Thermodynamics Demystified

How difficult could Thermodynamics be? This branch of Physics only has four laws (ref [1]), three laws are easy to comprehend. For the only difficult law, the 2nd Law, you can be the first one to disregard it, refuse to accept it, cheat it, break it & live forever.

0th Law

One catch is … there is no "Fourth" law in Thermodynamics. It's called the "Zeroth" Law, one of those corrections in Science that says "We made a mistake" & it's enshrined in this misnumbering of laws in Science. It lets everyone know, you point out something ***wrong*** with a theory; scientists say "We were wrong" & offer a correction; everyone agrees by consensus & things move on to other more important issues.

The Zeroth Law states: "if two thermodynamic systems are both in thermal equilibrium with a third system, then the two systems are in thermal equilibrium with each other" (ref [2]). This assumption is made ***before*** measured temperature can be made to establish the other 3 laws. Ralph Fowler (1889 –1944) (ref [3]) coined the term "0th law".

Further addressing the issue, Ludwig Boltzmann (1844 –1906) (ref [4]) developed Statistical Mechanics to relate temperature with other statistical measurements of a thermodynamic system. In so doing, his work quantifies implications of temperature for the assumption promoted by the 0th Law.

1st Law

The 1st Law encapsulates the Conservation of Energy & Mass (ref [5]). Let's consider Special Relativity & ($E = mc^2$) of Albert Einstein (1879 – 1955) (ref [6]). What happens to rest mass (m) in the 1st Law of Thermo? As it is, in (about all) chemical reactions, the energies are so low compared with reactants & products involved, the mass change in chemical reactions is minuscule. Then, for most everyday applications, the Conservation of Energy (refs [7] & [8] & [9]) & separate Conservation of Mass (ref [10]) are valid approximations. Only in a nuclear reaction is energy so large that change in mass is detected (ref [5]).

Sometimes, physicists state the 1st Law of Thermodynamics as: "Heat is a form of energy." The idea here is that Thermodynamics encompasses many forms of energy & how they are evaluated as an equivalent form of heat. After all, the basic alcohol thermometer measures ***only*** the thermal expansion of alcohol due to its change in internal energy content. This linear thermal expansion historically correlates to the Celsius temperature scale (ref [11]).

2nd Law

The 2nd Law can be stated in several different ways (refs [8] & [12]). There is no one "more correct" way to state this law. The 2nd Law is the "Arrow of Time." The 2nd Law measures the degree of "disorder" in a system (ref [13]). Because of the 2nd Law, homo sapiens suffer so much on the 3rd rock from the Sun (ref [14]). The 2nd Law is why we give birth / have sex / die, eat, pee & poop, steal, have envy, declare war. If the nations of the world could get together & repeal one Law of Physics, it would be the 2nd Law of Thermodynamics.

Thermodynamic Efficiency: There is always some dissipation loss in an engine, therefore "perpetual motion machines" are impossible on Earth (ref [15]). Nicolas Léonard Sadi Carnot (ref [16]) is the "Father of Thermodynamics". Monsieur Carnot was a Frenchman & his name is pronounced "CAR-know" (ref [17]). He expressed this inefficiency in Carnot's Theorem with (T_{Hi}) as the upper temperature at which a heated gas is raised in a machine. (T_{Lo}) is the environmental temperature @ which the gas is expelled. Then,

NLS Carnot
1796 – 1832

$$\eta_{eff} < 1 - (T_{Lo} / T_{Hi})$$

The above equation is a valid statement for the 2nd Law. The equation efficiency addresses heat energy turned into work (η_{eff}) & heat energy given out as waste ($1 - \eta_{eff}$).

3rd Law

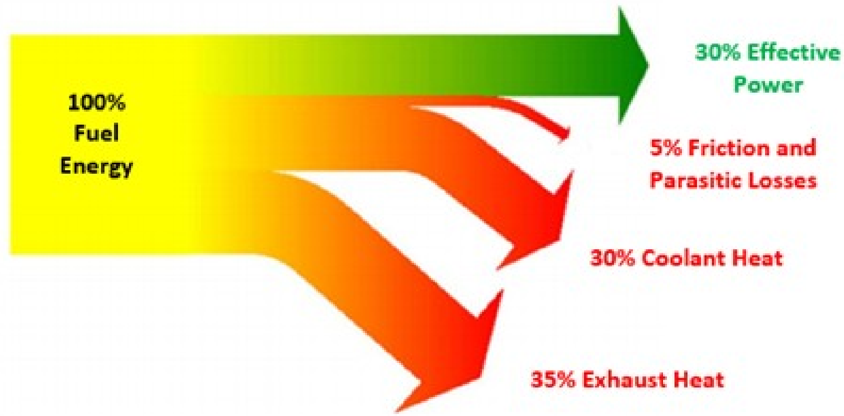
The 3rd law deals in frigid states where the atoms almost stop vibrating with thermal energy. There is an Absolute Zero in temperature where thermal vibration theoretically stops & the system has minimum thermodynamic energy (ref [18]). However, "matter does have random motion at Absolute Zero, called 'zero-point motion', thanks to a quantum concept known as the Heisenberg Uncertainty Principle." This concept "dictates that the position and momentum of an object cannot be known with complete certainty at the same time." (ref [19])

