Review of Global Warming Urban Heat Island Forcing Issues Unaddressed by IPCC Goals Including CO_2 Doubling Estimates and Albedo Modeling

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Abstract

In this paper we provide a review Urban Heat Island (UHI) important forcing effects related to albedo, humidity and rain water management issues unaddressed by IPCC goals. We first review historical global warming forcing trends by comparing CO_2 prediction to Urban Heat Islands (UHIs) complex forcing influences. We provide a timeline of CO_2 doubling theory and UHI global warming estimates which show that UHI warming effects should be more accurately accounted for by the IPCC. We review both CO_2 and UHI forcing influence by a number of authors indicating the difficulty of estimating UHI influences on global trends. This appears primarily due to making local ground measurements and comparing them to more rural trends. However, most authors are in agreement that there are strong influences. In order to investigate this independently we take a different approach and present a simplified global weighted albedo model that includes UHI solar surface area assessments. In so doing, we show discrepancies with IPCC UHI quoted global areas and CO_2 doubling issues. We then reviewed many other complex issues of UHIs pointing out additional related solar heating problems including humidity forcing and warm rain-water management from highly evaporating hot city surfaces. Our review concludes that IPCC CO_2 goals will likely not stop global warming trends without addressing UHI albedo problems.

1. Goal of this Paper

In this paper we review Urban Heat Island (UHI) important forcing effects that are unaccounted for in IPCC goals, It is apparent that the IPCC is focusing mainly on CO_2 reduction as the key global warming solution [1]. While UHIs have been studied for years [2-5], and the IPCC certainly recognizes many UHI issues, they have yet to address albedo reduction of cities and roads as part of their international goals in terms of global warming reduction efforts [1]. Possibly some studies have been short-sighted with push-back concerns of albedo changes to cities [6-9] which might create a need for more fossil fuel use in winter time periods. These studies likely did not take into account the complex warming issues related solar surface area increases, Hydro-HotSpot (HHS) activity and have assumed that CO_2 is the dominant issue in global warming. Here we term HHS as water evaporation from Highly Evaporating Hot Surfaces (HEHS). The IPCC goals may not be adequate as discussed in this review article since UHI pose a number of these complex issues that need serious attention especially in the area of albedo forcing. Some studies conservatively recognize that without adaptive urban design such as cool roofs [10], for example, that by 2100 cities could cause global temperatures rises of 1 to 2^{o}C [11,12]. Specifically a study in California calculated an offset of 1.31-1.47 °C with 100% deployment of "cool roofs" [11,12]. While such studies are helpful, we feel they may be far off in timing, as UHIs, as will be reviewed here, are already likely significantly contributing to current global warming trends.

To assess the need of UHI albedo corrective actions by the IPCC, the goal of this paper is to review the following UHI global warming issues (also see Table 1 Cause and Effects Reviewed):

- Review the timeline of CO_2 doubling theory and UHI warming assessment in order to look at global warming trends that have been made and understand estimated magnitudes of each
- Review IPCC CO_2 goals and their recognition of UHI forcing issues
- Review the UHI area and radiative forcing quoted by the IPCC in its latest release
- Provide an independent assessment of UHI albedo warming trends in order to demonstrate requirements, and investigate claims by other authors of UHI warming trends on a global basis
- Review current knowledge base of atmospheric humidity and propose possible UHI sources that could be contributing to global humidity changes
- Review yearly storm water cycling of higher temperature water from UHI to local streams, lakes and ocean raising local water surface temperatures and evaporation rates
- Review issues with UHI Rain Water Management (RWM) issues that can lead to increases in dry days and possibly drought
- Review loss of natural vegetation evapotranspiration and associated dryness

Table 2 Global Warming Cause and Effects Reviewed

Global Warming Causes →	**Urban Heat Islands & Roads, Greenhouse gases**
Global Warming Effects →	Increase in Specific Humidity, Decrease in Relative Humidity, Decrease in land albedo due to cities & roads*, Warming trend ~1°C

