EE80J/180J

Lecture 13

4/25/16

Read: *www.**withouthotair**.com/*

Personal Audit due 5/9/16. in class

Mid-Term Exam 5/9/16

No class this Friday, 4/29/16

Quiz Monday on reading

Sustainable Energy: Without the Hot Air, David MacKay

*www.**withouthotair**.com/*

Contents

Device	power	time per day	energy per day
Cooking			
– kettle	3 kW	⅓ h	1 kWh/d
– microwave	1.4 kW	⅓ h	0.5 kWh/d
– electric cooker (rings)	3.3 kW	½ h	1.6 kWh/d
– electric oven	3 kW	½ h	1.5 kWh/d
Cleaning			
– washing machine	2.5 kW		1 kWh/d
– tumble dryer	2.5 kW	0.8 h	2 kWh/d
– airing-cupboard drying			0.5 kWh/d
– washing-line drying			0 kWh/d
– dishwasher	2.5 kW		1.5 kWh/d
Cooling			
– refrigerator	0.02 kW	24 h	0.5 kWh/d
– freezer	0.09 kW	24 h	2.3 kWh/d
– air-conditioning	0.6 kW	1 h	0.6 kWh/d

Table 7.4. Energy consumption figures for heating and cooling devices, per household.

From "without hot air"