Still, it's not the Zeroes on the Fahrenheit or Celsius scales, but an extrapolation of data points approaching -273.15˚ Celsius (-459.67˚ Fahrenheit), but never reached (ref [20]). Such cold temps are not encountered on Earth, outside laboratory conditions. The cosmic background radiation is about 2.8 K almost everywhere. You have to get a refrigerator out even in deep space away from all stars to go below 2.8 K. The cosmic temperature of 2.8 K is still -276˚C or -454.6˚F which is still "shatter anything" cold (ref [21]).

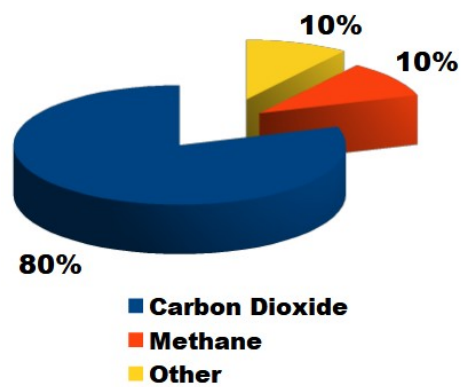
1st Law Example – Our Automobile Dependence

Cars are very prevalent in US Society. The United States is known for much land with relatively few people making personal cars an ideal form of transportation. In using cars, around 35% of a fuel's latent heat is used to power the vehicle's motion. The remaining heat energy is dissipated by the engine's radiator & still more is forced out in the exhaust (ref [22]). Yet, the driver transports himself / herself somewhere, people move from Point A to Point B which is the reason for burning fossil fuels in a vehicle.

If we used our cars to accelerate us to cruising speed & maintained cruising speed, we would be storing gasoline's chemical energy in our kinetic energy. But, @ the end of ***every*** trip, we ***always*** put on the brakes! Where does all of that motion energy go? We are just heating up the Earth even more. The fuel's chemical energy just makes a detour into work as transport motion for us until settling inevitably into waste heat within our environment.



Do Your Own Experiment: We have all walked along a busy highway & felt the wind of the passing cars, but not that much heat. The atmosphere is truly a thermodynamic ***heat sink*** able to accept almost limitless waste heat from our society & it's temperature cycles never seem to change. However, there is one more thing experienced when walking along the highway … that unique smell of gasoline & diesel fuel exhaust. It will be a long time before our societal waste heat moves the atmosphere a single degree Celsius. The 2023 chief "greenhouse" gas contributions, CO_2 @ ~80% & CH_4 @ ~10% are odorless & colorless (ref [23]). Nevertheless, our highly mobile society feels the need to expend large amounts of energy to live. It's the presence of that chemical exhaust & its by-products that could be our doom! The "greenhouse" gases are trapping too much solar heat in our atmosphere.



Call Us Cheap: The following Thermodynamic calculations will use the 1st Law to show that the motion energy expended by society's vehicles toward wind resistance contributes insignificant amounts to the change in temperature of Earth's atmosphere. "Greenhouse" gases from our relatively "cheap" fossil fuels trap the Sun's overabundant waste heat in addition to our trivial societal waste heat!

As an example of an application of the 1st Law & to show that large cars of today primarily heat up the Earth's atmosphere based on their CO_2 emissions, this "ballpark" analysis will generate some very rough approximate numbers for that answer. Fasten your seat belt … let's take a ride! From ref [24], the engineering equation for empirically evaluating wind force in Newtons (N) on a vehicle moving @ a given speed is:

$$F_L = 0.6 \cdot Cd \cdot A_f \cdot v^2$$

where

F_L	– air resistance force (N)	A_f	– vehicle frontal area (m²)
Cd	– drag coefficient (-)	v	– wind speed (m/s)

The factor (*0.6*) has conversion units of ($N \cdot s^2/m^4$) to Newtons as well as indicates the answer is a "ballpark" estimate only valid to one significant digit (a rough ±10% error). We want total energy expended for a trip route of distance (*d*) in miles with a miles to meters conversion factor (ref [25]). The work against wind (W_{wind}) is force (N) times distance (m) equals energy (J) or:

$$W_{wind} = F_L \cdot d = 0.6 \cdot Cd \cdot A_f \cdot d \cdot v^2$$

Drag coefficients & vehicle frontal areas (ft²) are supplied for select vehicles (ref [26]). A thermodynamic efficiency (η_{eff}) is included in this analysis. Evaluating thermodynamic efficiencies of today's vehicle engines @ about 30% (ref [22]), comparable efficiencies will be assumed for alternate energy sources powering Green vehicles. This analysis also assumes the waste heat of Green vehicles ends in worst case atmospheric waste heat. Energy expended for vehicle times energy generation efficiency ($E_{wind} \cdot \eta_{eff} = W_{wind}$), yields

$$E_{wind} = W_{wind} / \eta_{eff} \approx 0.6 \cdot Cd \cdot A_f \cdot v^2 \cdot d / \eta_{eff}$$

