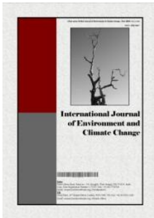

International Journal of Environment and Climate Change

9(12): 801-822, 2019; Article no.IJECC.2019.065
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

The Nature of Climate Change- equivalent Climate Change Model's Application in Decoding the Root Cause of Global Warming

Qinghan Bian[1*]

[1]*Victoria, BC, Canada.*

Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/IJECC/2019/v9i1230160
Editor(s):
(1) Dr. Anthony R. Lupo, Professor, Department of Soil, Environmental and Atmospheric Science, University of Missouri, Columbia, USA.
Reviewers:
(1) Clarence Semassou, University of Abomey-Calavi, Benin.
(2)Chadetrik Rout, Maharishi Markandeshwar University (Deemed to be University), India.
Complete Peer review History: http://www.sdiarticle4.com/review-history/52923

Original Research Article

Received 20 September 2019
Accepted 26 November 2019
Published 03 December 2019

ABSTRACT

Scrutiny and analysis of various energy applications show that the energy conversion to useful work or new products has been systematically inefficient. The global energy's total effective conversion efficiency is estimated only about 20% and about 80% of the energy has been discharged into the environment. It is this energy that leads to the unbalance of the climate system's energy budget balance and causes the global warming.

This article presents a simple equivalent climate change model to track the past global warming and to predict the future change trend at the global scale. The model comprises of an equivalent climate change surface air boundary layer, an equivalent climate change land surface boundary layer and an equivalent climate change seawaters surface boundary layer. It produces unique definitive relationships between the temperature changes and the heat entered the air, waters and land. The model can also be used to forecast future non-renewable energy consumption needed to keep the temperature rising under Paris Accord.

Analysis of currently available data by using this model confirms that temperature changes in air, seawaters and land closely correlate to the amount of heat discharged into the climate system from human activities. NASA and NOAA's observations of temperature anomalies for the surface air, sea surface and land surface are well consistent with the temperature changes calculated by this

**Corresponding author: E-mail: bianqinghan@hotmail.com;*

model, especially the calculated results at the depth of 70 meters of the surface air boundary layer and NASA's Lowess Smoothing trend are very close.
Flaring intensifies global warming. Reducing use of fossil fuels, nuclear and geothermal energies, developing surface renewable energies and increasing energy's total effective conversion efficiency and thus reducing the amount of residual/waste energy are the paths to effectively and efficiently control global warming.

Keywords: Energy budget balance; boundary layer; climate change; climate system; energy consumption; equivalent climate change model; ice melting; global energy's total effective conversion efficiency; global warming; non-renewable energy; renewable energy; residual/waste heat; temperature change/anomalies.

1. BACKGROUND

Current climate change or global warming is a result of anthropogenic activities, everyone contributes to it consciously or unconsciously.

More and more evidences and records indicate that climate change is unequivocal, the globe gets warmer and warmer since the beginning of industrialization: permafrost thaws [1,2,3], concealed methane evaporates into the atmosphere, leaving big holes on the ground [4], ice sheets/caps and glaciers melt and snow caps become thinner and smaller; ice breaks up nine days earlier in Spring, freezes up ten days later in autumn in the Northern Hemisphere than it did 150 years ago, and more than 4.6 meters subsidence of the ground has been observed in parts of Alaska due to permafrost thawing [5], seawaters (or oceanwaters) become warmer and more acidic [6,7,8]. Warming gets more evident and extreme weather events happen more frequently in the past few decades.

Climate change is a complicated interdisciplinary science. Although most scientists consent on that the current climate change is likely a result of anthropogenic activities, strong arguments exist on what from the human activities causes the climate change. Many scientists believe the increased greenhouse gases (GHG) in the atmosphere from human activities have incurred the current climate change due to their strong forcing and heat trapping capabilities, while many others challenge this theory [9]. GHG emissions from human activities has been at the center around climate change discussions, and efforts have been made on their reductions, however, no unique definitive relationship has been identified yet between the global warming and GHG concentration though a large number of models have been developed. For example, in IPCC's reports only those models satisfying a predetermined set of conditions (i.e. requirements for responses and feedbacks etc. are met) [10] are selected and their mean of various simulations are used to compare to the actual temperature measurements (e.g., in the AR4 [11] 58 simulations by 14 models with anthropogenic and natural forcings have been used in case (a) and 19 simulations by 5 models with natural forcing only in case (b); similarly in AR5 [12] several tens simulations by multi-models are also used), but still their mean values cannot get close enough to the actual observed anomalies, indicating these models' inherent restraints and uncertainties [10,13]. Additionally, this approach cannot either help to explain why or how the land and sea surface's temperatures change. All these suggest that the global warming be poorly correlated to GHGs, leaving the debates on the root cause of the global warming continue restlessly [9]. This is also supported by the fact that during 2014 and 2016 when the global GHG concentration stayed steadily [14,15], the globe still warmed at rapid rates [16]. On the other hand, if GHGs really trap heat strongly and have strong forcing capabilities, then it would be possible to capture and use them in high concentration to collect heat and develop new energy sources, however, it hasn't been seen yet.

So, what is the real root cause of the current global warming? Scientifically if two things are correlated, then a unique definitive relation must exist between them. Careful scrutiny of human activities indicates that huge amount of residual or waste heat has been continuously discharged into the climate system. It is believed this heat energy causes the current global warming, unfortunately it has been completely ignored.

2. THE CAUSE OF CLIMATE CHANGE AND GLOBAL ENERGY'S TOTAL EFFECTIVE CONVERSION EFFICIENCY

The climate system consists of atmosphere, land and oceans. The atmosphere caps the earth and filters some harmful solar radiations from reaching us. It also absorbs and stores some heat, while oceans and land absorb and retain the other parts of heat within the system. The atmosphere, oceans or waters and land regulate together the air temperature at about 15ºC through a dynamic equilibrium of energy budget balance, making the earth suitable for humans.

The climate system's dynamic energy budget balance can be expressed as:

$$E_{in\text{-}net} = E_{air} + E_{water} + E_{land} + E_{bio} + E_{consum} \quad (1)$$

where,

$E_{in\text{-}net}$ = net solar energy reaching the earth surface, i.e. total incoming solar energy subtracting the total reflected outgoing energy. It can be considered constant, though recent studies indicate that the change in total solar irradiance (TSI) brings about 0.05 [17] to 0.1ºC [18] variance in the 11-year solar cycle, debates continue [19];

E_{air} = solar energy absorbed by and stored in air;

E_{water} = solar energy absorbed by and stored in waters;

E_{land} = solar energy absorbed by and stored in land;

E_{bio} = bioenergy i.e. solar energy absorbed by and stored in plants or biomass as a result of photosynthesis;

E_{consum} = solar energy consumed by humans.

It is this dynamic energy budget balance that makes the climate system maintain the air temperature at a stable level. Any extra energy brought into the system from human activities such as combusting fossil fuels, using geotherm or nuclear energy will certainly shift the above energy budget balance to the right, making the air, seawaters and land warmer. As deforestation progresses, solar energy converted to E_{bio} becomes less, thus surplus energy exists in the system, which contributes to the temperature rising as well. However, details on deforestation's effect need further studies. It is worth noting that combusting biomass releases the long-term accumulated energy back to the system during a very short time, breaking the local energy budget balance and contributing to in-situ temperature risings.

Water, especially seawaters play the most important role in regulating the climate system due to its biggest specific heat capacity, whereas the land absorbs and releases heat much quicker because of its smallest specific heat capacity when the air temperature changes. The specific heat capacity of the atmosphere is greater than dry air because of existence of water vapor. The specific heat capacities are in the order: water > moisture-containing air >dry air >land. Waters store more heat than air and much more than land.

Theoretically, the system provides humans with enough renewable energies i.e. solar, wind, ocean and bioenergy to support their life within the energy budget balance without need to exploit underground resources, however, inefficient energy use has accelerated its consumption and resources development. The following facts demonstrate how humans contribute to the climate change by pouring energies into climate system from their routine activities.

Boiling Water and Cooking Foods in Daily Life: Boiling water by using a kettle is the simplest example of human's daily life impacting the climate system, which consumes energy to heat the water to its boilingpoint (100°C). During the process some energy is lost in the form of radiation from kettle case, from the heating element and with evaporation. Furthermore, from the just boiled water to urine discharged to the environment, heat is released during the cycle (note that our body itself also releases heat out). Clearly almost all the energy consumed for boiling water is lost into the system eventually. Additionally, when taking showers, the hot water and thus the heat energy are directly poured into the environment as well.

Similarly, almost all the energy consumed in food-cooking and storage is converted to heat and released into the system too (except for a little part is kept in the cooked foods as chemical energy through changing protein and starch's properties).

The energy getting into the system in these forms is certainly significant globally when considering the huge population, thus its impact couldn't be ignored.

Air Conditioning: Nowadays air-conditioning is inevitable at homes, in offices, in vehicles or in industrial processes. Air conditioning consumes energy that is converted to heat. Since the space is not adiathermic, heat transfer continues between the conditioned air and ambient air, this keeps the conditioner working continuously. As a result, air conditioning raises air temperature. Heat island effect is an evident example.

Using hot water for conditioning has the same impact. Consumed energy is released back to the environment in three parts: (1) boiler case heat loss – energy wastes through radiation from the boiler case and piping etc., (2) stack heat loss – energy loses through hot flue gas via stacks and (3) the most important part - the heat exchange with air from elements.

In general, almost all the energy consumed for residential and commercial uses like air conditioning, food cooking is eventually converted to heat, heating the climate system.

Energy Consumption in Transportation: With vehicles, completing tasks can be more efficiently. However, only about 12~30% [20], or 20~41% [21] of the energy consumed is used to move a vehicle itself and the load down to the road, called useful work, and the rest is wasted due to engine and driveline inefficiencies [20] in the form of heat either directly or through frictions (friction between parts, friction between the tires and road surface). Assuming 25% as a global average useful work efficiency in transportation is reasonable by considering the unbalanced technologies in the world, this means about 75% of the energy is wasted to the environment as heat.

Energy consumption in industries: Countless boilers, furnaces, heaters and kilns etc. in industrial processes consume a great deal of fuels to meet various production needs. However, only a part of the energy released from combusting fuels has been converted to new products, and the rest has been discharged into the climate system, for example, along with high-temperature exhaust gases. It is reported that flue gas temperature at a typical furnace stake is usually around 150ºC [22,23], though it varies depending on control technologies applied. Besides, heat retained in hot products will be lost to the environment when released from processes.