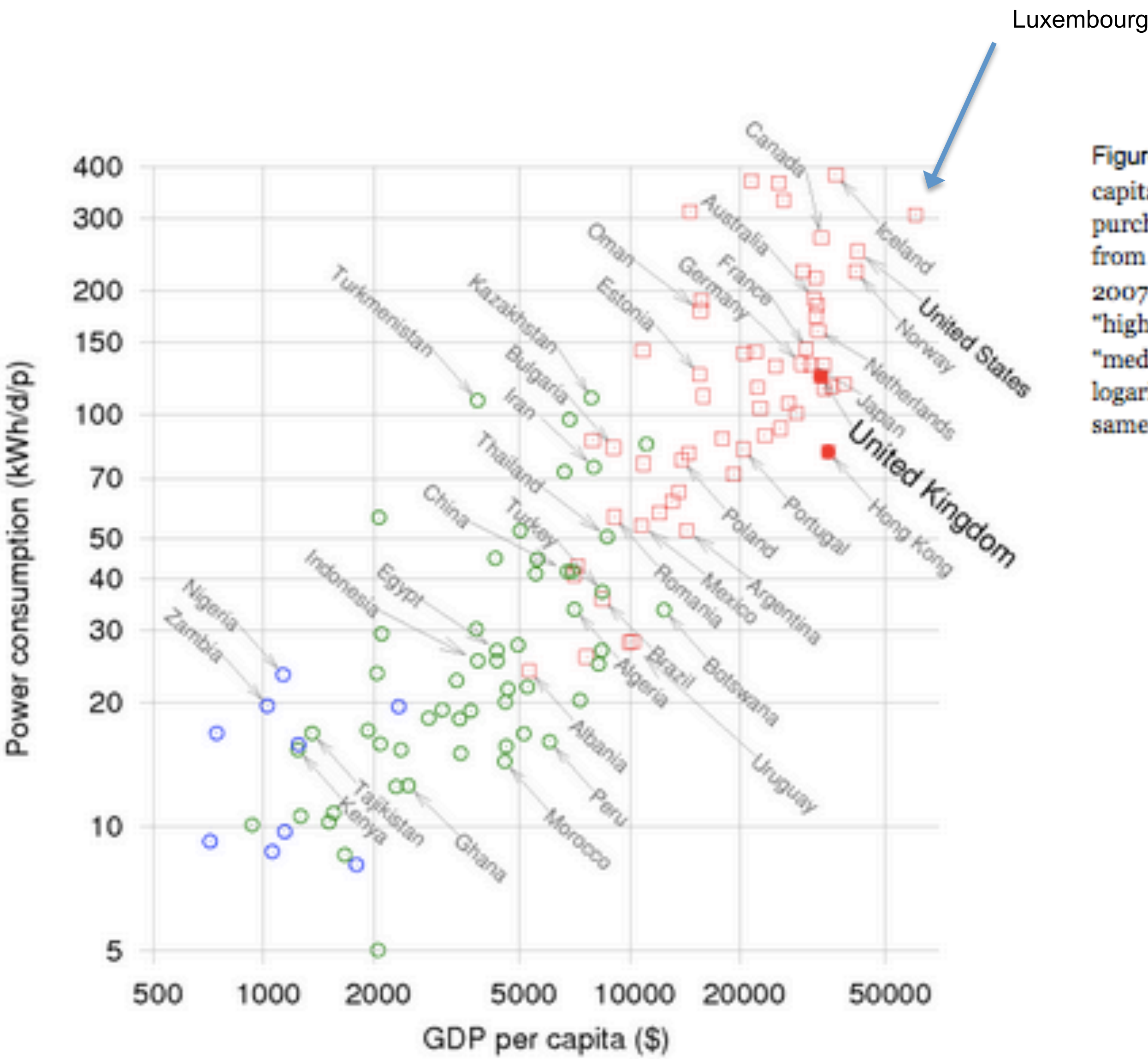

Figure 30.1. Power consumption per capita versus GDP per capita, in purchasing-power-parity US dollars. Data from UNDP Human Development Report, 2007. Squares show countries having "high human development;" circles, "medium" or "low." Both variables are on logarithmic scales. Figure 18.4 shows the same data on normal scales.

