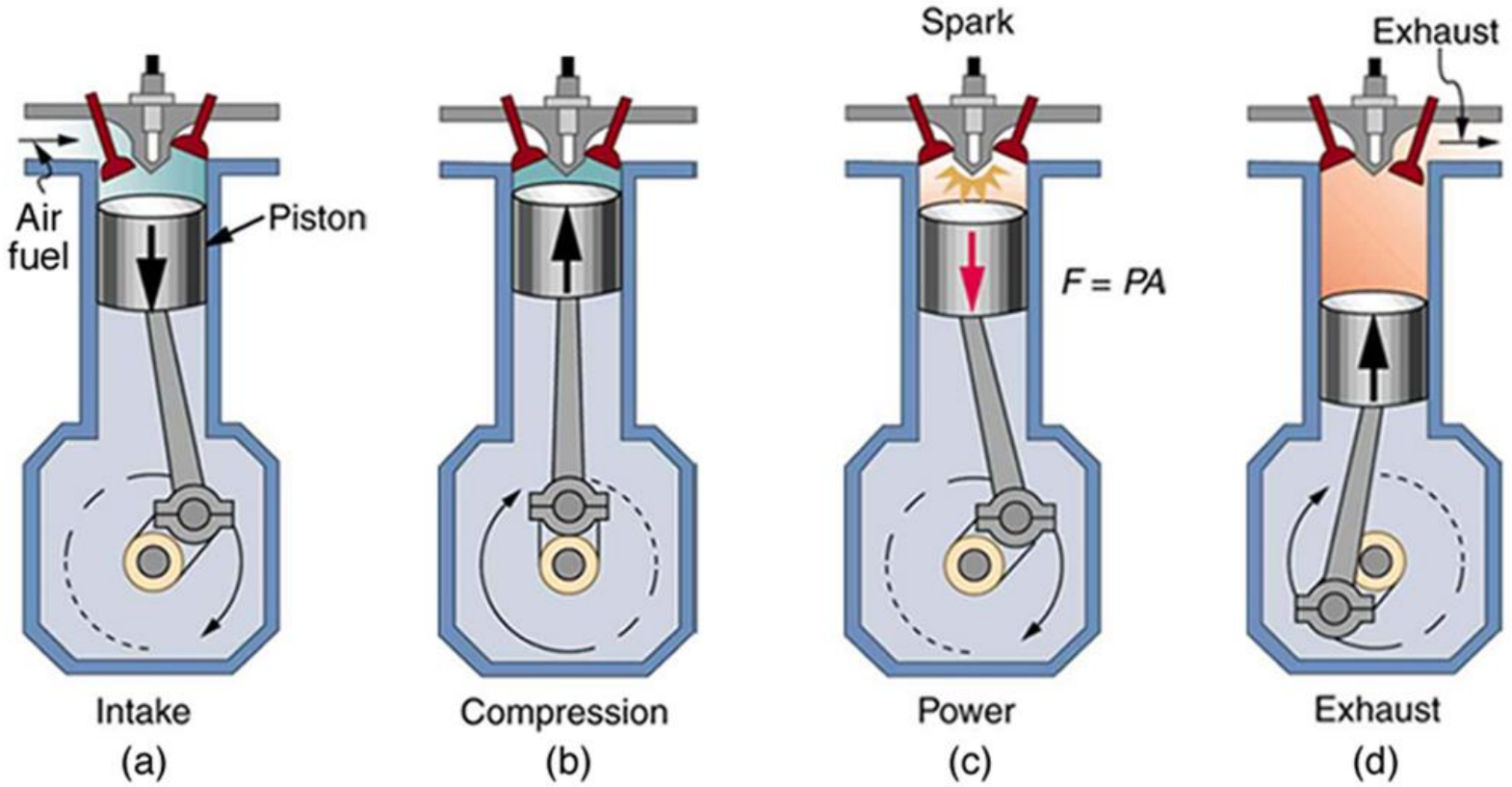
Efficiency

$$\frac{W}{Q_h} = \frac{Q_h - Q_c}{Q_h}$$

Carnot Efficiency

$$\frac{T_h - T_c}{T_h}$$

This Photo by Unknown author is licensed under CC BY.



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https://energyeducation.ca/encyclopedia/Piston

https://energyeducation.ca/encyclopedia/Waste_heat

Heat engine efficiency

$$\eta_w = \frac{\text{Work out}}{\text{Heat in}}$$

η is always less than 1.

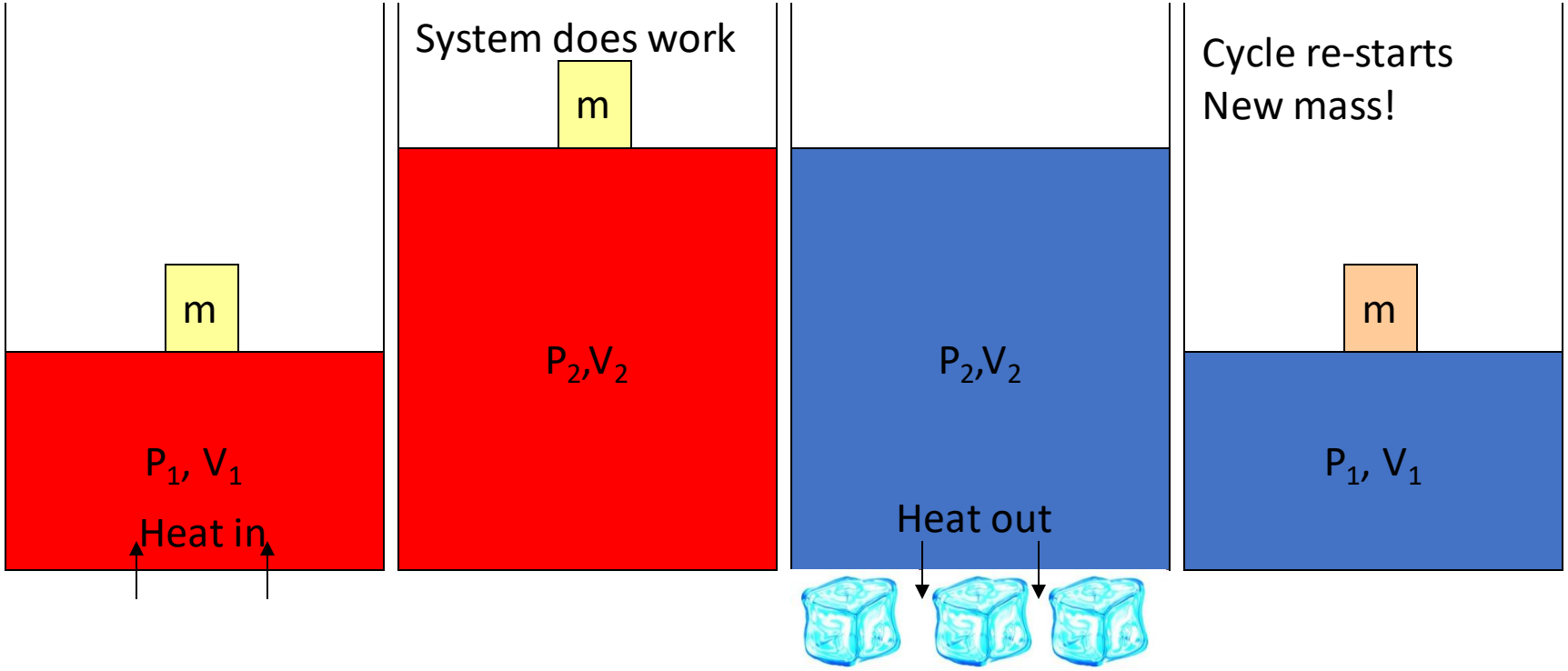
$$\text{Primary energy} \times \eta = \text{Work}$$

$$\frac{(\text{Work})}{\eta} = \text{Primary energy}$$

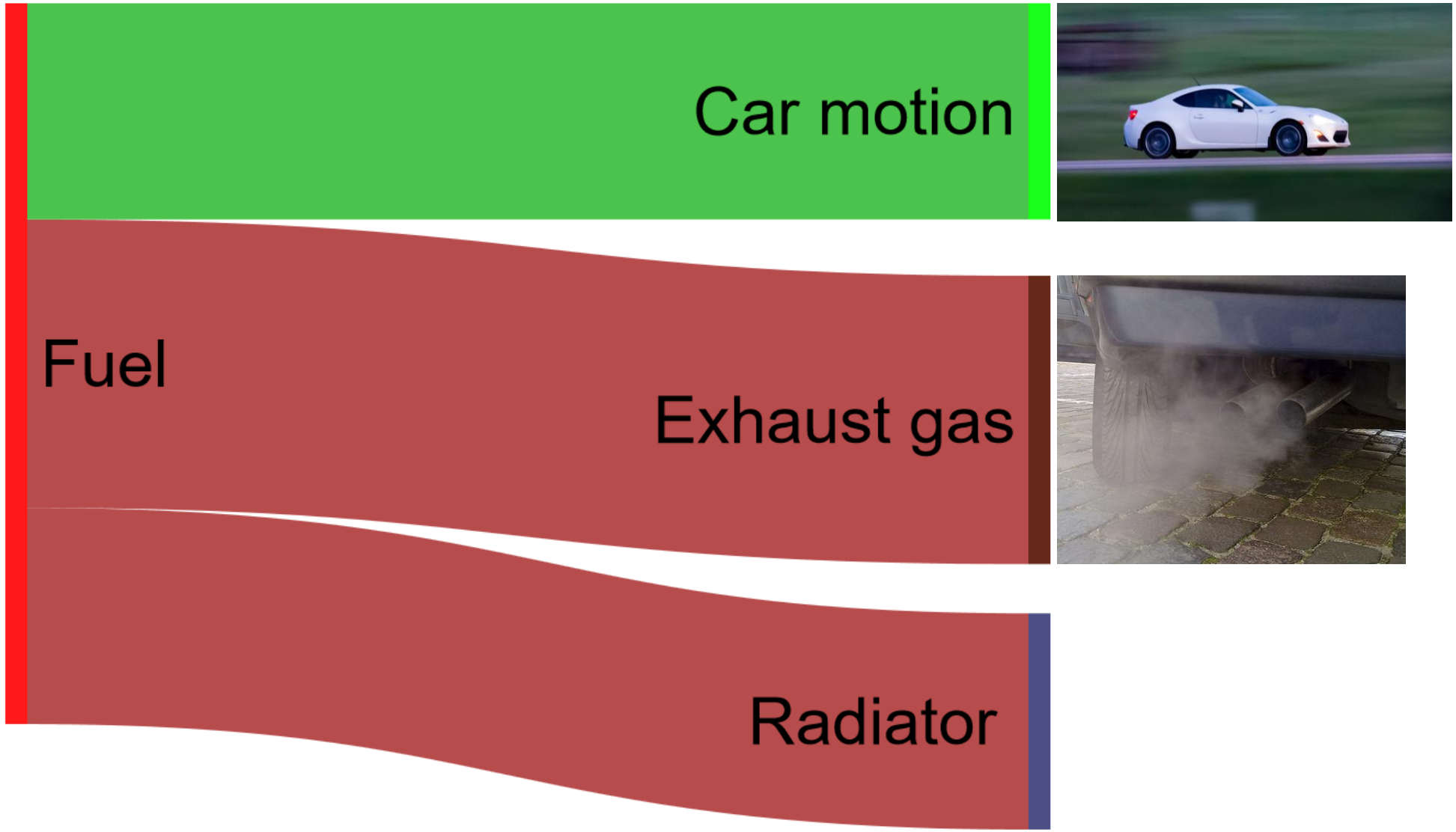
Heat engine efficiency

- Some heat is converted to useful work, but not all.

$$\eta_w = \frac{\text{Work out}}{\text{Heat in}}$$

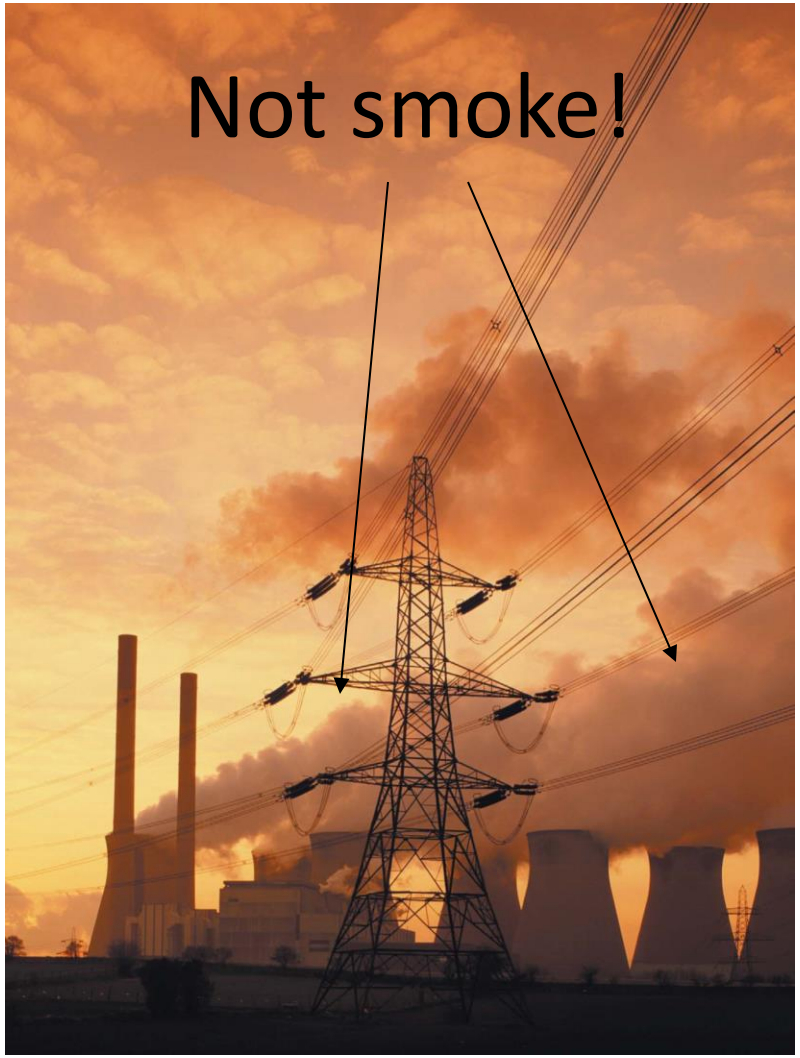


Motion of car



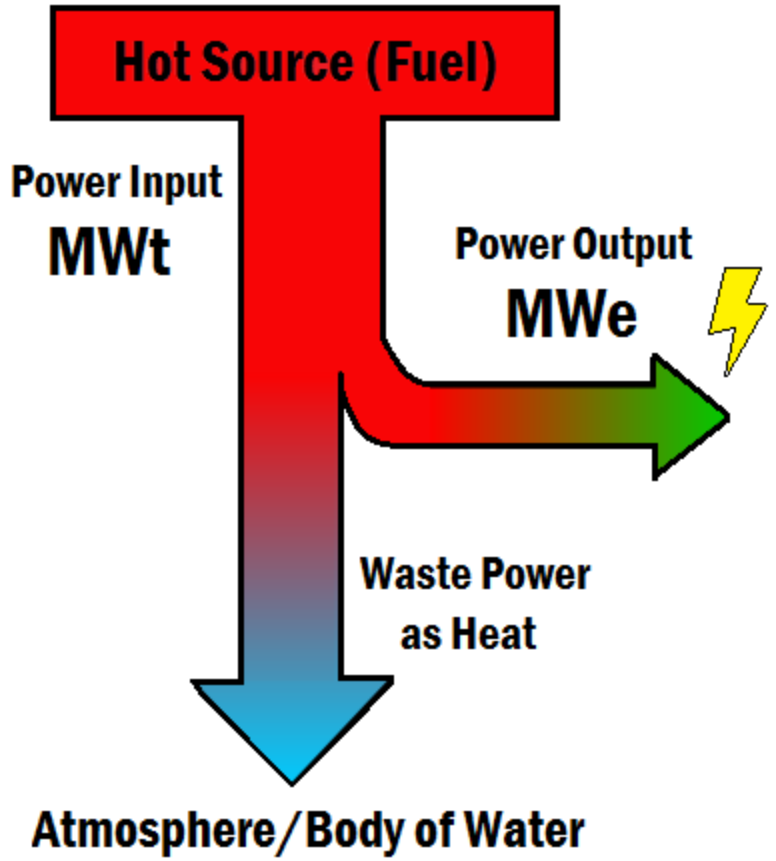
Dump water into the air

- Water vapor rises from the cooling towers.
- Power plants generate electricity by turning heat into work.



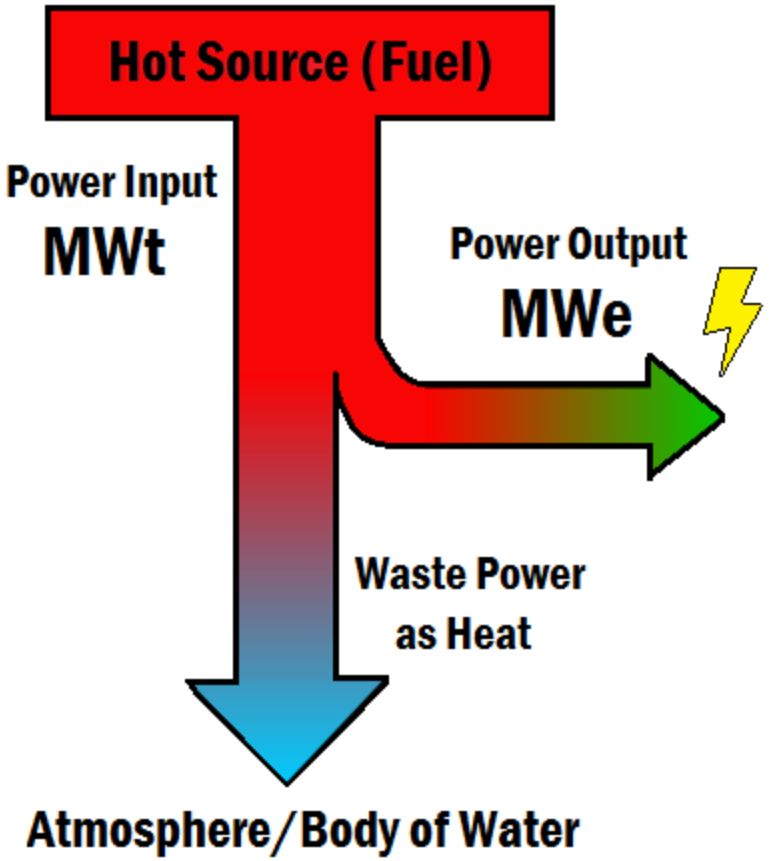
Modified model: Heat engines need heat, give work and waste heat

- T_H any source
  - Geothermal
  - Fossil fuels
  - Nuclear fuels
- T_c needs to stay cold
  - Should be *big*.
  - Waste heat always goes into that cold sink



Model: Heat engines give off waste heat

- How much waste heat needs to be given off?



Carnot engine

- Theoretical upper limit to heat engine efficiency

$$\eta_c = 1 - \frac{T_c}{T_h}$$

- Real engines always less than Carnot

$$\eta_w < \eta_c$$

$$\frac{W_{out}}{Q_{in}} < 1 - \frac{T_c}{T_h}$$

Real heat engines

$$\eta < \eta_{carnot}$$

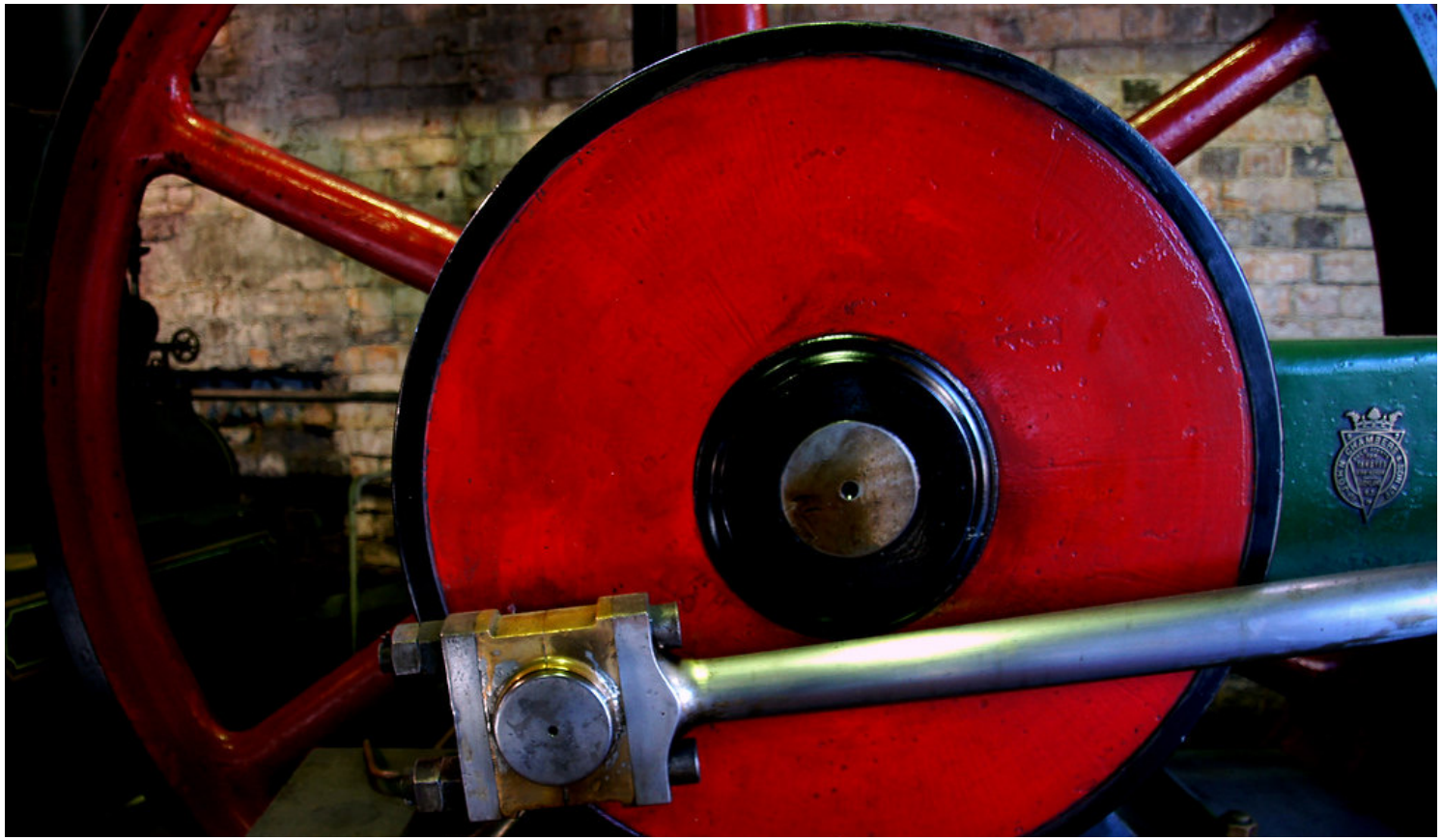
Type	T_h (K)	T_l (K)	Carnot (η_c)	Actual (η)	η/η_c
Coal	800	300	62.5%	35%	0.56
Nuclear	1200	300	75%	35%	0.47
Geo.	525	350	33%	16%	0.48

Wrapping it all together

Read:

http://matterandinteractions.org/wp-content/uploads/2016/07/Supplement1-Gasesandheatengines.pdf

http://animatedengines.com/

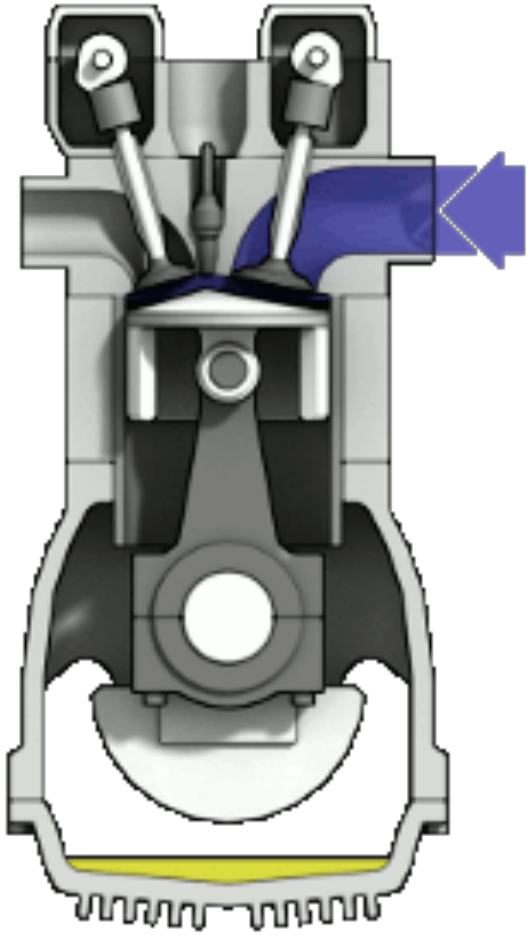


PHYS 371
Introduction to Energy

- LECTURE 20: HEAT ENGINES
- FRIDAY, OCTOBER 29, 2021
- (CUT OFF FOR MIDTERM 2)

Heat engines

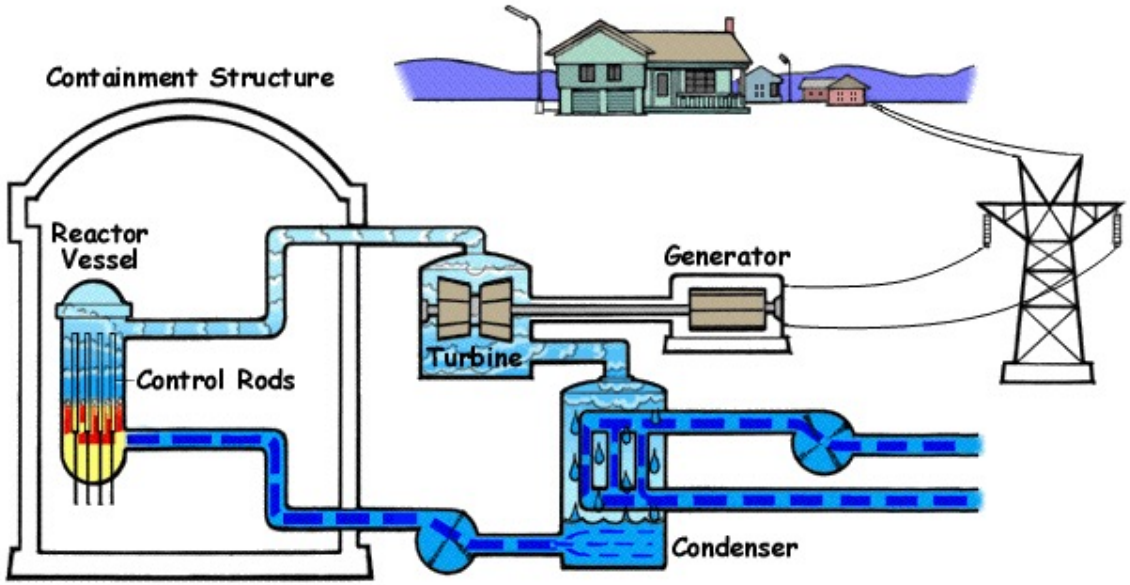
1



Run:

Power plants (most types)

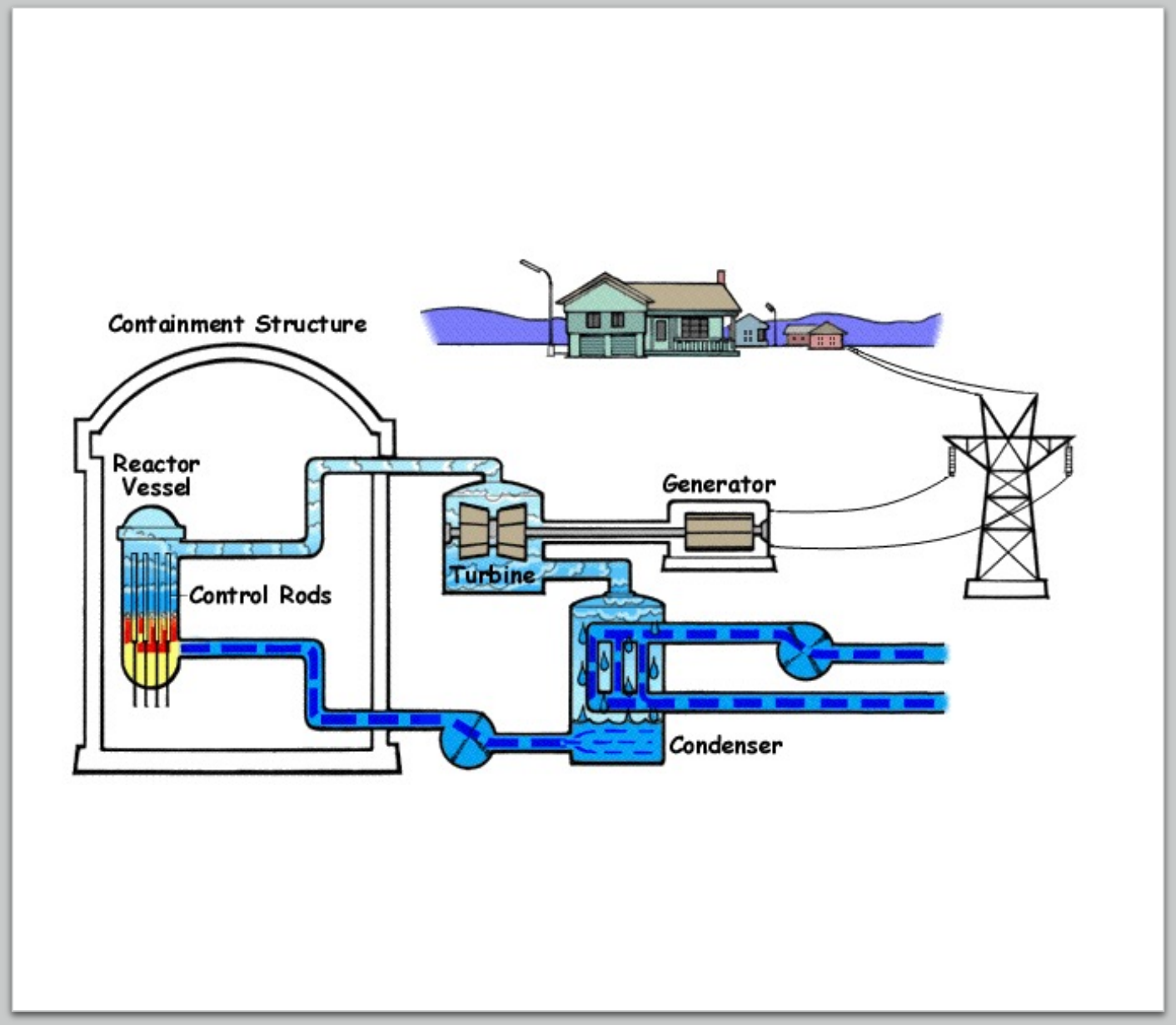
Cars, planes, boats, submarines



Overview – This week

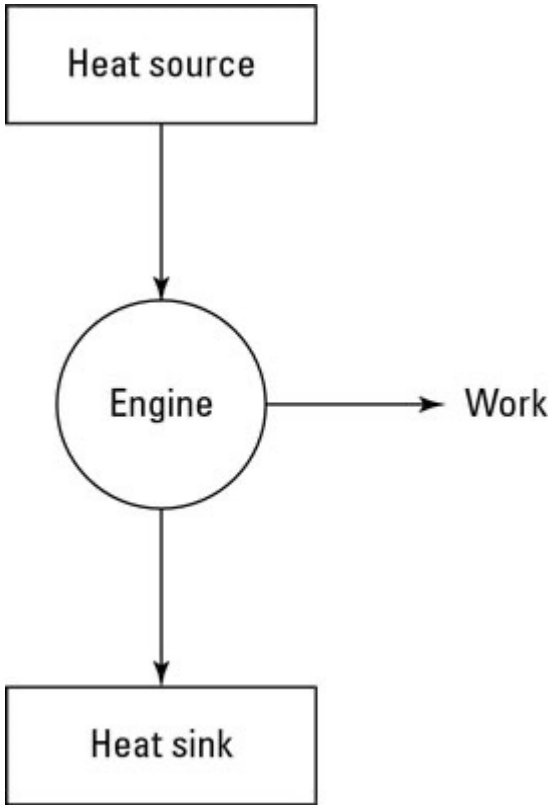
- ❑ **Fluids.** Machine for motion. Turbines
- ❑ Heat engines
- ❑ Efficiency
- ❑ Cogeneration
- ❑ (maybe) Refrigerators

- Next Week:
- Electricity. Electricity production. Power plants



Heat Engine

A heat engine turns heat into work.



Engines that rely on a heat source to do work are called *heat engines*.

A ***heat source*** provides heat to the engine, which does ***work***. The waste heat left over goes to a ***heat sink***.

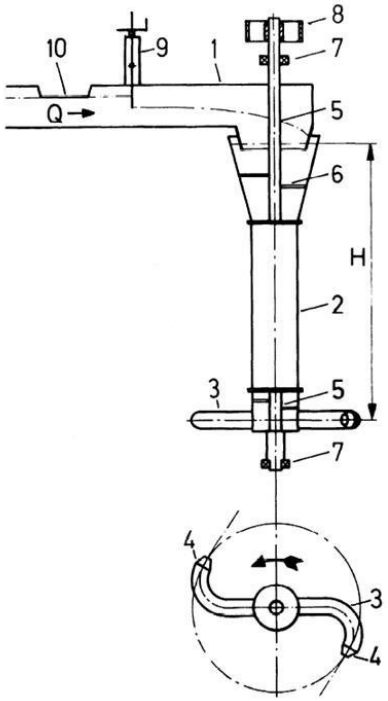
We will discuss all this at the end of this lecture and on Friday, once we have learned all the required background information and knowledge needed

Ancient technology!

~2000 years old!