As an example, in lime production only the calcining stage converts energy into new product, all the other heat required is just to raise limestone's temperature to and maintain at calcium carbonate's dissociation temperature around 850~1000ºC. After decomposition the final product (i.e. lime) must be cooled down to room temperature, the heat contained in it is then released into the environment. Theoretically, decomposing one mole of calcium carbonate requires only 178 KJ of heat energy [24] as below, which is equivalent to 3.179 GJ of heat energy per tonne of lime.

$$CaCO_3 \rightarrow CaO + CO_2 - 178\ \text{KJ/mole} \qquad (2)$$

However, in practice due to various factors such as kiln shell radiation, flue gas, hot product cooling and equipment frictions, the actual energy required is much higher than this theoretical value, at a range of 3.305~7.113 GJ per tonne of lime depending on the type of kiln and technology used [25], and the excessive energy consumed (0.126~3.934 GJ/t lime) is then wasted into the environment. In a rotary kiln process, waste through flue gas is about 32%, through kiln shell about 5.8%, residual heat in the product is about 2% and miscellaneous losses about 3.6%, with a total loss of 43.4%, implying only 56.6% of the input energy is used to convert limestone to lime [25]. Thus, producing one tonne of lime will require at least 5.617 GJ heat (i.e. 3.179/0.566), with 2.438 GJ (43.4%) of the input energy being dispersed into the environment.

As a much more complicated process, in Portland Cement clinker production the theoretical heat requirement is usually less than 2000 KJ [26], or about 1695 KJ [27], or 1803 KJ [28] per Kg of clinker (depending on the properties of raw materials and technologies used) while an additional sensible heat of 2134 KJ/Kg is required for raising raw meal's temperature from 25 to 1450ºC [27], making the total heat consumption between 3300~6000 KJ/kg of clinker [26]. The sensible heat doesn't participate in the chemical reactions but disperses into the environment through kiln shell, flue gas and hot product cooling etc. Though most modern plants have installations nowadays to recycle the sensible heat back to the process or generating electricity to increase the energy efficiency, part of it still enters the system.

As technology advanced, cement industry has experienced obvious enhancements in energy efficiency. Table 1 shows the Canadian Cement Industry's Energy Consumption Benchmark (GJ per tonne of clinker [29]). Therefore, 3.695 GJ (i.e. 5.39–1.695), about 68.6% (or 55.5% when comparing 1.803 to 5.39), of the input energy per tonne of clinker enters the environment.

Similarly, making iron from ore and further making steel from iron – the other energy intensive processes, also require lots of heat to raise the raw materials' temperatures to the melting points in order to remove impurities through physical changes and chemical reactions. Only chemical reactions expend a part of the input energy, with the rest dispersed into the environment both during the processes and after the process from the molten iron or steel and slag.

Drying moisture-containing materials is another important process in many industrial productions, during which the moisture is evaporated along with hot exhaust stream. The energy consumed is completely dispersed into the environment except for the part used for driving the associated equipment.

Electricity and lighting: According to BP Statistical Review of World Energy 2018 [30], only about 38% of consumed primary energy is converted to electricity in a modern power plant, meaning about 62% of the primary energy is wasted in various forms during electricity generation. Moreover, during electricity transmission, 8~15% of electricity is lost in the grid between a power plant and consumers [31].

Powering motors develops heat. Modern electrical motors have efficiencies between 75.5 ~ 95.4% [32]. Thus, even with the most efficient motors (95.4% efficiency) only about 36.3% (38% * 95.4%) of the primary energy is converted to useful work if the electricity is generated at a modern power plant, that means about 64% of the primary energy is still wasted. In addition, even using computers, mobile phones etc. also develop huge amount of heat, considering their population around the world.

Lighting releases heat and light (photons). The latter possesses energy according to $e=h\gamma$ or $e = mc^2$. The energy-carrying photons collide with air particles, transferring the energy to air molecules and raising their temperatures while the light itself attenuates and finally fades away after travelling a certain distance.

Based on the above analyses, although lack of detailed data on various industrial energy use or conversion efficiencies, it is reasonable to assume the global industrial energy's total conversion efficiency (i.e. the ratio of the amount of energy actually converted to a new product or to do effective work over the total input energy on the global scale) is about 30%, meaning only about 30% of the primary energy input is transformed into new products or effective work while the rest of 70% is just discharged into the environment.

Flaring: In oil & gas development and processing, coal mining and processing, petrochemical production, petroleum refinery etc., flaring is inevitable, which directly heats the air. Two types of flaring exist: stack flaring and pit flaring.

According to the World Bank, at oil development sites annually flared associated gas is steadily around 140~150 billion cubic meters worldwide since 2010 [33]. This is equivalent to about 25% of USA's annual natural gas consumption or about 30% of EU's annual gas consumption [34], or about 1% of the global annual primary energy consumption [30].

Coal mine fires, a type of pit flaring, like those in China [35,36,37], accidentally triggered by cigarette butt, lightning strike, self-ignition or spontaneous combustion, are not uncommon in the world. Low-temperature oxidation of coal spoil at mining sites occurs when ambient temperature exceeding 9ºC [38]. The coal fires in China alone consumes about 20 million tonnes of coal annually with temperature exceeding 1000ºF (538ºC) [35].

These are only two specific examples of flaring. If those from natural gas development and processing, refinery and chemical production, coal mining & processing, landfill, waste treatment etc. are considered together, one can imagine how much heat is sent into the environment globally.

In general, according to BP Energy Outlook 2018 [39], industrial sector consumes about 51% of the global energy, residential and commercial 29% and transportation 20%. Also based on the foresaid analyses, it is reasonable to estimate that the global energy's total effective conversion efficiency (GETECE) is about 20% (51% *30% +

Table 1. Canadian cement industry's energy consumption benchmark (GJ/tonne of clinker) [29]

1990	1991	1992	1993	1994	1995	1996	1997	1998	Average
5.67	6.21	5.69	5.39	5.29	5.15	5.16	4.78	5.16	5.39

29% * 0% +20% * 25%), meaning about 80% (industry 35%, residential and commercial 29% and transportation 15%) of the total primary energy enters the climate system, breaking the energy budget balance and contributing to the system's temperature rises.

3. EQUIVALENT CLIMATE CHANGE MODEL

Atmosphere or air, seawaters and land link one another. Thus, studying climate change must look at the changes and their synergies in these three components simultaneously. Any extra energy (except for surface renewable energies i.e. wind, solar, hydro and ocean energies; biomass to be discussed later) discharged into the climate system from human activities as discussed earlier will increase the respective temperatures of air, seawaters and land. The energy distributed among them is proportional to their relative specific heat capacities.

Let's consider an equivalent climate change model consisting of layers of air, seawaters and land, assuming their mass, heat and temperature distribute evenly under the constant barometric pressure at 1 atm. The depths of the air layer, seawaters layer and land layer are h, D_w and D_L meters, respectively.

The air layer's volume can be calculated as:

$$V_a = \frac{4}{3}\pi\left[(R_o + h)^3 - {R_o}^3\right] \tag{3}$$

Its mass (Ma) can be calculated as:

$$M_a = \frac{4}{3}\pi\left[(R_o + h)^3 - {R_o}^3\right] * \rho_a \tag{4}$$

The heat change ΔH_a associated with the air temperature change Δt_a in the layercan be calculated as:

$$\Delta H_a = M_a C_{Pa} \Delta t_a = \frac{4}{3}\pi\left[(R_o + h)^3 - {R_o}^3\right] \cdot \rho_a \cdot C_{pa} \cdot \Delta t_a \tag{5}$$

Thus,

$$\Delta t_a = \frac{3\Delta H_a}{4\pi\left[(R_o + h)^3 - {R_o}^3\right] \cdot \rho_a \cdot C_{pa}} \tag{6}$$

Clearly the air temperature change is a function of, and positively proportional to the heat change ΔH_a within the layer, but adversely proportional to $[(R_0+h)^3-R_0^3]$.

Similarly, the mass of seawaters layer can be calculated as:

$$M_w = S_w \cdot D_w \cdot \rho_w \tag{7}$$

The relation between heat change and the associated temperature change Δt_w can be expressed as:

$$\Delta H_w = S_w \cdot D_w \cdot \rho_w \cdot C_{pw} \cdot \Delta t_w \tag{8}$$

Thus, the temperature change in the seawaters layer can be written as:

$$\Delta t_w = \frac{\Delta H_w}{S_w \cdot D_w \cdot \rho_w \cdot C_{pw}} \tag{9}$$

It is a function of, and positively proportional to the heat change ΔH_w within the layer, but adversely proportional to its depth D_w.

Similarly, for the land:

$$\Delta H_L = S_L \cdot D_L \cdot \rho_L \cdot C_{p \cdot L} \cdot \Delta t_L \tag{10}$$

Thus, the temperature change in the land layer can be written as:

$$\Delta t_L = \frac{\Delta H_L}{S_L \cdot D_L \cdot \rho_L \cdot C_{pL}} \tag{11}$$

The temperature change is a function of, and positively proportional to the heat change, but adversely proportional to its depth D_L.

Additionally, part of the extra energy entered the climate system is used to melt ice and further to raise icy water's temperature to the bulk seawaters' temperature (~17°C), which can be written as:

$$\Delta H_{iw} = Q_i \cdot L_{pi} + Q_i \cdot C_{pw} \cdot (T_{sw} - T_{iw}) \tag{12}$$

According to NASA [40], the global average sea level has risen nearly 178 mm during the last 100 years, equivalent to an annual rate of about 1.78 mm, of which 1/3 is from the sea water warming itself, 2/3 from the ice melting [41]. Thus, it's reasonable to believe that the 1.19 mm (i.e. 1.78*2/3 mm) per year of sea level rise comes from the melted ice, which corresponds to the following ice mass:

M_i=361800000*1000000*0.00119*1000=4.305*10^{14}Kg

Ice latent heat is 333.5 KJ/Kg. For melting such a huge amount of ice, the total latent heat required is 1.436*10^{17} KJ; Further, to raise its temperature (0ºC) to bulk seawaters' temperature (i.e. 17ºC) a heat of 2.917*10^{16} KJ is required.

