EGEE 102

Energy Conversion Efficiency

Basics

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What is useful energy?

light

heat

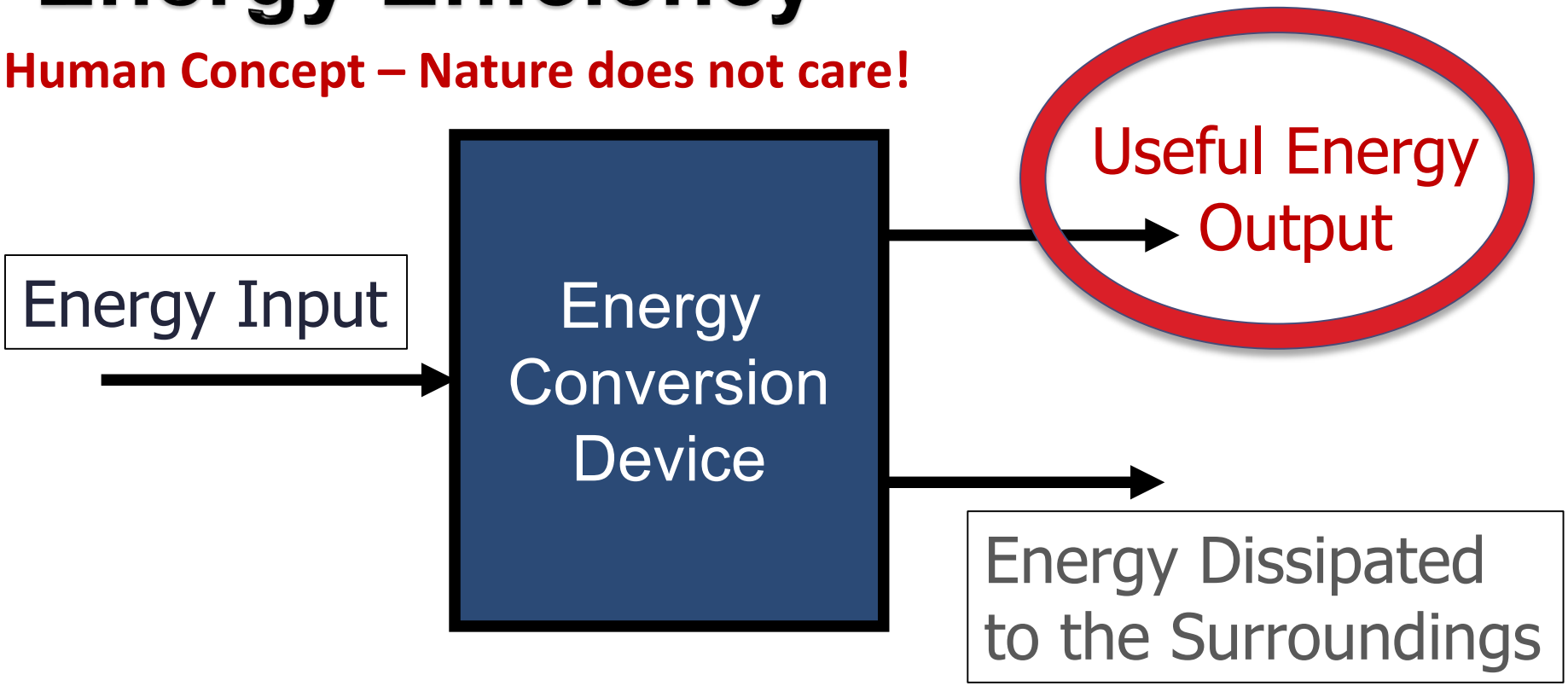
It always depends on what you need it for!