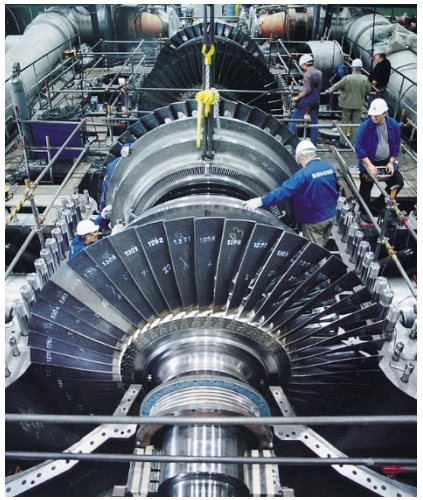


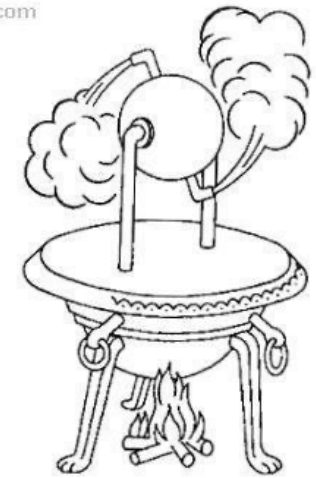
Hero’s Aeolipile

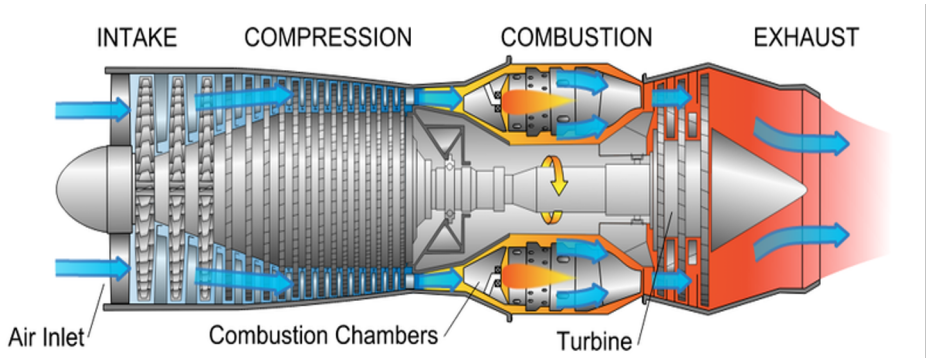


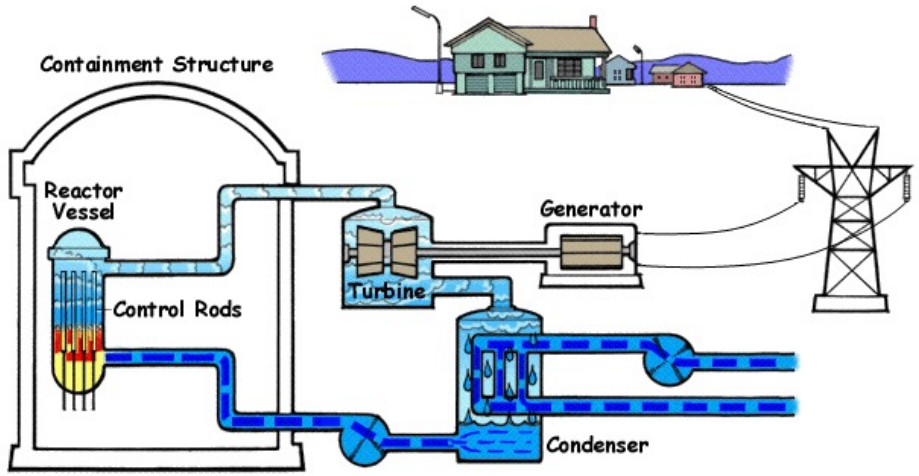
Segner Wheel

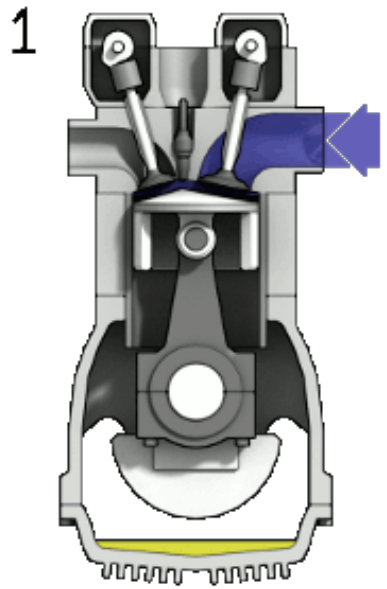
Model: Heat adds energy to fluids.











Heat engines

Almost all of our energy is harvested by using heat engines.

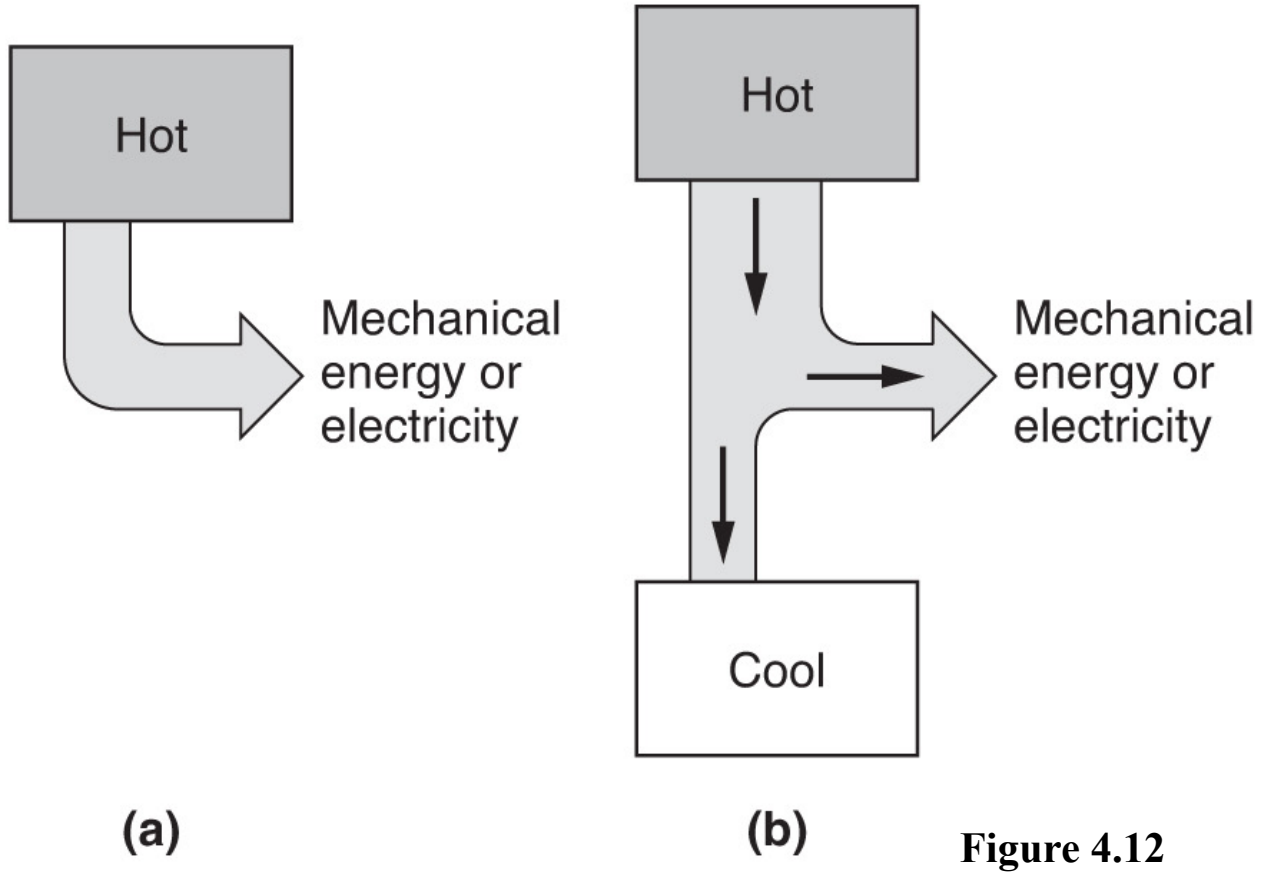


Figure 4.12

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How much work?

- If we send in 200 kJ of heat, and get out 130 kJ of waste heat, how much work did we get out, in kJ?

The energy must go somewhere!

$$200\ \mathrm{kJ} - 130\ \mathrm{kJ} = 70\ \mathrm{kJ}$$

Our efficiency

$$\eta = \frac{\text{Work out}}{\text{Heat in}}$$

η is always less than 1.

$$\text{Primary energy} \times \eta = \text{End use}$$

$$\frac{(\text{End use})}{\eta} = \text{Primary energy}$$

Different question

- If we send in 200 kJ of heat, and get out 130 kJ of waste heat, how much work did we get out, in kJ?
- What's our efficiency?

Find the efficiency

- η = ?
- If we send in 400 kJ of heat and get out 350 kJ of heat, what's the efficiency?

The Limits of Efficiency

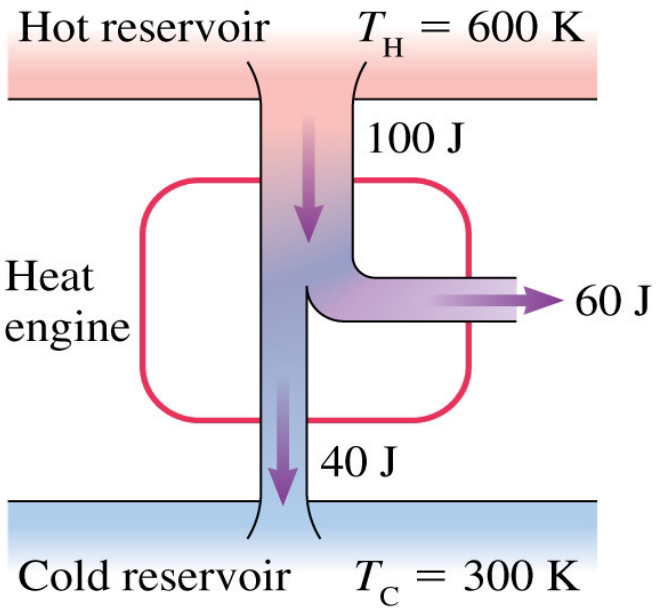
Everyone knows that heat can produce motion. That it possesses vast motive power no one can doubt, in these days when the steam engine is everywhere so well known. . . . Notwithstanding the satisfactory condition to which they have been brought today, their theory is very little understood. The question has often been raised whether the motive power of heat is unbounded, or whether the possible improvements in steam engines have an assignable limit.

Sadi Carnot

The result!
Theoretical efficiency
Only for Carnot engine

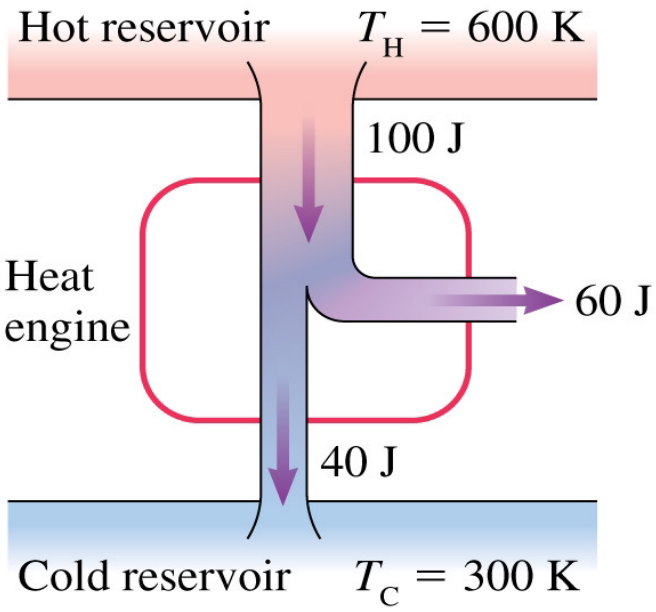
$$\eta = 1 - \frac{T_c}{T_H}$$

Could this heat engine be built?



A. No.
B. Yes.
C. It's impossible to tell without knowing what kind of cycle it uses.

Could this heat engine be built?



✔ **A. No.**

B. Yes.

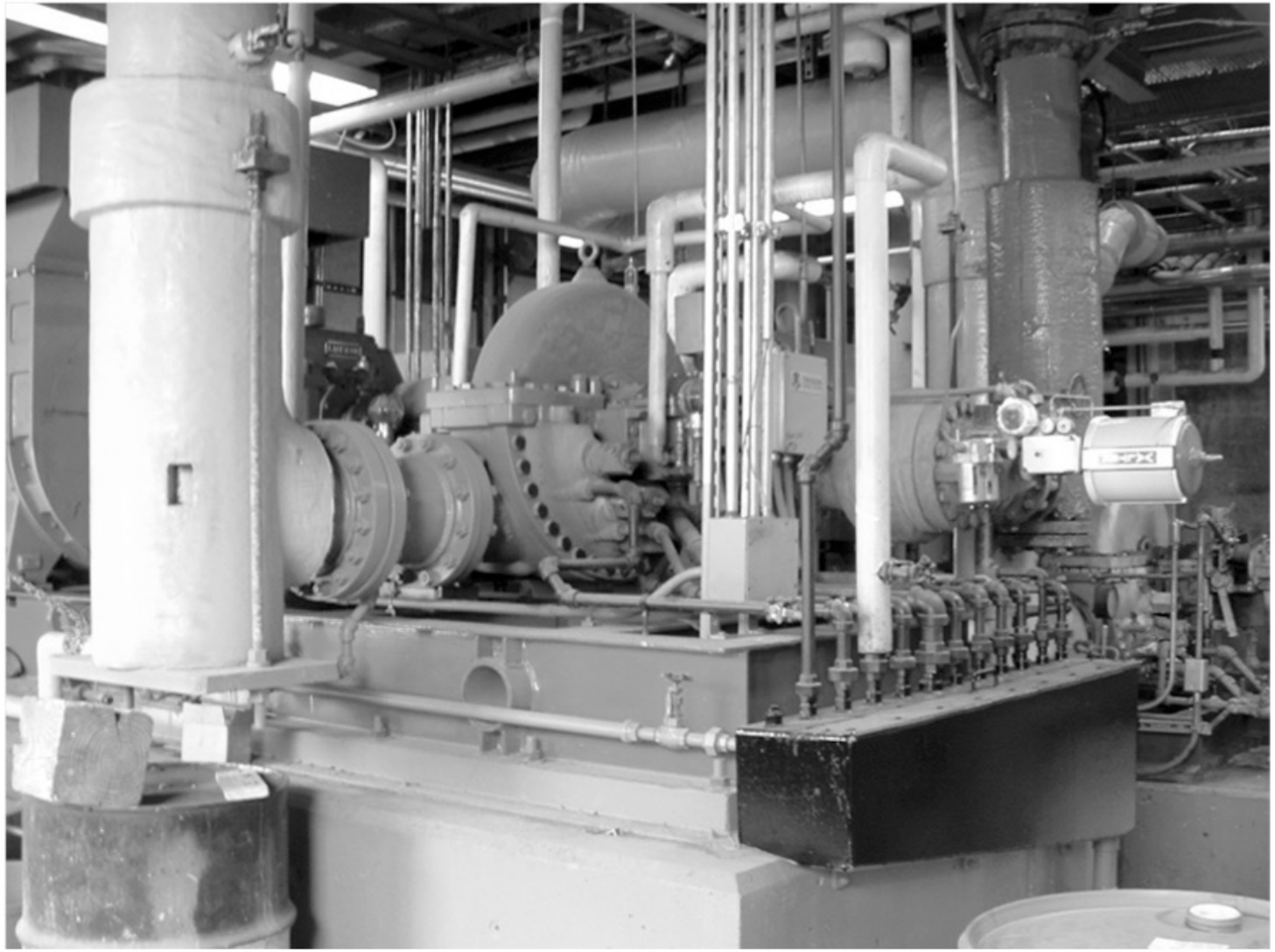
C. It's impossible to tell without knowing what kind of cycle it uses.

Cogeneration

- Cogeneration means using the heat for other processes.
  - Heating homes
  - Industrial processes
  - Processing bitumen

- BUT! The heat can’t travel far.

Cogen plants get work and use heat



Different types of engines

- External combustion engine
- Internal combustion engine
  - Continuous combustion
  - Intermittent combustion

How is an internal combustion engine different from an external combustion engine?

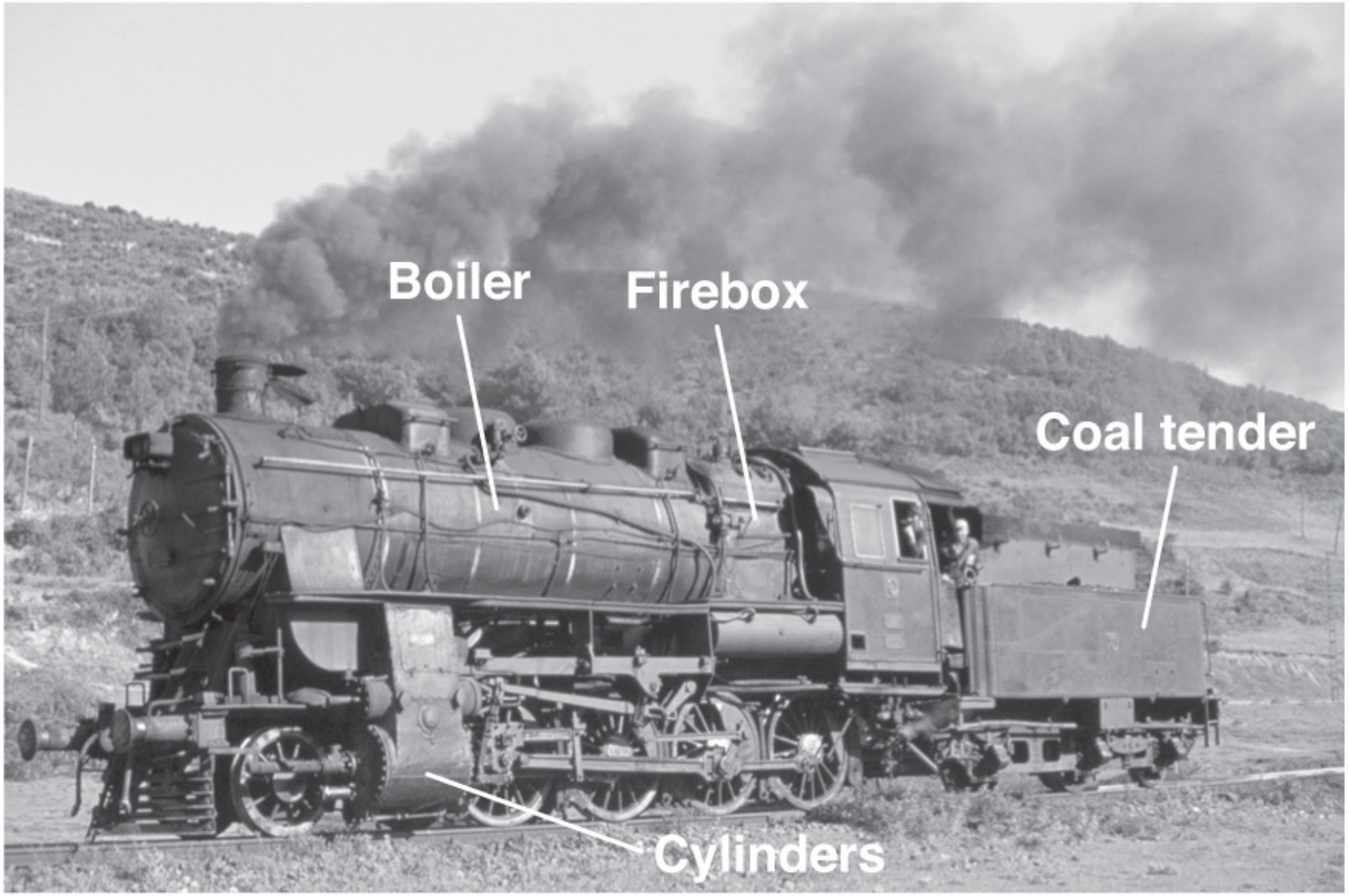
External combustion engine

- Fuel heats water outside of piston.
- Were used for transportation, but too inefficient.
- Still used for power plants.
  - Coal
  - Nuclear
  - Natural gas

Parts of steam locomotive

- Fuel (coal)
- Firebox (where the coal is burned)
- Boiler (the water boils)
- Cylinders (steam expands and pushes the wheels forward)

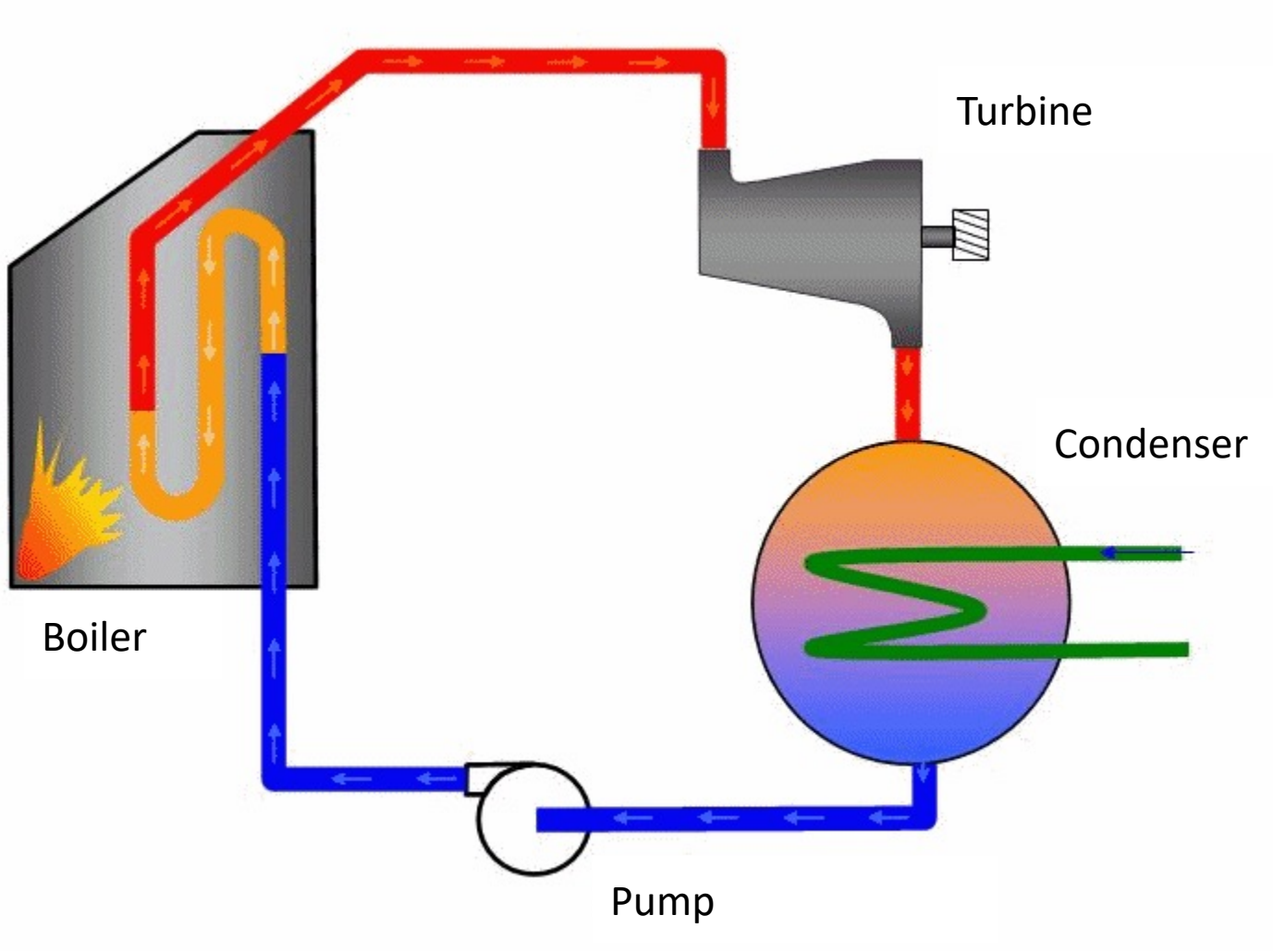
~1930 Steam locomotive



External combustion for power plants

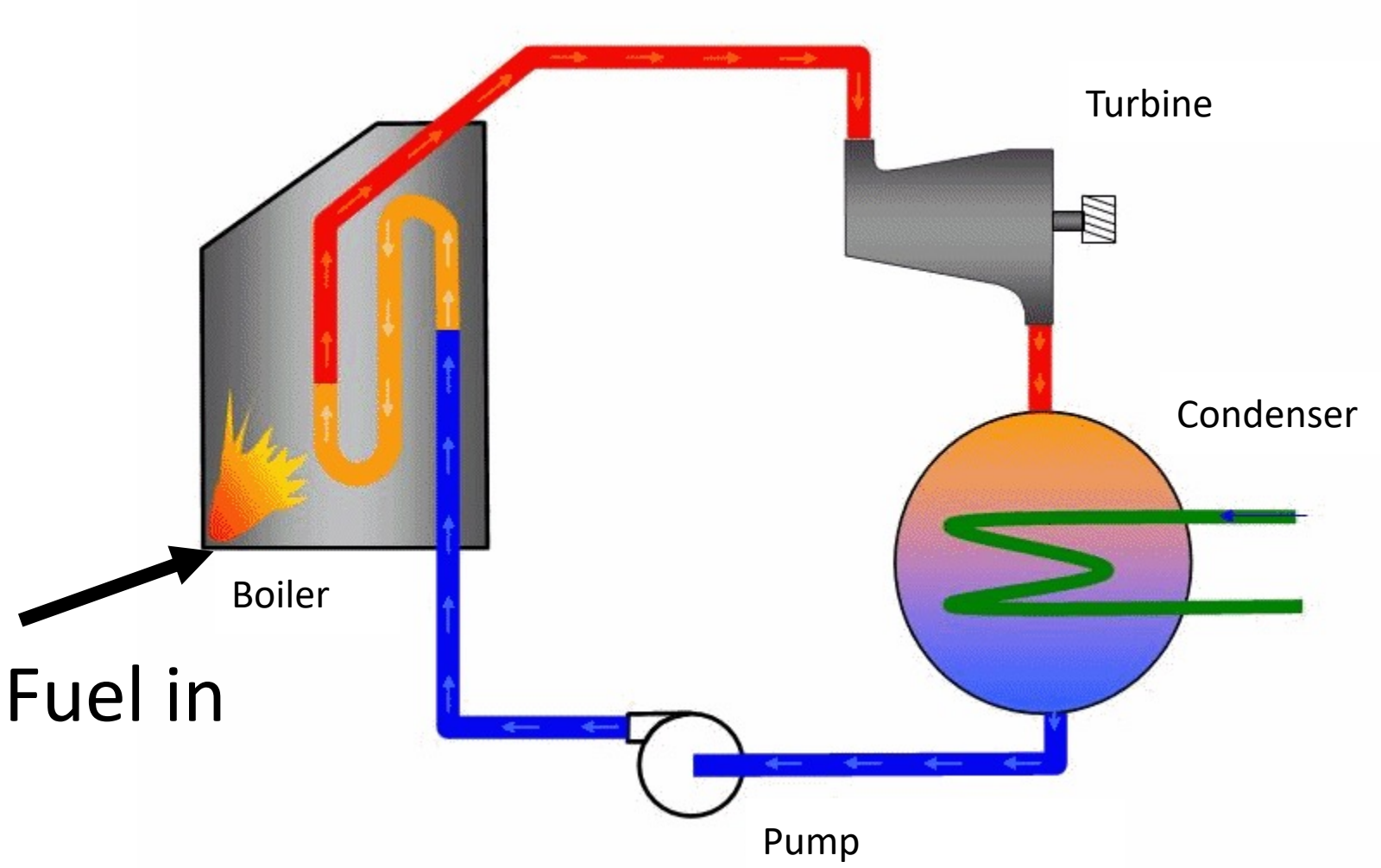
- Fuel (coal, natural gas, uranium, etc.)
- Boiler (where the water is boiled)
- Stack (CO_2 leaves, or other pollutants, not for nuclear plant)
- Turbine (steam pushes this around)
- Generator (makes electricity)
- Condenser (cools steam to repeat cycle)
- Cooling tower (Waste heat to atmosphere)

Steam Turbine



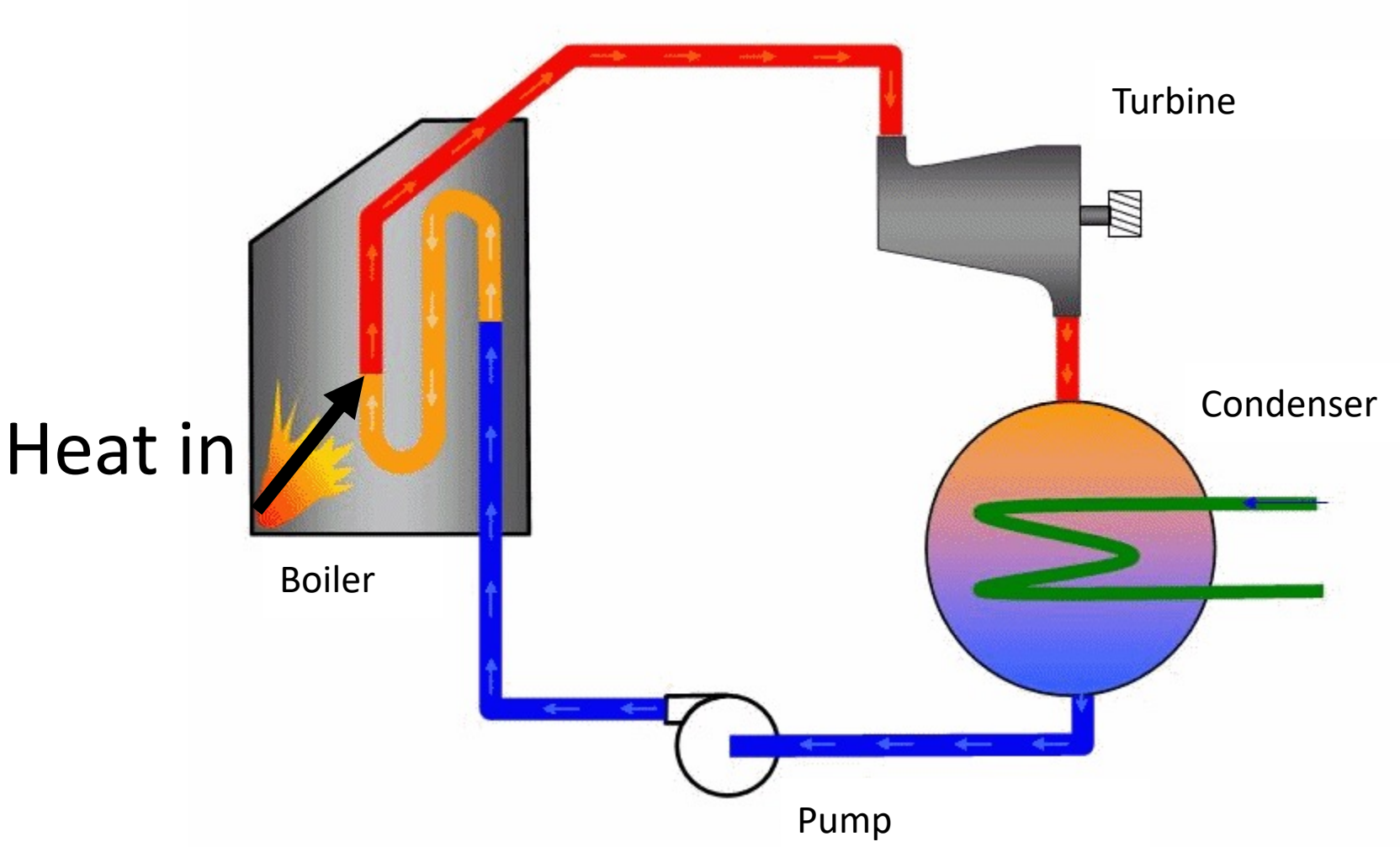
Source: http://e-learning.kku.ac.th/course/view.php?id=470&cal_m=3&cal_y=2008

Fuel runs boiler



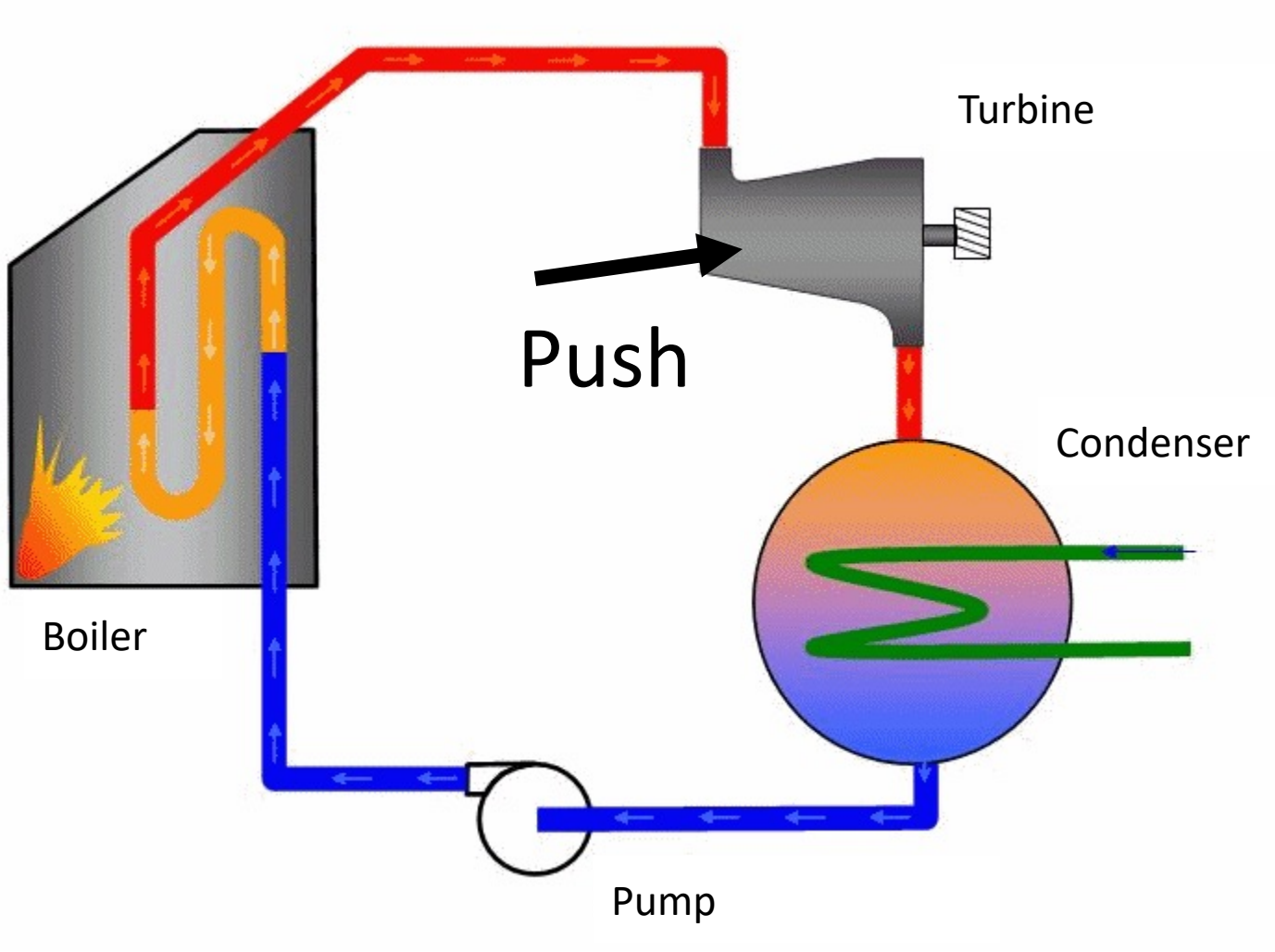
Source: http://e-learning.kku.ac.th/course/view.php?id=470&cal_m=3&cal_y=2008