Therefore, the total heat required for melting ice and then mixing with seawaters is about $1.728*10^{17}$ KJ as described by Equation 12 above.

where,

M_a	Mass of the air layer with a depth of h
V_a	Volume of the air layer with a depth of h
M_w	Mass of waters (mainly seawaters) layer with a depth of D_w
V_w	Volume of waters (mainly seawaters) layer with a depth of D_w
R_0	Earth's radius, 6371km
h	The depth (or altitude) of the air layer measured from the earth surface
S_w	Seawater surface area, 361800000 km^2
D_w	The depth of the sea waters' layer
ρ_a	Air density under normal pressure
C_{pa}	Air specific heat capacity under constant pressure, or the isobaric heat capacity
ΔH_a	The heat change in air layer associated with the temperature change Δt_a
Δt_a	The temperature change in the air layer after experiencing heat change ΔH_a
ρ_w	The seawaters (mainly seawaters) density
ΔH_w	The heat change in seawaters layer associated with the temperature change Δt_w
Δt_w	The temperature change in the seawaters layer after experiencing heat change ΔH_w
C_{pw}	Seawaters specific heat capacity under normal pressure
ρ_L	The land (soil) density
ΔH_L	The heat change in land layer associated with the temperature change Δt_L
Δt_L	The temperature change in the land layer after experiencing heat change ΔH_L
C_{pL}	Land (soil) specific heat capacity under normal pressure
S_L	Land area on the earth surface, is 148264472 km^2 based on the Earth's total surface area (510064472 km^2) and the total oceans' surface area (361800000 km^2)
D_L	Depth of land layer
L_{pi}	ice latent heat
t_{sw}	Bulk seawater's temperature (baseline, 17ºC)
t_{iw}	The temperature of Ice-water mixture, 0ºC
Q_i	Annual melted ice quantity

The specific heat capacity determines a material's heat absorption and storage capability per unit when experiencing 1ºC temperature change. In a large system consisting of different materials each material absorbs different amount of heat, depending on their specific heat capacities, when they are exposed to the same heat source. Therefore, in the climate system the respective amounts of heat allocated to air, land and seawaters are determined by their respective specific heat capacity ratios as discussed below.

The land on the Earth can be reasonably considered vegetated, its specific heat capacity is 0.830 KJ/KgK according to Timothy Bralower, et al. [42]. Seawaters' specific heat capacity is 3.985 KJ/KgK.

As for the air, according to Goddard Institute for Space Studies (GISS), the global average surface temperature in 2017 was 14.9ºC [43], thus let's simply take 15ºC in this study. Furthermore, based on the World Meteorological Organization [44] the global average relative humidity during 1956~1991 was 69.73%, and let's simply take 70%.

To obtain the specific heat capacity for moisture-containing air, it is necessary to know air's absolute humidity (AH, g/m^3), which can be calculated by the following equation [45]:

$$AH = \frac{6.112 \times e^{[\frac{17.67 \times t}{243.5+t}]} \times RH \times 2.1674}{(273.15+t)} \quad (13)$$

Where RH – relative humidity, T – the air temperature in Celsius (here 15ºC). Therefore, the absolute air humidity at relative humidity of 70% is 0.0897 g/m^3, or 0.0732 g/Kg with the density of 1.315 Kg/m^3.

For humid air at constant pressure, its specific heat capacity (C_{pa}) can be expressed as:

$$C_{pa} = C_{p,da} + C_{p,wv} \times AH \quad (14)$$

Where $C_{p,da}$ is dry air's specific heat capacity, and $C_{p,wv}$ is water vapor's specific heat capacity. Therefore, the humid air's specific heat capacity at the relative humidity of 70% is about 1.143 KJ/KgK.

Consequently, the heat allocated to air, land and oceans is 19.18%, 13.93% and 66.89%, respectively.

Table 2 shows the common constants and physical properties used in this research.

Table 2. Common values of physical properties

Item/property	Value	Item/property	Value
Earth's radius	6371 km	Water @ 15ºC vapor density	0.0128 kg/m^3 [47]
Earth surface area	510,064,472 km²	Water @ 15ºC liquid specific heat capacity	4.185 KJ/kgK [47]
Total land area	148,264,472 km^2	Water @ 15ºC vapor specific heat capacity	1.863 KJ/kgK [47]
Ocean surface area	361,800,000 km^2	Water density	1000 kg/m^3
Normal air pressure	1 atm	Sea water specific heat capacity	3.985 KJ/KgK
Sea water average temperature	17ºC [46]	Sea water density	1027 Kg/m^3 [48]
Normal air temperature	15ºC	Ice latent heat	333.7 kJ/kg [47]
Dry air density @15ºC	1.225 Kg/m^3 [47]	Vegetated land specific heat capacity	0.830 KJ/kgK [42]
Dry air specific heat capacity @ 15ºC, $C_{p,da}$	1.007 KJ/KgK [47]	Average density of earth surface material	3,000 kg/m^3 [49]
Moist air density @RH=70%	1.315 Kg/m^3	Water specific heat capacity @ 0ºC	4.22 KJ/kgK [47]
Moist air specific heat capacity @RH=70%	1.143 KJ/KgK	1 million tonne of equivalent oil (MTOe)	4.1868x10^{13} KJ
Water @ 0ºC liquid density	1000 kg/m^3 [47]		

4. RESULTS ANALYSES AND DISCUSSION

According to BP's World Energy Review [15], Table 3 shows the global consumptions of primary energy and non-renewable energy from 1965 to 2017, where the non-renewable energy includes oil, gas, coal, nuclear energy, but excludes geotherm since it is grouped together with biomass and other types of renewable energies and no separate data available. However, that doesn't impact the result because its amount is very small. On the other hand, the part of hydrocarbons used for chemical productions is included in both the consumptions of primary and non-renewable energies. It is believed that this inclusion doesn't affect the result either since this can compensate for the uncounted flares although each of their amounts is precisely unknown now but very small.

Table 3 also shows the extra energy discharged into the climate system (i.e. 80% of the non-renewable energy), the energy used for melting ice and then raising the icy water to bulk seawaters' temperature, and the respective energy allocated to air, land and seawaters.

4.1 Surface Air Temperature Change

Note that the term "air temperature change" here refers to the entire earth's surface air temperature change, i.e. the "land + sea surface temperature" (LSST) change used anywhere else, it is different from the individual "land surface" or "sea surface" temperature change.

Fig. 1 shows the results of global surface air temperature change calculated from Equation 6 based on the data in Table 3, where the air layer depths between 30 to 200 meters are considered. The temperature change increases as the energy entered the system increases. 1973 is the point before which the temperature change is negative, i.e. the climate system was in a cooling situation, which coincides with the fact of the "global cooling" between 1940s and 1970s [50,51,52,53].

On the other hand, as Equation 6 indicates the air surface temperature change decreases as the air layer's depth increases, i.e. the thicker the layer, the smaller the temperature change. For example, in 2017, the calculated temperature change at the depth of 30 meters is 1.98ºC, as the depth increasing to 40, 50, 60, 70, 80 and 90 meters, the corresponding calculated temperature changes are 1.48, 1.19, 0.99, 0.85, 0.74 and 0.66ºC, respectively.

NASA's air temperature mean anomalies, its Lowess Smoothing trend [54] as well as NOAA's observation measurements [55] are also shown in Fig. 1. Obviously in early years, especially

Table 3. Energy consumption and distribution in the climate system (10^{14}, KJ)

Year	**1965**	**1966**	**1967**	**1968**	**1969**	**1970**	**1971**	**1972**	**1973**	**1974**
Primary energy	1549.74	1633.86	1695.57	1798.40	1921.62	2040.98	2126.60	2241.19	2370.31	2381.66
Non-renewable energy	1462.62	1540.41	1599.95	1698.07	1815.29	1929.72	2010.87	2120.23	2247.84	2247.21
Energy entered climate system*[1]	1170.09	1232.32	1279.96	1358.46	1452.23	1543.78	1608.70	1696.19	1798.27	1797.77
Energy melting ice + raising temperature*[2]	1727.53	1727.53	1727.53	1727.53	1727.53	1727.53	1727.53	1727.53	1727.53	1727.53
Energy heating air, land & oceans	-557.44	-495.20	-447.57	-369.07	-275.30	-183.75	-118.83	-31.34	70.74	70.24
Atmosphere absorbed heat ΔH_a	-106.94	-95.00	-85.86	-70.80	-52.81	-35.25	-22.80	-6.01	13.57	13.47
Land absorbed heat ΔH_L	-77.66	-68.99	-62.35	-51.41	-38.35	-25.60	-16.55	-4.37	9.85	9.78
oceans absorbed energy ΔH_w	-372.84	-331.22	-299.36	-246.85	-184.13	-122.90	-79.48	-20.96	47.32	46.98
Year	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**
Primary energy	2394.10	2524.43	2614.11	2700.95	2794.61	2774.63	2759.52	2748.17	2792.22	2924.61
Non-renewable energy	2257.63	2388.45	2474.59	2550.44	2636.62	2613.71	2596.08	2577.92	2614.16	2740.71
Energy entered climate system*[1]	1806.11	1910.76	1979.67	2040.35	2109.29	2090.97	2076.86	2062.34	2091.33	2192.57
Energy melting ice + raising temperature*[2]	1727.53	1727.53	1727.53	1727.53	1727.53	1727.53	1727.53	1727.53	1727.53	1727.53
Energy heating air, land & oceans	78.58	183.24	252.14	312.82	381.77	363.44	349.33	334.81	363.80	465.04
Atmosphere absorbed heat ΔH_a	15.07	35.15	48.37	60.01	73.24	69.72	67.02	64.23	69.79	89.22
Land absorbed heat ΔH_L	10.95	25.53	35.13	43.58	53.18	50.63	48.67	46.64	50.68	64.78
oceans absorbed energy ΔH_w	52.56	122.56	168.64	209.23	255.34	243.09	233.65	223.94	243.33	311.04
Year	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**
Primary energy	2998.63	3064.57	3172.59	3292.54	3358.40	3396.16	3419.32	3445.69	3467.72	3514.06
Non-renewable energy	2811.09	2874.46	2979.84	3093.66	3160.47	3191.07	3209.23	3235.68	3245.04	3289.78
Energy entered climate system*[1]	2248.87	2299.57	2383.87	2474.93	2528.38	2552.86	2567.39	2588.54	2596.03	2631.82
Energy melting ice + raising temperature*[2]	1727.53	1727.53	1727.53	1727.53	1727.53	1727.53	1727.53	1727.53	1727.53	1727.53
Energy heating air, land & oceans	521.34	572.04	656.34	747.40	800.85	825.33	839.86	861.01	868.50	904.29
Atmosphere absorbed heat ΔH_a	100.02	109.74	125.91	143.38	153.64	158.33	161.12	165.18	166.62	173.48
Land absorbed heat ΔH_L	72.63	79.69	91.43	104.12	111.57	114.98	117.00	119.95	120.99	125.98
oceans absorbed energy ΔH_w	348.70	382.61	438.99	499.90	535.65	552.02	561.74	575.89	580.90	604.84
Year	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Primary energy	3586.08	3691.25	3732.70	3755.14	3821.12	3917.34	3961.34	4051.86	4199.86	4406.65
Non-renewable energy	3349.45	3451.25	3488.07	3508.14	3571.92	3662.71	3712.53	3797.20	3944.56	4132.25
Energy entered climate system*[1]	2679.56	2761.00	2790.45	2806.51	2857.54	2930.17	2970.02	3037.76	3155.65	3305.80
Energy melting ice + raising temperature*[2]	1727.53	1727.53	1727.53	1727.53	1727.53	1727.53	1727.53	1727.53	1727.53	1727.53
Energy heating air, land & oceans	952.03	1033.47	1062.93	1078.99	1130.01	1202.64	1242.49	1310.24	1428.12	1578.27