- *Ice and snow melt albedo effect is not reviewed

1.1 Review of the Timeline of CO_2 Doubling Theory and UHI Estimates

Greenhouse theory and early predictions started as far back as 1856 with CO_2 experiments by Foote, Tyndall in 1859, and what has become very popular, doubling theory by Arrhenius in 1896 [13,14]. Since Arrhenius, doubling temperature estimations based on theory and linked to environmental trends, have shown some decreasing effect and historically unaccounted UHI effects in CO_2 doubling theory. This is illustrated in Table 2 that summarizes some of the key CO_2 history and predictions with the next to last row calculated based on current data in the Reference Column 1 and Equation 1.

$$13.9C\ (57.02F)+\mathbf{2.36^{o}C}\ Ln\{412/311.8)/Ln2=14.85C\ (58.73F),\ 0.95C\ (1.71^{o}F)\ Rise \qquad (1)$$

Table 2 Key CO_2 doubling theory history and conflicts

Reference	**CO_2 Doubling Temperature**	**CO_2 Temperature Effect Estimates**	**Moisture Percent Effect***	**UHI Albedo % Forcing Estimates**
Arrhenius (1896) [13, 14]	5-6°C	5-6°C	-	-
Gillbert Plass (1950's) [15]	3.6°C	3.6°C	-	-
Manabe and Wetherald (1975) [16]	2.3°C	2.3°C	-	-
Feddema et al., 2005 [17]	Conflicting	-	-	Significant
McKitrick and Michaels (2007) [18]	Conflicting	-	-	50%
Ren et. al. (2007) [19]	Conflicting	-	-	Significant
Stone, 2009 [20]	Conflicting	-	-	Significant
Z.C. Zhao (2011) [21]	Conflicting	-	-	Significant
Yang et. Al. 2011 [22]	Conflicting	-	-	Significant
IPCC (1^{tst}-5^{th} Assessment 1990-2014,[1] (ECS) equilibrium change	1.5 - 4.5 °C	1/3	2/3	-
Q. Huang, Y.Lu (2015) [23]	Conflicting	-	-	30%
Current Trend, Eq. 1. Based on going from 311.8ppm to 412 PPM from 1951 to Dec 2019, with a *0.95°C (1.71°F)* rise	2.36°C *	1/3 (0.3°C)	2/3 (0.63°C)	0
UHI albedo modeling (this paper)	Conflicting (1.37°C*)	See Table 5	See Table 5	25.2%

*Ignoring other GHG

We would expect the doubling temperature to drop if one takes into account that UHI contribute significantly to global warming. This is shown in the last row due to our assessment in Appendix C3 where we estimate the doubling temperature decrease to 1.37°C with a UHI model that contributes 25.2% to global warming trends. The word "conflicting" (Column 2) indicates that that the authors conclude that UHI warming trends are more "Significant" (Column 5) than currently taken into account in CO_2 doubling theory by IPCC estimates and goals; this is part of our review. The word "Significant" or later we use "Conflicting Significant" is used to indicate that the authors have demonstrated aspects of UHI global trends but are not well quantified to provide a percentage value.

One issue well known and in IPCC reports (discussed in more detail in Section 2.1) is the fact that land surface air temperatures are in fact increasing at a higher rate than sea surface temperatures. The IPCC attributes this to (see Sec 2.1) the differences in evaporation, land–climate feedbacks and changes in the aerosol forcing over land with a warming ratio of about 1.6. It is also reported with high confidence that the difference in land and ocean heat capacity is not the primary reason for faster land than ocean warming. Given such observations, in an alternate view, it seems to strengthen views of the lower troposphere warming origin as described in the referenced "conflicting" studies in Table 2. As well, we could not find significant acknowledgement of these studies in IPCC reports or suggestions that UHI are significantly influential cause and effect (Table 1) to global warming large scale trends.

2. Review of Key IPCC 2020 Goals and Risks

The IPCC report SYR_AR5 [1] recommendations are to meet a goal of less than 2°C rise. This to be achieved by focusing on CO_2 reduction:

> "Multi-model results show that limiting total human-induced warming to less than 2°C relative to the period 1861–1880 with a probability of >66% would require total CO_2 emissions from all anthropogenic sources since

1870 to be limited to about 2900 Gt CO_2 when accounting for non-CO_2 forcing as in the RCP2.6 scenario, with a range of 2550 to 3150 GtCO_2 arising from variations in non-CO_2 climate drivers across the scenarios considered by WGIII. About 1900 [1650 to 2150] GtCO_2 were emitted by 2011, leaving about 1000 GtCO_2 to be consistent with this temperature goal"