Boiler heats water (Heat In)



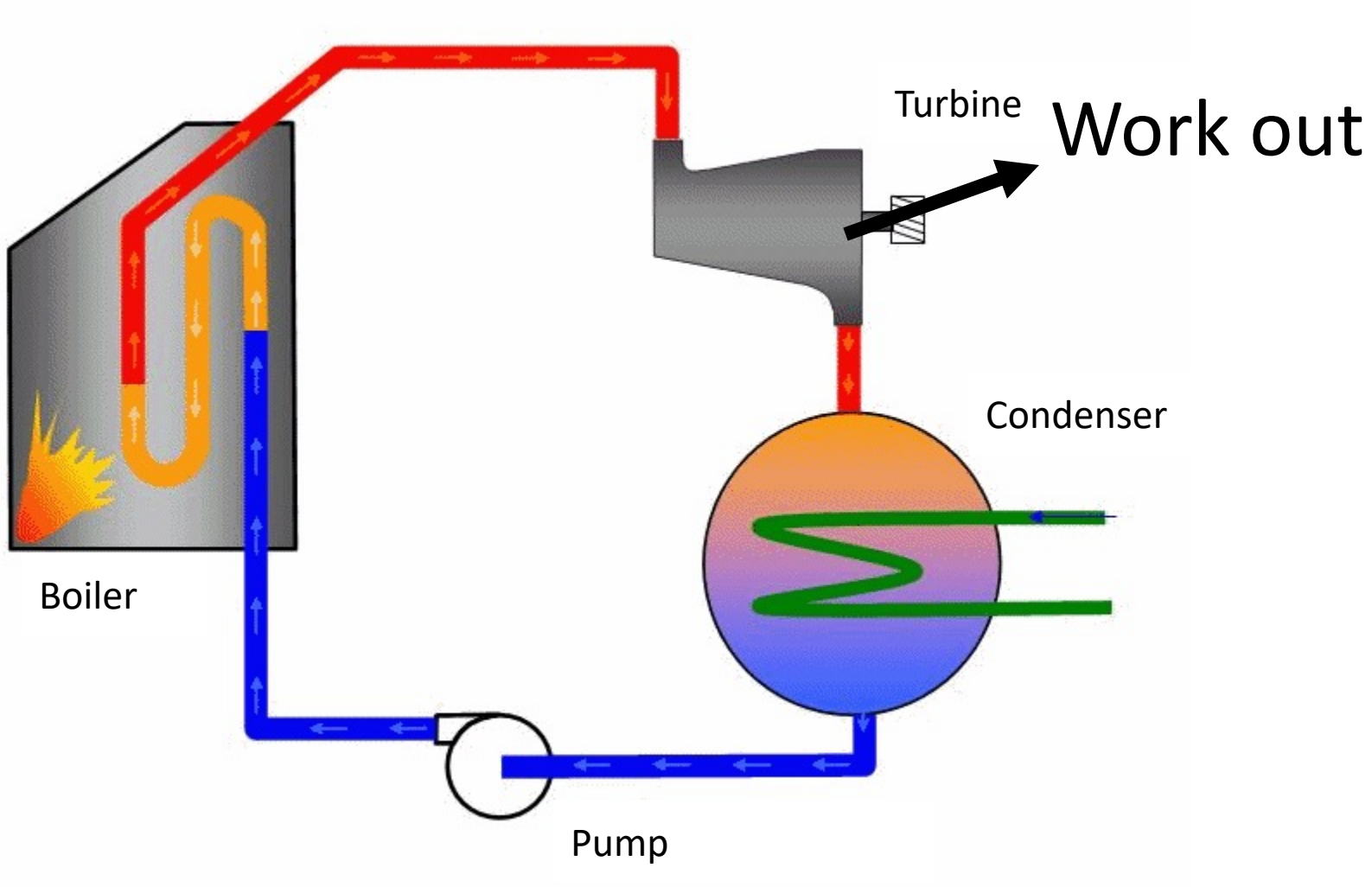
Source: http://e-learning.kku.ac.th/course/view.php?id=470&cal_m=3&cal_y=2008

Hot steam pushes turbine (like a fan blade)

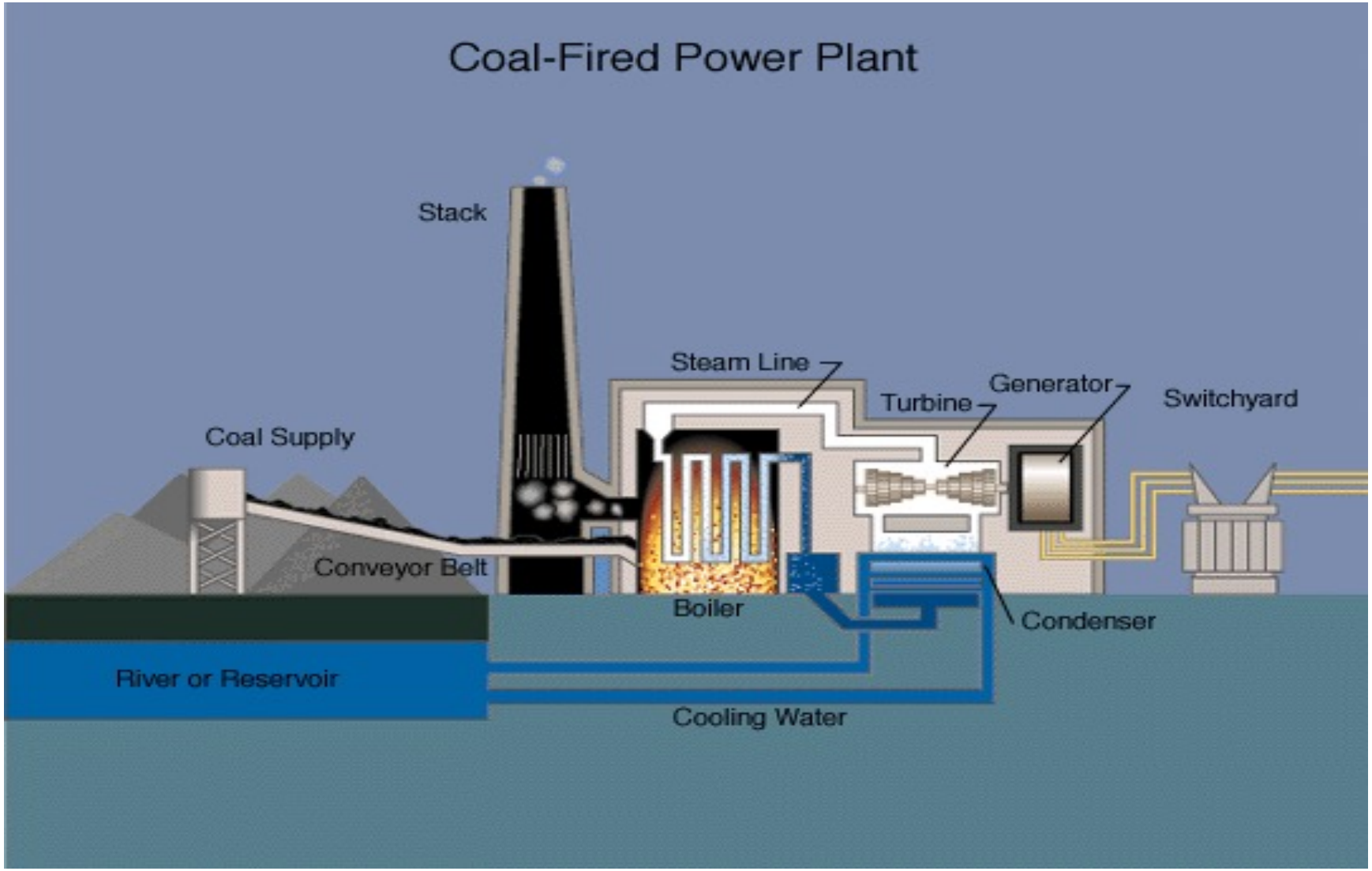


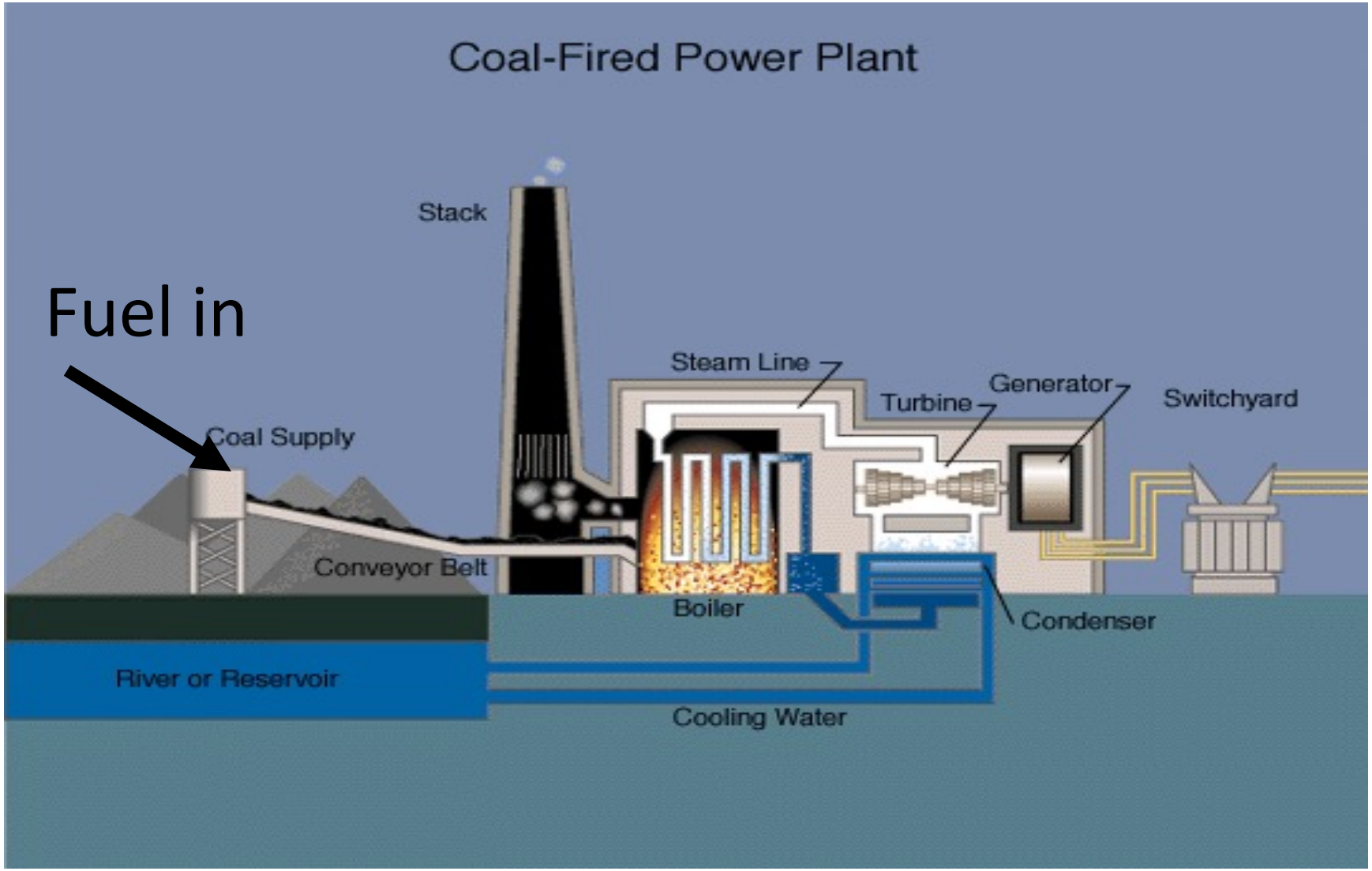
Source: http://e-learning.kku.ac.th/course/view.php?id=470&cal_m=3&cal_y=2008

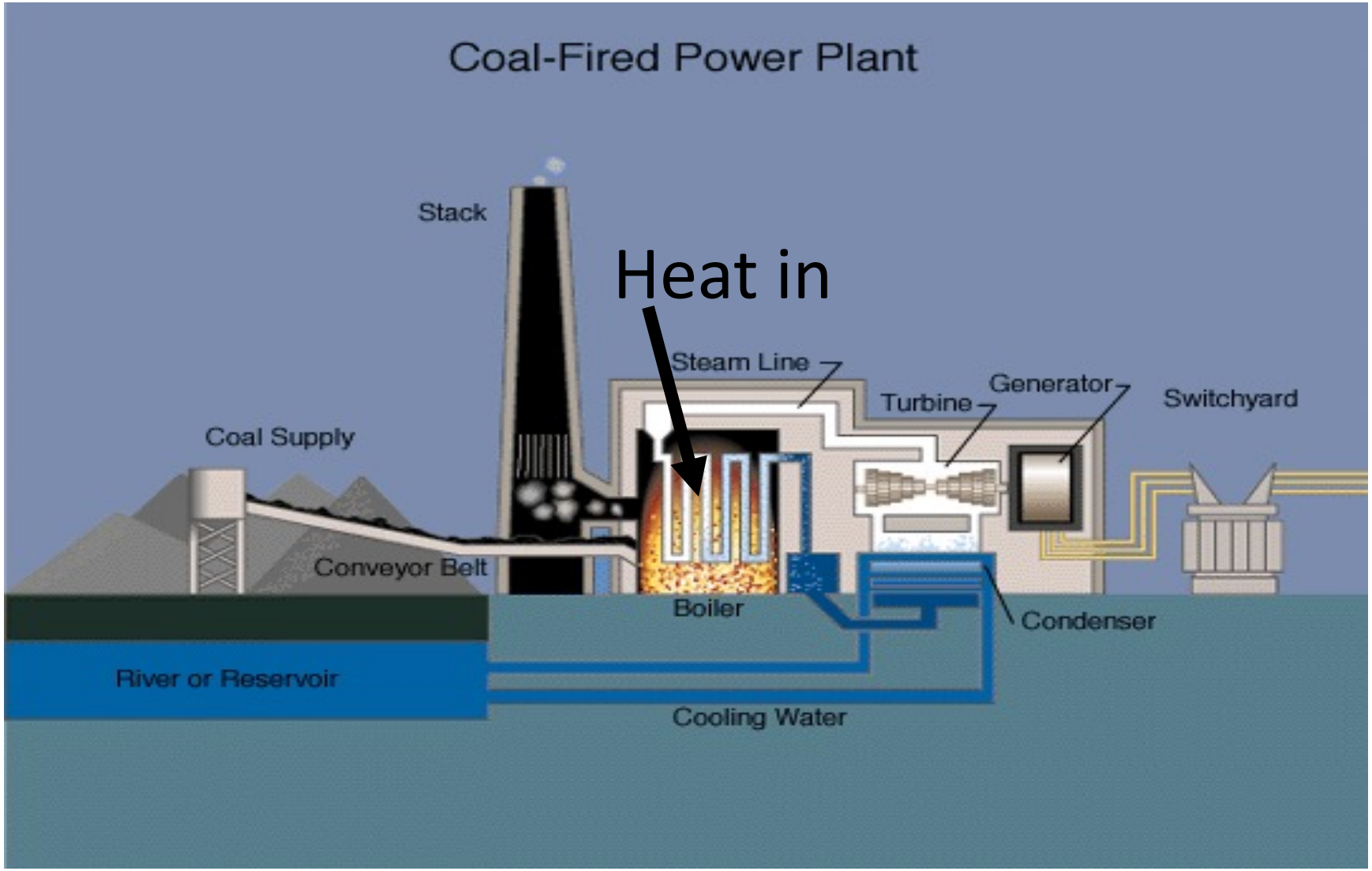
Spinning turbine makes useful work

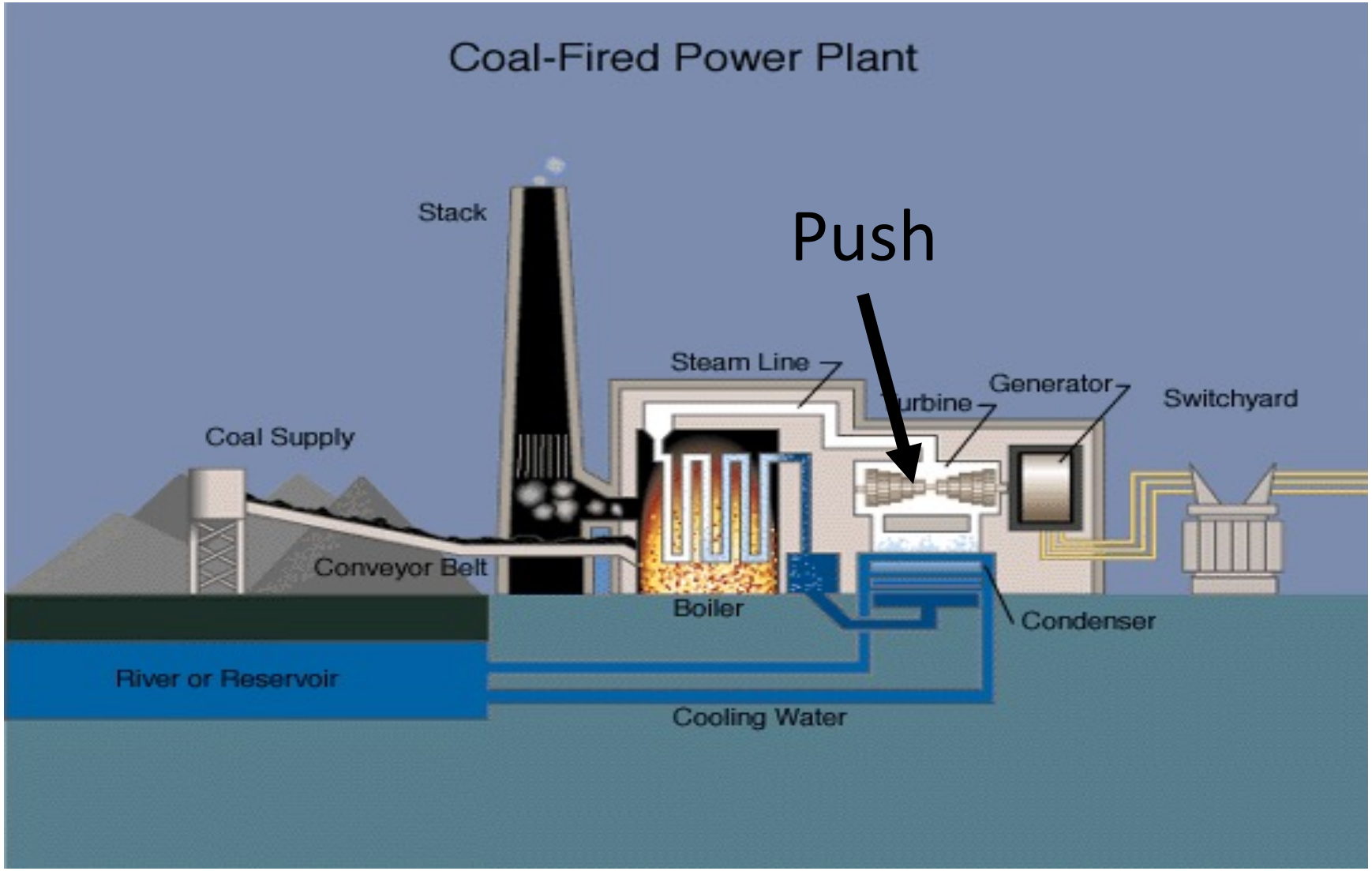


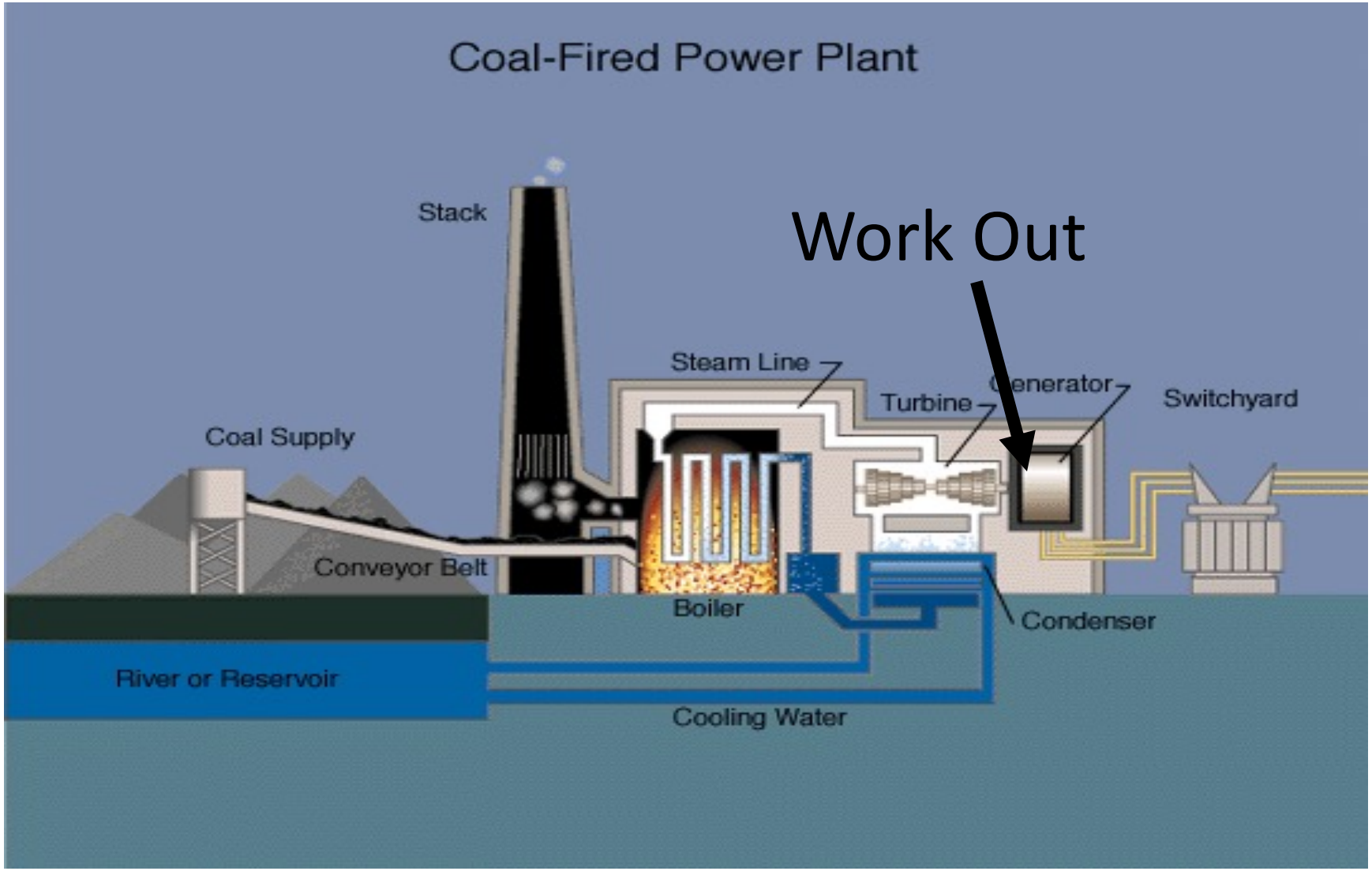
Source: http://e-learning.kku.ac.th/course/view.php?id=470&cal_m=3&cal_y=2008


Coal-Fired Power Plant
Stack
Steam Line
Turbine
Generator
Switchyard
Coal Supply
Conveyor Belt
Boiler
Condenser
River or Reservoir
Cooling Water


Coal-Fired Power Plant
Fuel in
Stack
Steam Line
Turbine
Generator
Switchyard
Coal Supply
Conveyor Belt
Boiler
Condenser
River or Reservoir
Cooling Water


Coal-Fired Power Plant
Stack
Heat in
Steam Line
Turbine
Generator
Switchyard
Coal Supply
Conveyor Belt
Boiler
Condenser
River or Reservoir
Cooling Water


Coal-Fired Power Plant
Push
Stack
Steam Line
Generator
Switchyard
Coal Supply
Conveyor Belt
Boiler
Condenser
River or Reservoir
Cooling Water


Coal-Fired Power Plant
Work Out
Stack
Steam Line
Turbine
Generator
Switchyard
Coal Supply
Conveyor Belt
Boiler
Condenser
River or Reservoir
Cooling Water

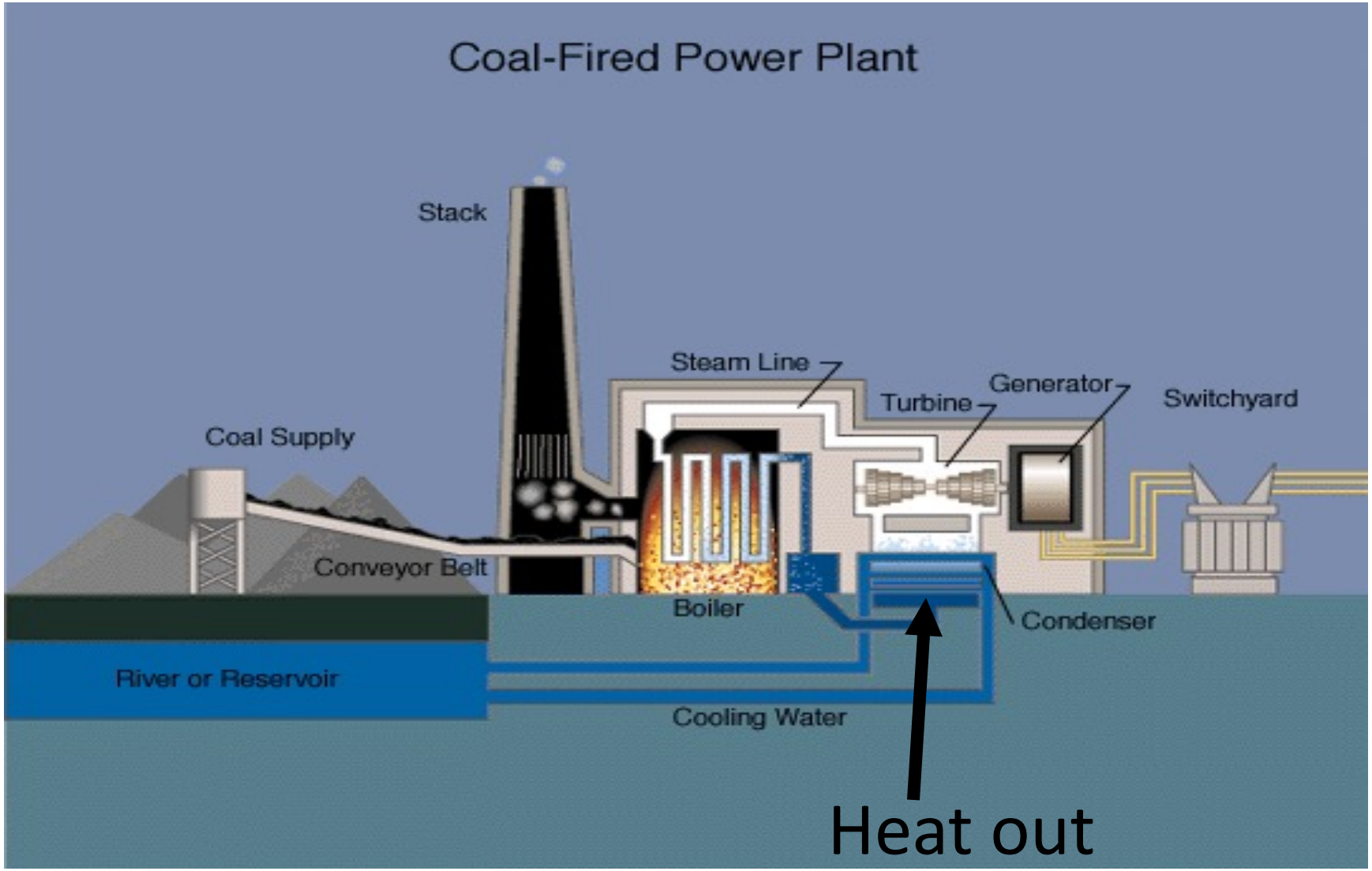
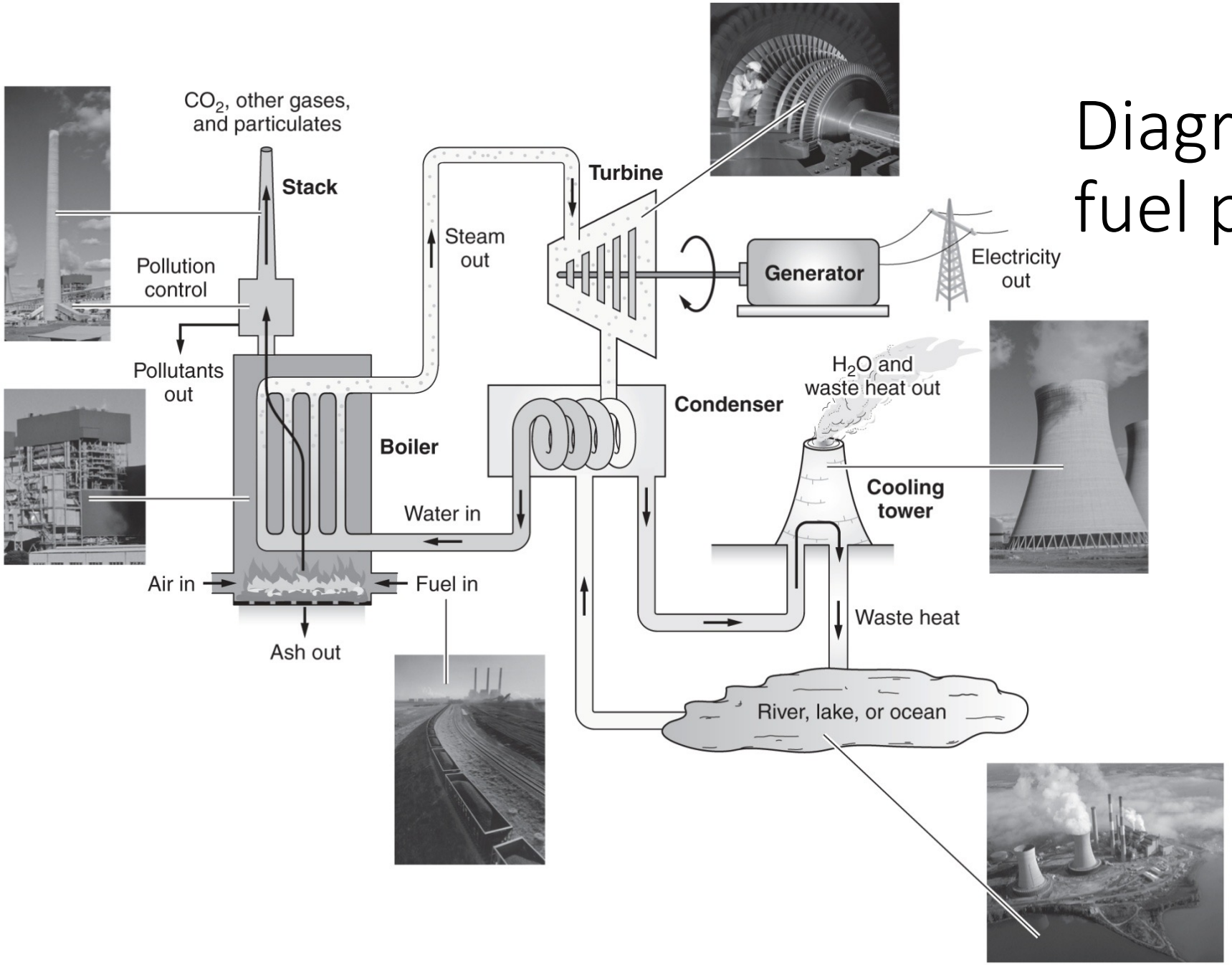
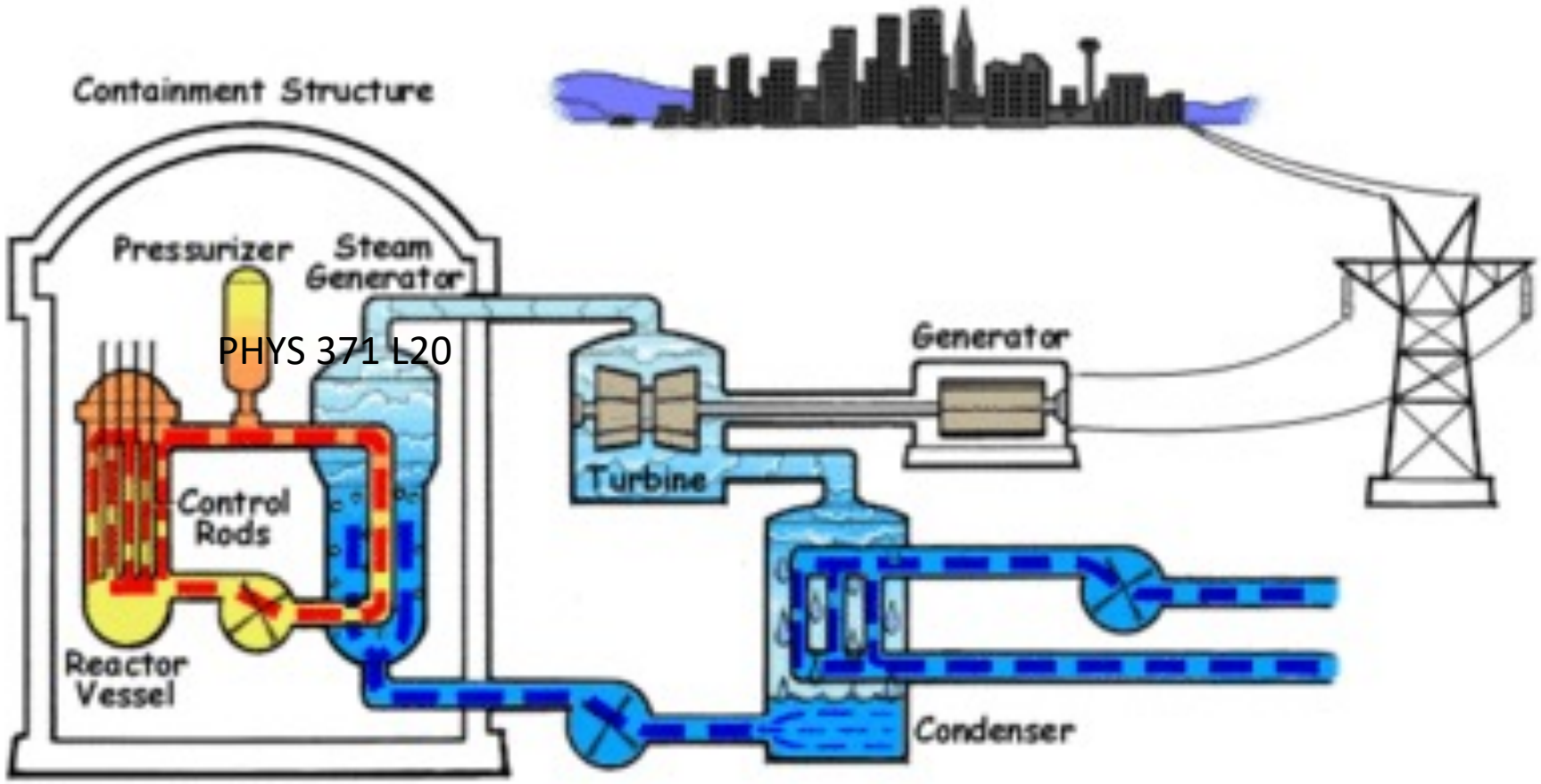