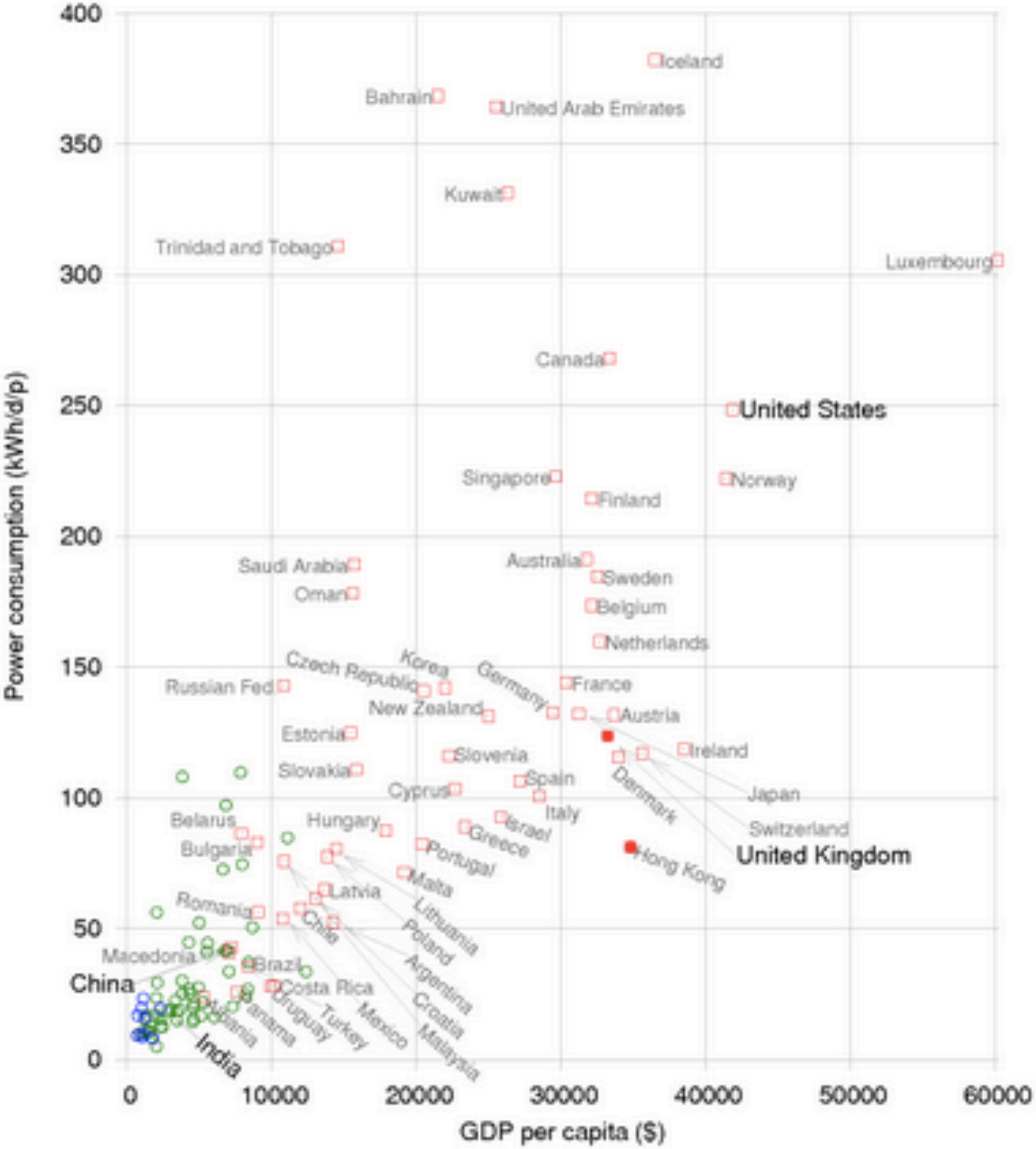

Figure 18.4. Power consumption per capita, versus GDP per capita, in purchasing-power-parity US dollars. Squares show countries having "high human development;" circles, "medium" or "low." Figure 30.1 (p231) shows the same data on logarithmic scales.

Linear scale

Example of Energy Use Calculation . 1

what is energy needed to power a 100 watt light bulb 3 hours/day for one year? //

$P_{BULB} = 100 \text{ watt}$

$$E_{USED} = Pt = 100\text{ watt} \times \frac{3\text{ hr}}{\text{day}} \times \frac{365\text{ days}}{\text{year}}$$

$= 109.5$ kWh/year needed.

If this power coming from a utility power plant, efficiency of plant ≈ 0.28 / $\eta = 28\%$

$\therefore$ plant needs to produce

$$E_{produce} = \frac{E_{used}}{.28} = \frac{109.5\text{ kWh/yr}}{.28}$$

$$\underline{E_{produce} = 391.1\text{ kWh/year}}$$

$$= 1.4 \times 10^9 \frac{\text{Joule}}{\text{yr}} \quad (\text{at } 3.6\text{ MJ/kWh})$$

what does this mean in terms of CO_2 released into atmosphere?

Energy Use Calculations. 2 (cont)

for a coal fired power plant

$94\ kg\ CO_2 / GJ$ energy

for a gas fired power plant

$57\ kg\ CO_2 / GJ$ energy

∴ we need $1.4 \times 10^9 \frac{\text{Joule}}{\text{year}}$ to power that 100 watt bulb

$$\therefore\ 1.4 \times 10^9 \frac{\text{Joule}}{\text{year}} \times \frac{57\ kg\ CO_2}{1 \times 10^9\ \text{Joule}} = 79.8\ kg\ CO_2$$

emitted for gas fired plant

$$= 131.6\ kg\ CO_2$$

emitted for coal fired plant

what are the CO_2 emissions from the "new" Moss Landing power plant (1060 M watts)?

Moss Landing Power Plant Project

Docket Number:

99-AFC-04 (Application For Certification)
99-AFC-4C (Compliance Proceeding)

Project Status: **Licensed; In Compliance Phase. Operational: July 11, 2002**

Moss Landing Power Plant

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GENERAL DESCRIPTION OF PROJECT

On May 7, 1999, Duke Energy Moss Landing LLC filed an Application for Certification (AFC) seeking approval from the California Energy Commission (Energy Commission) to construct and operate the proposed 1,060-megawatt (MW) Moss Landing Power Plant Project. The project is proposed to be located at the existing Moss Landing Power Plant site that was previously operated by PG&E for about 50 years. This site is located at the intersection of Highway 1 and Dolan Road, east of the community of Moss Landing near the Moss Landing Harbor.

The project, as proposed by Duke Energy, consists of replacing the existing electric power generation Units 1-5, (a total of 613 MW built in the 1950s and shut down in 1995), with two 530 MW, natural gas-fired, combined cycle, units. Each combined cycle unit consists of two natural gas fired combustion turbine generators (CTGs), two unfired heat recovery steam generators (HRSGs) and a reheat, condensing steam turbine generator (STG). Each combined cycle unit will use seawater for once-through cooling. Duke Energy also proposes to upgrade each of the existing Units 6 and 7 by 73 MW.