We also want wind speed to equal car speed in miles per hour (mph).

$$\left[\left(\frac{2.54\,cm}{1\,inch}\right)\left(\frac{12\,inch}{1\,ft}\right)\left(\frac{1\,m}{100\,cm}\right)\right]^2 = \left(\frac{0.3048\,m}{ft}\right)^2 \approx 0.0929\,\left(\frac{m^2}{ft^2}\right)$$

$$\left[\left(\frac{8\,km}{5\,mi}\right)\left(\frac{1\,hr}{3600\,s}\right)\left(\frac{1000\,m}{1\,km}\right)\right]^2 = \left(\frac{0.444\,m/s}{mph}\right)^2 \approx 0.198\,\left(\frac{m/s}{mph}\right)^2$$

$$\left(\frac{8\,km}{5\,mi}\right)\left(\frac{1000\,m}{1\,km}\right)\left(\frac{1\,J}{1\,N\,m}\right)\left(\frac{1\,MJ}{10^6\,J}\right) \approx 0.0016\,\left(\frac{MJ}{N\,mi}\right)$$

Instead of energy in Joules (J), let's select the gauge as change in total average atmospheric temperature. This quantity is measured through a unit of temperature change in a column of atmospheric air from a discrete introduced energy amount. The column of air has a unit surface area of the Earth (ref [27]). I will get a rough estimate of the heat capacity of the earth's atmosphere as the heat capacity of the atmospheric column with unit area ($\bar{C}_a$) multiplied by the surface area of the Earth. This coefficient is derived from experimental data.

$$E = A_e \bar{C}_a \Delta T \qquad \delta T = \frac{E}{A_e \bar{C}_a} \approx \frac{0.6 \cdot Cd \cdot A_f \cdot v^2 \cdot d}{A_e \bar{C}_a \eta_{eff}} \qquad A_e = 4\pi \bar{r}_e^{\,2}$$

$$k_{wind} = \frac{0.6}{A_e \bar{C}_a} = \frac{0.6}{(4\pi \bar{r}_e^{\,2}) \bullet (\bar{C}_a)} \qquad \text{where} \qquad \bar{C}_a = 10.2 \left(\frac{MJ}{{}^\circ C\, m^2}\right)$$

Earth's average radius ($\bar{r}_e$) is about 6371 km (the largest rocky planet in our Solar System) (ref [28]). To determine change in atmospheric temperature, the conversion is:

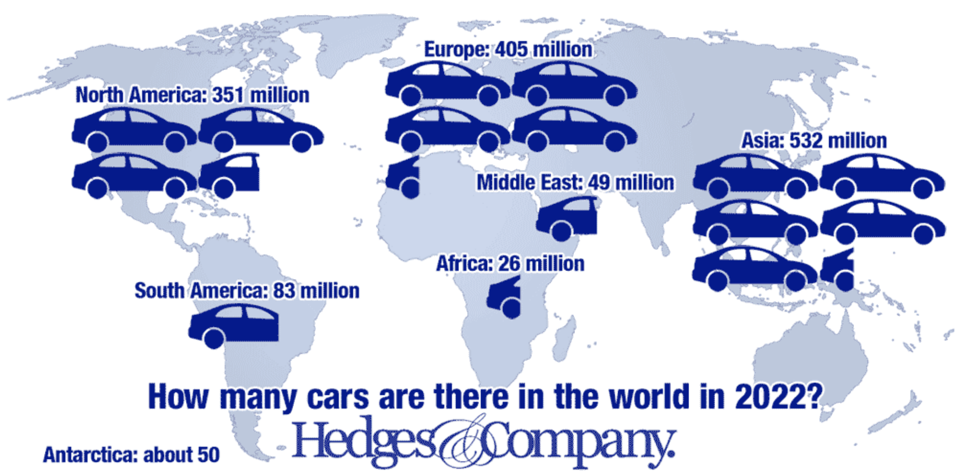
$$\left(\frac{1}{4\pi}\right)\left[\left(\frac{1}{6371\,km}\right)\left(\frac{1\,km}{1000\,m}\right)\right]^2\left(\frac{0.6\,N\,s^2}{m^4}\right)\left(\frac{{}^\circ C\, m^2}{10.2\,MJ}\right)\left(\frac{9\,{}^\circ F}{5\,{}^\circ C}\right) \approx 207.6\times 10^{-18}\left(\frac{{}^\circ F\, N\, s^2}{MJ\, m^4}\right)$$