Year	**1965**	**1966**	**1967**	**1968**	**1969**	**1970**	**1971**	**1972**	**1973**	**1974**
Atmosphere absorbed heat ΔH_a	182.64	198.26	203.91	207.00	216.78	230.72	238.36	251.36	273.97	302.78
Land absorbed heat ΔH_L	132.63	143.97	148.07	150.31	157.42	167.54	173.09	182.53	198.95	219.87
oceans absorbed energy ΔH_w	636.77	691.24	710.94	721.68	755.81	804.39	831.04	876.35	955.20	1055.63
Year	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Primary energy	4560.93	4697.72	4851.83	4914.68	4835.71	5074.15	5197.66	5270.76	5371.37	5423.54
Non-renewable energy	4274.22	4397.50	4543.13	4583.40	4499.35	4713.10	4818.20	4863.78	4937.20	4969.00
Energy entered climate system*[1]	3419.37	3518.00	3634.50	3666.72	3599.48	3770.48	3854.56	3891.02	3949.76	3975.20
Energy melting ice + raising temperature*[2]	1727.53	1727.53	1727.53	1727.53	1727.53	1727.53	1727.53	1727.53	1727.53	1727.53
Energy heating air, land & oceans	1691.84	1790.47	1906.97	1939.19	1871.95	2042.95	2127.03	2163.50	2222.23	2247.67
Atmosphere absorbed heat ΔH_a	324.57	343.49	365.84	372.02	359.12	391.93	408.06	415.05	426.32	431.20
Land absorbed heat ΔH_L	235.69	249.43	265.66	270.15	260.78	284.60	296.31	301.39	309.58	313.12
oceans absorbed energy ΔH_w	1131.59	1197.55	1275.48	1297.03	1252.05	1366.42	1422.66	1447.05	1486.34	1503.35
Year	**2015**	**2016**	**2017**							
Primary energy	5468.04	5551.07	5656.87							
Non-renewable energy	4995.95	5046.71	5123.94							
Energy entered climate system*[1]	3996.76	4037.37	4099.15							
Energy melting ice + raising temperature*[2]	1727.53	1727.53	1727.53							
Energy heating air, land & oceans	2269.23	2309.84	2371.62							
Atmosphere absorbed heat ΔH_a	435.34	443.13	454.98							
Land absorbed heat ΔH_L	316.12	321.78	330.39							
oceans absorbed energy ΔH_w	1517.77	1544.94	1586.26							

Note: Primary and non-renewable energy consumptions are based on BP's report [15]
**1 80% of the "non-renewable energy"*
**2 refers to the energy used to melt ice and thereafter raise the icy water temperature to bulk seawaters temperature*

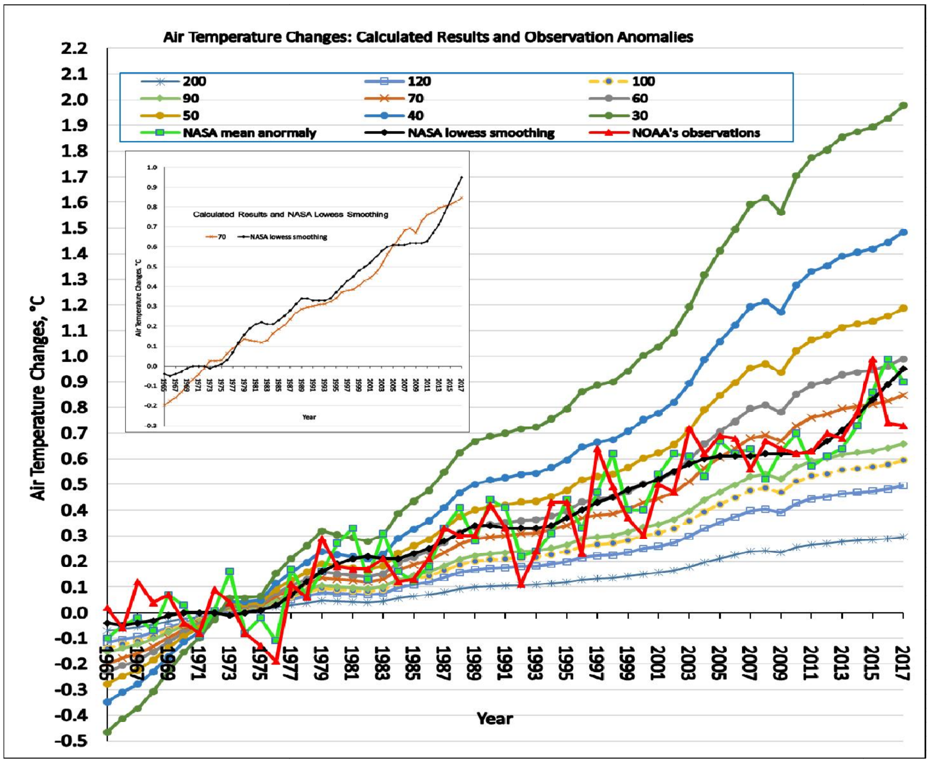

Fig. 1. Relations between calculated surface air temperature change and the heat entered an air layer with depth from 30 to 200 meters during 1965 ~ 2017. NASA's observation anomalies, NASA's Lowess Smoothing trend [54] and NOAA's observations [55] are also exhibited. The small insert shows the results calculated at depth of 70 meters and NASA's Lowess Smoothing, they are very consistent. The energy data can be found in Table 3

before 1973, the observed temperature anomalies are bigger than and largely deflected from the calculated results. Thereafter the observation results tend to be more consistent with the calculated results and fall into a range of values calculated between air layer depths of 50 and 100 meters, with the calculation result at the depth of 70 meters being intuitionally representative.

The fact is that an air layer with a depth ranging from 50 to 100 meters covers most of the residual/waste energy discharging sources from human activities, and the discharged energy is then allocated among air, land and oceans. Therefore, in order to properly track and simulate the air temperature change, an air layer depth between 50 and 100 meters should be considered. The observations of the temperature anomalies by NASA, NOAA etc. represent this allocated energy distribution within such an air layer.

Like the meteorological definition of night air boundary layer's depth (up to 100 meters) [56], here we define the above air layer as an equivalent climate change surface air boundary layer (ECCSABL), and its depth being the ECCSABL depth. Therefore, 50 and 100 meters are considered its lower and upper limits, and the 70-meter is its representative depth, respectively. The results calculated at these ECCSABL depths are clearly shown in Fig. 1 together with NASA and NOAA's observations. The small insert in Fig. 1 demonstrates that the calculated results at the representative 70-meter depth and NASA's Lowess Smoothing trend are very close. Apparently, these results provide direct evidence that the extra heat discharged into the climate system from human activities does cause the temperature change in the air layer.

In Fig. 1 the fluctuations in observations can be attributed to the combined effects of ice melting & sea level rising [57], El Niño and La Niña phenomena, hurricanes/tornados, volcanic eruptions, wildfires, oil/gas fires, vast amount of explosive uses, nuclear tests/accidents, and wars etc. Ice melting plays a very important role in global warming by taking a big portion of the heat. However, assuming constant ice melting rate here might have led to overestimate at the early years, which can explain to some extent why the calculation results are less and even negative. NASA has stated that in the past two decades sea level has risen at an unprecedented doubled rate [57] than ever before, indicating much less ice melted in early days than recently.

While discharging huge amount of heat into the climate system, volcanic eruptions also blow out vast quantity of particulates (dust). After cooling down, this dust also absorbs energy, cancelling the effect on temperature rising of the heat both from volcanic eruption and human activities for a longer term.

Again, note that the air is not static, it moves heat dynamically through convection and advection to redistribute temperature simultaneously within the air layer and beyond. This is why we haven't experienced extremely hot weather yet. However, if the atmosphere were completely closed and static, the heat would cumulate up, and the accumulated temperature rising would be very big during the period, for example, when considering an air layer with a depth of 70 meters, the accumulated temperature rising since 1965 would be 18.2ºC; if the depth were 1,000 or 10,000 meters, the respective temperature rising would be 1.27 or 0.13ºC. The patterns of air movements and circulations affect air surface temperature distribution, temperature rising and the climate change.

Furthermore, the extra heat may also have intensified extreme natural events such as El Nino, La Nina, tornados and hurricanes, and wildfires. In fact, the heat entered the system is localized initially. This may explain why such extreme events frequently incur in North America [58], especially the USA since it consumes a big part of the world's energy and thereby discharges more heat into the system. This tendency has been seen in Asia especially China, India and South Eastern Asia as their energy consumptions have dramatically increased in recent years.

4.2 Seawater Surface Temperature Change

Seawaters play a very significant role in global warming, to the greatest extent regulate the weather and climate patterns. The atmosphere is mostly affected by the water on Earth, since water evaporates and condenses in continuous cycles with huge amount of heat accompanied. It is reported that the amount of water evaporated into the atmosphere as vapor or returned back to the earth surface in the form of rainfall is about 4.5×10^{17} Kg annually [59], and about 8.4×10^{17} KJ of heat (about 20024 MTOe) is involved, which is about 9 times the USA's annual primary energy consumption and also about 1.5 times the entire world's primary energy consumption in 2017. Consequently, the movement of this part of water in the climate system will significantly affect the system's energy distribution and its temperature change. Atmospheric and land temperatures vary a lot and are volatile while seawaters temperature is quite stable [60]. Moreover, the heat energy retained in oceans can warm the planet for decades after its initial absorption [61] because of its vast volume and tremendous energy storage capability.