Not useful output:

- by-product / losses / energy dissipated to surroundings
- real systems always have “losses”

Energy Efficiency

Human Concept – Nature does not care!



$$Efficiency = \frac{Useful\ Energy\ Output}{Total\ Energy\ Input}$$

Efficiency quantified

Example:

An electric motor consumes 100 watts (a joule per second - J/s) of power to produce 90 watts of mechanical power. Determine its efficiency.

$$\text{Efficiency } (\eta) = \frac{90\text{ W}}{100\text{ W}} \times 100 = 90\ \%$$

Where is the other 10% ??

$$Efficiency = \frac{Useful\ Energy\ Output}{Total\ Energy\ Input}$$

Answer this question:

Calculate efficiency of a solar panel under solar flux of 1000 W/m^2 if the panel's output power density is 115 W/m^2

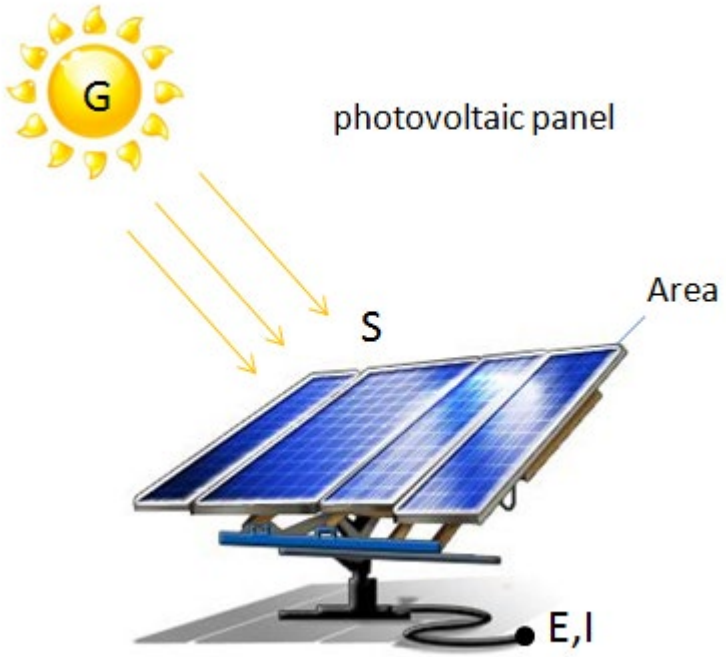
A. 1%

B. 8.5%

C. 11.5%

D. 85%

E. 100%



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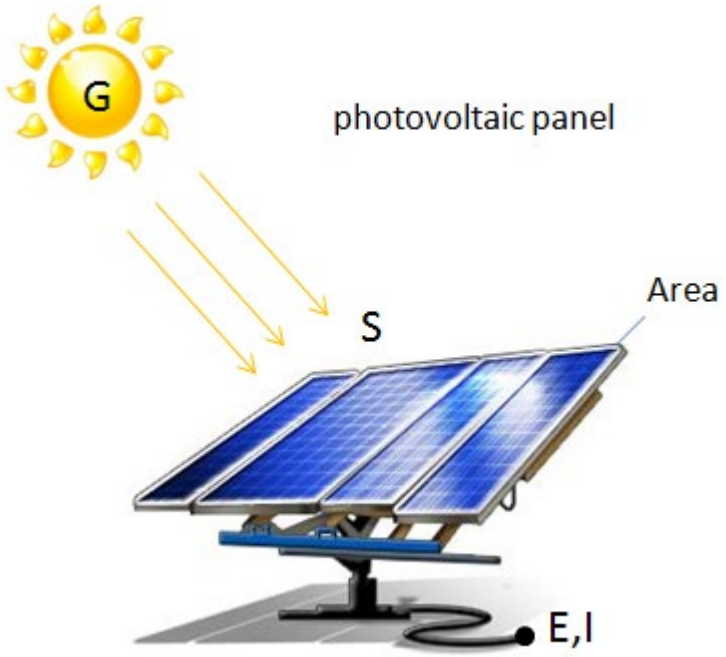