Total Conversion factor per vehicle (k_{wind}) is:

$$k_{wind} \approx \left(\frac{0.0929\,m^2}{ft^2}\right)\left(\frac{0.198\,m^2}{s^2 mph^2}\right)\left(\frac{0.0016\,MJ}{1\,N\,mi}\right)\left(\frac{207.6\times 10^{-18}\,{}^\circ F\,N\,s^2}{MJ\,m^4}\right)$$

$$k_{wind} \approx 6.095\times 10^{-21}\left(\frac{{}^\circ F}{mi\; ft^2\, mph^2}\right) \qquad \delta T \approx k_{wind}\frac{Cd\bullet A_f\bullet v^2\bullet d}{\eta_{eff}}$$

The microscopic magnitude of (k_{wind}) relates the ability of a single vehicle to change the overall temperature of Earth's atmosphere by an infinitesimal amount (δT). The magnitude shows that for a single vehicle traveling on the Earth, the atmosphere is truly a heat sink. The atmospheric ability to store waste heat of a single car is almost infinite. Let's consider the atmospheric ability to store waste heat of all vehicles estimated on Earth. Per ref [29], 1.446 billion cars are estimated to be functioning in our various societies.



$K_{wind} = N_{cars} \bullet k_{wind}$

$$K_{wind} = (1.446\times 10^{9})\bullet(6.095\times 10^{-21}) \qquad \left(\frac{{}^\circ F}{mi\; ft^2\, mph^2}\right)$$

$$K_{wind} = 8.814\times 10^{-12} \qquad \left(\frac{{}^\circ F}{mi\; ft^2\, mph^2}\right)$$

$$\Delta T = N_{cars}\frac{E_{wind}}{A_e \bar{C}_a} = N_{cars}\frac{W_{wind}}{A_e \bar{C}_a \eta_{eff}} \approx N_{cars}\frac{0.6 \bullet Cd \bullet A_f \bullet v^2 \bullet d}{(4\pi r_e^2)\bullet(\bar{C}_a \eta_{eff})} \approx K_{wind}\frac{Cd \bullet A_f \bullet v^2 \bullet d}{\eta_{eff}}$$

Even considering all the vehicles on Earth, (K_{wind}) is still a very small number to influence the Earth's atmospheric Temperature (ΔT). Let's find the travel miles per car required to raise the atmosphere about (1ºF). Then,

$$d \approx \frac{\eta_{eff}\Delta T}{K_{wind}\bullet Cd \bullet A_f \bullet v^2} = \left(\frac{\Delta T}{K_{wind}}\right)\left(\frac{\eta_{eff}}{Cd \bullet A_f \bullet v^2}\right)$$

$$K_{wind} = 8.814\times10^{-12} \qquad \left(\frac{°F}{mi\ ft^2\ mph^2}\right)$$

where

- d – travel distance (mi)
- ΔT –Temperature change (ºF)
- Cd – drag coefficient (-)
- A_f – vehicle frontal area (ft²)
- v – vehicle speed (mph)
- η_{eff} – efficiency (-)
- K_{wind} – K-factor (ºF / mi ft² mph²)

The following table illustrates how detrimental "greenhouse" gases are to human existence on Earth. If society used an alternative energy source, considering the waste heat of vehicle transportation alone, each of the 1.4 billion vehicles on Earth would have to drive hundreds of thousands of miles each for the Earth's atmosphere to increase a degree Fahrenheit. The above data is a bit esoteric, but about 1.4 billion Ford F-150 pickup trucks would have to travel about 600 thousand miles each @ a constant 70 mph using an alternative Green form of energy to raise the Earth's atmosphere about 1º Fahrenheit.

Vehicle Fleet Trip Miles to Raise Atmosphere 1ºF

30% efficiency			Cd	Area	vehicle trip (million miles)		
make	model	year	(-)	(ft^2)	30 mph	50 mph	70 mph
Chevy	Astro 2	2005	0.40	34.1	2.8	1.0	0.5
Ford	F-150	2004	0.36	31.5	3.3	1.2	0.6
Hyundai	Elantra	2005	0.34	21.4	5.2	1.9	1.0
Toyota	Prius	2015	0.25	23.4	6.5	2.3	1.2
typical vehicle average			0.34	27.6	4.1	1.5	0.7