Fig. 2 shows the results of temperature changes at different depths of the seawaters surface layer, calculated based on the allocated heat in Table 3. It is evident that the more heat absorbed, the bigger the temperature change.

It is obvious that the temperature changes in seawaters surface layer have the similar tendency as those in surface air layer described above, being adversely proportional to the layer's depth as illustrated in Equation 9. For example, the temperature change at the depth of 10 cm is half (e.g. 1.07ºC in 2017) of that at the depth of 5 cm (e.g. 2.14ºC in 2017).

The measurements of seawaters surface temperature (SST) anomalies by NOAA [62] through various approaches like satellite sensors, drifters, buoys and ships at different depths from the surface skin (about 10 micrometers) to several meters (e.g., below 5 meters) [63] are also shown in Fig. 2.

Clearly in the past three decades NOAA's results correspond well with those calculated at depth between 0.1 to 0.2 meters that are referred to as the upper and lower depths of an equivalent climate change water surface boundary layer (ECCWSBL), respectively. The calculated results at the depth of 0.15 m (i.e. representative depth) are indicative. In early years NOAA's results are bigger than the calculated and remain relatively steady (except for 1969). The negative calculated results in this period may be attributed to the overestimated ice melting rate as describe above. As for the bigger-than-expected observation results, wars [64], nuclear accidents [65,66]/tests [67] etc. during that time may also have contributions by bringing huge quantities of heat directly into the climate system. Because of water's big specific heat capacity, as a huge buffer the oceans also absorbed most of the heat from these sources, which keeps the surface layer temperature steady. That another point can also support the observations suggests that the cooling period between 1940s~1970s [53] be an artefact during the naval wars when many warships were deployed and moved the deep lower temperature water up to the surface layer, which then absorbed more heat from the air. Furthermore, the exceptional high observation at 1969 may be attributed to frequent nuclear tests (there were 67 tests in 1969 only) [68,69] and wars, conflicts etc.

Nonetheless, all these indicate that seawaters surface temperature change be closely correlated to the absorbed heat from human activities. This heat contributes to seawaters warming. However, due to the strong movement of water in oceans (waves, tides and currents) and its conductivity, the absorbed heat is not constrained within a water layer with a limited depth of a couple of decimeters, instead it will be transferred, conducted/diffused down to deeper levels. In fact, the warming has been observed more than 400 meters deeper [70]. Additionally, seawaters temperature changes are not evenly distributed globally as well, some regions may experience big positive anomalies, others may experience small or even negative anomalies (i.e. cooling).

4.3 Land Surface Temperature Change

To a small extent land does impact the weather and climate change patterns. Unlike waters that can hold and slowly release the absorbed heat for a long period of time, land quickly absorbs from and releases heat to the atmosphere when the ambient experiences temperature change. The land surface temperature - another climate change indicator - represents the energy balance at the Earth's surface and indicates the energy fluxes between the atmosphere and the ground [71].

Land (or soil) surface temperature varies with the depth during diurnal cycle, and the variance depends on its composition, structure, moisture content and porosity etc. UK Meteorological Office [72] and the agencies in USA [73,74] have measured the temperatures at different depths from 5 up to 225 cm.

Analyzing North Dakota Agricultural Weather Network's (NDAWN) deep soil temperature measurements record [74] demonstrates that the diurnal temperature change can extend up to a depth of 20 cm (Fig. 3). That means an up-to-20-cm land surface layer experiences quick temperature variance when its surrounding condition changes in a diurnal cycle. However, in an annual cycle, the land surface can experience evident temperature changes even over 225 cm deep as shown in Fig. 4 where monthly average temperatures at different depths are presented from all participating stations during 2014 to 2018. Temperature rising gradually extends to deeper levels as getting into warmer months until September. For example, at skin levels the temperatures rise from February and reach the highest in July, whereas at deeper levels (i.e. 200 and 225 cm) the temperatures start to rise from May and reach the highest in September. Thereafter, the temperatures at various levels gradually go down. These suggest that heat exchange occur between the land surface skin and deeper levels even over a depth of 225 cm in a long run beside of the diurnal fluxing between the skin level and air. This implies that almost all the energy absorbed during the warm season by the land will be gradually released back to atmosphere during the colder season, and that it is almost unlikely that geothermal energy comes up to the land surface and impact the climate (unless in the areas where hot springs and volcanoes exist).

Based on Equation 11 and Table 3, the equivalent climate change land surface boundary layer's (ECCLSBL) temperature change with depth is shown in Fig. 5, where the depths up to 60 cm are considered. Note that, as discussed above, some of the energy absorbed by the land surface layer can still transfer down gradually and raise the deeper levels' temperatures up while the rest returns to air. Fig. 5 also exhibits NOAA's Land Surface Temperature (LST) measurements [75]. These measurements fall, especially in the last three decades, into a range of calculated results between the depths of 5 and 10 cm, and the calculation results at the depth of 7.5 cm can be representative. As with the ECCSABL and ECCWSBL, let's define the 5 cm as the ECCLSBL's upper depth and 10 cm the lower depth, and the 7.5 cm the representative one. Note that NOAA's measurements contain satellite sensing results at a very thin surface skin layer.

The fluctuations seen on NOAA's measurement line can be attributed to various events as discussed earlier for air and seawaters. The land is more susceptible to even small heat changes due to its smallest specific heat capacity.

In summary, it can be drawn that the temperature changes in air, oceans and land as observed by NOAA, NASA are the direct result of heat discharged into the climate system from human activities. With the increase in heat entered the system, the temperature changes in these three components have increased simultaneously by following the respective unique relations as the equations indicate. The temperature in land is more sensitive to any heat change than in air, and much more than in waters. Because of its high specific heat capacity, seawaters become a huge heat storage tank and thus a big temperature change buffer against any extra heat entered the system, leading to the smallest change compared to land and air. Fig. 6 shows the calculated results at the representative depths of ECCLSBL (0.075 m), ECCSABL (70 m) and ECCWSBL (0.15 m) and NOAA's

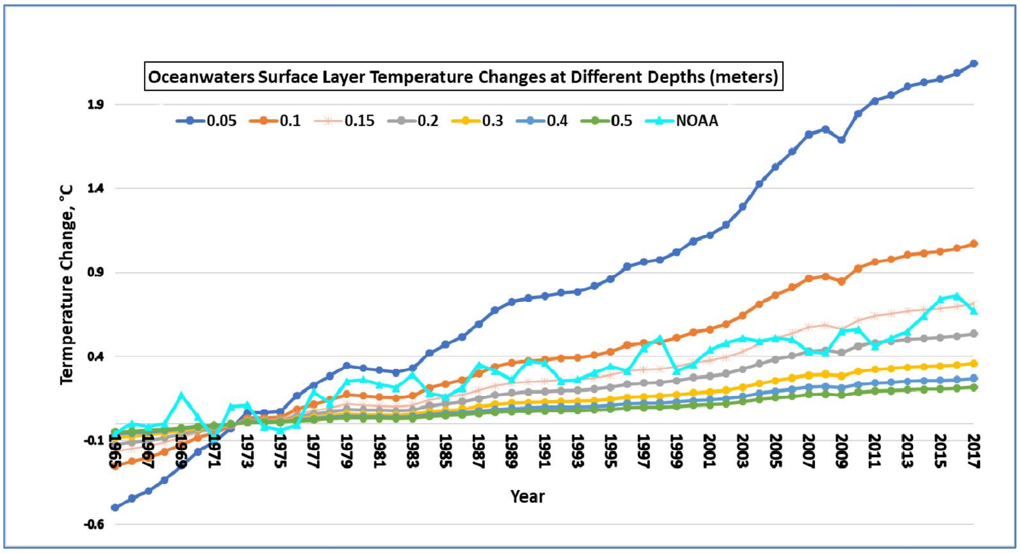

Fig. 2. Calculated seawaters surface temperature change at depth between 0.05 to 0.5 meters as the absorbed heat increases from 1965 to 2017 (Table 3). 0.1 and 0.2 meters are the respective upper and lower depths of the ECCWSBL. NOAA's measurement results [63] are also displayed for comparison where 1901 – 2000 average is used as baseline

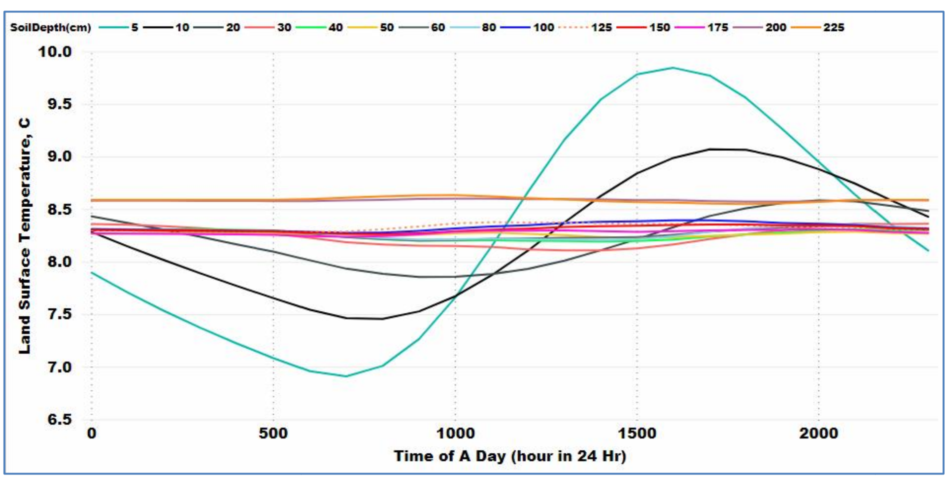

Fig. 3. Relations between land surface layer temperatures and the time in a diurnal cycle at various depths, according to the statistical analysis of NDAWN's deep soil temperature measurements record [74]. The temperature experiences obvious changes at depth up to 20 cm (average of the data from 2014 to 2018 for all participating stations)