Coal-Fired Power Plant
Stack
Steam Line
Turbine
Generator
Switchyard
Coal Supply
Conveyor Belt
Boiler
Condenser
River or Reservoir
Cooling Water
Heat out

Diagram of a fossil fuel plant

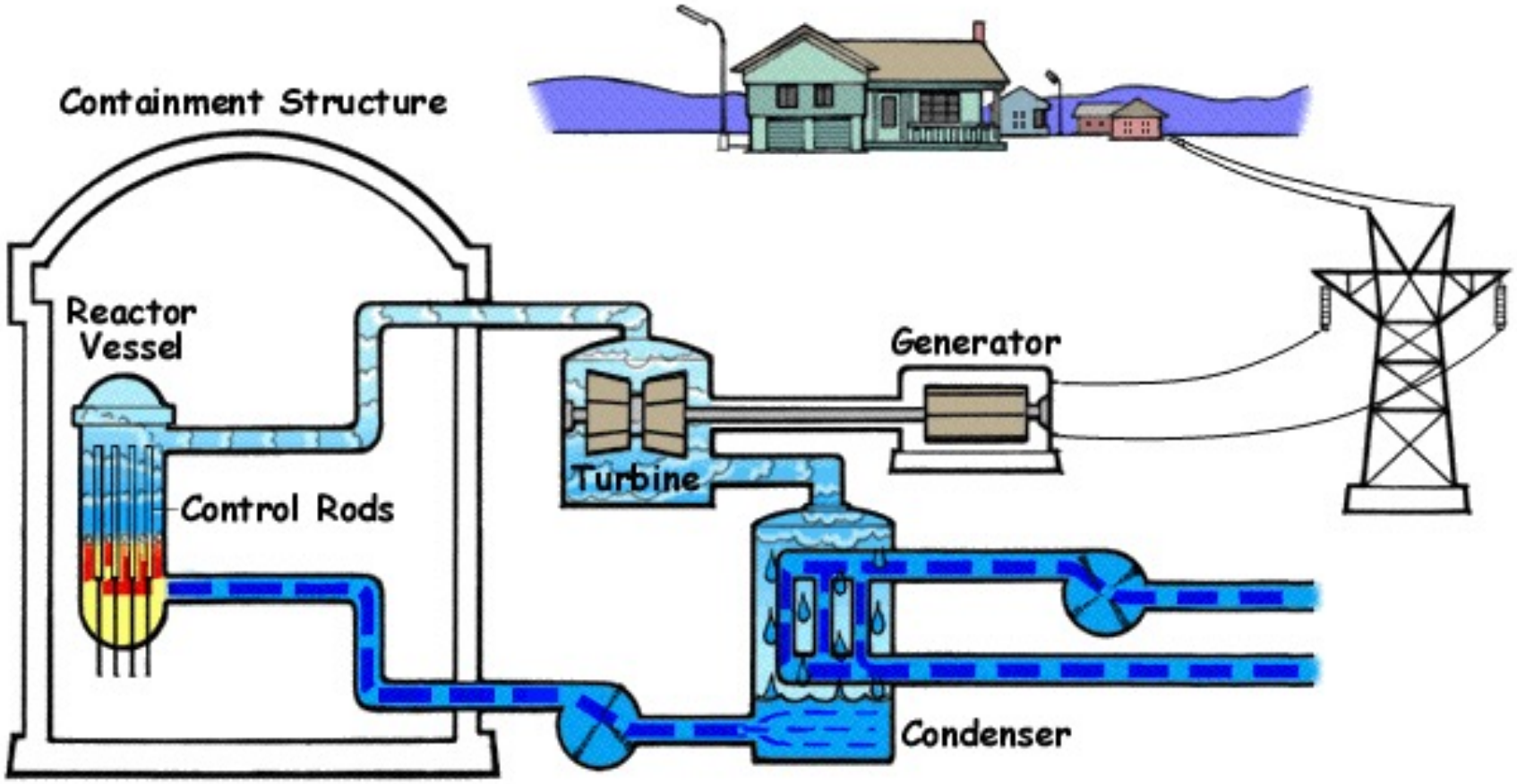


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From Wiki: Pressurized water reactor

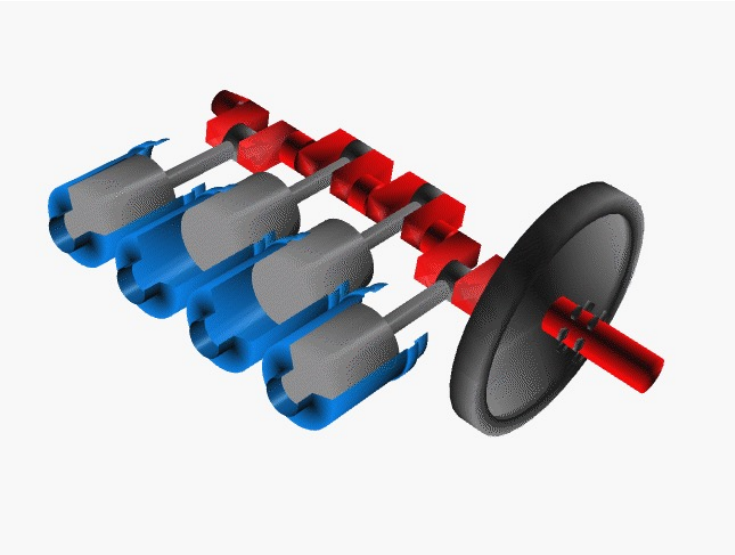


From wiki:
Boiling Water reactor



Work is done!

- Gas explosions can move a piston.
- Several pistons could be attached to a crank.
- Crank can be attached to a wheel and run a car!



Canada's Energy Flow – 2002 (Exajoules)

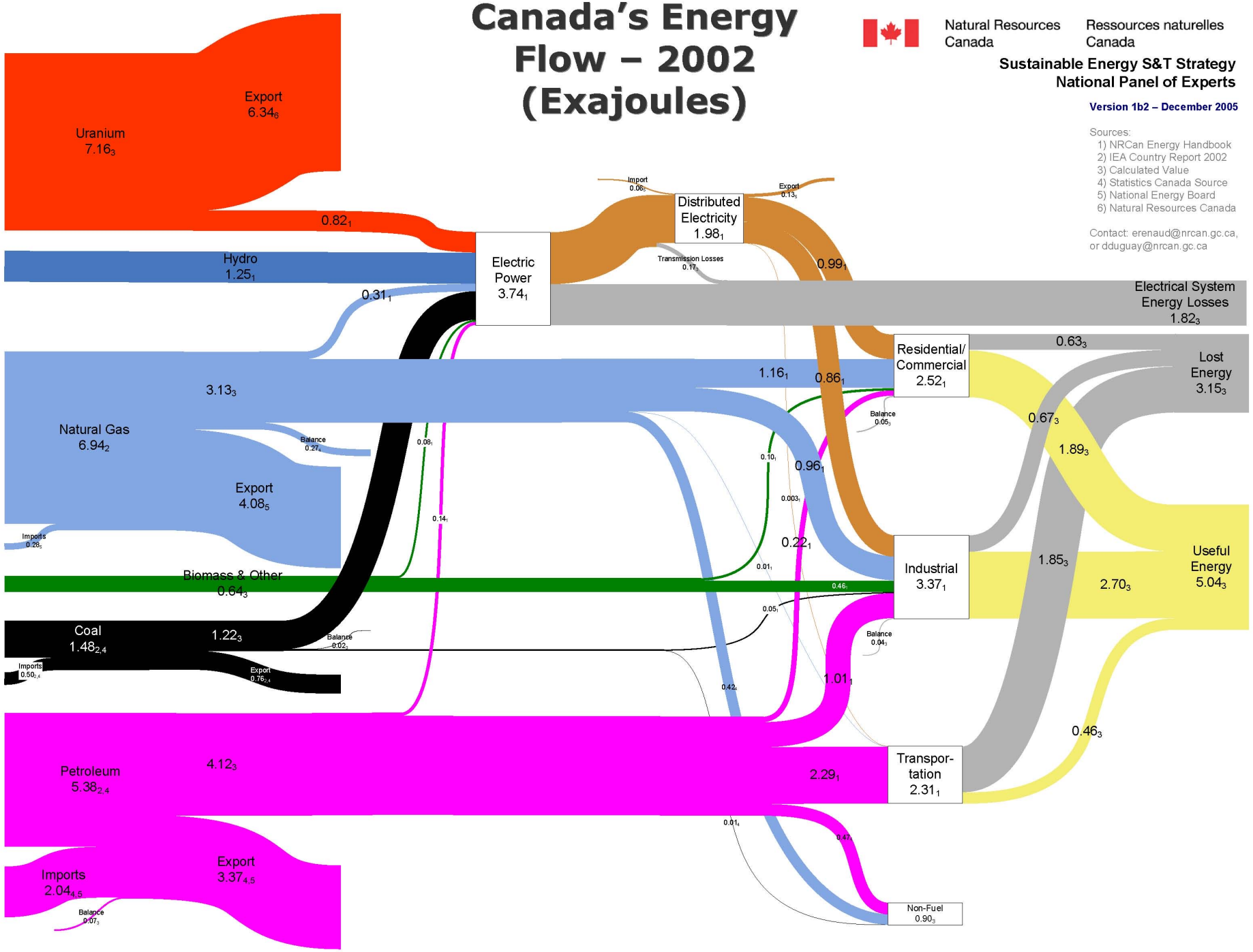
Natural Resources Canada | Ressources naturelles Canada

Sustainable Energy S&T Strategy
National Panel of Experts

Version 1b2 – December 2005

Sources:
1) NRCan Energy Handbook
2) IEA Country Report 2002
3) Calculated Value
4) Statistics Canada Source
5) National Energy Board
6) Natural Resources Canada

Contact: erenaud@nrcan.gc.ca, or dduguay@nrcan.gc.ca



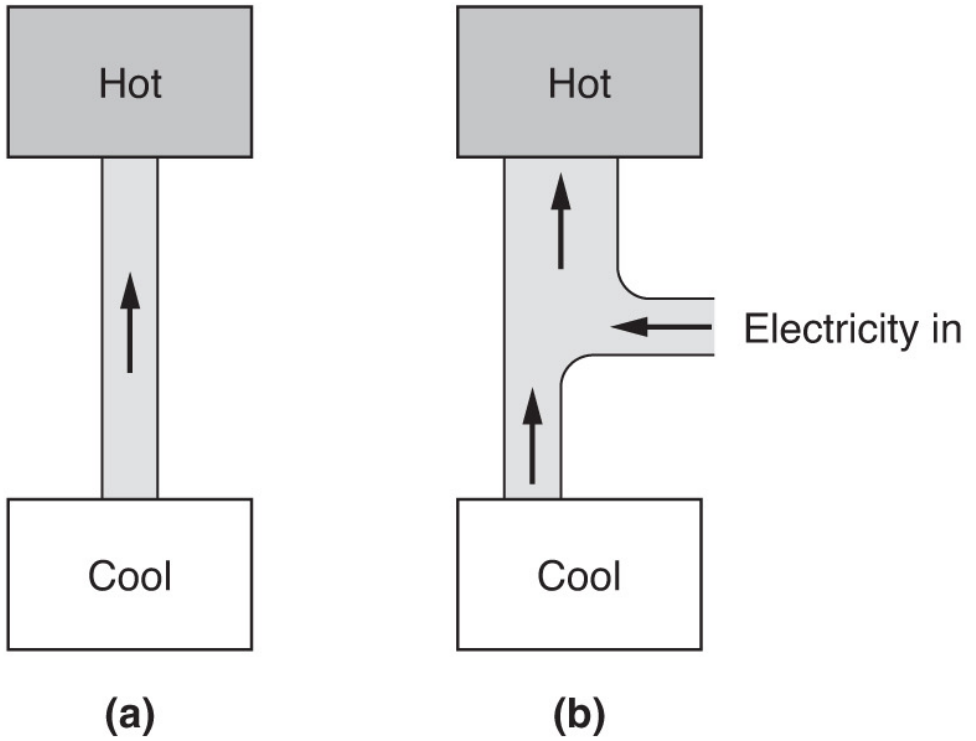
If we used breeder reactors

Breeders make more fuel

- Known technology but isn`t being used could make for a LOT more nuclear fuel.

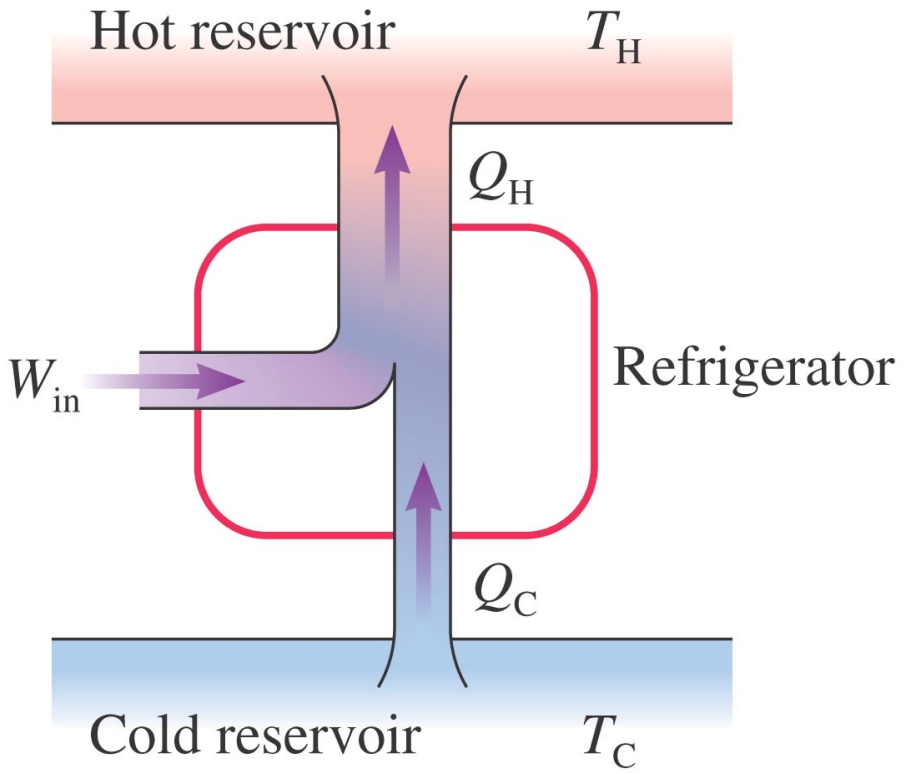
Model: World has heat, move heat to where it is wanted, remove unwanted heat

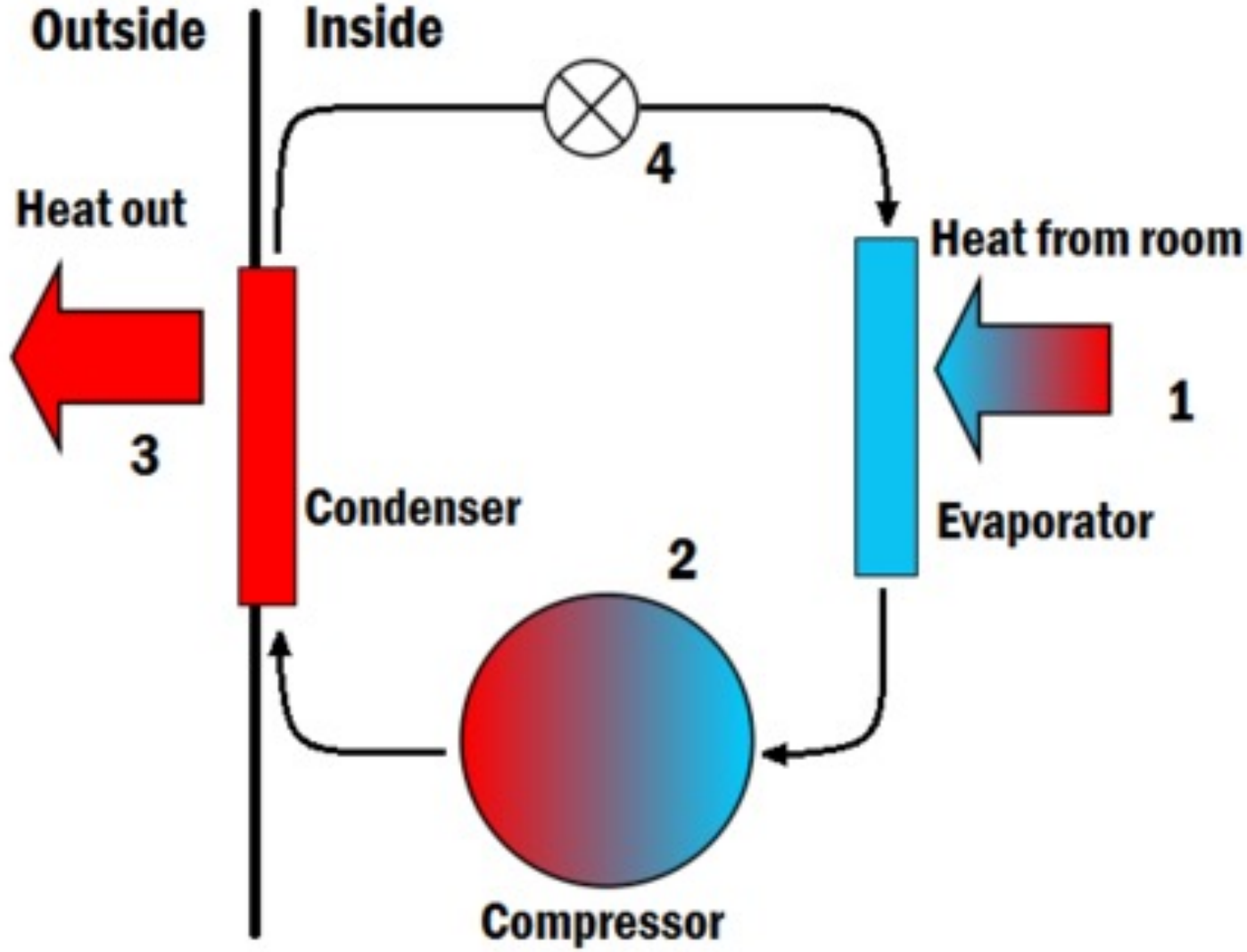




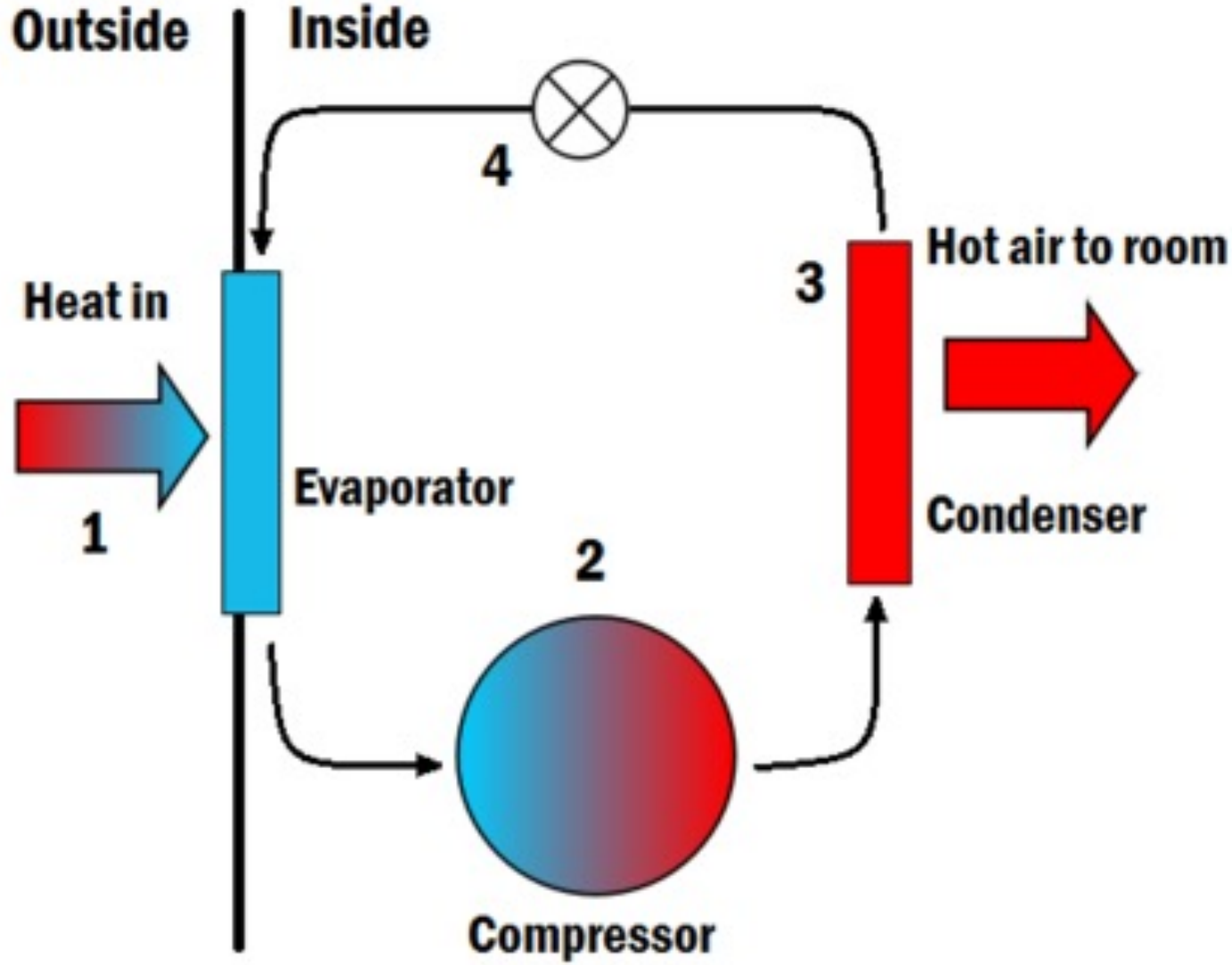
Refrigerators

A refrigerator that extracts heat from the cold reservoir and exhausts heat to the hot reservoir.





Cooling Cycle



Heating Cycle

Refrigerators



These cooling coils are the refrigerator's high-temperature heat exchanger. Heat energy is being transferred from hot gas inside the coils to the cooler room air.

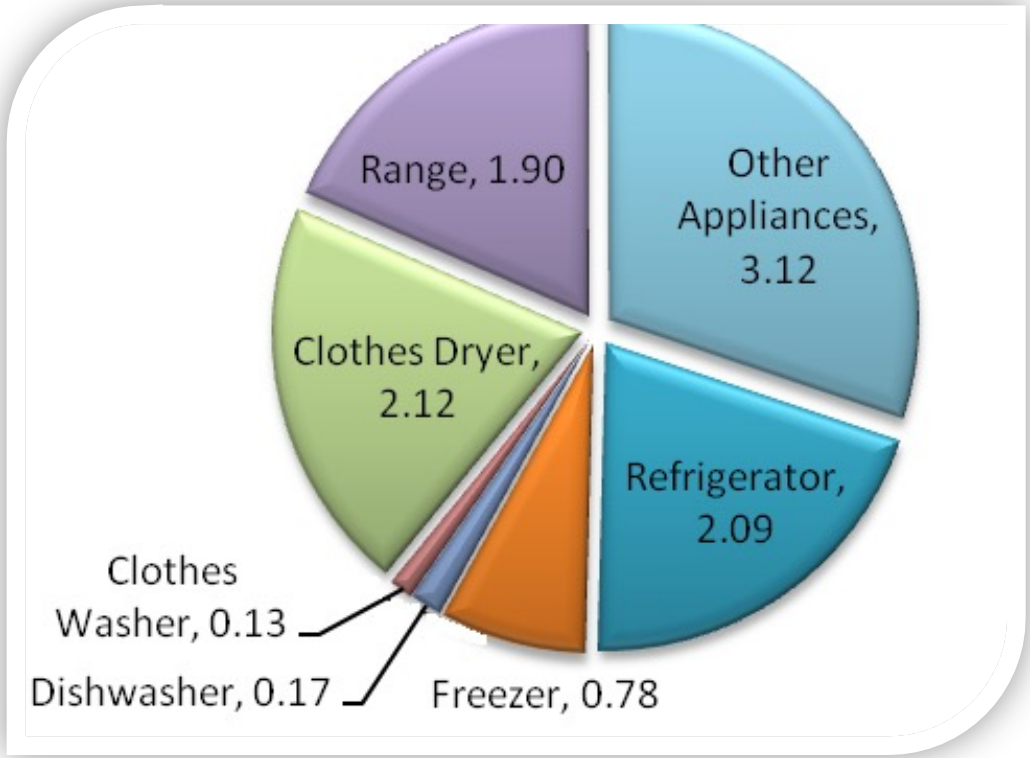
Usually:





- Human use determines electricity consumption.
- Exception, refrigerators and freezers, improved because technology improves
- Old fridge store drinks in the garage?!?

Refrigerators and Freezers



- Increase in efficiency :
  - Better design
  - Improved condensers
  - Improved compressors
  - Improved evaporators
  - Improved fan motors
  - Improved door seals
  - Foam insulation.





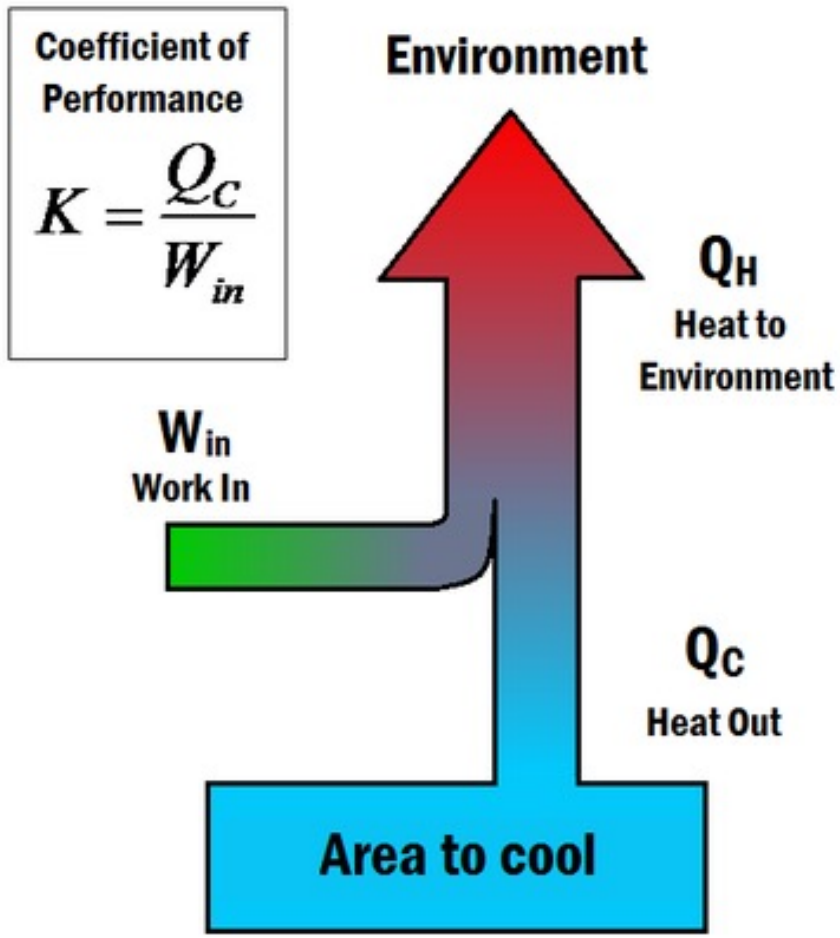
Chest freezers

- more efficient
  - air doesn’t spill out
  - Often no defrosters, which reduce efficiency
- less convenient

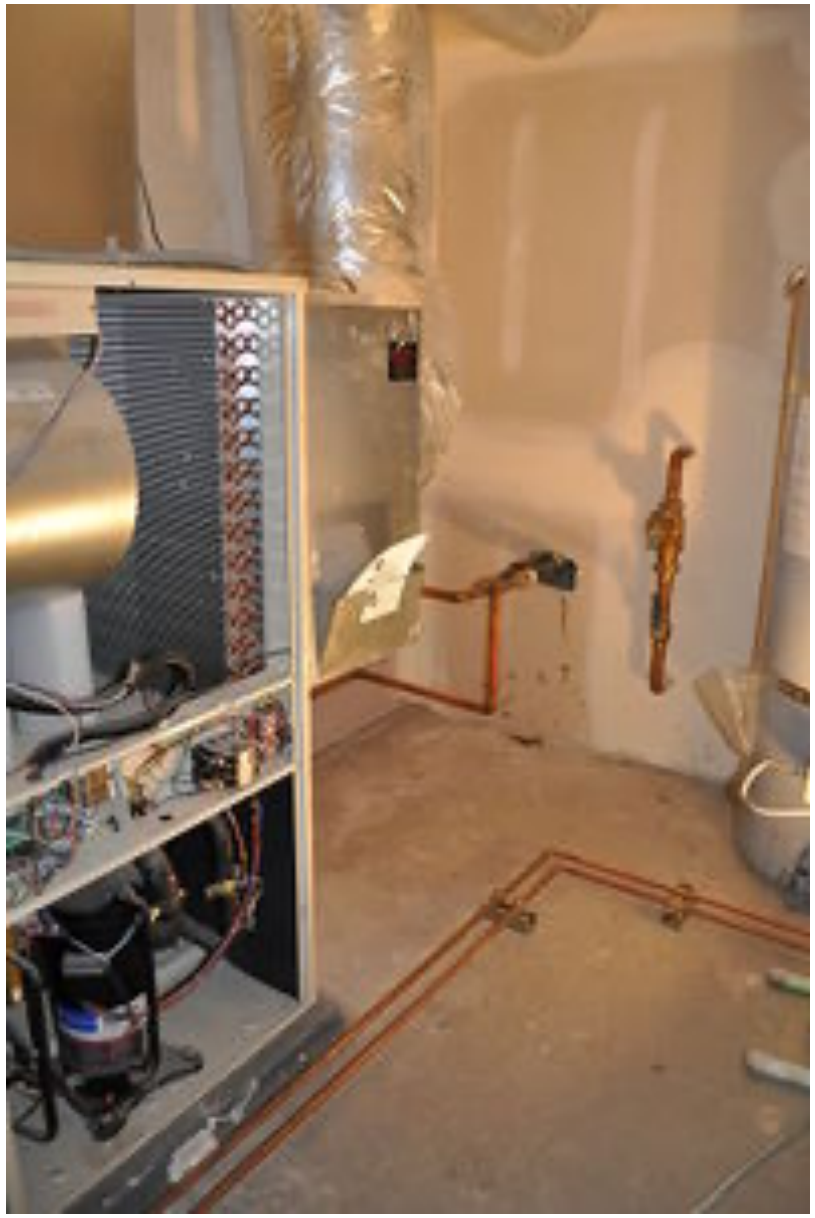
Coefficient of performance

- Like efficiency, but inverted.

$$K = \frac{Q_c}{W_{in}} = \frac{\text{What you get out}}{\text{What you pay}}$$



Ground source Heat pumps





- Air is not dense
- Ground more dense
- Same T ground more thermal energy.