For the metrically hip:

$$d \approx \frac{\eta_{eff}\Delta T}{K_{wind}\bullet Cd \bullet A_f \bullet v^2} = \left(\frac{\Delta T}{K_{wind}}\right)\left(\frac{\eta_{eff}}{Cd \bullet A_f \bullet v^2}\right)$$

$$K_{wind} = 12.87\times10^{-12} \qquad \left(\frac{°C}{km\ m^2\ kph^2}\right)$$

where

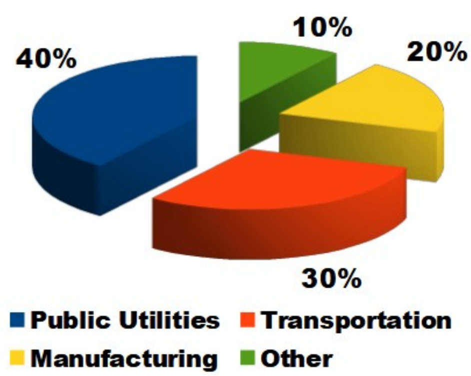
d	– travel distance (km)	v	– vehicle speed (kph)
ΔT	–Temperature change (ºC)	η_{eff}	– efficiency (-)
Cd	– drag coefficient (-)	K_{wind}	– K-factor (ºC / km m² kph²)
A_f	– vehicle frontal area (m²)		

For the metric version, about 1.4 billion of the very popular Ford F-150 US pickup trucks would have to travel about 900 thousand kilometers each @ a constant 110 kph using an alternative Green form of energy to raise the Earth's atmosphere about ½º Celsius.

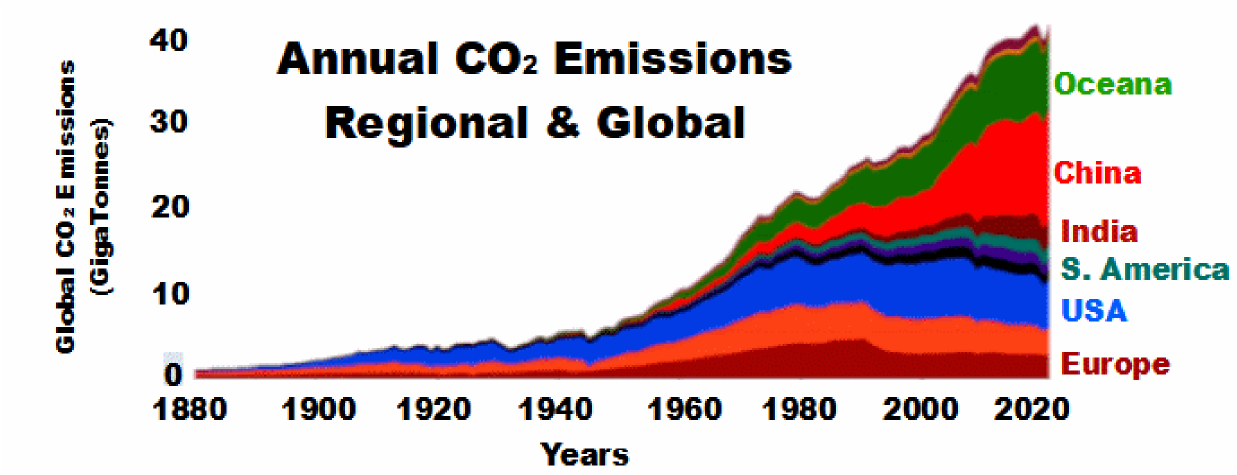
Vehicle Fleet Trip Distance to raise Atmosphere ½ºC

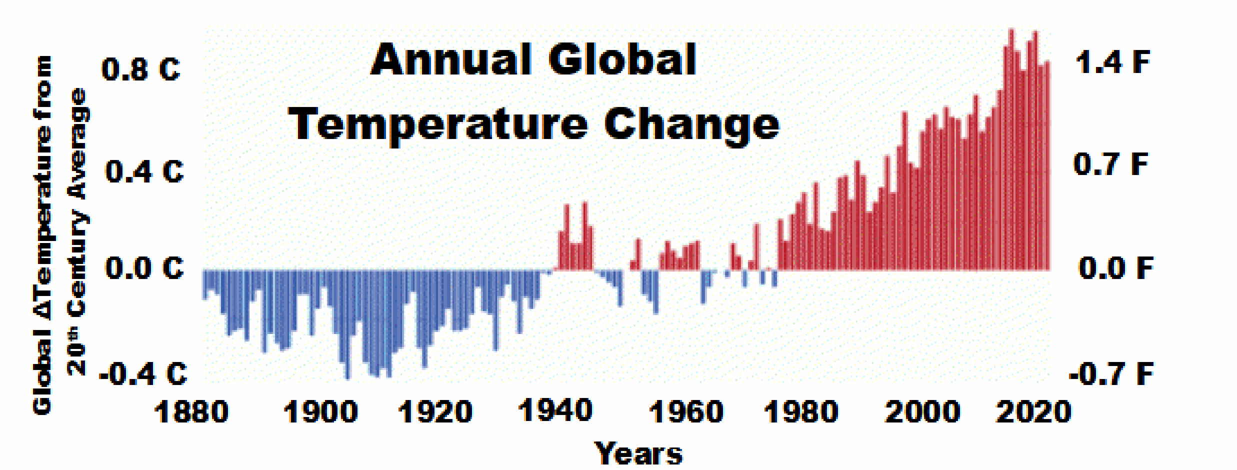
30% efficiency			Cd	Area	vehicle trip (million km)		
make	model	year	(-)	(m^2)	50 kph	80 kph	110 kph
Chevy	Astro 2	2005	0.40	3.17	3.7	1.4	0.8
Ford	F-150	2004	0.36	2.93	4.4	1.7	0.9
Hyundai	Elantra	2005	0.34	1.99	6.9	2.7	1.4
Toyota	Prius	2015	0.25	2.17	8.6	3.4	1.8
typical vehicle average			0.34	2.56	5.4	2.1	1.1