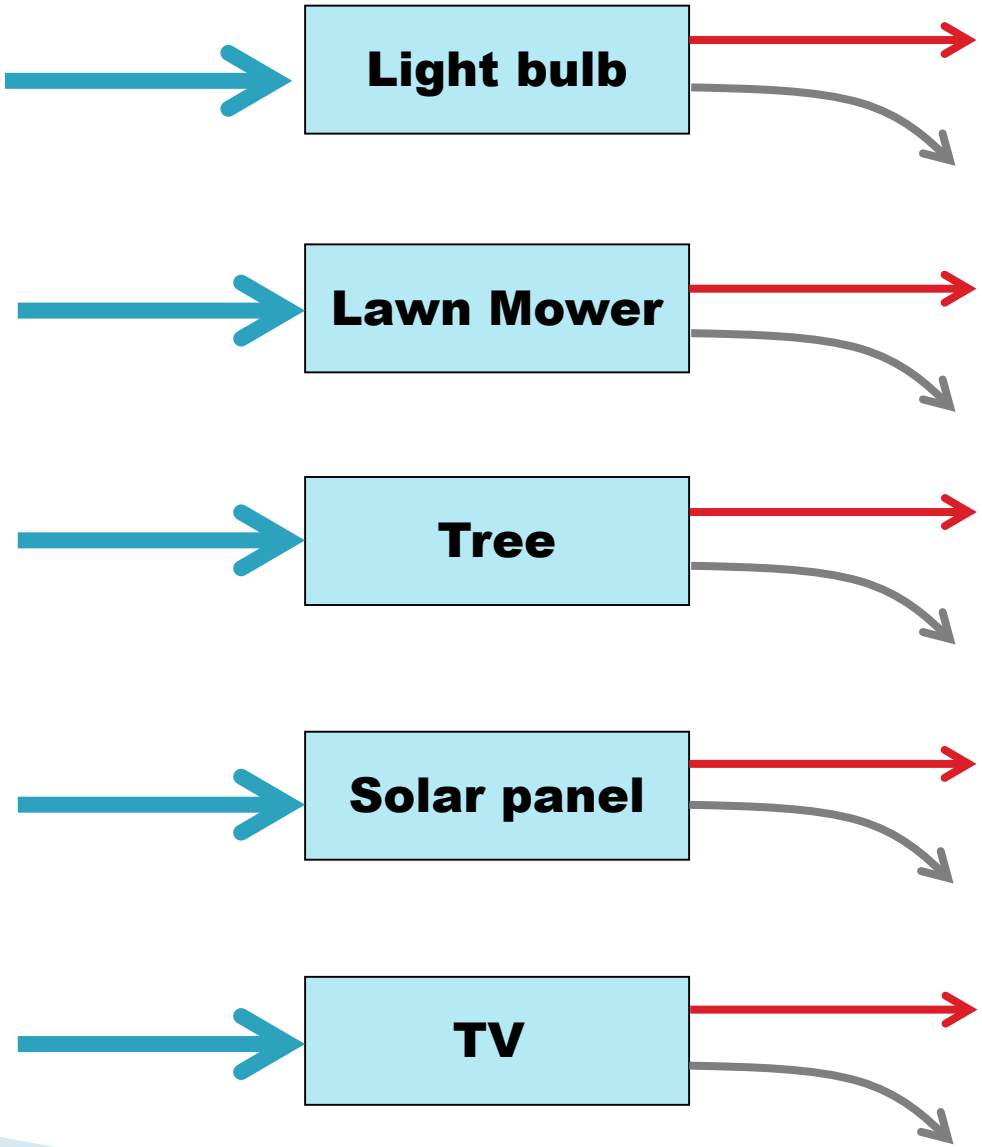


For each system:

Identify Energy Inputs



Identify Energy Outputs

useful

not useful

exercise

Efficiency of Some Common Devices

Device	Efficiency (%)
Electric Motor	90
Home Oil Furnace	65
Home Coal Furnace	55
Steam Boiler (power plant)	89
Power Plant (thermal)	36
Solar cell (maximum)	33
Automobile Engine	25
Light Bulb - Fluorescent	20
Light Bulb - Incandescent	5

Can conversion efficiency be above 100%?

Can conversion efficiency be above 100%?

No – because of the laws of thermodynamics, which say that losses are unavoidable

First Law of Thermodynamics

Conservation of Energy

"Energy can neither be created nor be destroyed; it can only be transformed from one form into another"

Hence we understand that energy is not "lost" upon conversion, it just changes to other forms.