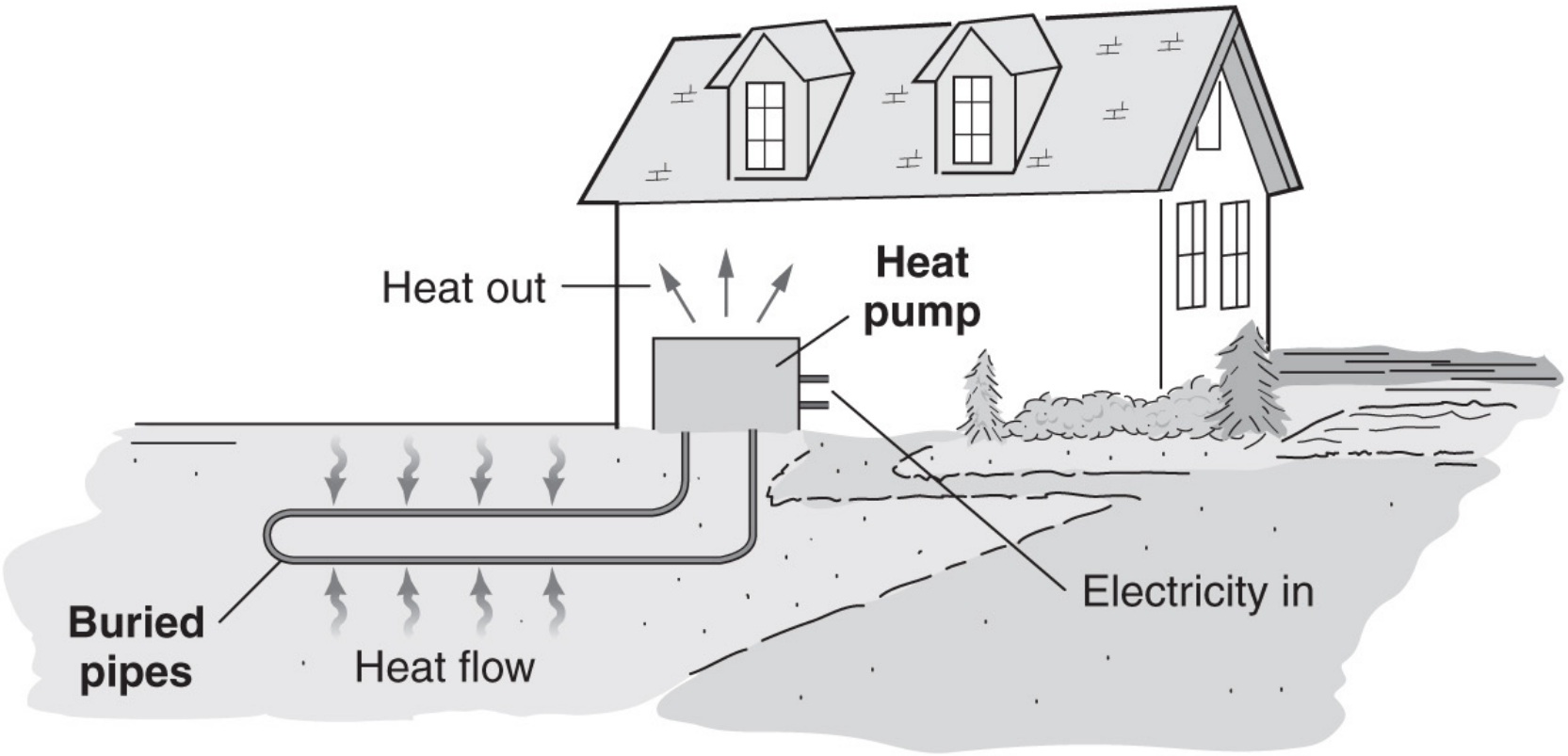
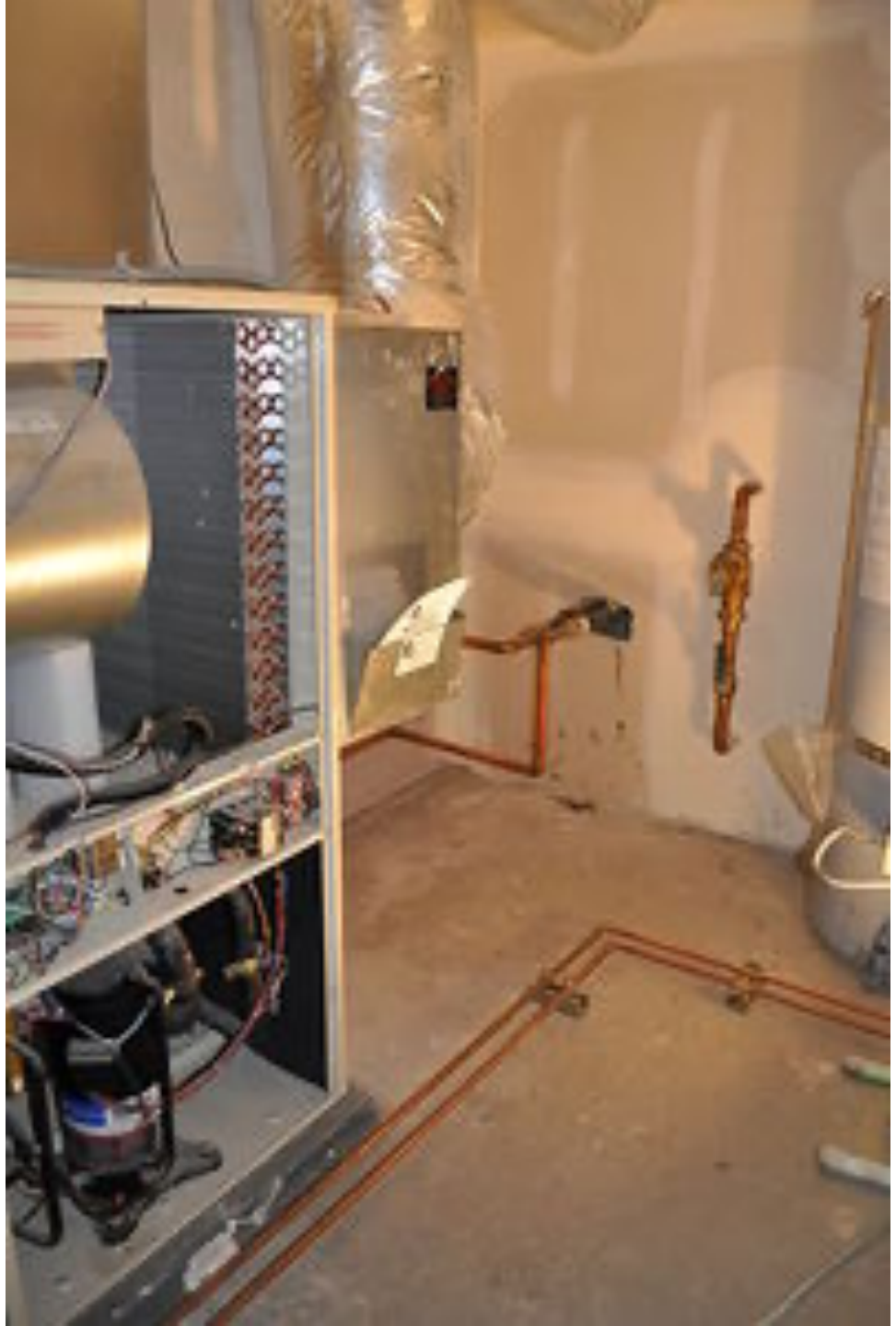


Figure 8.10

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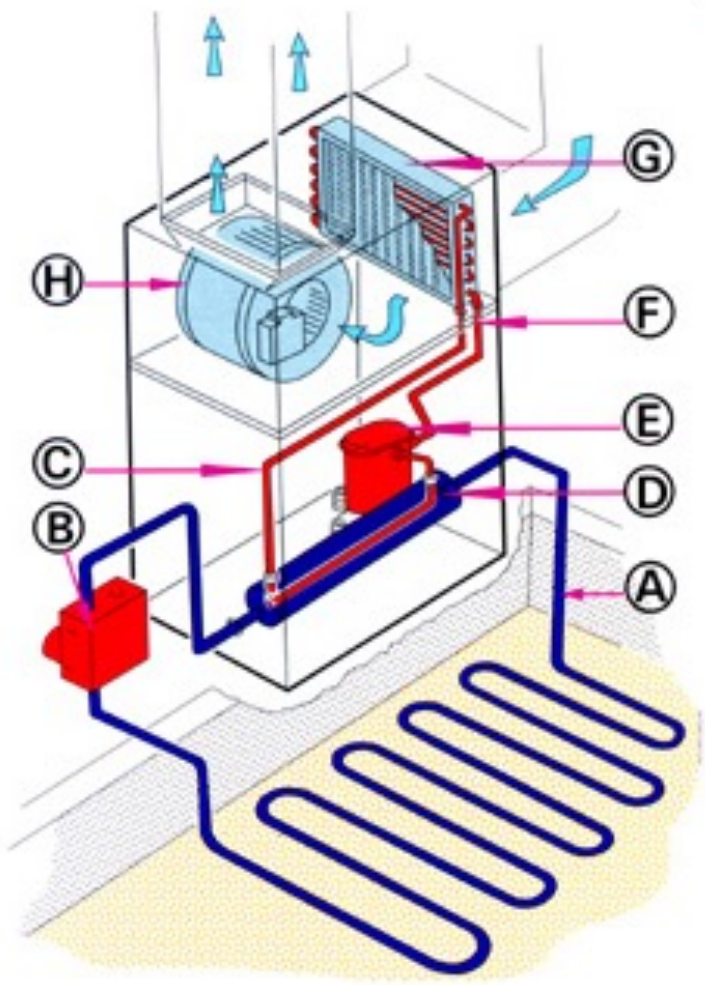
Ground Source heat pumps
Not actually geothermal, but close



Heat from ground

- Ground is denser, so more thermal energy is available at the same temperature.

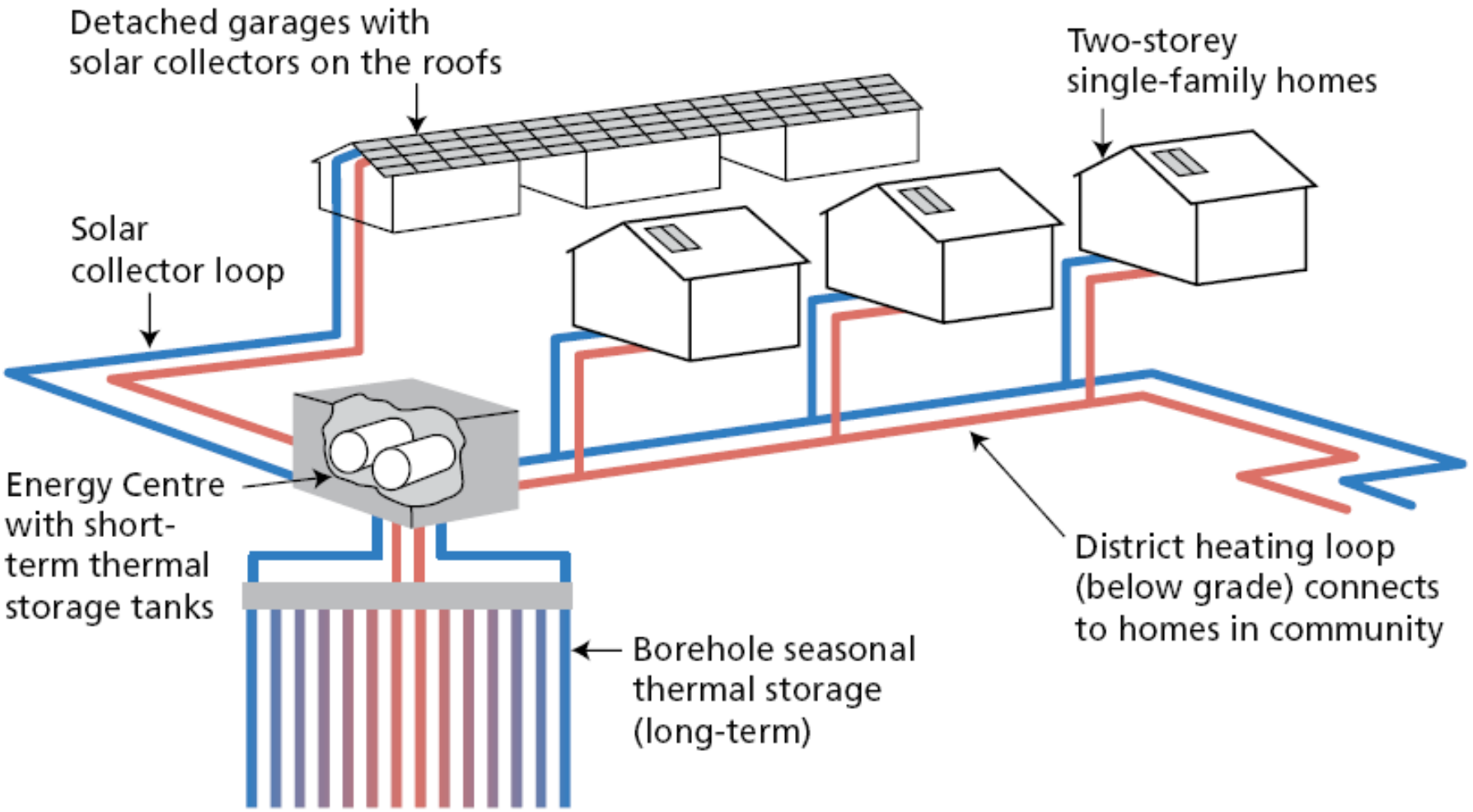
Schematic Ground source Heat Pump



A. Ground loop
B. Pump
C. Refrigerant loop
D. Evaporator
E. Compressor
F. Refrigerant loop outlet
G. Radiator
H. Distribution fan

(my.dteenergy.com/home/savings/geothermal.html)

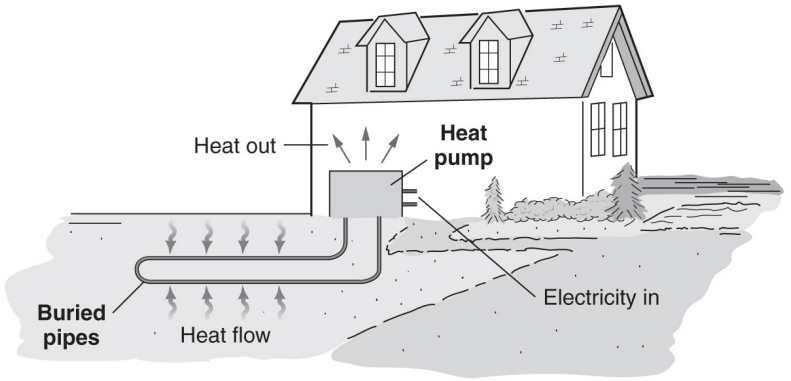
Drake Landing, Okotoks, AB



(www.dlsc.ca/DLSC_Brochure_e.pdf)

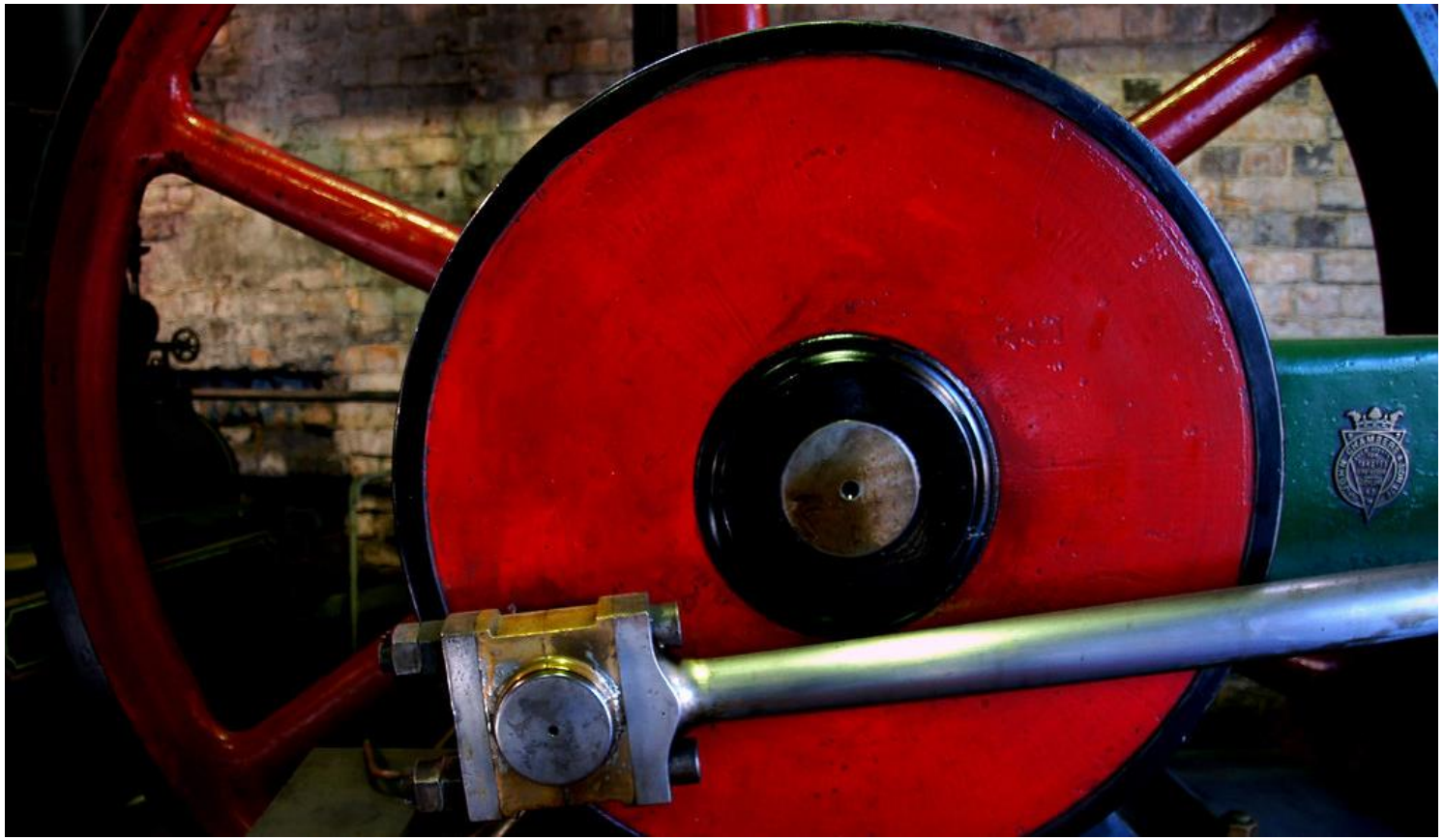








Model: Refrigerators, heat pumps and air conditioners move heat using work (often electricity)



PHYS 371
Introduction to Energy

- LECTURE 21:

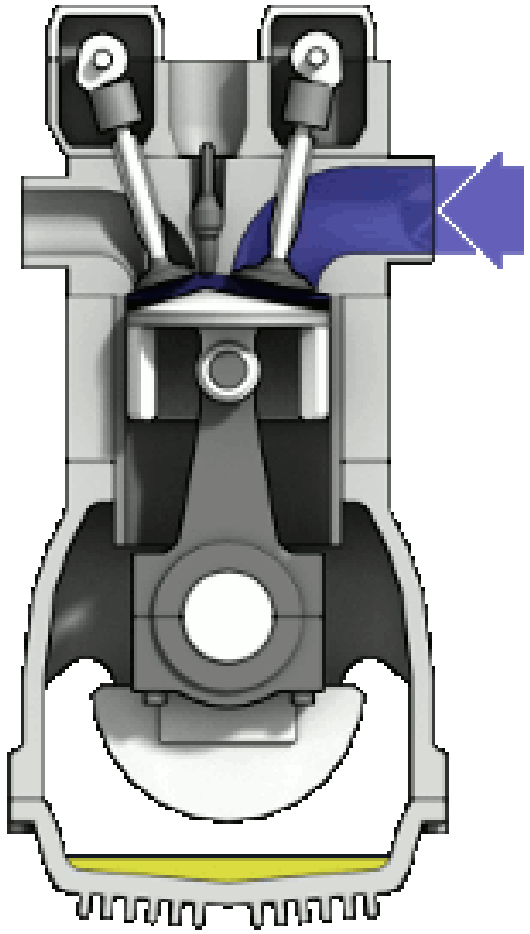
HEAT ENGINES AND POWER PLANTS

- MONDAY NOV 1, 2021
- (NOT INCLUDED ON MIDTERM 2)

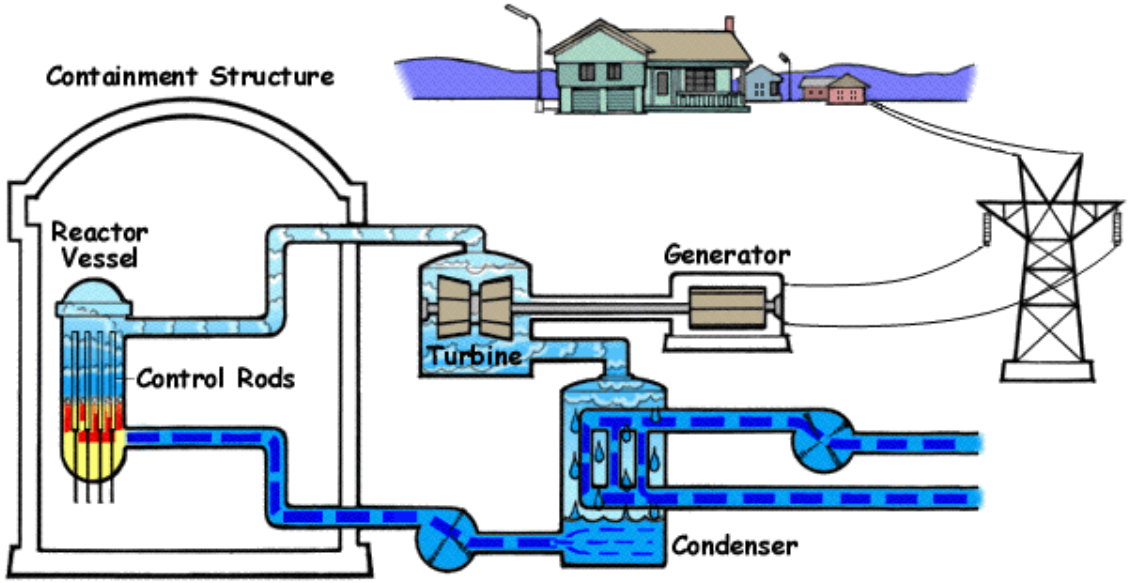
Heat engines

Lecture 19
Slide 2 review

1



Run:
Power plants (most types)
Cars, planes, boats, submarines

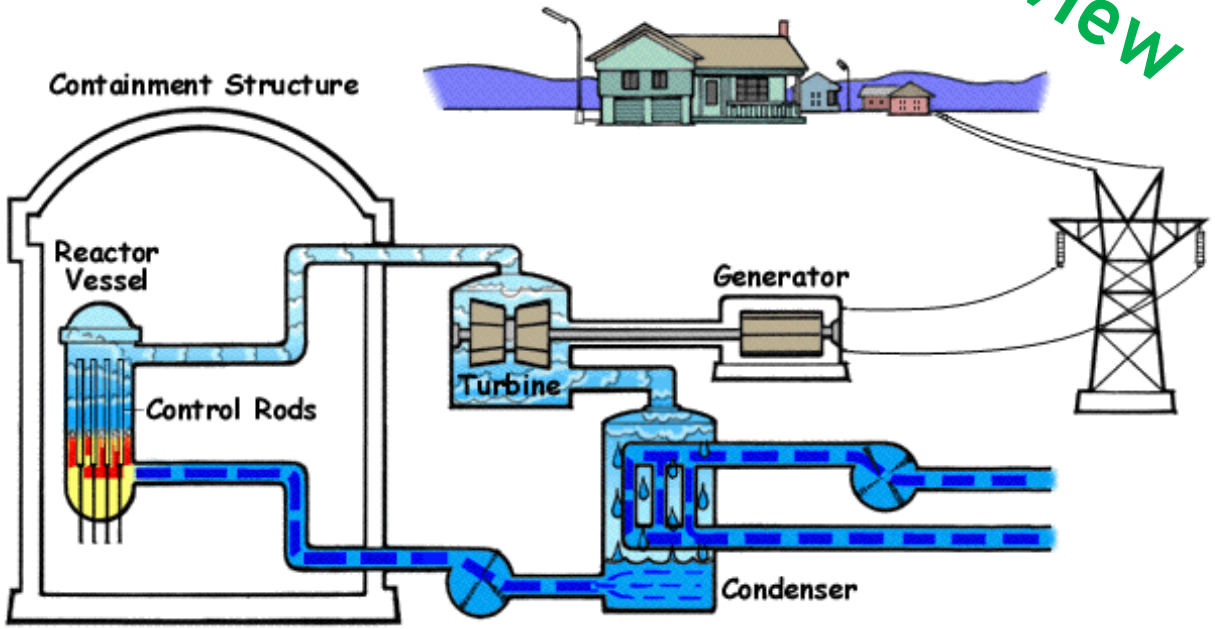


Overview – This week

- ❑ **Fluids.** Machine for motion. Turbines
- ❑ Heat engines
- ❑ Efficiency
- ❑ Cogeneration
- ❑ (maybe) Refrigerators

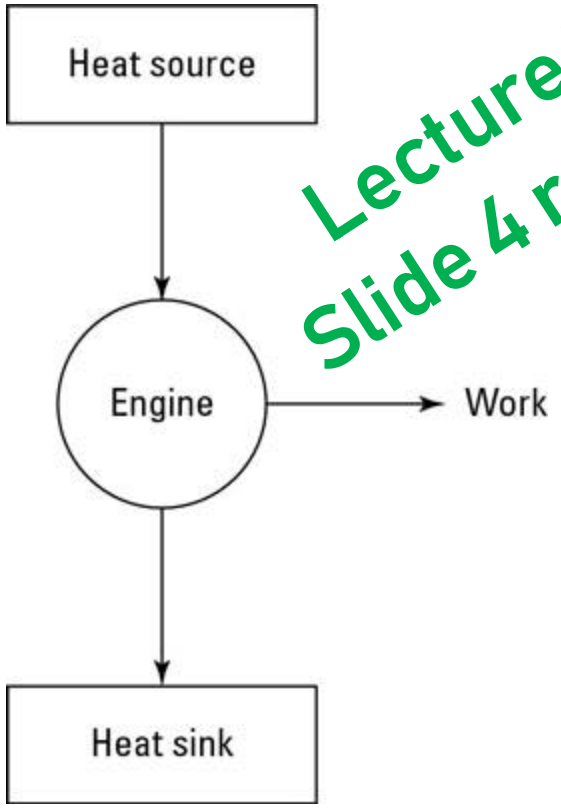
- Next Week:
- Electricity. Electricity production. Power plants

Lecture 19
Slide 3 review



Heat Engine

A heat engine turns heat into work.



Lecture 19
Slide 4 review

Engines that rely on a heat source to do work are called *heat engines*.

A ***heat source*** provides heat to the engine, which does ***work***. The waste heat left over goes to a ***heat sink***.

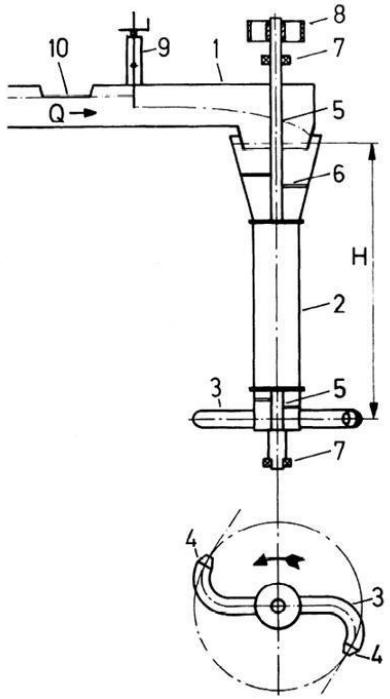
We will discuss all this at the end of this lecture and on Friday, once we have learned all the required background information and knowledge needed

Ancient technology!

~2000 years old!



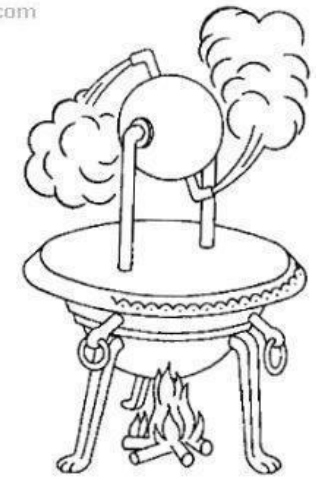
Hero’s Aeolipile

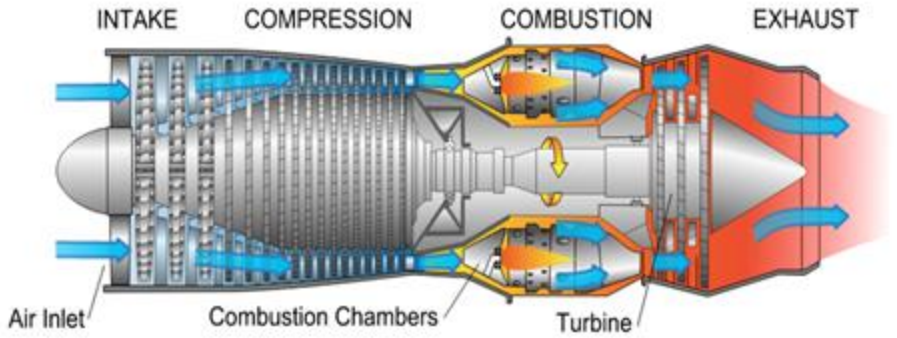


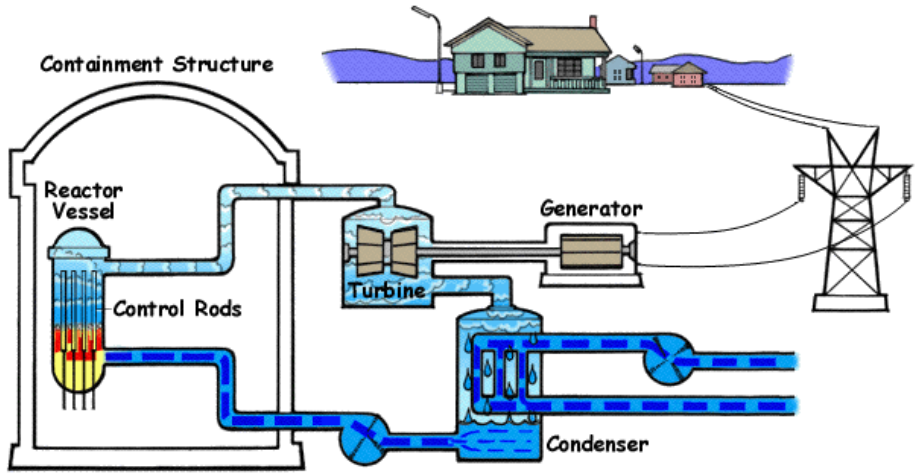
Segner Wheel

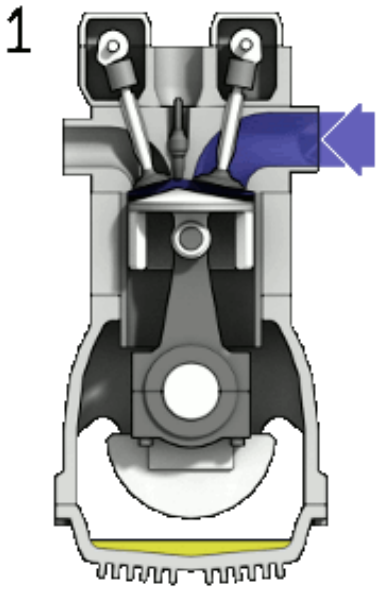
Model: Heat adds energy to fluids.











Heat engines

Almost all of our energy is harvested by using heat engines.

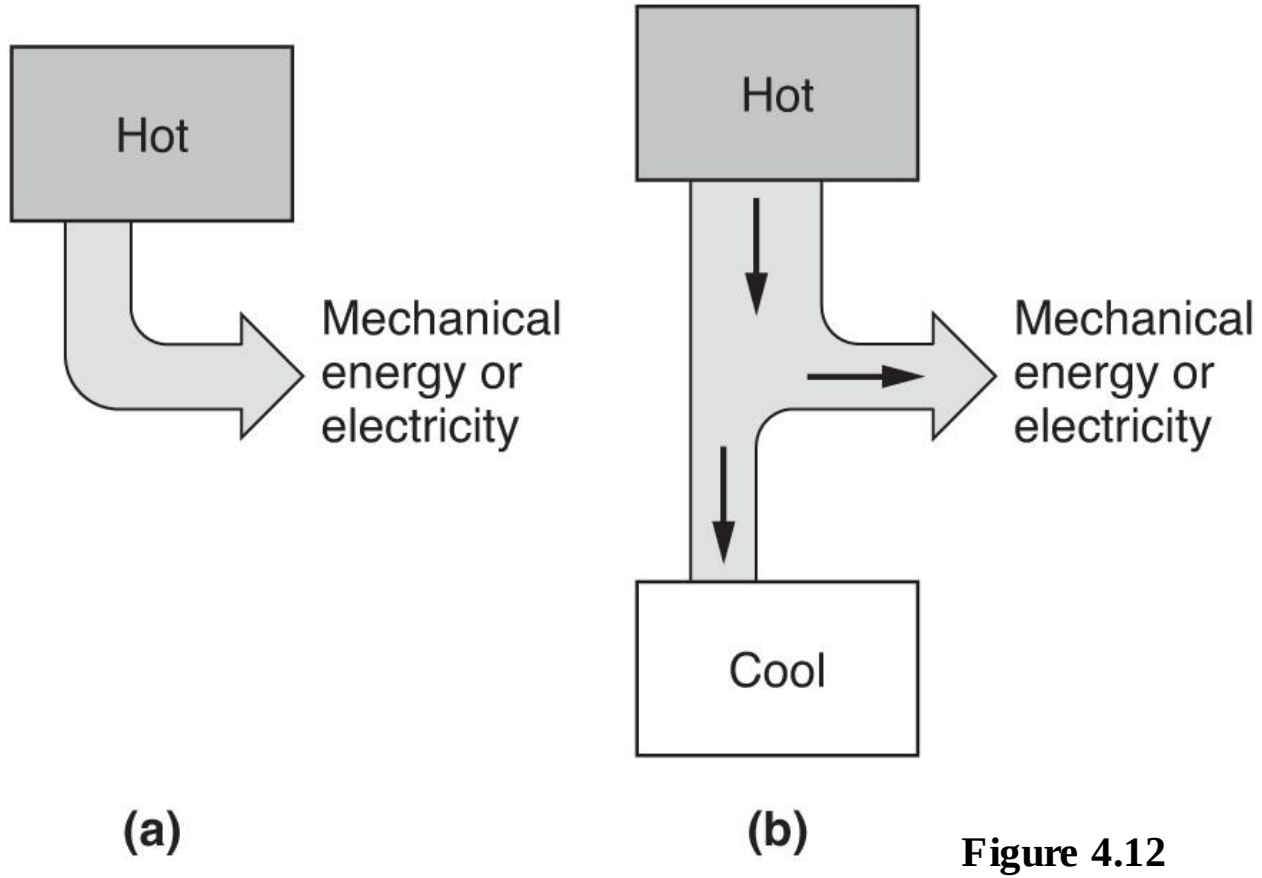


Figure 4.12

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How much work?

Lecture 19
Slide 15 review

- If we send in 200 kJ of heat, and get out 130 kJ of waste heat, how much work did we get out, in kJ?

The energy must go somewhere!

$$W = Q_{in} - Q_{out}$$

$$200\ \text{kJ} - 130\ \text{kJ} = 70\ \text{kJ}$$

Our efficiency

Lecture 19
Slide 28 review

η is always less than 1.

$$\text{Primary energy} \times \eta = \text{End use}$$

$$\frac{(\text{End use})}{\eta} = \text{Primary energy}$$

$$\eta = \frac{\text{Work out}}{\text{Heat in}}$$

Different question

Lecture 19
Slide 28
application

- If we send in 200 kJ of heat, and get out 130 kJ of waste heat, how much work did we get out, in kJ?