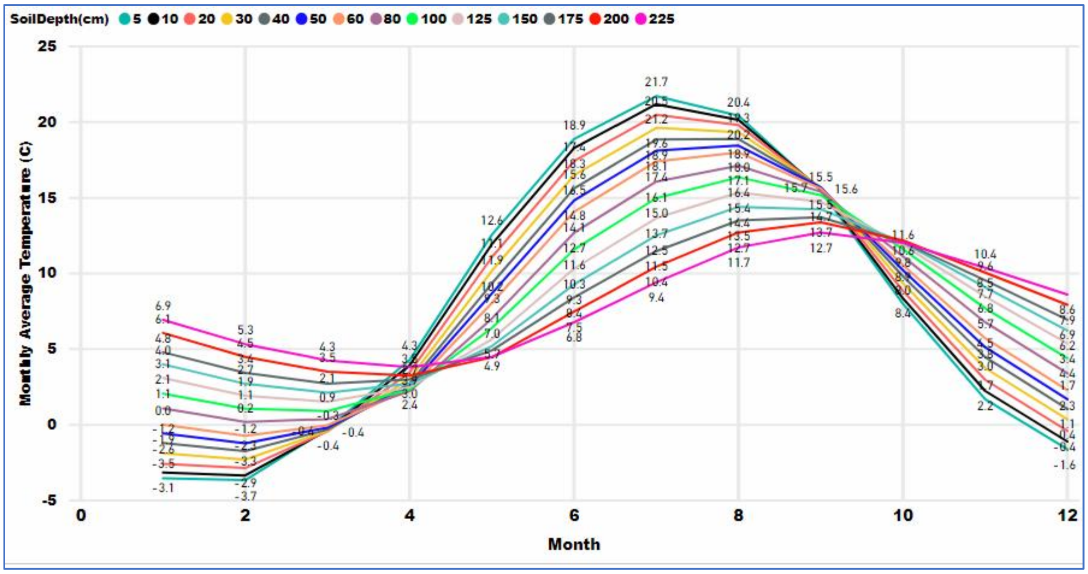

Fig. 4. Monthly average land surface temperatures at various depths between 2014 and 2018 from all participating stations, based on statistical analysis of the raw data from NDAWN [74]

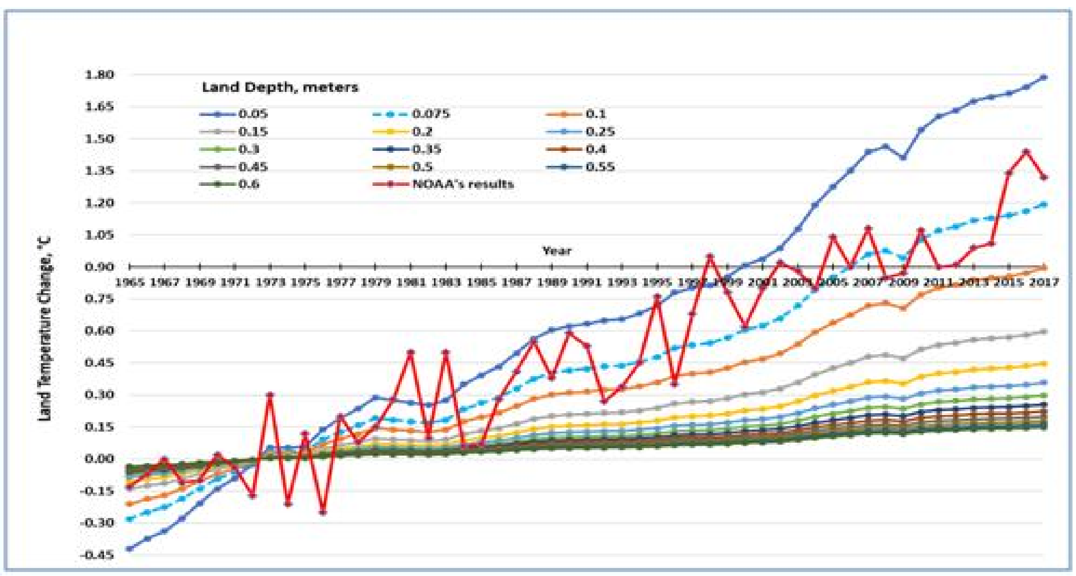

Fig. 5. Calculated temperature changes in land surface layer at different depths and NOAA's observation anomalies [75]

corresponding observations. Clearly the calculated results are well in line with these observation results especially the NASA's Lowess Smoothing trend for air, suggesting that the residual/waste energy entered the system from human activities is the root cause of the current global warming. Thus, increasing GETECE is essential to mitigate climate change. Eliminating flaring will be conducive.

On the other hand, burning biomass in large quantity in a very short time can release huge amount of heat "concentratedly" into the system, breaking the energy budget balance as described by Equation 1 and resulting in localized (air, land and oceanwaters) temperature rising. Therefore, using biomass should be prudent and in a well-planned manner. Similarly, wildfires impact local climate patterns

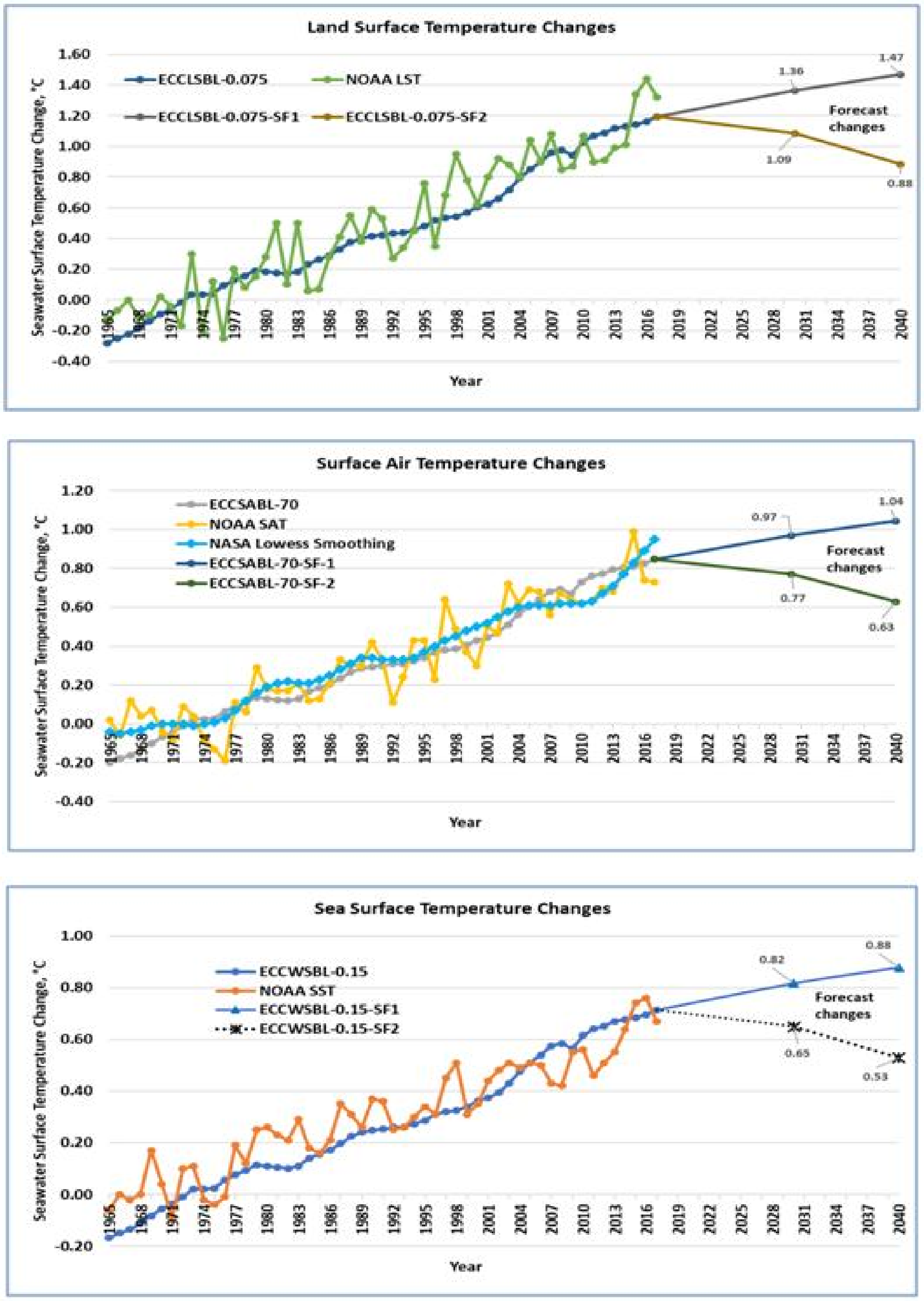

Fig. 6. Comparisons of calculated temperature changes and NOAA's temperature anomalies in land (ECCLSBL at depth 0.075 m vs. NOAA's LST [75]), in air (ECCSABL at depth of 70 m vs. NOAA's Surface Air Temperature i.e. SAT and NASA's Lowess Smoothing trend [55]) and in waters (ECCWSBL at depth of 0.15 m vs NOAA's Sea Surface Temperature i.e. SST [63]) from 1965 to 2017, respectively. Meanwhile, the future temperature changes calculated by using the equivalent climate change model at 2030 and 2040 are also demonstrated under different scenarios (SF1 - business as usual; SF2 - ice melting rate at the current level, GETECE increased to 30% at 20030, and further to 40% at 2040)

Table 4. Prediction of future air temperature risings under various scenarios

Scenarios	Symbol
GETECE = 20%, world primary energy consumption as predicted by BP [76], ice melting remains at current rate	**SF1**
GETECE = 30% by 2030, GETECE = 40% by 2040, world primary energy consumption as predicted by BP [76], ice melting remains at current rate	**SF2**

Table 5. Predication of maximum primary energy consumption required by the end of 21st century

Scenarios	Maximum energy required, MTOe
GETECE = 20%, the ice melting rate remains at the current level	**17685**
GETECE = 40%, the ice melting rate remains at the current level	**23580**

and in turn the climate change will affect wildfire occurrences as well. Additionally, using geotherm and nuclear energy breaks the energy budget balance as well and thus leads to global warming. However, surface-renewables such as solar energy (solar hot water and photovoltaic), wind energy, ocean energy and hydro won't cause climate change.