For any device:

Sum of inputs = Sum of outputs

First Law of Thermodynamics

Sum of inputs = Sum of outputs

Total Energy Input = Useful Energy Output + Energy Dissipated

Efficiency relies on these

$$\eta = E_{useful} / E_{in\ total}$$

This energy can be:
- Converted to other forms
- Reflected
- Transmitted
-….

It is never a real "loss" – just loss to a consumer

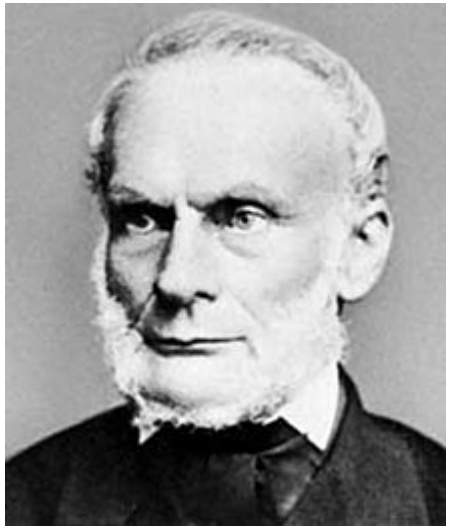
Second Law of Thermodynamics

"Any spontaneous process goes with an increase in entropy"

"Entropy" = measure of disorder

In other words:

"In any conversion of energy from one form to another there is always a decrease in the amount of useful energy."



Rudolf Clausius
German physicist and mathematician
1865

Implications of entropy for energy conversion

- The efficiency cannot practically reach 100%
- Theoretically efficiency cannot exceed 100%
- In any spontaneous process a system will increase its degree of disorder (entropy) => there will always be losses to the surroundings
- The more steps in a conversion process, the more energy is lost along the way
- Most natural energy conversions are irreversible

Review Question

A new breakthrough technology claims its conversion efficiency to be 110% What is your reaction?

A. It is possible if we eliminate all losses
B. It is impossible because of the 1st Law
C. Everything is possible with innovative technology
D. Yeah, maybe, but they probably lie
E. I feel that this is a trick question

Review Question

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Watch for units in efficiency problems!

Example problem

The useful output from a heat engine is 249 calories. The energy that is wasted is 5675 joules. What is the efficiency of the engine?

Can you solve it?