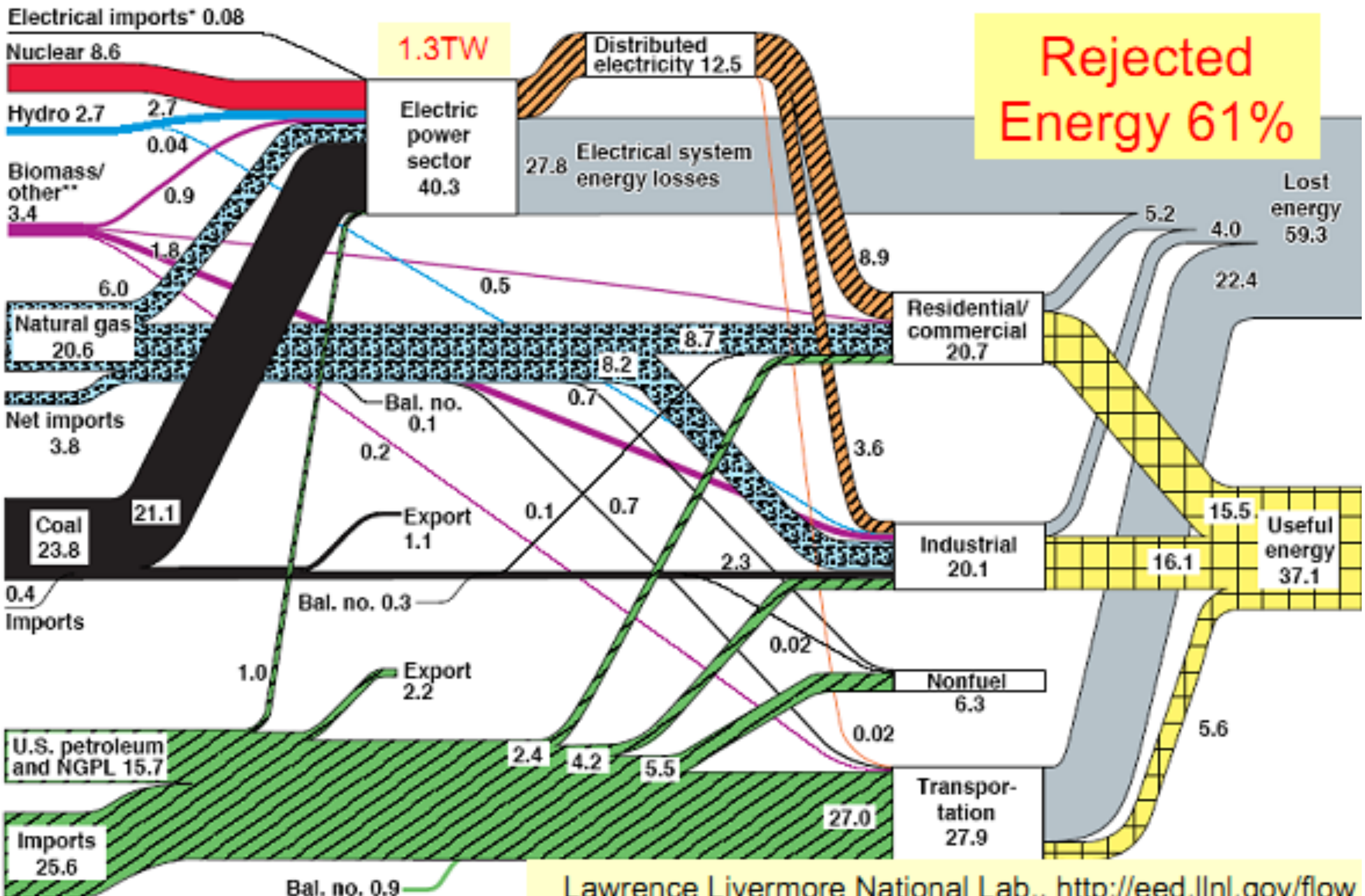
Duke also planned to remove eight 225-foot stacks and ten large oil tanks.

In 2006, Duke Energy sold the plant to LS Power (LSP) Moss Landing LLC, a subsidiary of LSP General Finance Co. LLC. The April 2007, the power plant was purchased by Dynegy Moss Landing LLC, a subsidiary of Dynegy of Houston, Texas.