70 kJ

What's our efficiency?

η=Work out / Heat in

η=70kJ/200kJ

η= 0.35

Find the efficiency

Lecture 19
Slide 28
application

If we send in 400 kJ of heat and get out 350 kJ of heat, what's the efficiency?

$W = ?$

$W = Q_{in} - Q_{out}$

$W = 400kJ - 350kJ$

$W = 50kJ$

$\eta = ?$

$\eta = Work_{out} / Heat_{in}$

$\eta = 50kJ/400kJ$

$\eta = 0.125$

$\eta = 0.13$

The Limits of Efficiency

Everyone knows that heat can produce motion. That it possesses vast motive power no one can doubt, in these days when the steam engine is everywhere so well-known. . . . Notwithstanding the satisfactory condition to which they have been brought today, their theory is very little understood. The question has often been raised whether the motive power of heat is unbounded, or whether the possible improvements in steam engines
have an assignable limit.

Sadi Carnot

The result!
Theoretical efficiency
Only for Carnot engine

$$\eta = 1 - \frac{T_c}{T_H}$$

Carnot engine

Lecture 19
Slide 34

- Theoretical upper limit to heat engine efficiency

$$\eta_c = 1 - \frac{T_c}{T_h}$$

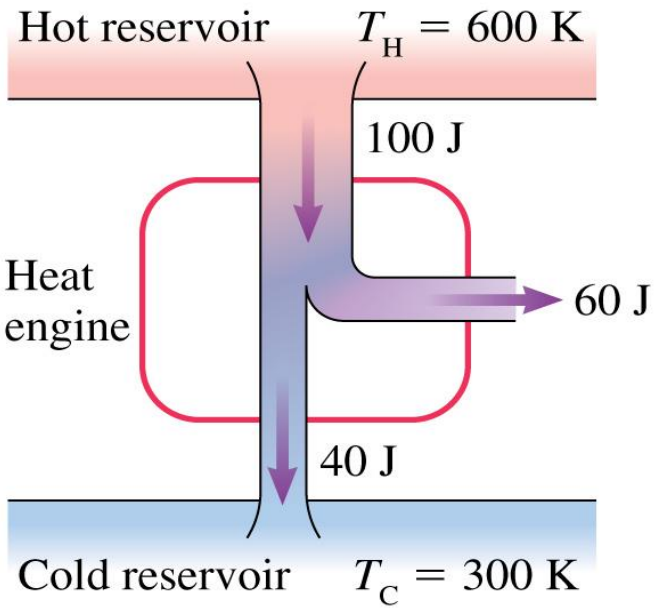
- Real engines always less than Carnot

$$\eta_w < \eta_c$$

$$\frac{W_{out}}{Q_{in}} < 1 - \frac{T_c}{T_h}$$

Lecture 19
Slide 34
Application practice

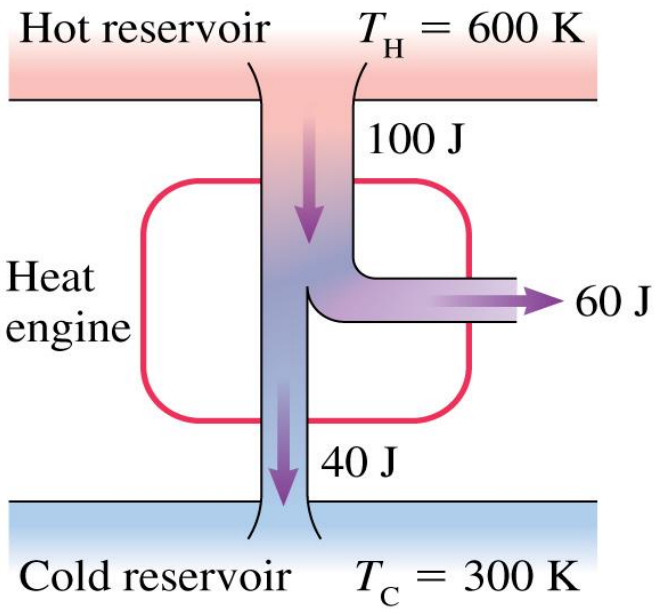
Could this heat engine be built?



A. No.
B. Yes.
C. It's impossible to tell without knowing what kind of cycle it uses.

Lecture 19
Slide 34
Application practice

Could this heat engine be built?



✔ **A. No.**

B. Yes.

C. It's impossible to tell without knowing what kind of cycle it uses.

$$\eta_w = \frac{\text{Work out}}{\text{Heat in}} = 0.60$$

$$\eta_c = 1 - \frac{T_c}{T_H} = 1 - 0.5 = 0.5$$

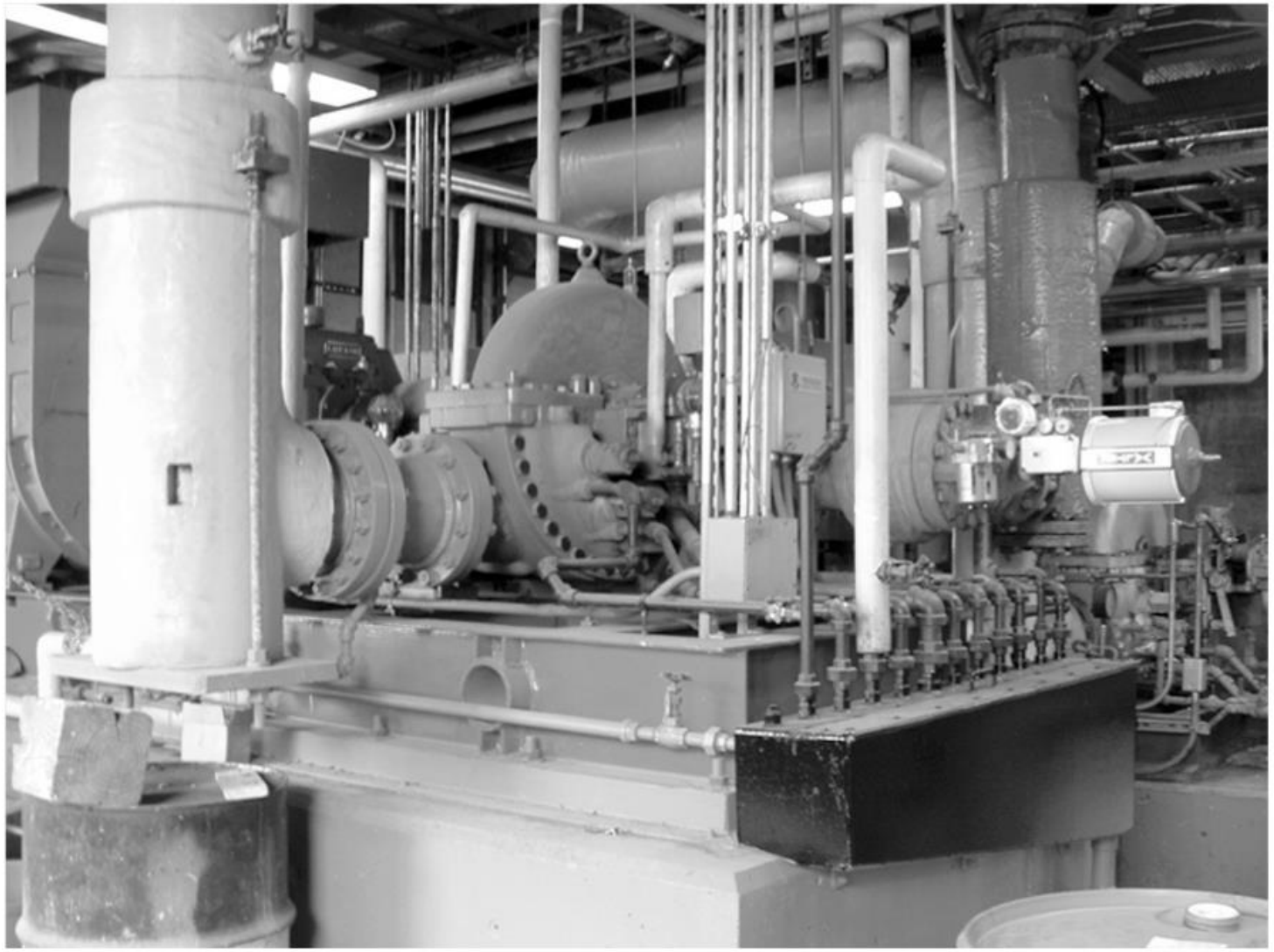
This heat engine could not be built because this heat engine's η_w is greater than η_c. Real heat engines always have a η_w less than η_c

Cogeneration

- Cogeneration means using the heat for other processes.
  - Heating homes
  - Industrial processes
  - Processing bitumen

- BUT! The heat can’t travel far.

Cogen plants get work and use heat



Different types of engines

- External combustion engine
- Internal combustion engine
  - Continuous combustion
  - Intermittent combustion

How is an internal combustion engine different from an external combustion engine?

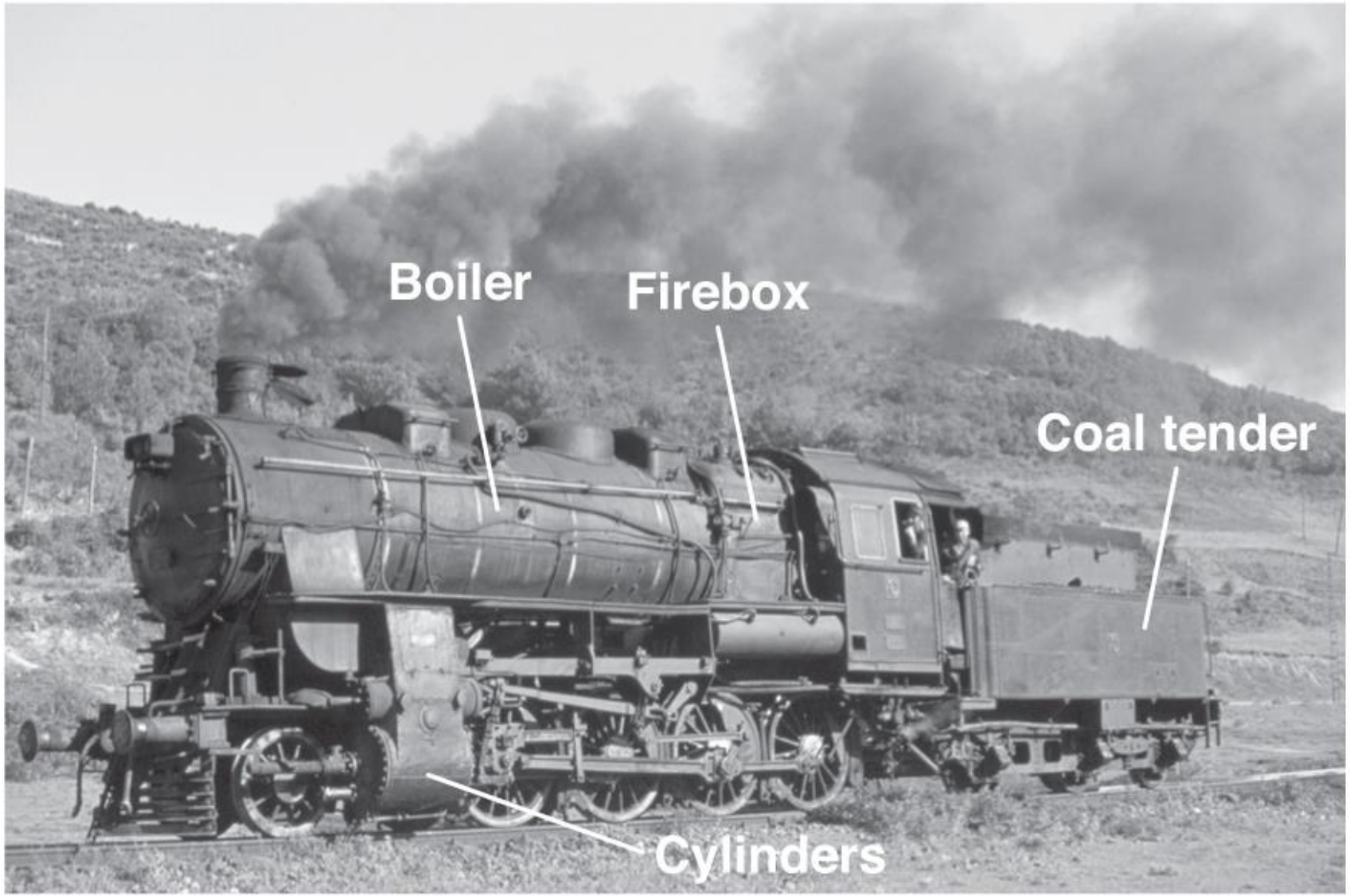
External combustion engine

- Fuel heats water outside of piston.
- Were used for transportation, but too inefficient.
- Still used for power plants.
  - Coal
  - Nuclear
  - Natural gas

Parts of steam locomotive

- Fuel (coal)
- Firebox (where the coal is burned)
- Boiler (the water boils)
- Cylinders (steam expands and pushes the wheels forward)

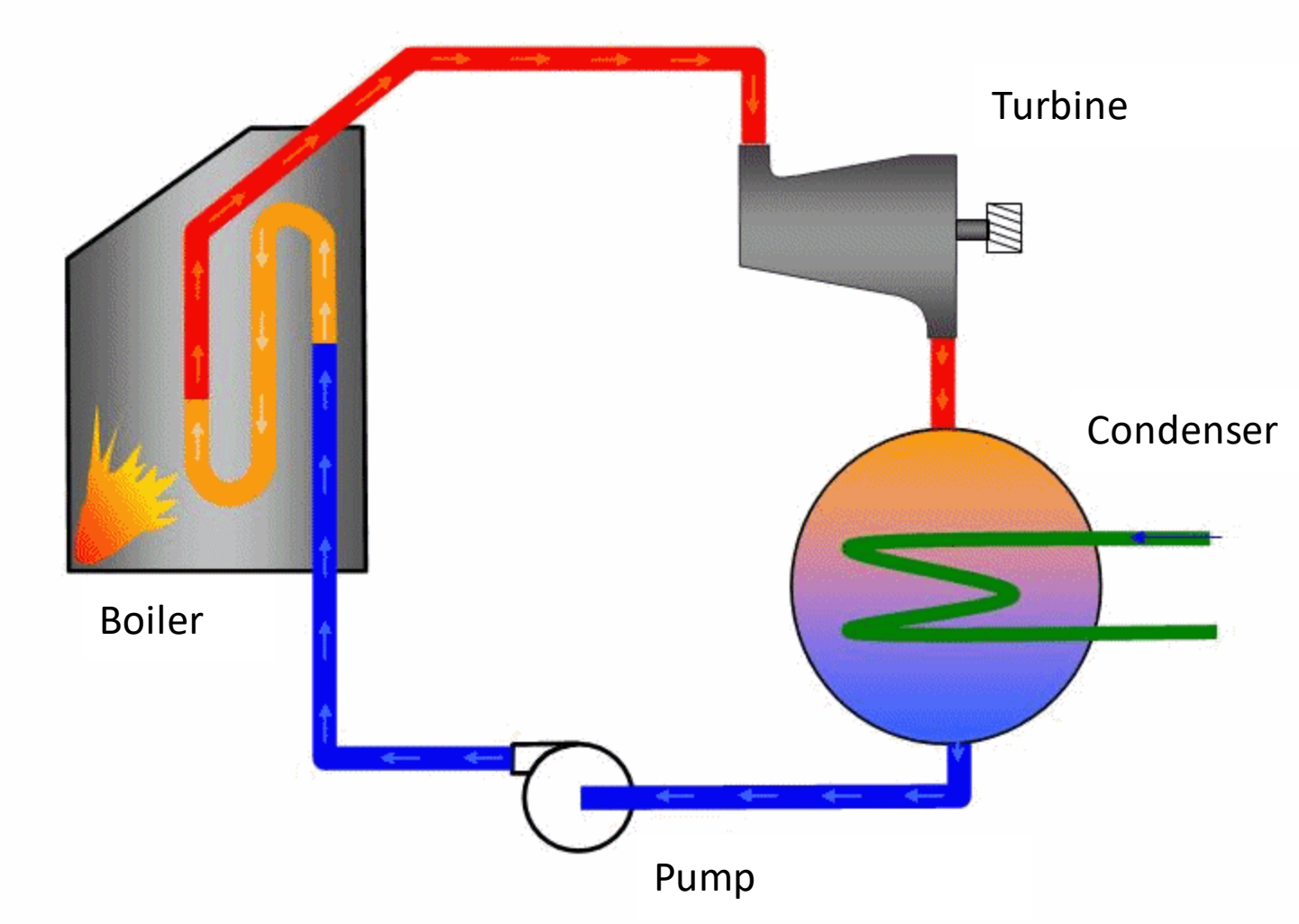
~1930 Steam locomotive



External combustion for power plants

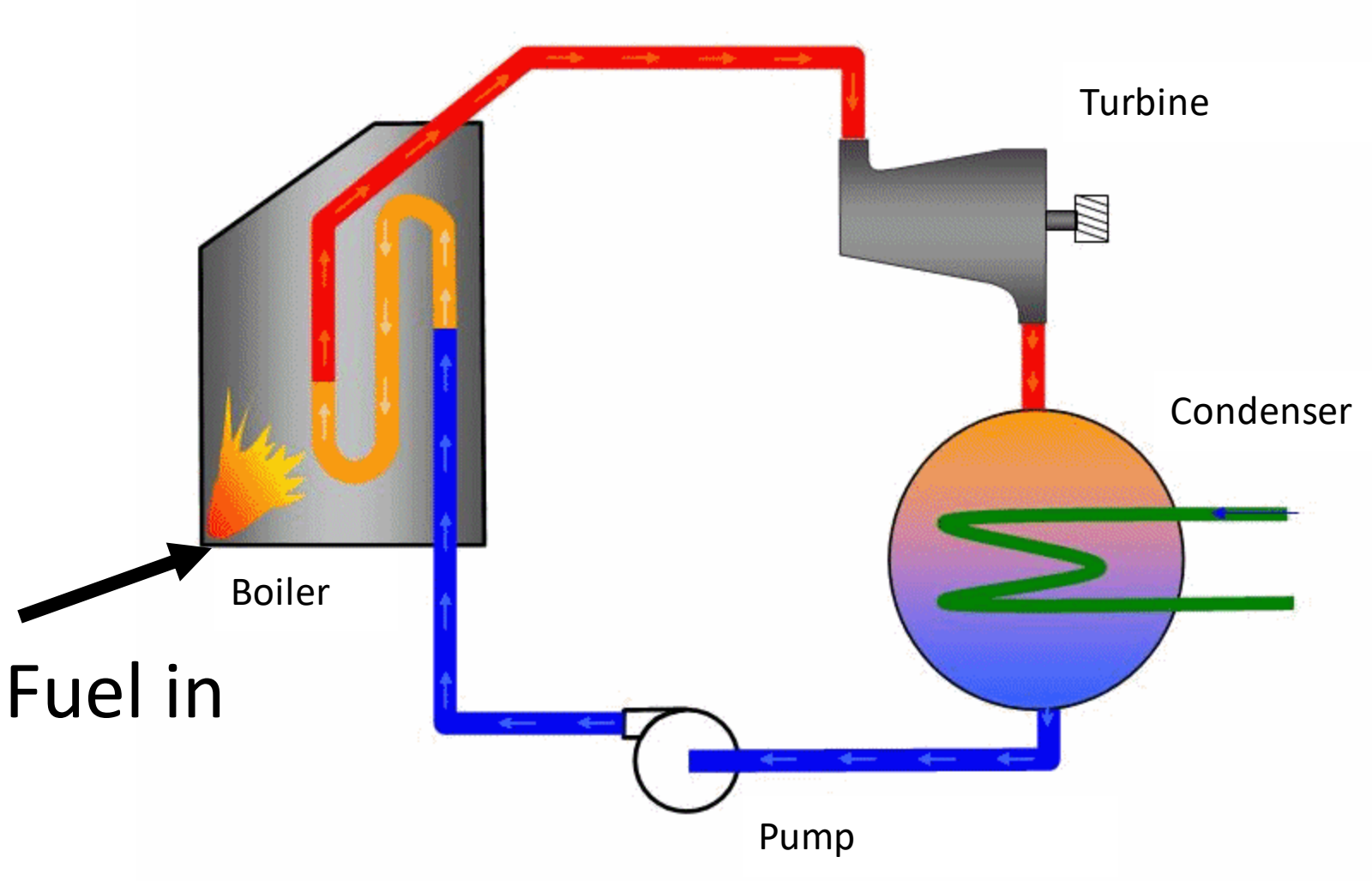
- Fuel (coal, natural gas, uranium, etc.)
- Boiler (where the water is boiled)
- Stack (CO_2 leaves, or other pollutants, not for nuclear plant)
- Turbine (steam pushes this around)
- Generator (makes electricity)
- Condenser (cools steam to repeat cycle)
- Cooling tower (Waste heat to atmosphere)

Steam Turbine



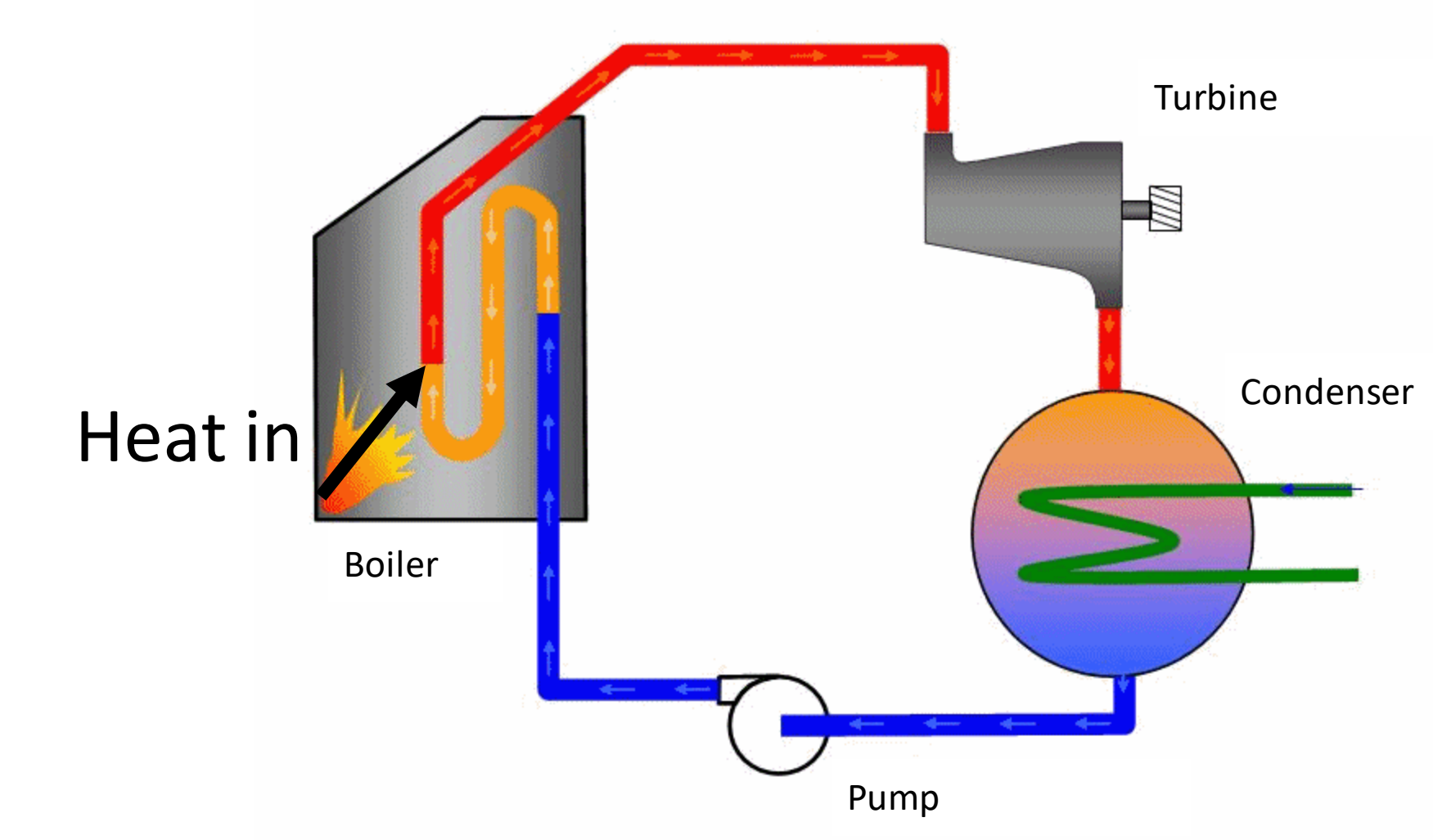
Source: http://e-learning.kku.ac.th/course/view.php?id=470&cal_m=3&cal_y=2008

Fuel runs boiler



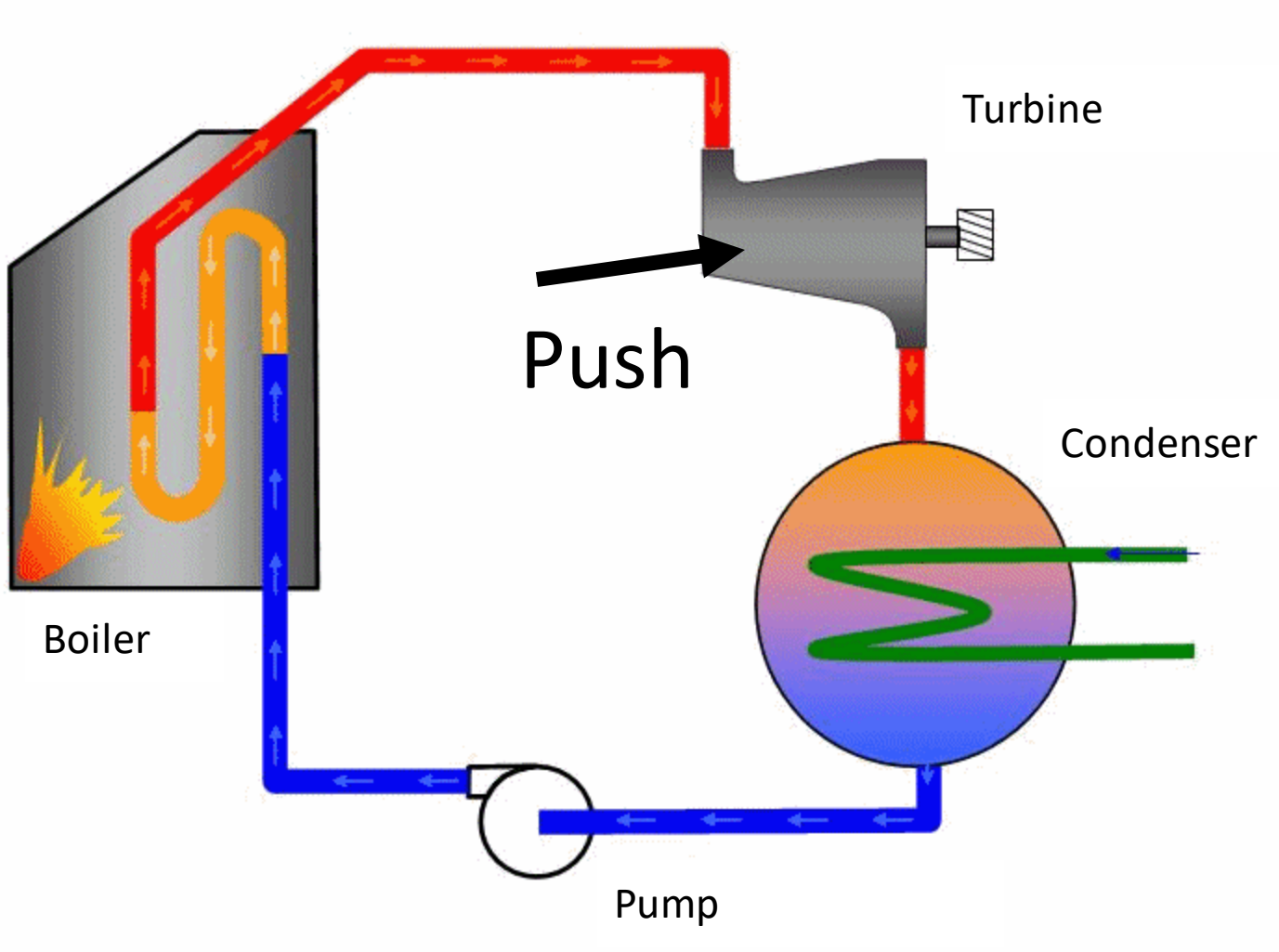
Source: http://e-learning.kku.ac.th/course/view.php?id=470&cal_m=3&cal_y=2008

Boiler heats water (Heat In)



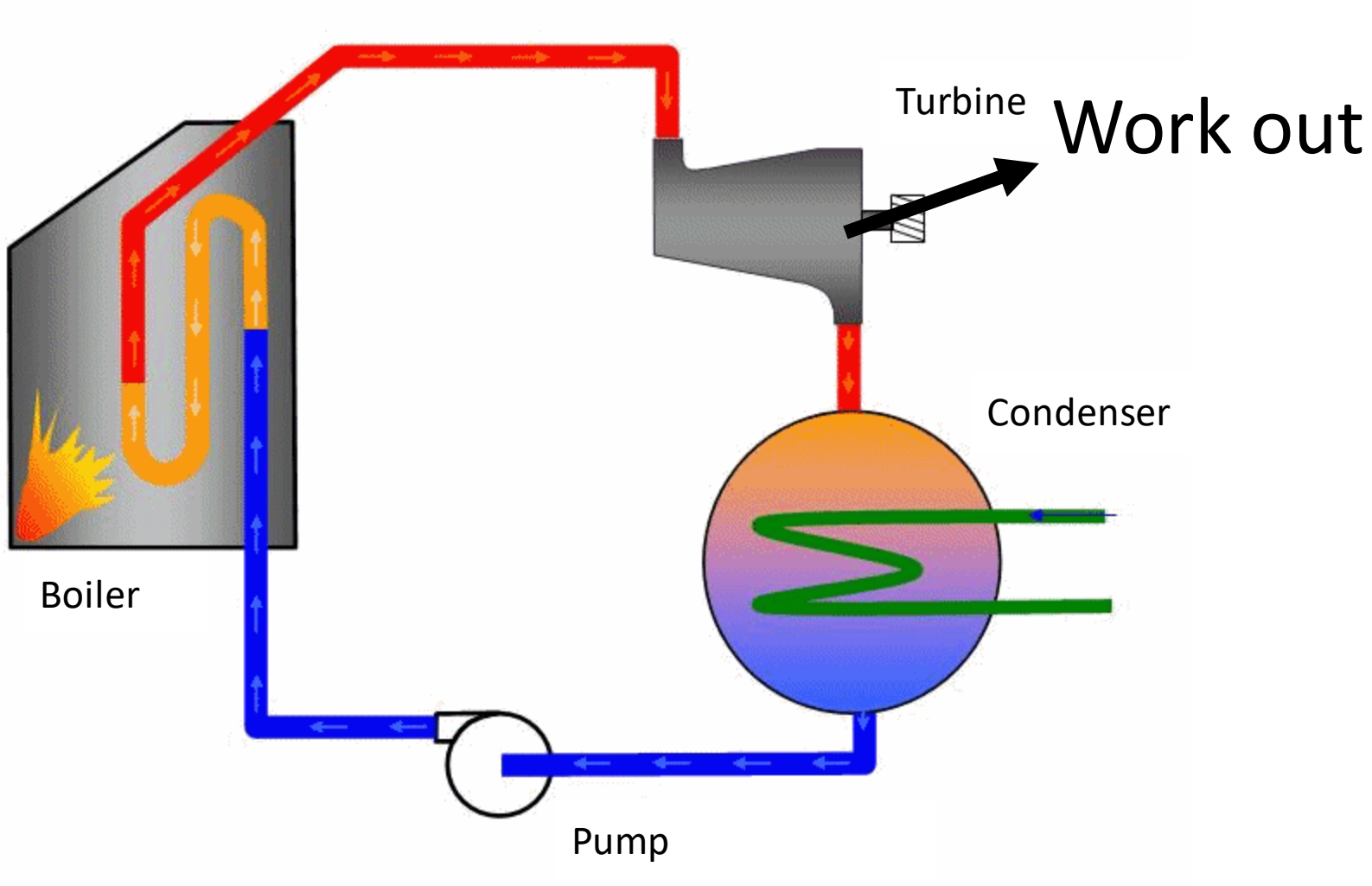
Source: http://e-learning.kku.ac.th/course/view.php?id=470&cal_m=3&cal_y=2008

Hot steam pushes turbine (like a fan blade)