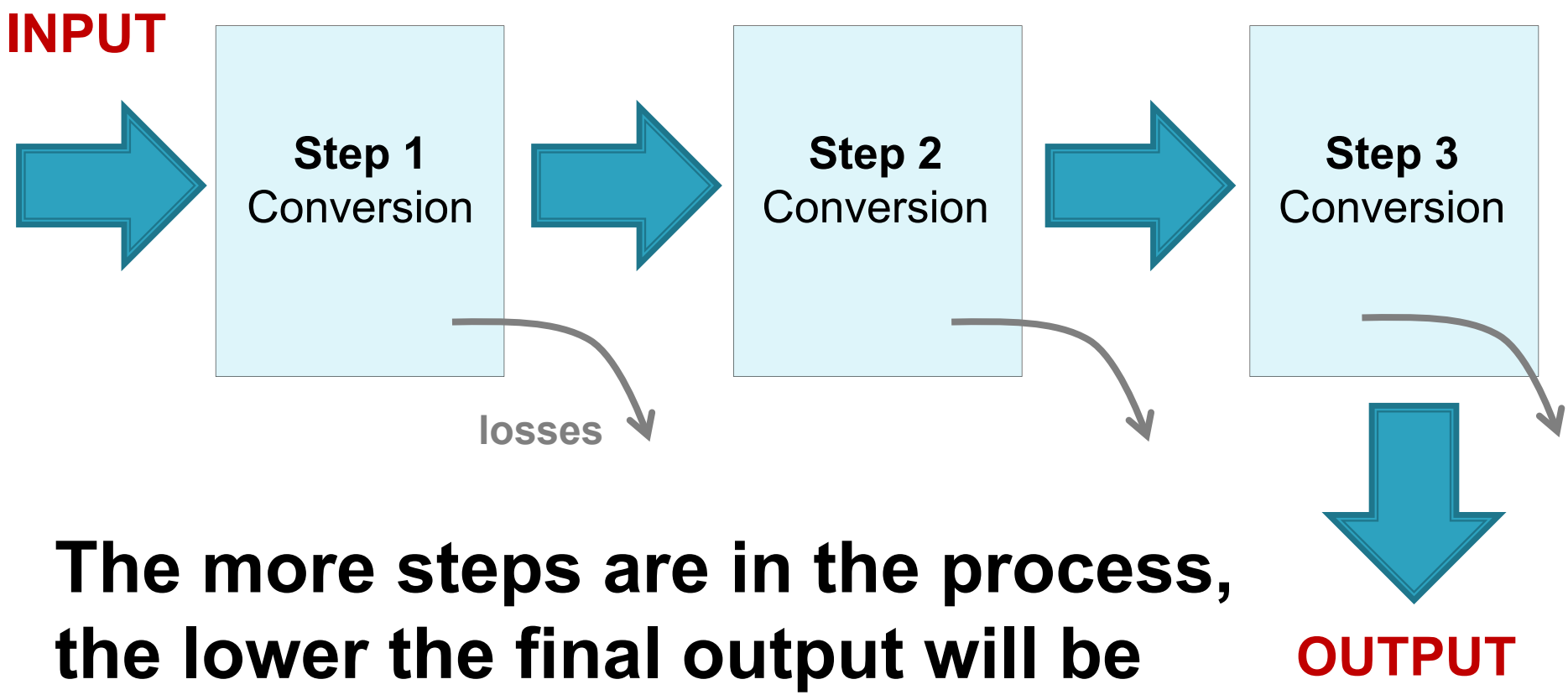
tips

- 1 calorie = 4.184 joules
- Input = Useful output + Losses (1st Law)
- Efficiency = Useful / Total

Online energy conversion calculator:

http://www.onlineconversion.com/energy.htm

System efficiency



The more steps are in the process, the lower the final output will be

System efficiency

The efficiency of a system is equal to the <u>product</u> of efficiencies of the individual devices (sub-systems)

$$\eta_{(system)} = \eta_1 \times \eta_2 \times \eta_3 \times \ldots$$

multiply them together

Self-check question

Estimate the overall system efficiency of a hypothetical car if:

- Engine efficiency (fuel to mechanical) = 20%
- Engine to wheel transmission efficiency = 75%
- Wheel to car momentum transfer efficiency 47%

A. 35%

B. 15%

C. 7%

D. 2.3%

Self-check question

Estimate the overall system efficiency of a hypothetical car if:

- Engine efficiency (fuel to mechanical) = 20%
- Engine to wheel transmission efficiency = 75%
- Wheel to car momentum transfer efficiency 47%

Eliminate this, since its higher than bottleneck engine efficiency of 20% System efficiency is always lower than that of any component

A. 35%

B. 15%

C. 7%

D. 2.3%

Coal burning Power Plant Components

Chemical Energy (coal)

100 BTU

Boiler

Thermal Energy (steam)