U.S. Energy Flow Trends – 2002
Net Primary Resource Consumption ~103 Exajoules

Power ~3.3TW

A. Shakouri 11/25/2008



Lawrence Livermore National Lab., http://eed.llnl.gov/flow

Thermoelectric Conversion

significant amount of energy used to create electricity is LOST in the form of heat/

thermoelectric devices convert heat → electricity

remember/ Carnot efficiency (best we can do)

$$\eta_{MAX} = 1 - \frac{T_{COLD}}{T_{HOT}}$$

$\eta_{thermo} \sim 5\text{-}10\%$! today

figure of merit of thermoelectric devices:

$$(ZT) = \frac{\sigma}{\lambda} S^2 T$$

T → temp.

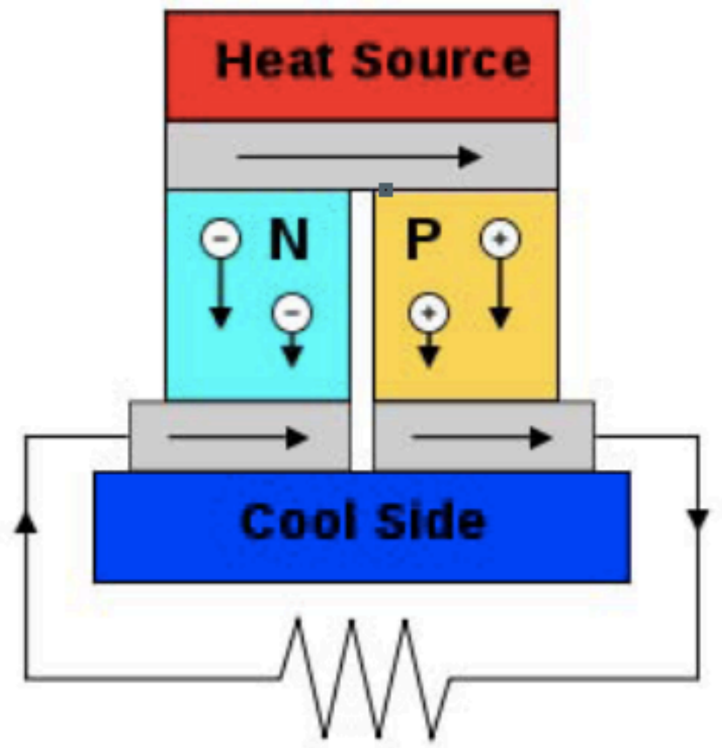
λ → thermal conductivity

σ → elec. conductivity

S → "Seebeck coefficient"

// usually good elec. conductors are good thermal conductors //

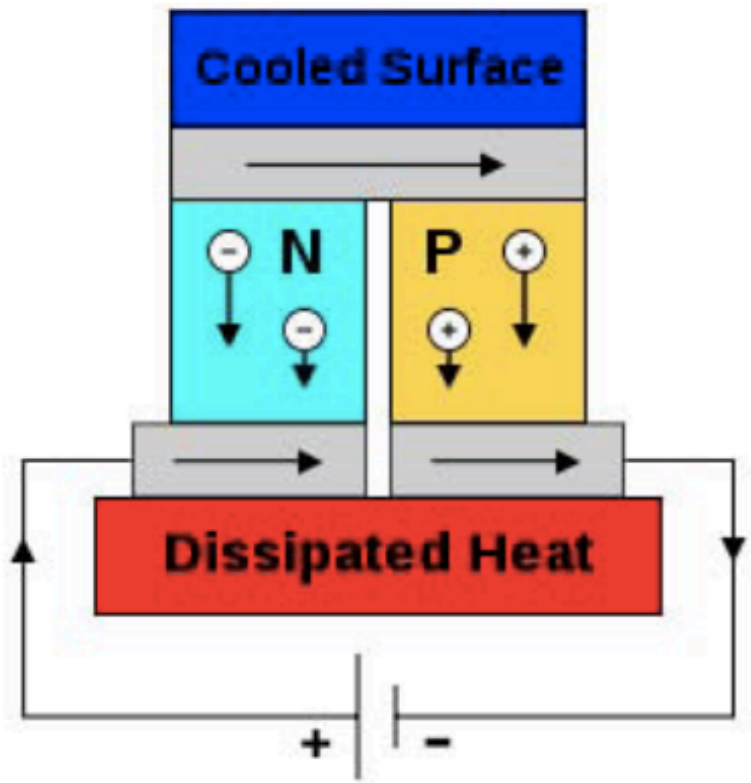
Seebeck Effect : temperature gradient causes a voltage/current