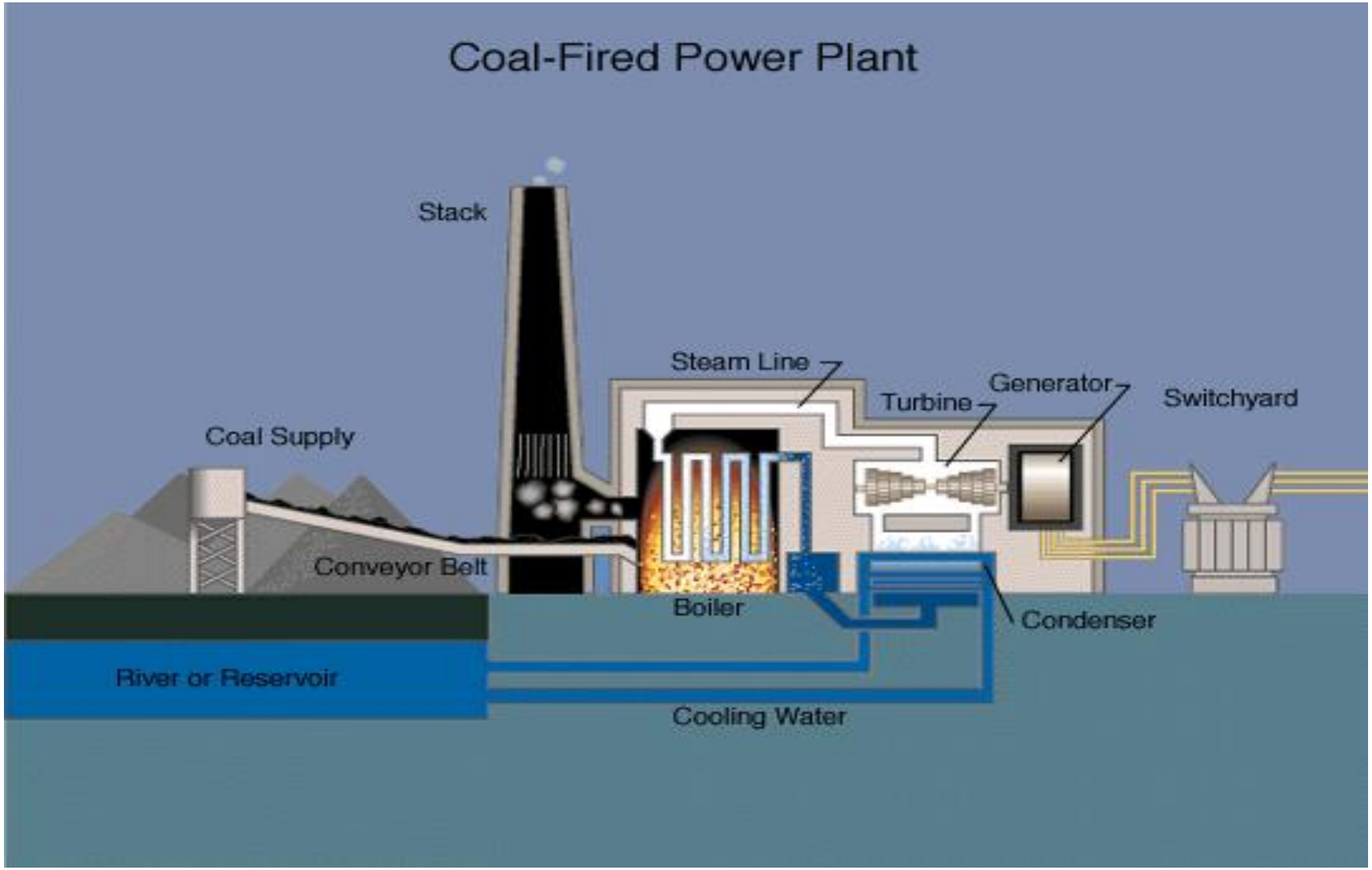


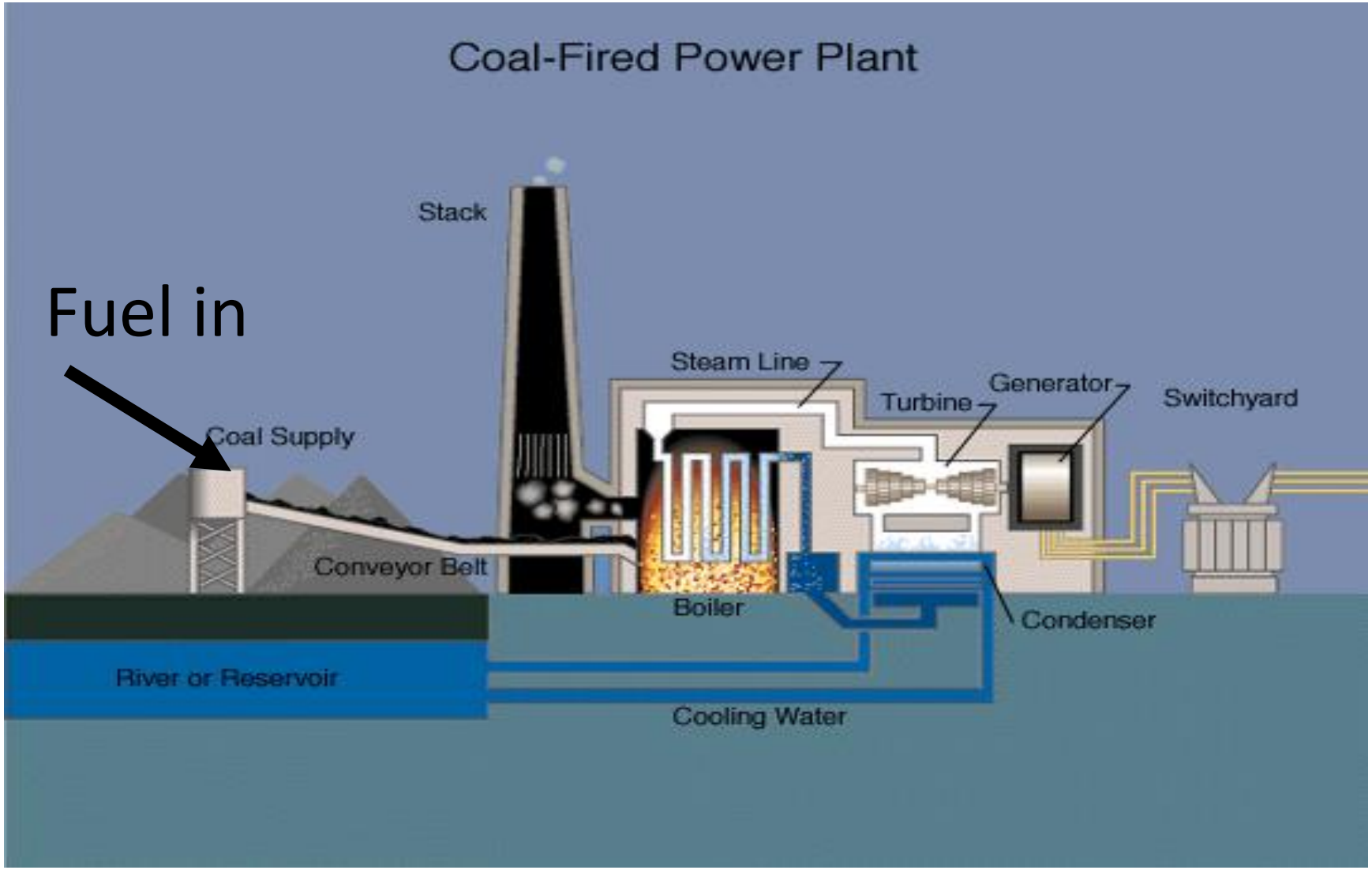
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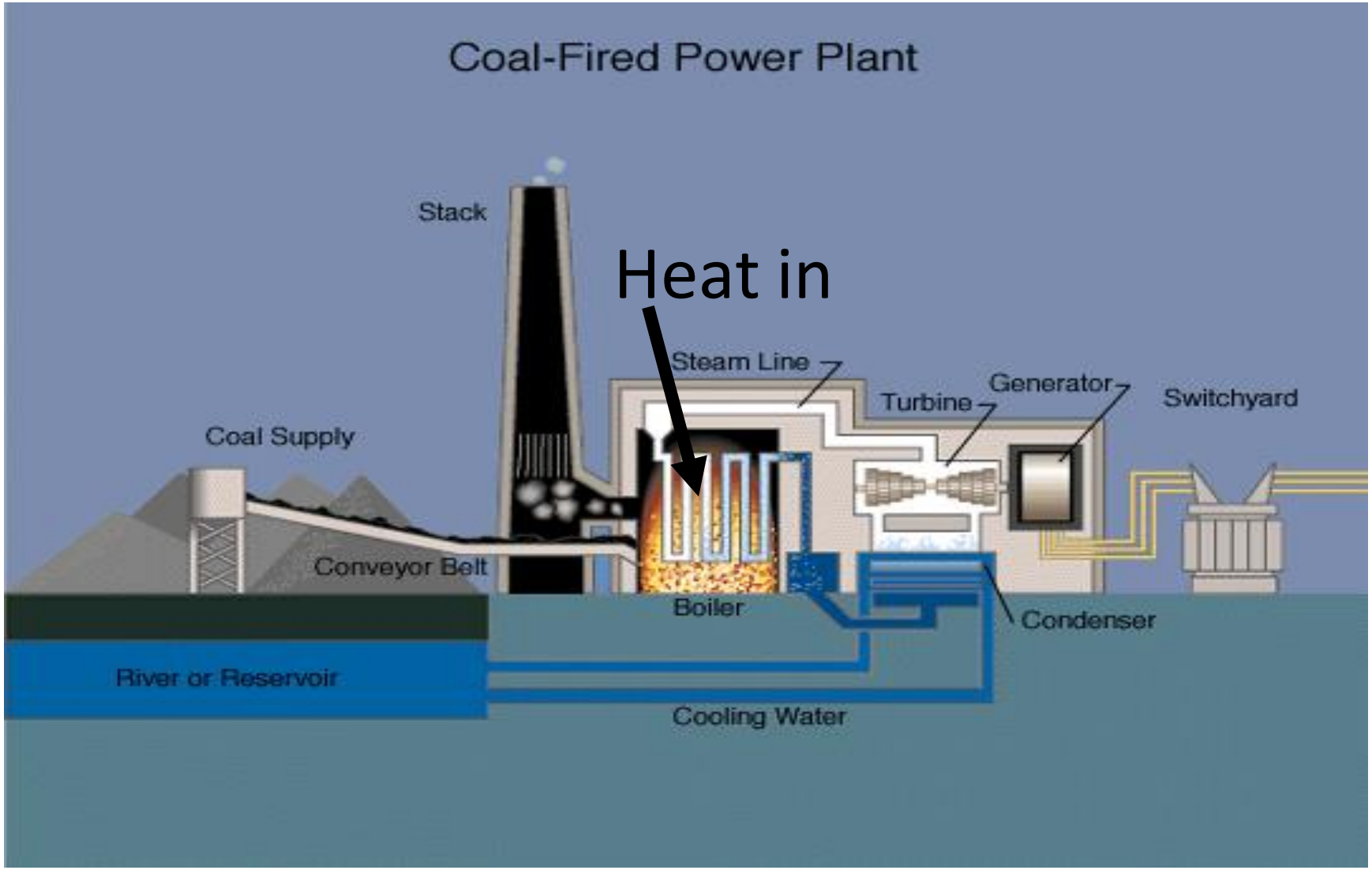
Spinning turbine makes useful work

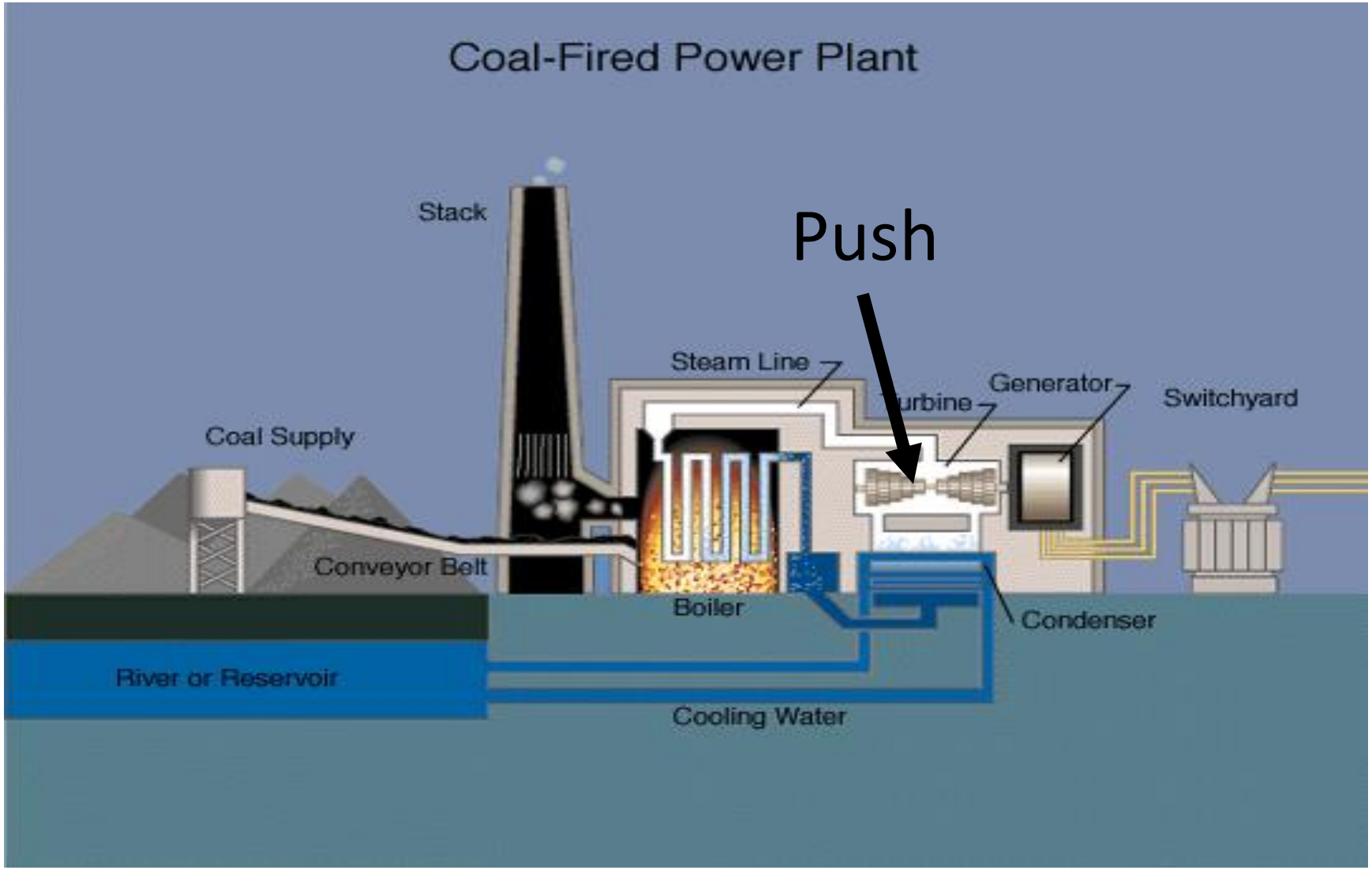


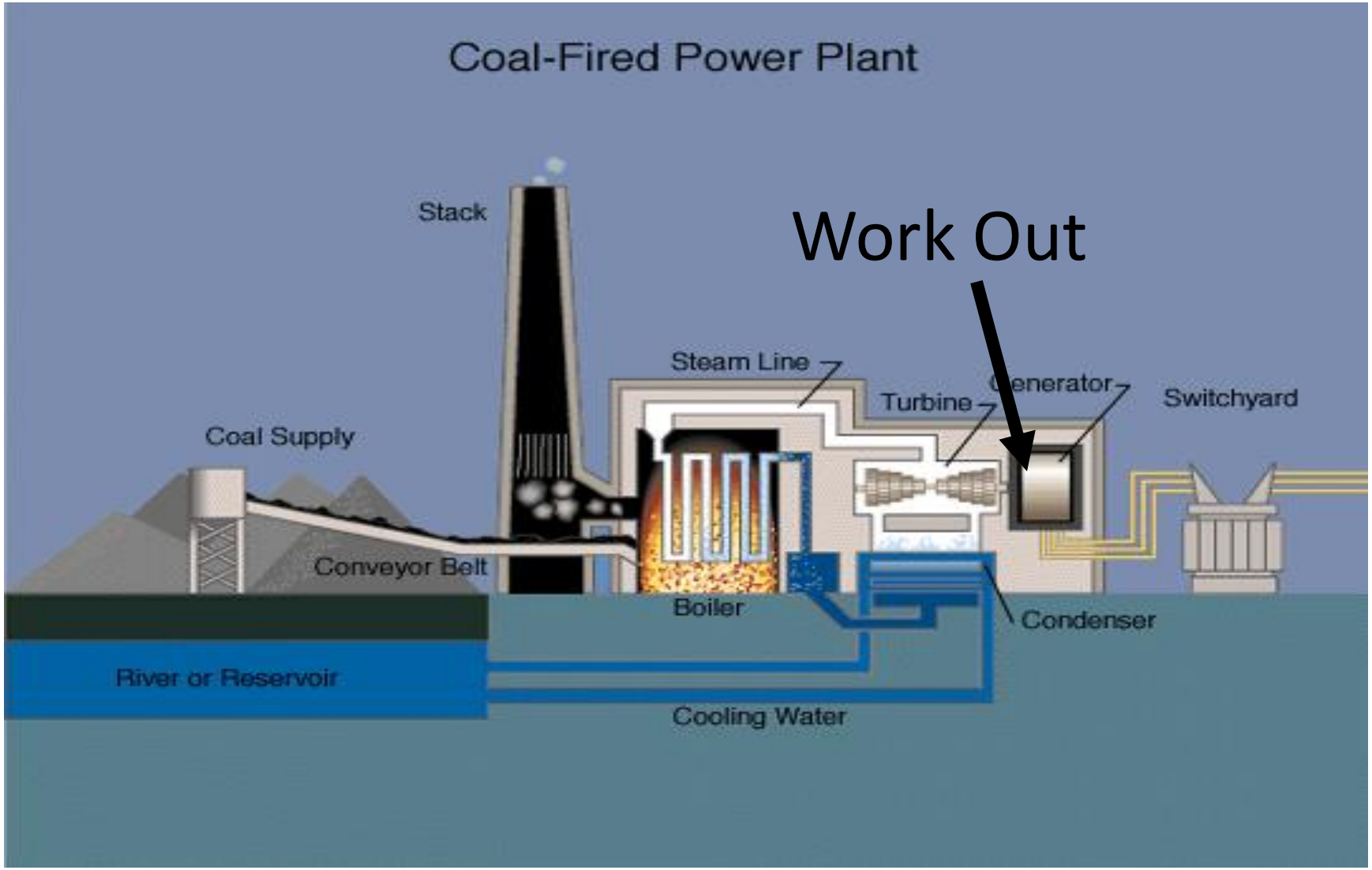
Source: http://e-learning.kku.ac.th/course/view.php?id=470&cal_m=3&cal_y=2008


Coal-Fired Power Plant
Stack
Steam Line
Turbine
Generator
Switchyard
Coal Supply
Conveyor Belt
Boiler
Condenser
River or Reservoir
Cooling Water


Coal-Fired Power Plant
Fuel in
Stack
Steam Line
Turbine
Generator
Switchyard
Coal Supply
Conveyor Belt
Boiler
Condenser
River or Reservoir
Cooling Water


Coal-Fired Power Plant
Stack
Heat in
Steam Line
Turbine
Generator
Switchyard
Coal Supply
Conveyor Belt
Boiler
Condenser
River or Reservoir
Cooling Water


Coal-Fired Power Plant
Stack
Push
Steam Line
Generator
Switchyard
Coal Supply
Conveyor Belt
Boiler
Condenser
River or Reservoir
Cooling Water


Coal-Fired Power Plant
Work Out
Stack
Steam Line
Turbine
Generator
Switchyard
Coal Supply
Conveyor Belt
Boiler
Condenser
River or Reservoir
Cooling Water

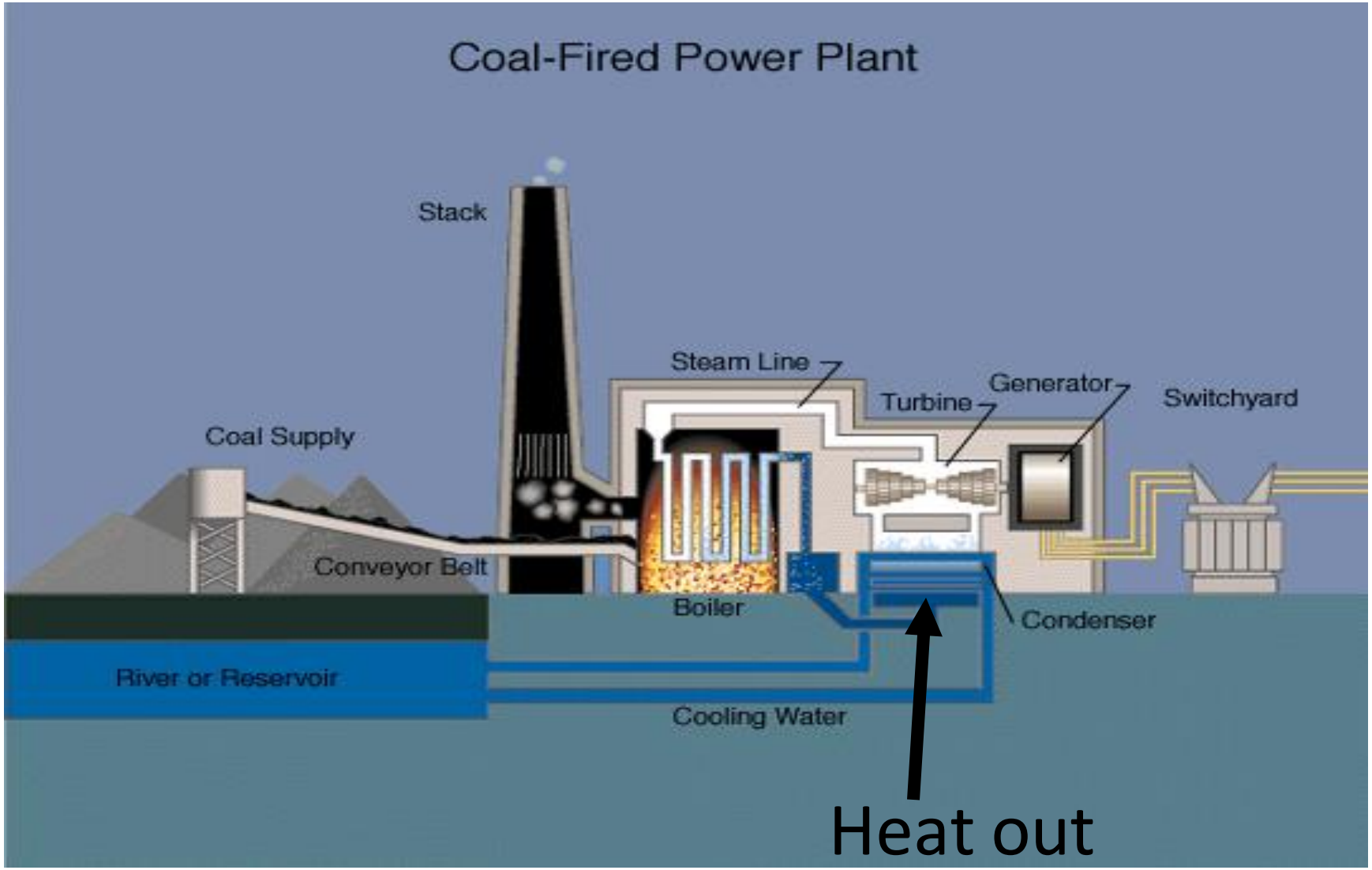
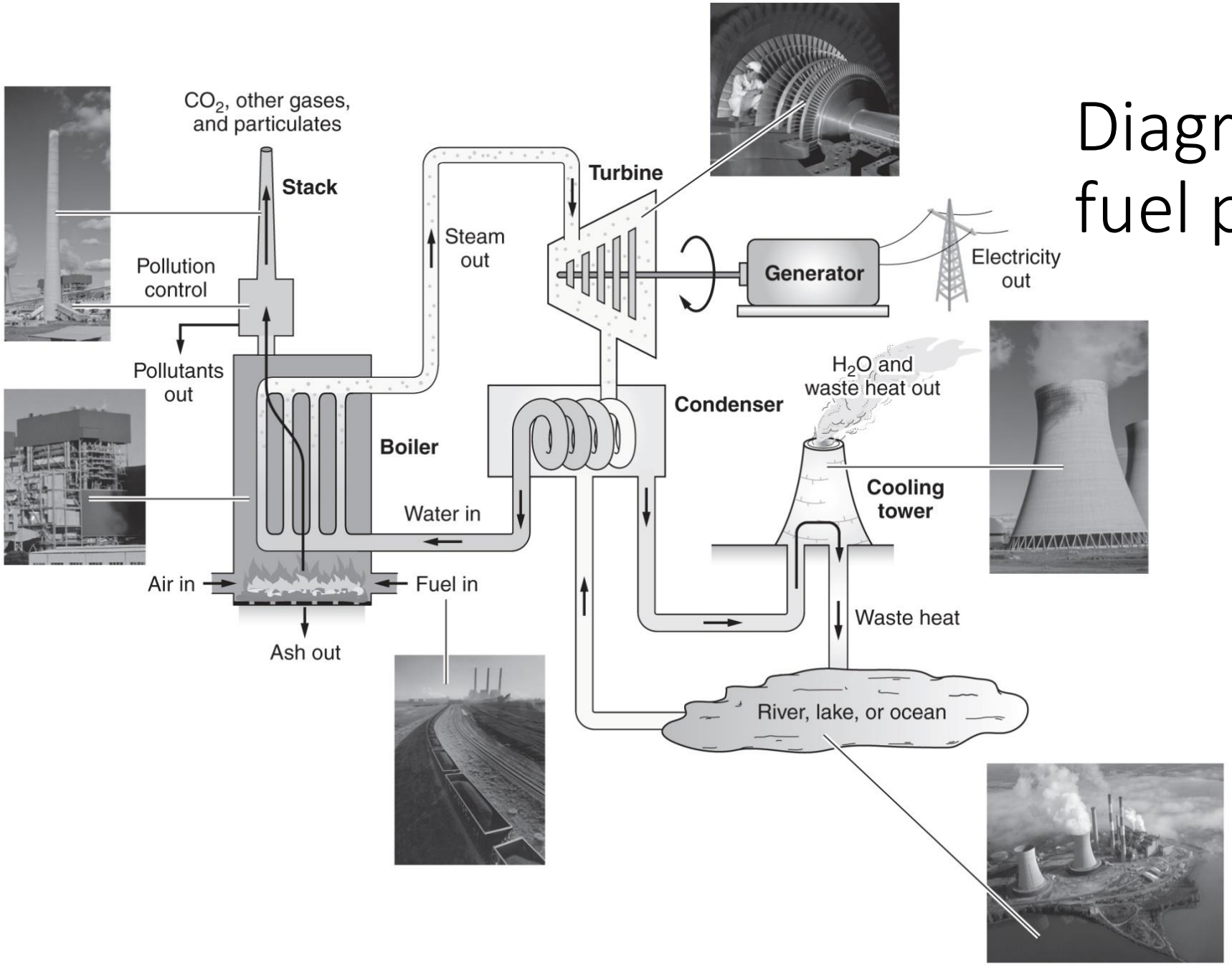
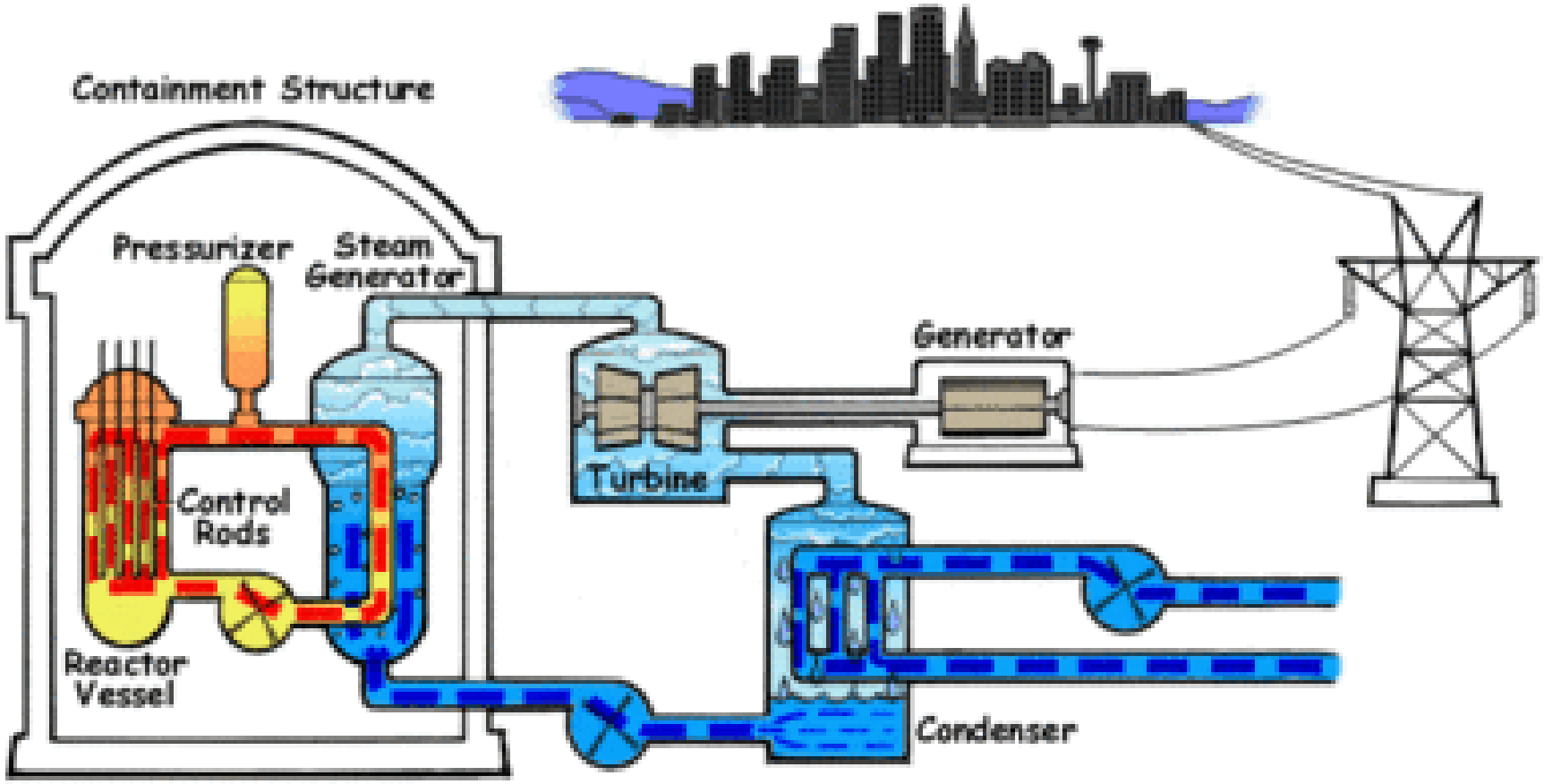

Coal-Fired Power Plant
Stack
Steam Line
Turbine
Generator
Switchyard
Coal Supply
Conveyor Belt
Boiler
Condenser
River or Reservoir
Cooling Water
Heat out

Diagram of a fossil fuel plant

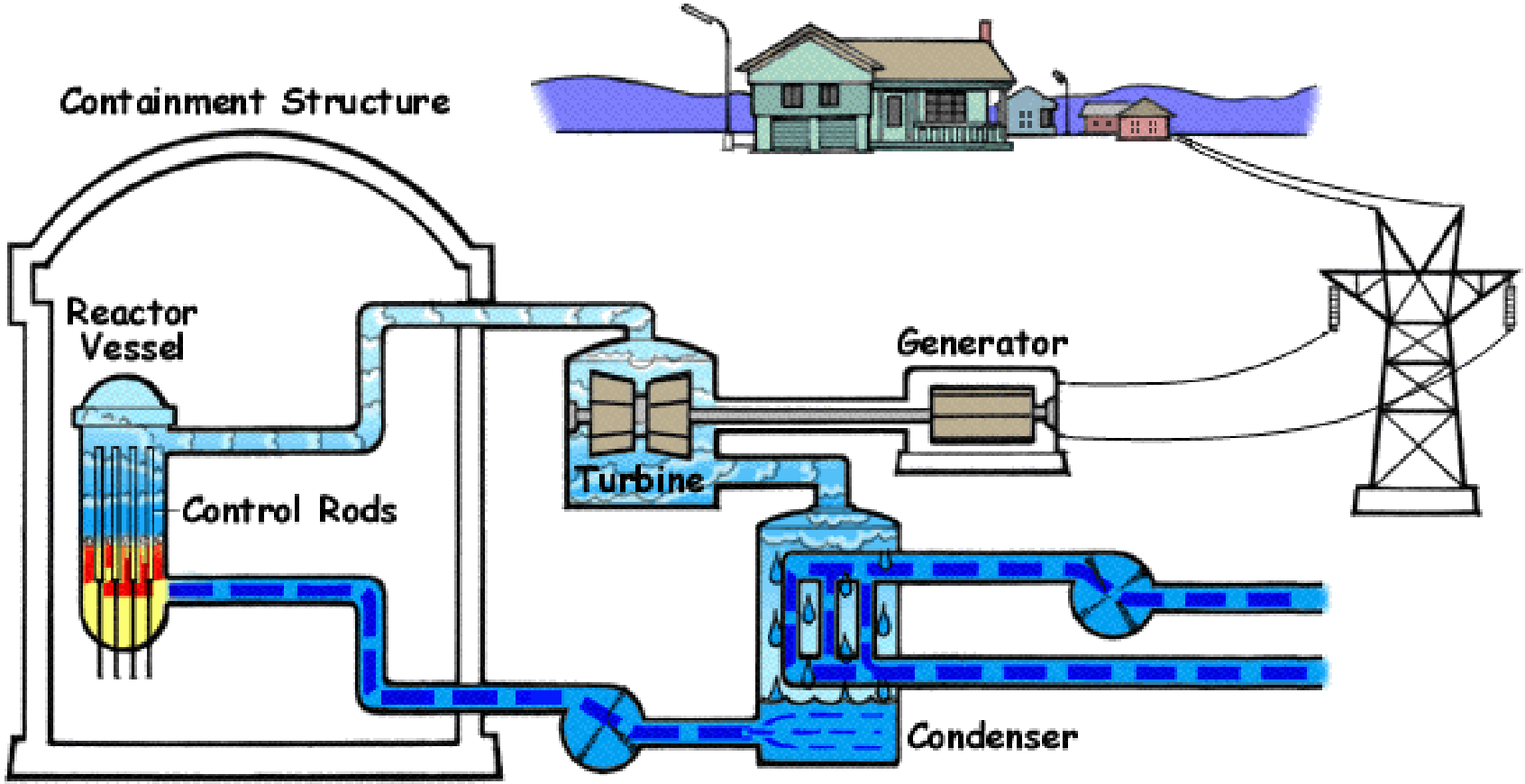


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From Wiki: Pressurized water reactor

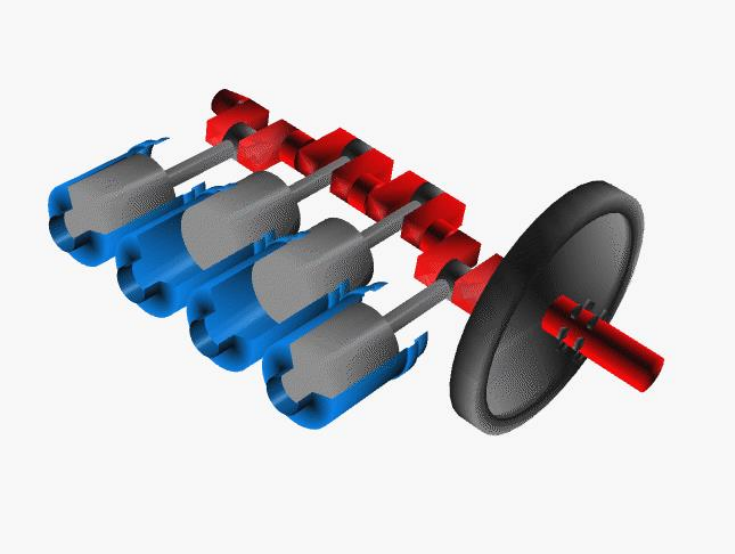


From wiki:
Boiling Water reactor



Work is done!