The pie chart @ the right shows the amount of US "Greenhouse" gas emissions by sources in 2018 (ref [30]). Producing energy for public utilities contributes most to US emissions @ ~40%. Second is transportation emissions @ ~30%. From the data, transportation emissions are comparable to that from public utilities. If another Green energy source were found for vehicle travel, our societal "Greenhouse" emissions would reduce significantly overall.



The top graph below shows metric tonnes of atmospheric CO_2 (ref [31]) emitted since 1880. The bottom 2023 "hockey stick" graph (ref [32]) shows the noticeable global surface temperature increase since the 1970's. This is presumably due to the societal CO_2 increase plotted in the top graph.





In the top graph, world CO_2 emissions are expressed in billions of metric tonnes. A metric tonne is 1000 kilograms or a Megagram (1 Mg = 10^{+6} grams). Likewise, a billion mega-tonnes is (10^{+9}) times (10^{+6}) times (10^{+3}) grams or a Petagram (1 Pg = 10^{+18} grams) (ref [33]). Finally, for the un-metric, a gram is about the weight of a cubic-centimeter (cc) of water; a cc is about the volume of a sugar cube; a kilogram weighs about 2.2 pounds.

2nd Law Example – Human Muscle Efficiency

The chemical reactions that cause our muscles to contract are only about 25% efficient (ref [34]). The rest of the energy is turned into heat. Let's get some perspective. To lift a box @ 20 kilograms (44 lbs.) vertically one half a meter (20 inches) requires (ref [21]):

$$E_{work} = (20\,kg)\left(\frac{1}{2}\,m\right)\left(9.8\,\frac{m}{s^2}\right)\left(\frac{J\,s^2}{kg\,m^2}\right)\left(\frac{1\,cal}{4.184\,J}\right) \approx 23.42\,calories$$

This work is one quarter or one part in four of total energy expended. The heat energy will be three parts in four or three times the work energy expended. Then,

$E_{total} = E_{work}/(25\%) = E_{work}/(¼) = 4 \cdot E_{work} \approx 4(23.42\ cal) = 93.69\ calories$

$E_{heat} = E_{total} - E_{work} = 4 \cdot E_{work} - E_{work} = 3 \cdot E_{work} \approx 3(23.42\ cal) \approx 70.27\ calories$

If one fresh plum gives about 30 edible calories (ref [35]), to lift about a 44 pound box about 20 inches would require about 3 plums (90 calories) for a regenerative snack. Over 2 plums (60 calories) of the 3 would be required just for the inefficient heat generated!

3rd Law Example – Too Many Zeros

Temperature is the most difficult measure to convert from metric Celsius to customary units Fahrenheit & vice versa, because the zero scales are different. In all other metric / customary quantities the zero points coincide. I lived through the US metric conversion “attempt” back in the 1970’s. When it came to temperature, people’s minds from US public schools @ the time were just overwhelmed with the required conversion (ref [36]).

$T_{Celsius} = (5/9)\ [T_{Fahrenheit} - 32\ ]$ $\qquad$ $T_{Fahrenheit} = [\ (9/5)\ T_{Celsius}\ ] + 32$

I didn’t fully understand temperature conversions until college. However, born in the state of Georgia in 1959 & educated in US grade schools, I consider myself Metrically Challenged.

Below is the *Celsius Temperature Poem* to help understand weather temperatures in Celsius for the Metrically Challenged (ref [37]).

Celsius Temperature Poem	same old same old
30 °C is hot	30 °C = 86 °F
20 °C is nice	20 °C = 68 °F
10 °C is cold	10 °C = 50 °F
0 °C is ice	0 °C = 32 °F

The real ***Absolute Zero*** Kelvin of temperature (-273.15 °C or -459.67 °F) is far below the Zeroes of Celsius & Fahrenheit (ref [38]). In temperature scales, there are 3 Zeroes; you can't have enough Zeroes. A significant epiphany … two of these Zeroes are chosen strictly for convenience! BTW, I can perform several customary ↔ metric conversions mentally (ref [39]), but not Temperature.