4.4 Prediction of Future Temperature Rising

The same procedures as discussed above can also be used to forecast future global warming. Table 4 shows the assumptions under various scenarios used to forecast global warming at 2030 and 2040. The results are shown in Fig. 6 above, where the representative depths of the ECCLSBL, ECCSABL and ECCWSBL are 0.075 m, 70 m and 0.15 m, respectively, and the ice melting rate keeps at the current level. In the case of business as usual (SF1) i.e. the GETECE remains at 20% unimproved, and the world primary energy consumption is about 16095 MTOe (including 1674 MTOe renewable energy) at 2030 and 17866 MTOe (including 2748 MTOe renewable energy) at 2040 as predicted by BP [76], the temperatures will continue to increase in land, air and seawaters as indicated in Fig. 6, for example, the most concerned air temperature will increase by 0.97ºC at 2030 and 1.04ºC at 2040, respectively. However, if the GETECE is increased by 10% by 2030 and another 10% by 2040 (i.e. SF2), then the global warming will be effectively controlled, the warming trend will turn down as Fig. 6 demonstrates, for example, the air temperature rising will be 0.77ºC at 2030 and 0.63ºC at 2040, respectively.

Additionally, in order to keep the global warming below 1.5ºC, the energy consumption required by the end of the century under various scenarios can also be estimated by assuming that the total world primary energy consumption doesn't include any renewable energy. Table 5 below tabulates the results.

Therefore, even if the GETECE and the ice melting rate remain as today's levels, the total global primary energy consumption should be below 17685 MTOe of non-renewable energy by the end of the century; if the GETECE is increased to 40%, the total primary energy consumption should be no more than 23580 MTOe of non-renewable energy in order to keep the temperature rising below 1.5ºC.

However, using any renewable energy to replace part of the above estimated non-renewable energy will further mitigate the global warming; and even by the end of the century the global surface air temperature rising won't reach 1.5ºC as long as the total primary energy consumption including renewable energy does not exceed those cited in Table 5 i.e. 17685 or 23850 MTOe under their respective scenarios.

5. CONCLUSION

From the above analysis and discussion, the following can be concluded:

1. The root cause of current climate change is the residual/waste energy discharged into the climate system from human activities. Industry contributes about 35%, residential and commercial 29% and transportation 15%. Global warming directly correlates to this extra energy.

2. Studying climate change needs to consider air, land and oceans simultaneously and interconnectedly. An equivalent climate change model, consisting of an equivalent climate change surface air boundary layer with a depth between 50~100 meters, an equivalent climate change land surface boundary layer with a depth between 0.05 ~0.10 meters, and an equivalent climate change seawaters surface boundary layer with a depth between 0.1~0.2 meters, provides a useful and appropriate approach to looking at the influence of residual/waste energy on the climate change, to tracking the temperature change and to predicting future global warming.
3. The observed measurements of temperature anomalies in air, seawaters and land by NASA and NOAA fall well into the ranges calculated based on the allocated heat quantity from human activities by using this equivalent climate change model at the upper and lower depths of the respective air, seawaters and land layer, further confirming that global warming is a direct result of the heat discharged into the climate system.
4. The model also provides reasonable forecasts on global warming. If the GETECE and the ice melting rate remain at today's levels, the respective air temperature risings at 2030 and 2040 would be 0.97 and 1.04ºC when the world's primary energy consumption goes as BP forecasted. If the GETECE increased by 10% by 2030, and another 10% by 2040, then the corresponding temperature risings would be 0.77 and 0.63ºC, respectively, with the same world primary energy consumption. However, if we want to restrain the global warming below 1.5ºC by end of the century, the world's non-renewable primary energy consumption should not be more than 17685 MTOe when the GETECE is at today's level (i.e. 20%), or 23580 MTOe when the GETECE is increased to 40%. Furthermore, if renewable energy is used to replace the non-renewable energy, then the global warming will be less than what is forecasted in this study.
5. Efforts in fighting climate change should be focused onto enhancing GETECE, ultimately reducing the residual energy entering the climate system from human activities, and onto changing personal and social energy use behavior. Merely pursuing reductions in greenhouse gas emissions won't help mitigate global warming or climate change, but to some extent slow down the economic development; Flaring intensifies global warming. Developing and using surface renewable energies (solar, wind and ocean energies etc.) are ideal.
6. Accurate data records, especially the consumption of a variety of energies, ice melting rate and patterns, energy use/conversion efficiencies are all essential for studying climate change and tracking global warming. Thus, properly documenting the data in detail and monitoring ice melting closely etc. are vital to advance this climate change model and better understand climate change.

ACKNOWLEDGEMENT

The author is gratitude to his family for their unconditional support and help since this research has been conducted completely at their leisure time at home since early 2013. He also wants to extend his heartful thanks to his friends: Mr. Ted Sheldon, a former colleague, Prof. Zhiping Qi with Institute of Electric Engineering, Chinese Academy of Science, and Dr. Xiurong Sun, who reviewed the draft and provided relevant advices.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Tom Yulsman. Permafrost in coldest Arctic areas will melt faster than thought, releasing large amounts of greenhouse gases. The Magazine Discover; 2018. Available:http://blogs.discovermagazine.com/imageo/2018/03/08/permafrost-in-coldest-arctic-areas-will-melt-faster-than-thought/#.W3Jg7-hKhPY.
2. Ruptly.tv. Russia: It moves! Grass bizarrely bubbles in Siberia; 2016. Available:https://www.youtube.com/watch?v=ULqhLhpECPw.
3. W5. What happens when the permafrost thaws; 2017. Available:https://www.youtube.com/watch?v=BFfuHmrW2gc.

4. Belinda Robinson. Mystery as HUGE craters emerge in Russia: Scientist claims they are major warning to world. Express UK; 2017. Available:https://www.express.co.uk/news/world/835180/Mystery-huge-craters-northern-Siberia-Russia-50ft-wide-permafrost-thawing.
5. DenielGlack. The big thaw - As the climate warms, how much, and how quickly, will Earth's glaciers melt?
6. National Geographic. Available:https://www.nationalgeographic.com/environment/global-warming/big-thaw/?user.testname=lazyloading:1.
7. National Snow and Ice Data Center. Arctic Sea Ice News and Analysis – Sea ice data updated daily with one-day log. (Accessed April 7, 2018) Avaliable:http://nsidc.org/arcticseaicenews/.
8. Steiner N, Azetsu-Scott K, Galbraith P, Hamilton J, Hedges K, Hu X, Janjua MY, Lambert N, Larouche P, Lavoie D, Loder J, Melling H, Merzouk A, Myers P, Perrie W, Peterson I, Pettipas R, Scarratt M, Sou T, Starr M, Tallmann RF,Van der Baaren A. Climate change assessment in the Arctic Basin Part 1: Trends and projections - A contribution to the Aquatic Climate Change Adaptation Services Program. Can. Tech. Rep. Fish. Aquat. Sci. 2013;3042: xv + 163.
9. NASA. Global Climate Change Vital Signs of the Planet. Available:https://climate.nasa.gov/vital-signs/global-temperature/
10. Robert M Carter, Craig D Idso, Fred Singer S. Why scientists disagree global warming? The NIPCC Report on Scientific Consensus; 2015
11. IPCC Data Distribution Centre. What is a GCM? and Criteria for Selecting Climate Scenarios in Scenario Selection etc. Available:https://www.ipcc-data.org/guidelines/index.html
12. Hegerl GC, Zwiers FW, Braconnot P, Gillett NP, Luo Y, Marengo Orsini JA, Nicholls N, Penner JE, Stott PA. Understanding and attributing climate change. In: Climate change 2007: The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA; 2007.
13. Flato G, Marotzke J, Abiodun B, Braconnot P, Chou SC, Collins W, Cox P, Driouech F, Emori S, Eyring V, Forest C, Gleckler P, Guilyardi E, Jakob C, Kattsov V, Reason C, Rummukainen M. Evaluation of climate models. In: Climate Change 2013: The physical science basis. contribution of working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker TF, Qin D, Plattner GK, Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V, Midgley PM. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA; 2013.
14. Anonymous. General circulation model. Wikipedia. Available:https://en.wikipedia.org/wiki/General_circulation_model
15. Chris Mooney. Stunningly good news for the planet: Carbon emissions were flat for the third straight year. The Washington Post; 2016. Available:https://www.washingtonpost.com/news/energy-environment/wp/2016/11/13/stunningly-good-news-for-the-planet-carbon-emissions-were-flat-for-the-third-straight-year/
16. BP Statistical Review of World Energy. bp-stats-review-2018-all-data from 1965; 2018. Available:https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/downloads.html.
17. Rebecca Lindsey. Did global warming stop in 1998? NOAA Climate.gov.; 2018. Available:https://www.climate.gov/news-features/climate-qa/did-global-warming-stop-1998
18. Wigley TML, Raper SCB. Climatic change due to solar irradiance changes. J. of Geophysical Research Letters. 1990;17 (12). Available:https://doi.org/10.1029/GL017i012p02169.
19. Wang Shaowu, Luo Yong, Zhao Zongci, Wen Xinyu, Huang Jianbin. Controversy over the causes of global warming. Adv. Clim. Change Res. Chinese. 2011;7(2):79-84.
20. Sami K Solanki, Natalie A Krivova, Joanna D Haigh. Solar irradiance variability and climate. Annu. Rev. Astron. Astrophys. 2013;51:311–51.
21. US Department of Energy. where the energy goes: Gasoline vehicles.

Available:https://fueleconomy.gov/feg/atv.shtml.