88 BTU

Turbine

Mechanical Energy

36 BTU

Generator

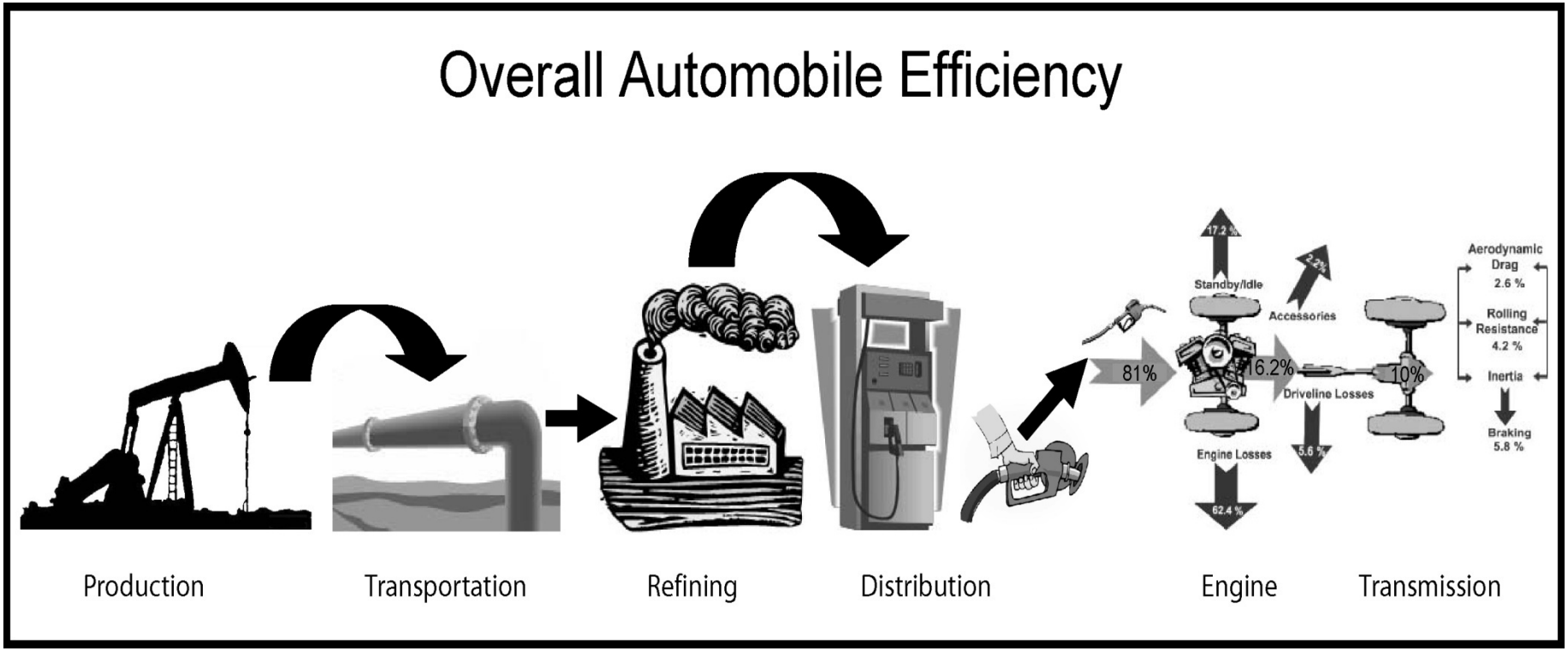
10.25 Wh

Electric Energy

Can you calculate efficiency of the plant?

Unit conversion needed: 1 Wh = 3.412 BTU

Lifecycle efficiency



Energy sources are traced back to their origin – all processes and systems are included in the chain of conversions.

Lifecycle Efficiency of an Automobile

Step	Step Efficiency	Cumulative Efficiency
Production of Crude Oil	96%	96%
Refining	87%	84%
Transportation	97%	81%
Thermal to Mech Energy	25%	20%
Mechanical Efficiency-		
Transmission	50%	10%
Rolling Efficiency	66%	6.6%

Approach to calculate the lifecycle efficiency is similar to calculation of system efficiency: multiply efficiencies for all steps in the lifecycle

In summary..

The efficiency of a system is equal to the product of efficiencies of the individual devices (sub-systems). The more components – the lower overall efficiency.

No system can deliver as much useful energy as is put into it. (No 100% systems) *according to 2nd Law of Thermodynamics*

No system can deliver more energy than is put into it. (No 110% systems) –

that would violate 1st Law

Reading and review sources:

Energy Conversion Devices

https://www.e-education.psu.edu/egee102/node/1937

Efficiency calculation examples

https://www.e-education.psu.edu/egee102/node/1938

More explanation on Power:

https://www.e-education.psu.edu/egee102/node/1912

https://www.e-education.psu.edu/egee102/node/1913

Online unit conversion:

http://www.onlineconversion.com/energy.htm

Heat engines and Carnot efficiency

https://www.e-education.psu.edu/egee102/node/1942