- Gas explosions can move a piston.
- Several pistons could be attached to a crank.
- Crank can be attached to a wheel and run a car!



Canada's Energy Flow – 2002 (Exajoules)

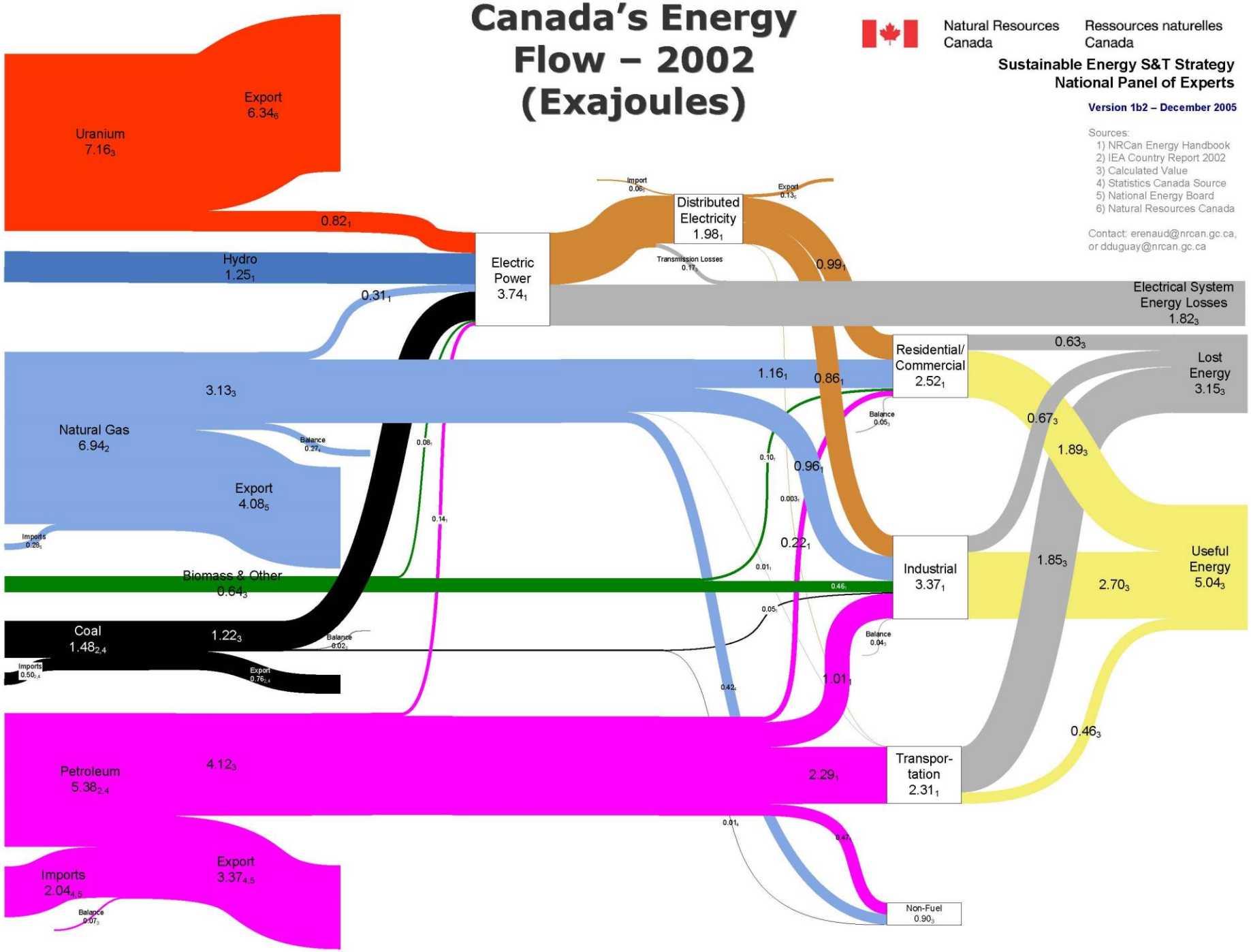
Natural Resources Canada | Ressources naturelles Canada

Sustainable Energy S&T Strategy
National Panel of Experts

Version 1b2 – December 2005

Sources:
1) NRCan Energy Handbook
2) IEA Country Report 2002
3) Calculated Value
4) Statistics Canada Source
5) National Energy Board
6) Natural Resources Canada

Contact: erenaud@nrcan.gc.ca, or dduguay@nrcan.gc.ca



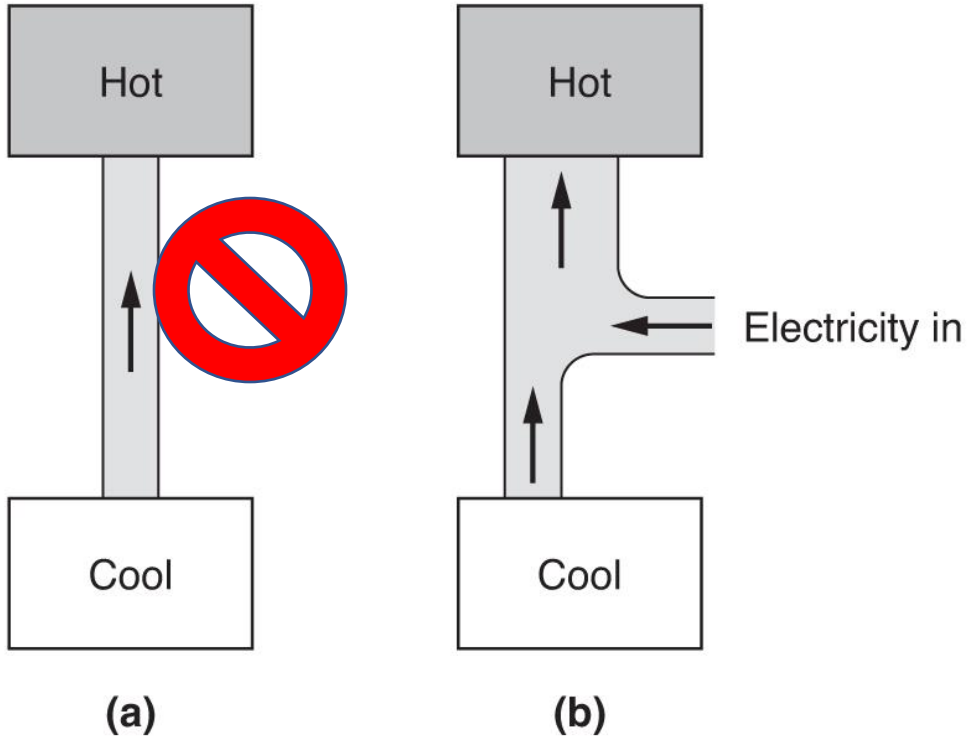
If we used breeder reactors

Breeders make more fuel

- Known technology but is not being used could make for a LOT more nuclear fuel.

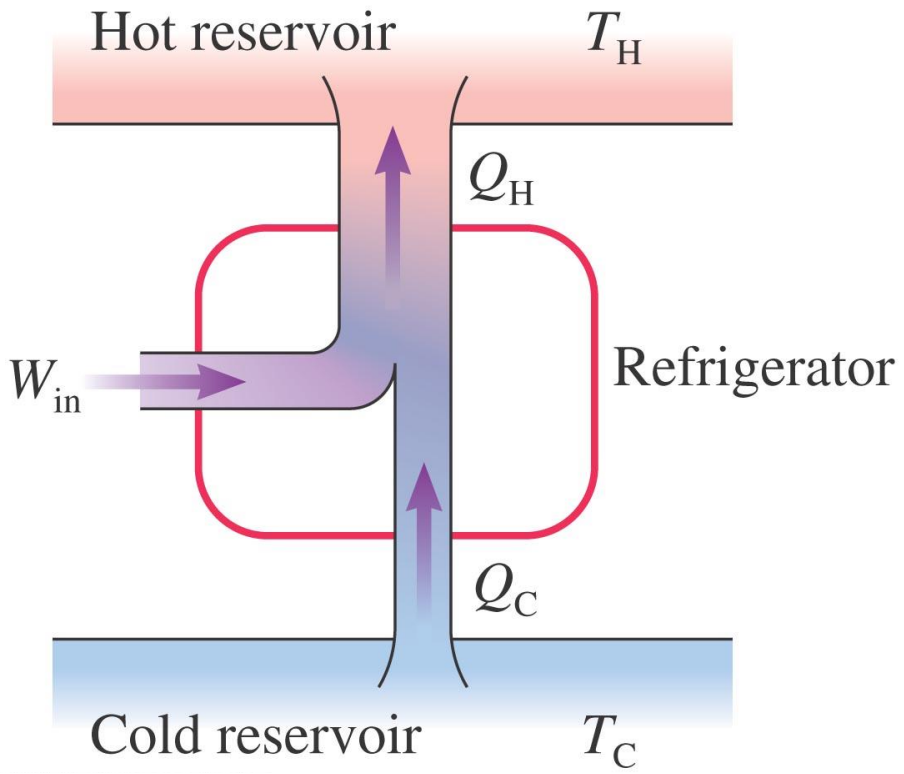
Model: World has heat, move heat to where it is wanted, remove unwanted heat

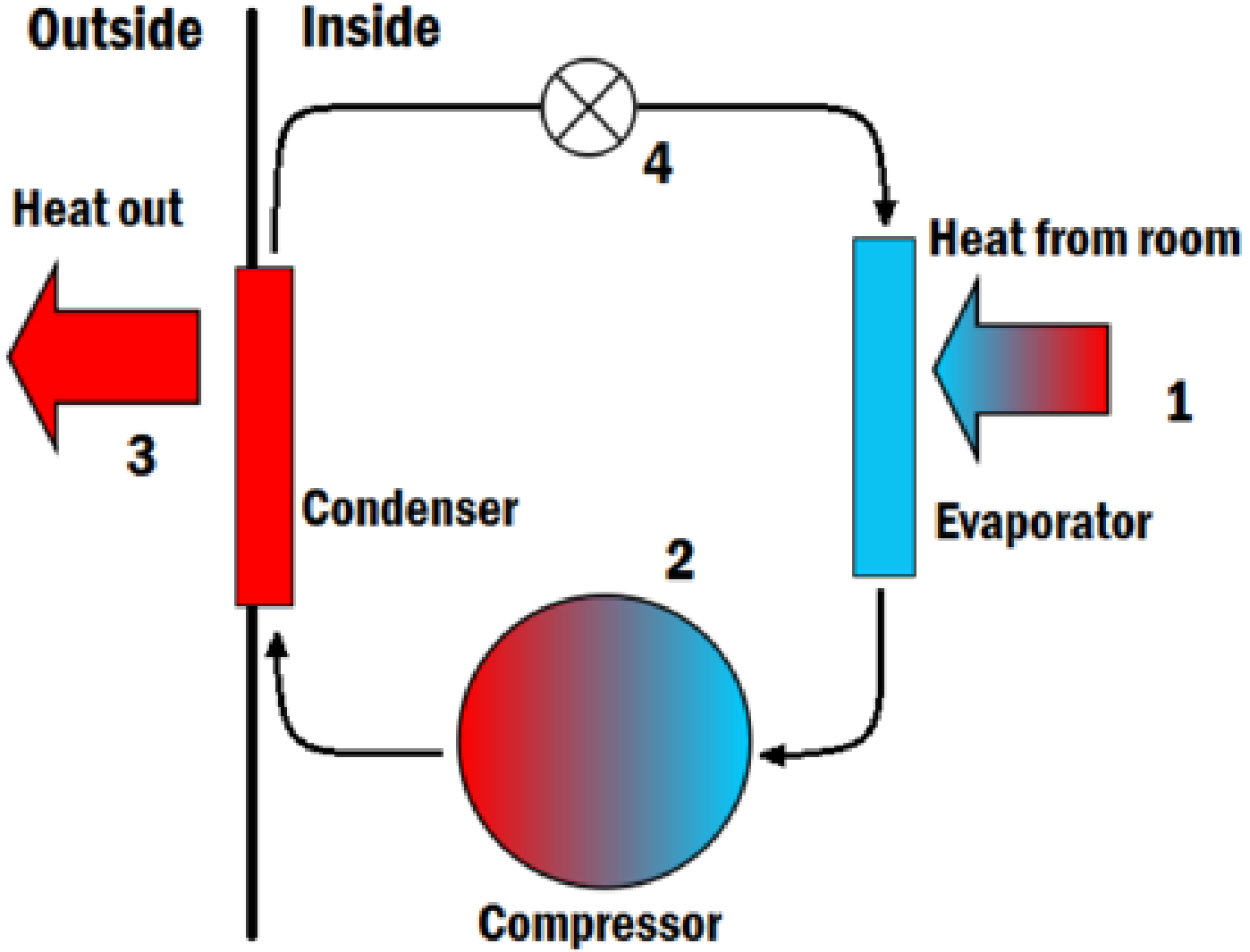




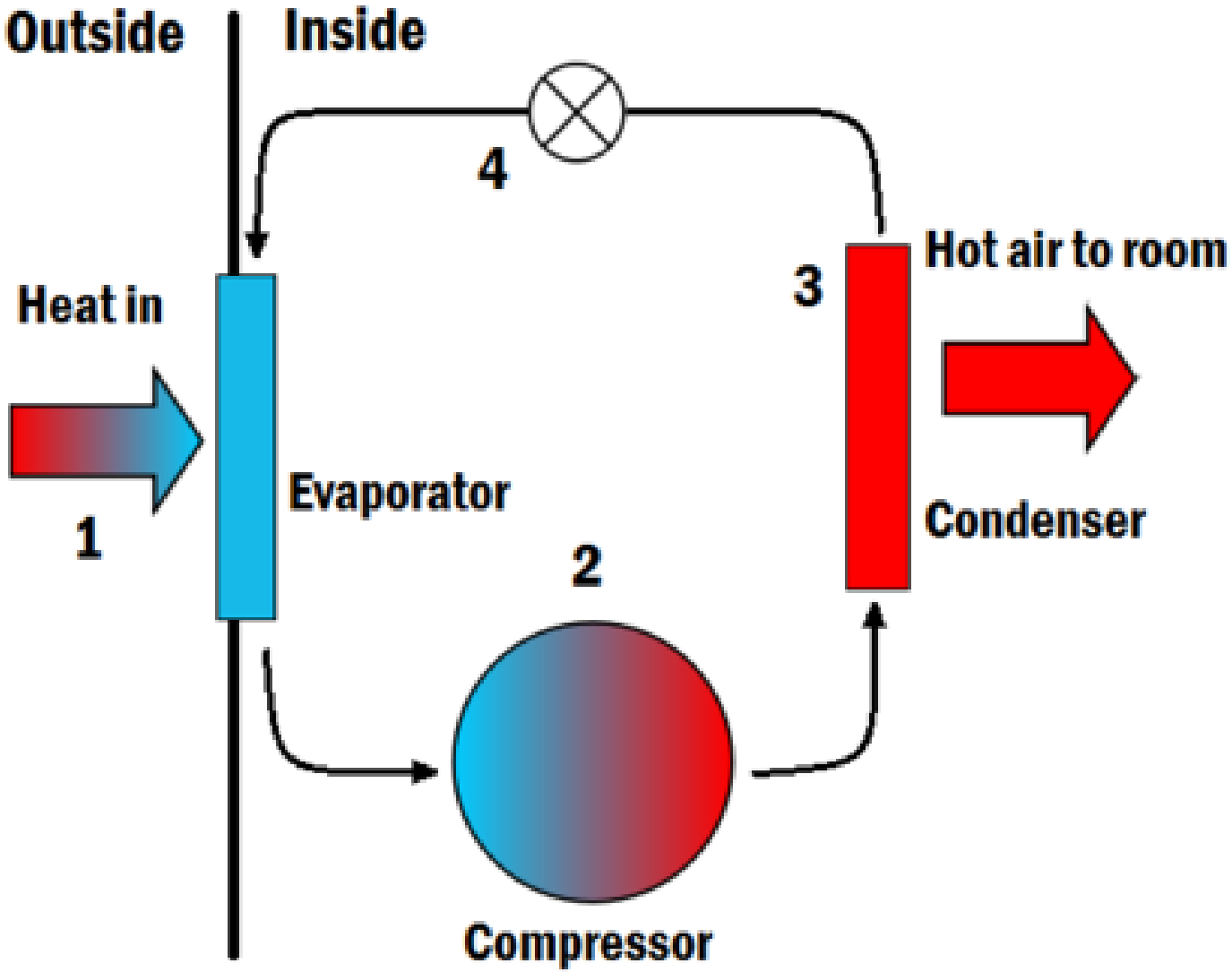
Refrigerators

A refrigerator that extracts heat from the cold reservoir and exhausts heat to the hot reservoir.





Cooling Cycle



Heating Cycle

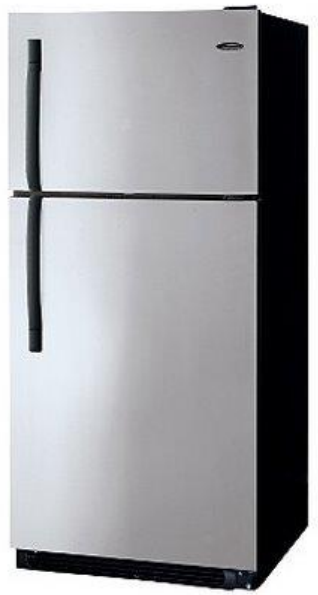
Refrigerators



These cooling coils are the refrigerator's high-temperature heat exchanger. Heat energy is being transferred from hot gas inside the coils to the cooler room air.

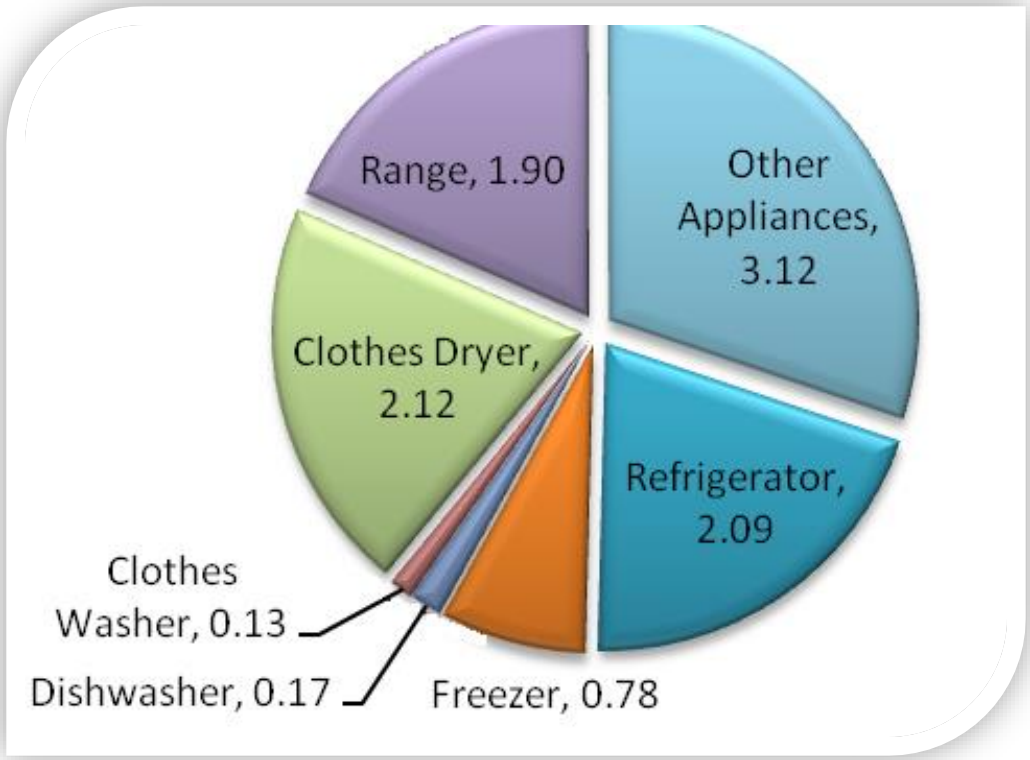
Usually:





- Human use determines electricity consumption.
- Exception, refrigerators and freezers, improved because technology improves
- Old fridge store drinks in the garage?!?

Refrigerators and Freezers



- Increase in efficiency :
  - Better design
  - Improved condensers
  - Improved compressors
  - Improved evaporators
  - Improved fan motors
  - Improved door seals
  - Foam insulation.





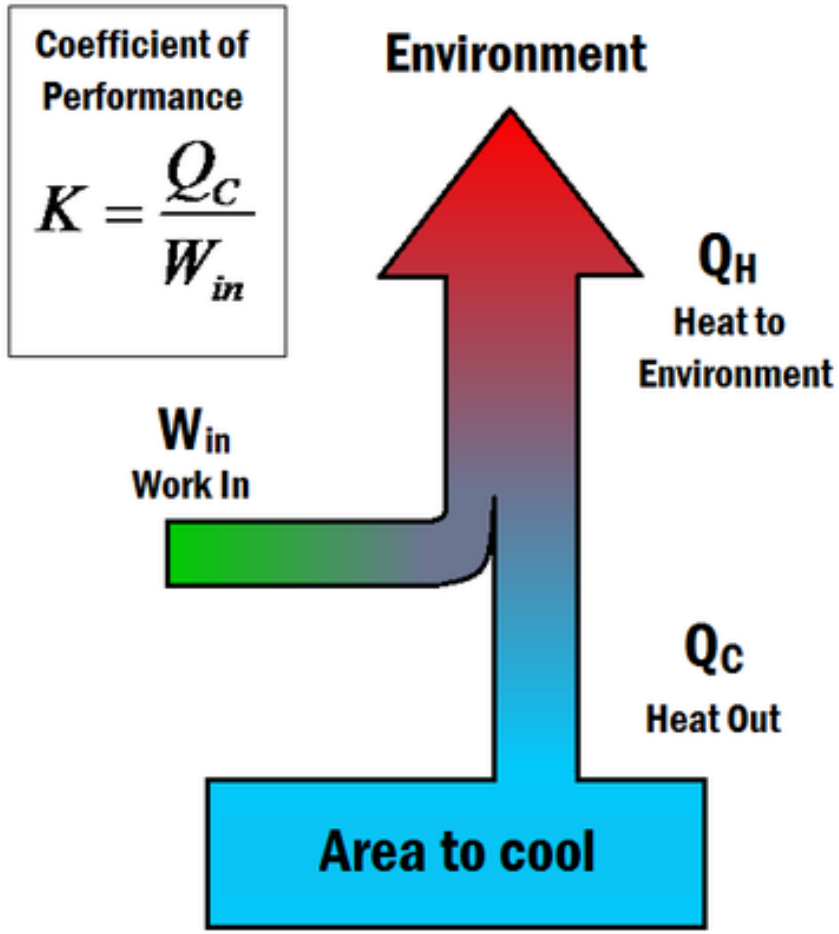
Chest freezers

- more efficient
  - air doesn’t spill out
  - Often no defrosters, which reduce efficiency
- less convenient

Coefficient of performance

- Like efficiency, but inverted.

$$K = \frac{Q_c}{W_{in}} = \frac{\text{What you get out}}{\text{What you pay}}$$



Ground source Heat pumps





- Air is not dense
- Ground more dense
- Same T ground more thermal energy.

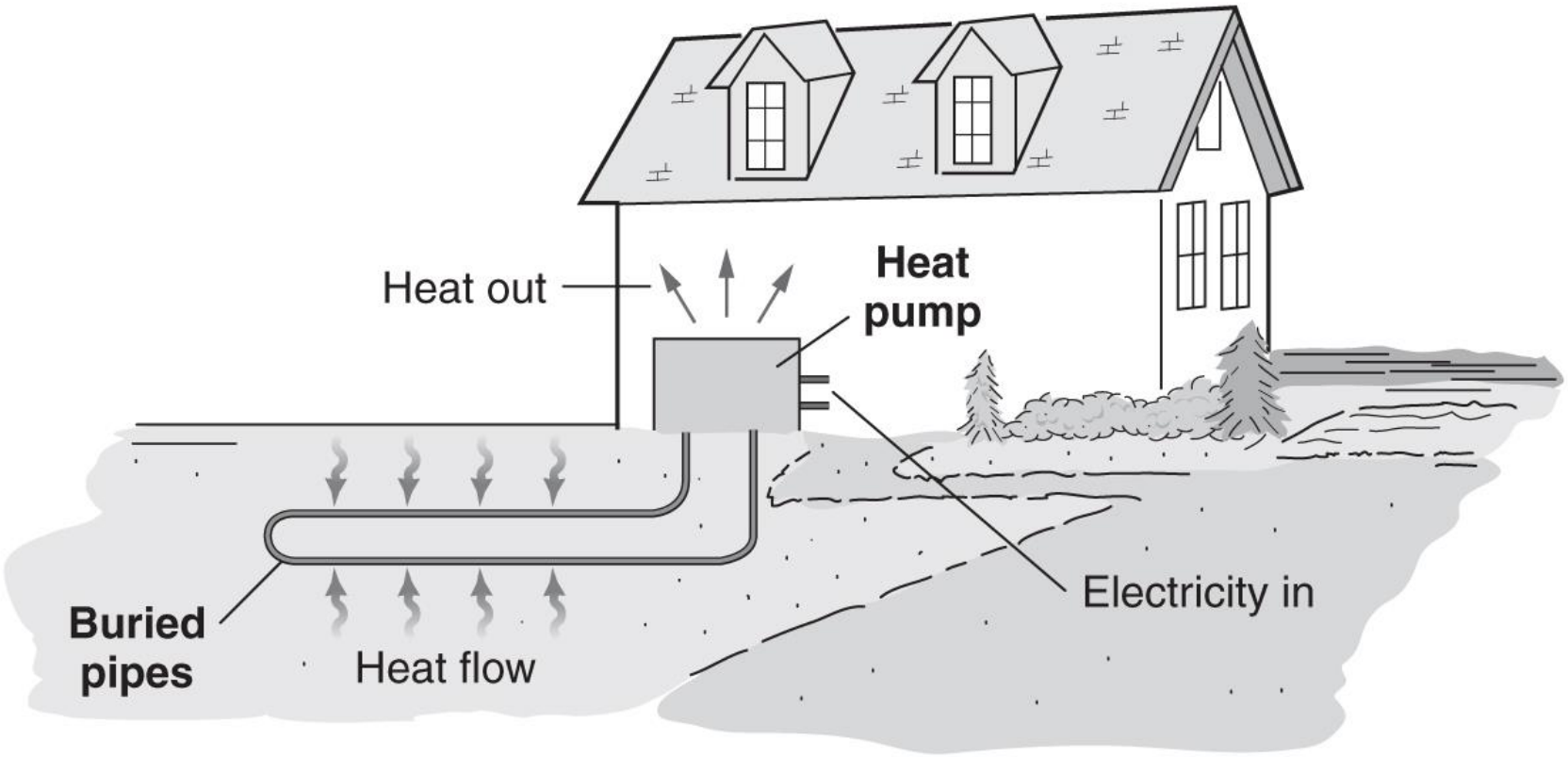


Figure 8.10

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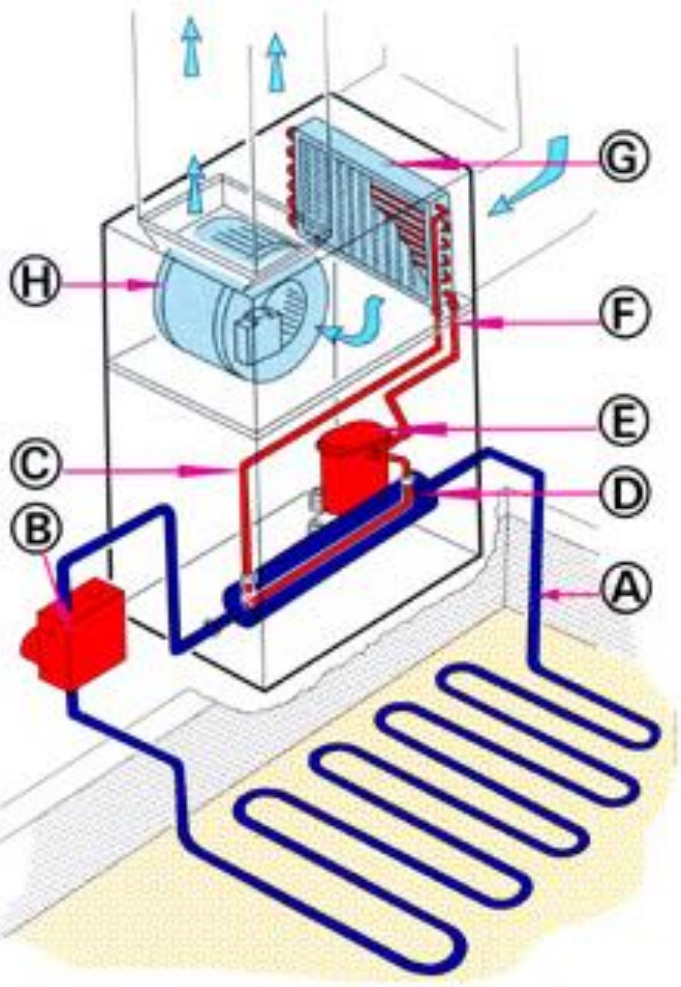
Ground Source heat pumps
Not actually geothermal, but close



Heat from ground

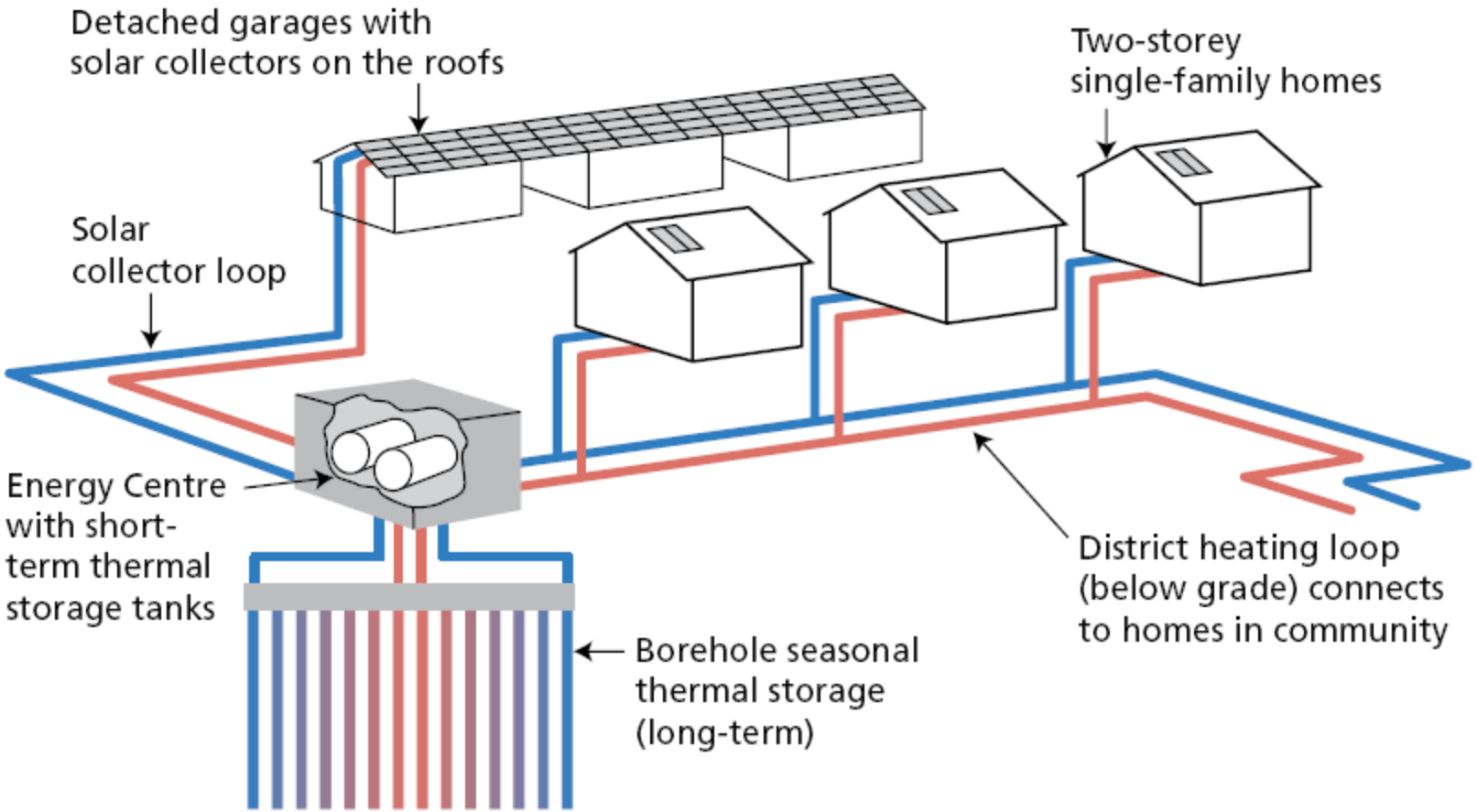
- Ground is denser, so more thermal energy is available at the same temperature.

Schematic Ground source Heat Pump



A. Ground loop
B. Pump
C. Refrigerant loop
D. Evaporator
E. Compressor
F. Refrigerant loop outlet
G. Radiator
H. Distribution fan

(my.dteenergy.com/home/savings/geothermal.html)

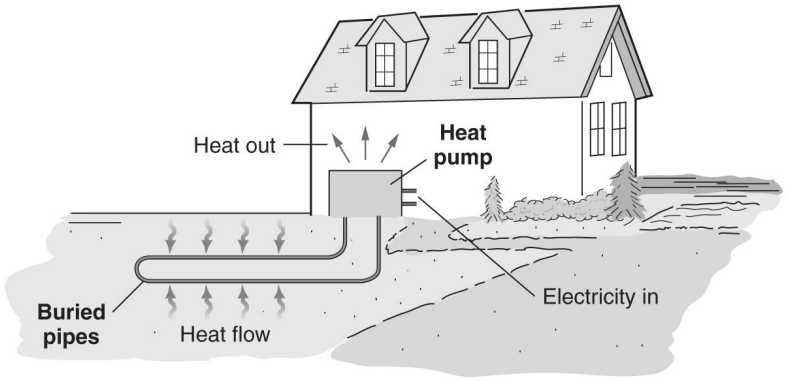


s, AB

(www.dlsc.ca/DLSC_Brochure_e.pdf)









Model: Refrigerators, heat pumps and air conditioners move heat using work (often electricity)