22. 212. Anonymous. Fuel efficiency. Wikipedia. Available:https://en.wikipedia.org/wiki/Fuel_efficiency
23. Chunshan Song, Wei Pan, Srinivas T. Srimat, Jian Zheng, Yan Li, Yu-He Wang, Bo-Qing Xu, Qi-Ming Zhu. CO_2 Conversion to syngas with desired H_2/CO ratios using flue gas of power plants without CO_2separation. Studies in Surface Science and Catalysis. 2004;153:315-322. Available:https://doi.org/10.1016/S0167-2991(04)80270-2
24. NenadSarunac. Power 101: Flue gas heat recovery in power plants, Part I. Power; 2010. Available:https://www.powermag.com/power-101-flue-gas-heat-recovery-in-power-plants-part-i/?pagenum=2
25. Shiying Lin, Takashi Kiga, Yin Wang, Katsuhiro Nakayama. Energy analysis of $CaCO_3$ calcination with CO_2 capture. Energy Procedia. Energy Procedia. 2011;4: 356-361. ScienceDirect. Available:https://doi:10.1016/j.egypro.2011.01.062
26. Wicky Moffat, Walmsley MRW. Understanding lime calcination kinetics for energy cost reduction. 59th Appita Conference. Auckland, New Zealand; 2006. Available:https://www.scribd.com/document/177117629/Understanding-Lime-Calcination
27. Huang Tuyuan, Jiang Jiafen, Yang Nanru, Zhou Zhaotong, etc. Concrete material foundation, modern concrete technology. P.11. Shaanxi Science and Technology Press Chinese; 1998.
28. Anonymous. Clinker Thermochemistry. Cement Kilns. Available:https://www.cementkilns.co.uk/ckr_therm.html
29. Kurt E Peray. The rotary cement kiln. chemical publishing Co., Inc. New York. 1986;107.
30. Natural Resources Canada. Energy Consumption Benchmark Guide: Cement Clinker Production; 2001. Avaialble:https://www.nrcan.gc.ca/energy/publications/efficiency/industrial/6005
31. BP. P.l.c. BP. Statistical Review of World Energy; 2018. Available:https://www.bp.com/en/global/corporate/news-and-insights/speeches/bp-statistical-review-of-world-energy-2018.html
32. Jacques Schonek. How big are power line losses? Schneider Electric Blog; 2013. Available:https://blog.schneider-electric.com/energy-management-energy-efficiency/2013/03/25/how-big-are-power-line-losses/
33. Green Riverside. Energy Efficient Motors. Available:https://www.energydepot.com/RPUcom/library/MISC003.asp.
34. The World Bank. Global Gas Flaring Reduction Partnership (GGFR), Press Release; 2018. Available:http://www.worldbank.org/en/news/press-release/2018/07/17/new-satellite-data-reveals-progress-global-gas-flaring-declined-in-2017.
35. The World Bank. Global Gas Flaring Reduction Partnership – Issue Brief; 2006. Available:http://siteresources.worldbank.org/INTGGFR/Resources/GGFR-IssueBrief.pdf.
36. Audrey Wozniak. The world's longest burning fires: China's unseen story. ChinaDialogue; 2013. Available:https://www.chinadialogue.net/article/show/single/en/6296-The-world-s-longest-burning-fires-China-s-unseen-story.
37. Anonymous. Coal seam fires. Wikipedia. Available:https://en.wikipedia.org/wiki/Coal_seam_fire
38. Anonymous. China's Centuries Old Underground Coal Fires. China Uncensored; 2013. Available:https://www.youtube.com/watch?v=GI2wkwYIU8c
39. Stuart J. Day, Jon N. Carras, Robyn Fry and David J. Williams. Greenhouse gas emissions from Australia open-cut coal mines: contribution from spontaneous combustion and low-temperature oxidation. Environ Monit Assess. 2010;166(1–4): 529–541. Available:https://doi.org/10.1007/s10661-009-1021-7
40. BP. P.l.c. BP Energy Outlook 2018 Edition. Available:https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/energy-outlook/bp-energy-outlook-2018.pdf
41. NASA. Global climate change – Vital Signs of the Planet. Sea Level. Available:https://climate.nasa.gov/vital-signs/sea-level/

42. Maria-Jose Viñas, Carol Rasmussen. Warming seas and melting ice sheets; 2015. Available:https://climate.nasa.gov/news/2328/warming-seas-and-melting-ice-sheets/
43. Timothy Bralower, David Bice. Heat capacity and energy storage, Earth 103: Earth in the Future. Available:https://www.e-education.psu.edu/earth103/node/1005
44. Tim Sharp. What Is Earth's Average Temperature? Space.com; 2018. Available:https://www.space.com/17816-earth-temperature.html
45. World Meteorological Organization. Relative Humidity. UNData – a World of Information. Available:http://data.un.org/Data.aspx?d=CLINO&f=ElementCode%3A11
46. Anonymous. How to convert relative humidity to absolute humidity. Carnotcycle - The classical blog on thermodynamics; 2012. Available:https://carnotcycle.wordpress.com/2012/08/04/how-to-convert-relative-humidity-to-absolute-humidity/
47. Jennifer Bergman. Temperature of ocean water. Windows to the Universe; 2011. Available:https://www.windows2universe.org/earth/Water/temp.html
48. Anonymous. Appendix 1 - Property Tables and Charts (SI UNITS). Available:http://homepages.wmich.edu/~cho/ME432/Appendix1Udated_metric.pdf
49. Jennifer Bergman. Density of ocean water. windows to the Universe; 2001. Available:https://www.windows2universe.org/earth/Water/density.html
50. Earnest Hooton. Earth. New World Encyclopedia. Available:http://www.newworldencyclopedia.org/entry/Earth
51. Anonymous. History rewritten, Global Cooling from 1940–1970, an 83% consensus, 285 papers being “erased”. JoNova; 2016. Available:http://joannenova.com.au/2016/09/history-rewritten-global-cooling-from-1940-1970-an-83-consensus-285-papers-being-erased/
52. Marc Morano. Before 1960s-’70s Global cooling was erased, it caused droughts, crop failures,glacier advance, Ice Age Threats. Climate Depot; 2017. Available:https://www.climatedepot.com/2017/11/27/before-1960s-70s-global-cooling-was-erased-it-caused-droughts-crop-failures-glacier-advance-ice-age-threats/
53. Catherine Brahic. Climate myths: The cooling after 1940 shows CO_2 does not cause warming. New Scientist; 2007. Available:https://www.newscientist.com/article/dn11639-climate-myths-the-cooling-after-1940-shows-co2-does-not-cause-warming/
54. Admin. Global Cooling 1940–1975 explained for climate change experts. Oceans Govern Climate; 2017. Available:https://oceansgovernclimate.com/global-cooling-1940-1975-explained-for-climate-change-experts/.
55. NASA’s Land-Ocean Temperature Index (C). Available:https://climate.nasa.gov/system/internal_resources/details/original/647_Global_Temperature_Data_File.txt
56. NOAA National Centers for Environmental information, climate at a glance: Global Time Series - Global Land and Ocean Temperature Anomalies; 2018. (Accessed December 13, 2018) Available:https://www.ncdc.noaa.gov/cag/global/timeseries/globe/land_ocean/1/10/1880-2018.csv
57. Oke TR. Boundary layer climates, second edition, Routledge, London & New York. 1987;4-5.
58. NASA. Rising seas. Available:https://www.nasa.gov/goddard/risingseas.
59. Nation Ocean Service. National Oceanic and Atmospheric Administration. What are El Niño and La Niña? Available:https://oceanservice.noaa.gov/facts/ninonina.html
StumnW, Morgan JJ. Aquatic chemistry - An introduction emphasizing chemical equilibria in natural waters, 2nd Edition. John Wiley & Sons, Inc. 1981. Chinese version, Translated by Tang Hongxiao, Science Press; 1987.
60. James Conca. Climate change has the Earth in hot water. Forbes; 2015. Available:https://www.forbes.com/sites/jamesconca/2015/08/31/climate-change-has-got-the-earth-in-hot-water/#3830f534d89e
61. LuAnn Dahlman, Rebecca Lindsey. Climate change: Ocean heat content. NOAA Climate.Gov.; 2018. Available:https://www.climate.gov/news-features/understanding-climate/climate-change-ocean-heat-content.

62. NOAA. Global ocean temperature anomalies, January-December (Base Period: 1901-2000); 2018. Available:https://www.ncdc.noaa.gov/cag/global/time-series/globe/ocean/ytd/12/1880-2018.csv
63. NASA California Institute of Technology – Jet Propulsion Laboratory: PODAAC. Sea Surface Temperature. Available:https://podaac.jpl.nasa.gov/SeaSurfaceTemperature.
64. Wikipedia. List of wars: 1945–1989. Available:https://en.wikipedia.org/wiki/List_of_wars:_1945%E2%80%931989#1960%E2%80%931969
65. Anonymous. A Brief history of nuclear accidents worldwide. Union of Concerned Scientists; 2013. Available: https://www.ucsusa.org/nuclear-power/nuclear-power-accidents/history-nuclear-accidents
66. Wikipedia. Lists of nuclear disasters and radioactive incidents. Available:https://en.wikipedia.org/wiki/Lists_of_nuclear_disasters_and_radioactive_incidents
67. Wikipedia. Historical nuclear weapons stockpiles and nuclear tests by country. Available:https://en.wikipedia.org/wiki/Historical_nuclear_weapons_stockpiles_and_nuclear_tests_by_country#/media/File:Worldwide_nuclear_testing_multilang.svg
68. Wikipedia. Soviet nuclear tests; 1969. Available:https://en.wikipedia.org/wiki/1969_Soviet_nuclear_tests
69. Arms Control Association. The Nuclear Testing Tally – Fact Sheets and Briefs. Available:https://www.armscontrol.org/factsheets/nucleartesttally
70. Sandrine Mulet, Bruno Buongiorno Nardelli, Simon Good, Andrea Pisano, Eric Greiner, MaevaMonier, Emmanuelle Autret, Lars Axell, Fredrik Boberg, Stefania Ciliberti, Marie Drévillon, Riccardo Droghei, Owen Embury, Jérome Gourrion, Jacob Høyer, MélanieJuza, John Kennedy, Benedicte Lemieux-Dudon, ElisavetaPeneva, Rebecca Reid, Simona Simoncelli, Andrea Storto, Jonathan Tinker, Karina von Schuckmann and Sarah L. Wakelin, 1.1 Ocean temperature and salinity, 1.1.1.1. Temperature. In: Copernicus Marine Service Ocean State Report, Journal of Operational Oceanography. 2000;11(2): Sup1,s13–s16. Available:https://doi.org/10.1080/1755876X.2018.1489208.
71. NEO (NASA Earth Observations). Land Surface Temperature [Night] (1 Month - TERRA/MODIS). Available:https://neo.sci.gsfc.nasa.gov/view.php?datasetId=MOD_LSTN_M
72. UK Met Office. How we measure soil temperatures? Available:https://www.metoffice.gov.uk/guide/weather/observations-guide/how-we-measure-temperature
73. US NOAA Nation weather services. Soil Temperature Maps by Depth. Available:https://www.weather.gov/ncrfc/LMI_SoilTemperatureDepthMaps
74. North Dakota Agricultural Weather Network. Current Deep Soil Temperature. (Accessed Jan 3, 2019) Available:https://ndawn.ndsu.nodak.edu/deep-soil-temperatures.html
75. NOAA National Centers for Environmental information. Climate at a Glance: Global Time Series; 2019. (Accessed June 4, 2019) Available: https://www.ncdc.noaa.gov/cag/
76. BP. P.l.c. BP Energy Outlook, 2019 Edition; 2019. Available:https://www.bp.com/en/global/corporate/energy-economics/energy-outlook/energy-outlook-downloads.html

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/52923