In addition, because the Kelvin scale is absolute, it gets no degree symbol with its capital “K” abbreviation (ref [11]). The degree symbol is reserved for those arbitrary placed Zeroes in Fahrenheit (°F) & Celsius (°C). Currently, the increments in the Kelvin temperature scale are defined by the more fundamental Boltzmann Constant (k_B) (si4x6.pdf):

$k_B = 1.380649\times10^{-23}$ (J / K)

The Boltzmann Constant (k_B) estimates statistical or averaged molecular energies (J) within a Thermodynamic system given their corresponding measured absolute temperature (K).

Thermodynamics Impacts Almost Everything

You can further investigate the myriad applications of Thermodynamics in ref [40].

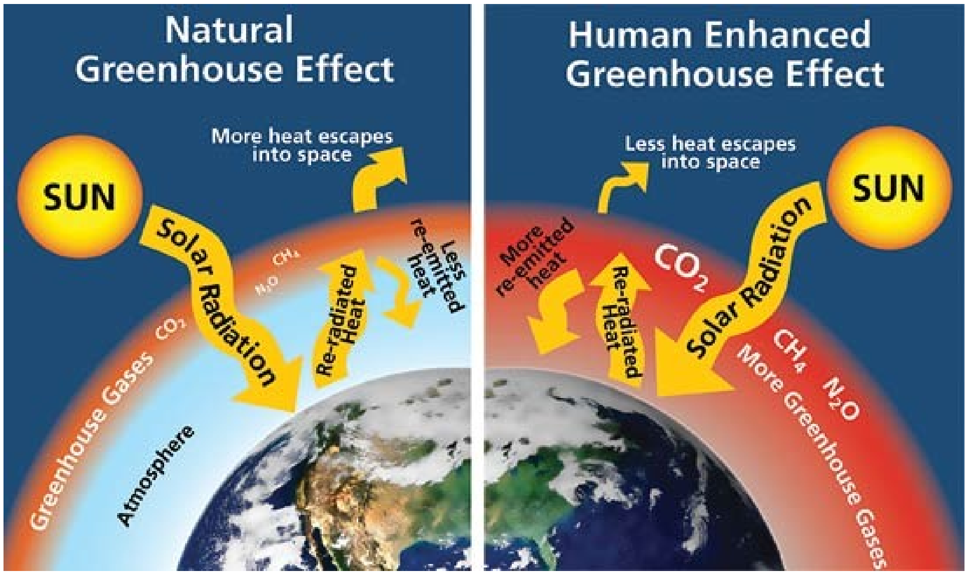
Thermodynamic States & Realm: The fundamental measurement indicating an application of Thermodynamics is absolute temperature (T), or change in temperature (ΔT). Absolute temperature singularly identifies the Thermodynamic state of a relevant system. By definition, absolute temperature is ***always*** measured in a Thermodynamic Equilibrium. This requires statistical averaging energies of molecules or other entities belonging to a statistical ensemble over a period of time. More specifically, “the thermodynamic temperature of … a substance ... is directly proportional to the mean average kinetic energy of ... translational motion” of a system of particles (ref [41]). It follows, a single “electron does not have a temperature.”

Rank of the Thermodynamic Laws: The 0th & 3rd Laws of Thermodynamics are not frequently cited in Thermodynamic applications. The 0th Law states the obvious for temperature evaluations. The 3rd Law deals in temperatures seldom encountered on Earth. In contrast, the 1st & 2nd Laws of Thermodynamics are heavy duty rules of the macroscopic Universe & the chief reasons this branch of Physics was invented. The 1st Law gives basic limits on how much energy is available for a process. The 2nd Law evaluates the qualities of the energies involved.

Pull outer electrons from their atomic nuclei & they have high-quality electrical energy that can be converted almost totally into work. Evaluate the latent energy of a thermal sink in a body of water & its energy, although abundant, can not be an energy source for useful work. Energies of the world exist in many forms: potential, chemical, thermal, radiant, kinetic. At times unequal, these energies are driven by the arrow of time to inevitably redistribute & maximize entropy.

The 1st & 2nd Laws of Thermo are applied over & over by power engineers / scientists to increase some order in their locality from work generated through energy transfer. The final state of these energies is ***always*** heat. The power engineers / scientists seek energy sources & ask the question: “How much work can be generated from the available energies passing into heat to make society’s existence a little easier!” Indeed, we each, individually, are our own power engineers as we seek the chemical energy in food for own existence, or we perish in the search.

Thermodynamics of Global Warming: Thermodynamic analyses are often not exact; here are some further approximations in calculating data of the wind resistance analysis of the world vehicle fleet. If the elevation of Point A & Point B differ, some gravitational energy is stored or expended, but usually the driver ends up back @ his / her abode. In hilly travel, the work the vehicle engine expends climbing a hill is roughly gained by going down the same hill. Constant cruising speed is assumed, which is usually not the case. What is not considered is the energy required to accelerate a vehicle to cruising speed. This is stored kinetic energy. When one watches Formula One @ night, the vehicle's kinetic energy is gone in a flash ... as seen dramatically dissipating in sparks & the orange glow of very hot disc brakes.