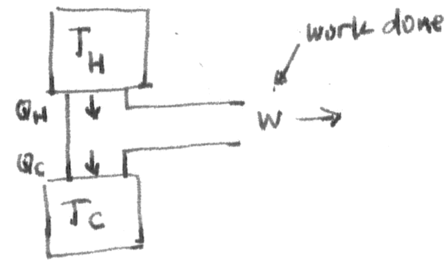
Material	Seebeck coefficient *relative to platinum* (μV/K)
Selenium	900
Tellurium	500
Silicon	440
Germanium	330
Antimony	47
Nichrome	25
Molybdenum	10
Cadmium, tungsten	7.5
Gold, silver, copper	6.5
Rhodium	6.0
Tantalum	4.5
Lead	4.0
Aluminium	3.5
Carbon	3.0
Mercury	0.6
Platinum	0 (definition)
Sodium	-2.0
Potassium	-9.0
Nickel	-15
Constantan	-35
Bismuth	-72

From wikipedia

Peltier Effect: heating or cooling at junction of 2 different conductors when a voltage is applied



HEAT ENGINES (review)



$$Q_H = Q_c + W$$

removed from HOT

deposited in COLD

$$Q_c / Q_H = T_c / T_H$$

ratio of temps. give ratio of heat

efficiency $\eta = 100\left(1 - \frac{T_c}{T_H}\right)$ in %

$\left(\text{or } \eta = \left(1 - \frac{T_c}{T_H}\right)\right)$

comes from $\eta = 100 \frac{W}{Q_H}$

W is the "useful" work this engine can do

ENTROPY

A measure of the amount of thermal energy that cannot be used to do work.

the change in entropy $\Delta S = \frac{\Delta Q}{T}$ ← heat in/out, ← temperature

2ND Law of thermodynamics

$\Delta S \geq 0$ always increasing

example: melting ice in glass of water

in glass: ΔQ from surroundings transferred to to cooler system (ice + water)

~~ΔQ~~ $\Delta S = \frac{\Delta Q}{273°K}$ — ice temp. 0°C

ΔQ = energy required to change ice → water

surrounding: $\Delta S = \frac{\Delta Q}{298°K}$ (assuming room temp ≐ 25°C)

note: smaller than that for the ice water system

energy has become more dispersed // and entropy increased.

EXERGY

1^{st} LAW THERMO $\Longrightarrow$ CONSERVATION OF ENERGY

2^{ND} LAW THERMO $\Longrightarrow$ ENTROPY ALWAYS INCREASES //

every irreversible process results in
loss of EXERGY (the ease of being able to do work)

$$E_x = S \times T_{AMBIENT}$$

entropy

think of Exergy as a measure of the ability
of a systems to do ~~useful~~ work //

ambient

$$E_x = W_{MAX} = \left(1 - \frac{T_0}{T_1}\right) Q_1$$

heat supplied at T_1

for a given ambient ~~...~~ T_0, increase in T_1
gives more W_{MAX} // for given Q_1 //

EXERGY goes down as ENTROPY goes up —

EXERGY. 2

example/

consider heat source at $T_1 = 40°C, 60°C, 80°C$

and ambient temp. $T_0 = 20°C$.

what is max. work available of input heat, $Q_1 = 150$ KWh

$$\therefore \; W_{MAX} = E_X = \left(1 - \frac{T_0}{T_1}\right) Q_1$$

remember T_0, T_1 are in °K not °C. ←

∴

T_1 (°C)	T_1 (°K)	W_{MAX} (KWH)	T_0/T_1
40	313	9.58	293/313 = .94
60	333	18.0	293/333 = .88
80	353	25.5	293/353 = .83

as source temp goes up, max. work goes up

as does the exergy //

$$\text{EXERGY EFFICIENCY} = \epsilon = \frac{\text{EXERGY OUTPUT}}{\text{EXERGY INPUT}}$$

review: wind turbines

- Kinetic energy = $0.5 \times \rho \times A \times v^3$ from any fluid
  - ρ= fluid density, A = area of rotors, v = fluid velocity

- Wind velocity varies with height from the ground

- Difference between HAWT and VAWT