When gasoline is used to fuel a car, over 50% of it's latent heat goes into the environment as waste heat. Most engines in which this equation applies have efficiencies (η_{eff}) much less than the upper limit, and well below 50%. The less efficient a car engine is, because it is not maintained properly, or because it is driven with poor gas mileage, the more heat it is spewing into the atmosphere.

Still, this excess heat is not the prime cause of global warming (ref [42]). We derive our energy primarily from fossil fuels. These "cheap" energy sources produce waste CO_2, CH_4 & other gases we then dump into the Earth's atmosphere. Meanwhile, our Sun is forging hydrogen into helium, and producing abundant waste heat that, in turn, heats Earth. It's just our luck that our fossil fuel waste gases react in the worst way possible to store the Sun's waste heat because of the "greenhouse effect" (ref [43]). The Sun's heat contributes to climate change much more than the waste heat from our collective society which is significantly less. Global warming seems to be an ***unnecessary*** hobby of ours!!!

Life & Death in Thermodynamics

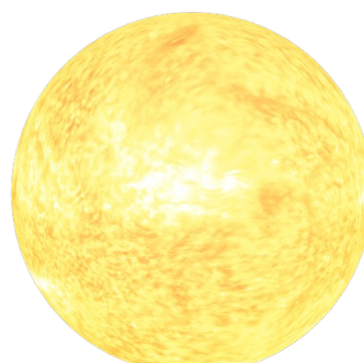
Our Birth / Life / Death: The 2nd Law defines entropy as a measure of disorder. In closed systems, the 2nd Law states the total entropy of the system always increases (ref [44]). The environment will always change due to ever increasing entropy (the arrow of time). Evolution takes an ever-changing Earth into account by putting out many sets of genes, finding out which ones work best @ the time, shuffling the genes, killing off the old sets & starting over.

From a Darwinian biology standpoint, our "sole-cold-goal" is to test if our own set of genes can do well in an ever-changing environment of the moment (ref [45]). We are in such great debt to our soldiers who risk sacrifice of their lives so that our similar genes can be passed on. There are also other noble "Mother Teresa" lives we can lead to transcend this biological goal like Mary Teresa Bojaxhiu (1910 – 1997) (ref [46]). So, as homo sapiens, "Death is the price we pay for sex." (ref [47])

If we want to live forever, based on current knowledge, we can ***not*** make our bodies into "perpetual motion machines." However, through gene-modifications or mind-transfer to silicon chips (ref [48]), we can try to live lengthy time spans in thermodynamic "stead-state" conditions. With sufficient modifications to our vessels, as long as we can find a fuel source to extract energy from & an environment to dump our waste in, we can live-out an existence. Will it be fulfilling? Who knows? We won't be homo sapiens!!!

Heat Death: From the above discussions, it may look like we will eventually have too much heat to deal with. From Carnot's efficiency equation, when all possibly attainable upper temperatures (T_{Hi}) approach (T_{Lo}), lower efficiencies of any process create less change in the Universe. Eventually, (@ $T_{Hi} \approx T_{Lo}$), no change in the Universe indicates marking the passage of time has essential stopped (ref [49]).

However, the Earth is radiating heat as fast as it can into that 2.8 K universal darkness. In the near term, experts predict that is not enough. Earth's intermediate future will be like its sister planet Venus (ref [50]). The surface temperature of Venus is over 800°F or 400°C, primarily because of its 96.5% atmospheric CO_2. The Sun's energy output will increase as it grows older, increasing CO_2 out-gassing stored in the Earth's crust, driving Earth's conditions to be similar to Venus (ref [51]) within the next few hundred million years.



The Big Chill: Extrapolating from the present even further, our Sun, a yellow dwarf main-sequence G2 V star (ref [52]), will run out of fuel in about 5 GigaYears (billion years) (ref [53]). Changing to a red giant, "the outer layers of the Sun's atmosphere will expand so far out into space that they'll engulf Earth." At about 6 GigaYears, our "Sun collapses into a white dwarf." Eventually, any excess heat our Solar System has will be distributed into the Cosmic Background Radiation @ 2.8 K or less.

A long term "Heat Death" is no longer thought possible, though. The Universe is expanding "like a bat out of hell" & appears to be increasing its rate. If things are on their current trend, radiation wavelengths will continue to stretch & cool. The characteristic Cosmic Background Temperature of 2.8 K will approach Absolute Zero (0 K). Long after all of the stars are extinguished & in total darkness, the Cosmic Background Temperature will be asking itself, “How close can I get to Absolute Zero?”

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