2.1 Review of IPCC Report and the Attention Given to UHI Radiative Albedo Forcing

A review of the IPCC report AR4 [1] indicates that UHI concerns occupy a very small portion of that report which does not recognize UHI concerns on global warming. One paragraph discusses it

- In WG1-AR4 (2007) (Chapter 2) city areas indicates that UHI occupy only 0.046% of the Earth's surface and uses a reference by Loveland et al. (2000) as verification, and shows only 0.03 W-m^2 heat flux (reference to Nakicenovic, 1998).

The actual paragraph and statements made about UHI is narrow in scope. The assessment of the area does not look at the solar city area adjustment for building and appears to disagree with a 2005 GRUMP [24-26] study by a factor of about 10-20 (see Appendix A) and needs to be updated. Their statement on energy per unit area relates to anthropogenic activities of local appliance and building heating flux, possibly pointing to concerns related to CO_2 emissions. Since fossil fuel heating accounts for <0.1 Watt/M^2 then the argument would need to be updated in order to properly address global warming concerns. We note that the area referenced of Loveland et. al. study is not meant to take into account cites' solar heating area so it is not the best estimate . This seems to be the only area in the IPCC report providing some consideration to UHI effects, The minor assessment is apparently incomplete and leads one to believe that UHIs do not contribute significantly to global warming.

In AR5 (2014) there are no relevant updates related to Table 2, one statement indicates that there is a high confidence that: "UHI effect makes heat waves more intense in cities by 1.22–4°C, particularly at night".

In an updated Chapter 2 (2018-2019) on Land-Climate interactions [1] regarding to land vs. sea warming trends we find.

- "Analyses of paleo records, historical observations, model simulations and underlying physical principles are all in agreement that land surface air temperatures are increasing at a higher rate than sea surface temperature as a result of differences in evaporation, land–climate feedbacks and changes in the aerosol forcing over land (*very high confidence*). For the 2000–2016 period, the land-to-ocean warming ratio (about 1.6) is in close agreement between different observational records and the CMIP5 climate model simulations (the *likely* range of 1.54–1.81)." Also see (Lickley and Soloman 2008)… There is also *high confidence* that difference in land and ocean heat capacity is not the primary reason for faster land than ocean warming."

Chapter 8 (2014) AR5 Urban Areas, Aromar Revi et. Al [1], does provide a reference to UHI influence related to cool roofs or white reflective roofs … "which lowers the surface temperature of buildings compared to conventional (black) roofs…There is also some work on roads and pavements with increased reflectivity". However there was no recommendations/goals for UHI changes on a large scale and no significant acknowledgement of the references in Table 2 or similar discussion found.

The main recognition for UHI influences are for local climates in Chapter 8 (2013):

- "Urbanization alters local environments via a series of physical phenomena that can result in local environmental stresses. These include urban heat islands (higher temperatures, particularly at night, in comparison to outlying rural locations) and local flooding that can be exacerbated by climate change. It is critical to understand the interplay among the urbanization process, current local environmental change, and accelerating climate change. For example, in the past, long-term trends in surface air temperature in urban centers have been found to be associated with the intensity of urbanization (numerous cited references not included)."

We conclude that there has been no significant acknowledgement of UHI influence on global warming similar to the ones in Table 2 [17-23] in the many IPCC reports.

3. Short Review of Conflicting Assessments Showing Significance

Of the numerous studies on Urban Heat Island (UHI) effects, only a handful has tried to show "significance" for global warming. Most of the studies are related to local effects. We try to capture some of the ones in Table 2 that are in some way "conflicting" with the IPCC views on such "significance"

McKitrick and Michaels [18] used data grids doing specific hypotheses testing regarding the independence of observed temperature trends from surface processes and determinants of inhomogeneities and determined from 1979 to 2002:

- "our analysis does suggest that nonclimatic effects are present in the gridded temperature data used by the IPCC and that they likely add up to a net warming bias at the global level that may ***explain as much as half the observed land-based warming trend."***

Huang et. Al. [23] estimate are from surface stations and locally oriented, using regression t-test and p-test assessments to make conclusions that influence a very large area mass in China:

> "Our results on the relative contribution of the UHI to climate warming are consistent with previous studies. Ren et al. [19] found that urbanization-induced warming for Beijing (Wuhan) was significant and accounted for 80.4% (64.5%) of the warming over 1961−2000 and 61.3% (39.5%) of the warming over 1981−2000… The warming rate due to the UHI and its contributions to the climate warming in the ***fifth report of the IPCC can still be regarded as conservative in the urban agglomeration region.*** Some studies (Yang et. Al [22]) have ***suggested that "significant" contribution of urbanization to temperature changes might be comparable to that of GHG emission for metropolises and large cities.***
>
> "Our analysis of daily average, minimal and maximal air temperature observations at 41 stations in the YRDUA over 1957−2010 has revealed significant long-term warming due to the background warming and the UHI. The warming rate ranging from 0.108 to 0.483 °C/decade for average air temperature is generally consistent with the warming trend of other urban regions ***in China and in other urban agglomerations worldwide***. Significant positive correlations were found between three urbanization factors (urbanization rate, population, and built-up area) and the warming rates. All three factors could explain more than 80% of the variability in the warming rate. Our attempt to estimate the contribution of the UHI to the observed warming based on multiple linear regression and warming rates suggests that 37.1%–78.3% of the warming in the last few decades could be explained by local urbanization at various urban sizes. The results of this study showed that urbanization significantly enhanced local climate warming."

Ren et. Al.(2007) [19]noted:

> "In summary, temporal trends of annual and seasonal mean SAT for time periods of 1961-2000 and 1981-2000 at Beijing and Wuhan stations and their ***nearby rural stations are all significantly positive***, and the annual and seasonal urban warming for the two periods for Beijing and Wuhan stations ***is also positive and significant***. The annual urban warming at the city stations can account for about 65-80% of the overall warming in 1961-2000, and about 40-61% of the overall warming in 1981-2000."

Yang et. Al. 2011 noted:

> "Therefore, for metropolises and large cities in east China, the significant contribution of urbanization to temperature change may be comparable to that of GHG concentration, suggesting that land-surface processes can play a vital role in shaping future climate change Feddema et al., 2005 [17]… The increasing divergence between urban and rural surface temperature trends highlights the limitations of the response policy to climate change; these policies focus only on GHG reduction Stone, 2009 [20]. ***Policymakers need to address the impact of land use such as urbanization*** and deforestation on climate change in addition to that of GHG emissions. ***Serious measures for broadening the range of management strategies beyond GHG reductions and a land-based mitigation framework should be included in the scheme for mitigating climate change***.

These references cited here reported issues as early as 2005, but so far most do not appear in the updated IPCC report or are reflected in any of their goals. No considerations in goals for UHI influences on global warming trends despite numerous findings of "significance" in global warming trends by UHIs.

4. UHI Albedo Modeing – A Model in Review for Alternative Assessment

In order to investigate independently, we took a different approach to ground station assessment with actual radiative forcing values using a straight forward method that can more easily be refined with better data. We developed a simplified global weighted albedo model with solar surface area assessed in Appendix A and a formulated albedo model in Appendix B. Our model uses a direct approach that is independent of surface temperature data and only based on solar surface areas and estimated albedo city values. Such a model in review has some advantages, it is non probabilistic and in line with the way typical energy budgets are calculated, it uses only two key parameters (area, and surface albedo). This provides some simplistic transparency. Absolute numbers are obtainable, although the actual numbers are not as important as the conceptual approach and trends to help verify UHI "significance". In review, the role of UHI area forces conflicting issues which need to be formulated:

- What is the area of cities (24-26)?

- What is the UHI Solar Heating Area (Appendix A, [27])?
- How much do UHI changes the surface area of the Earth requiring renomalization (Appendix B)?
- What is the average albedo of cities (Appendix B)?

Appendix A describes our estimates for solar surface area and in Appendix B are renormalized Earth weighted global albedo modeling results. From our results, Table 2 illustrates what basic assumptions would be needed for albedo changes of city and their solar surface areas to support conclusions since the 3rd industrial revolution (~1950). Column 2, 3, and 4, indicate numbers that did not seem unreasonable, to obtain supporting [17-23] "Conflicting Significance" from warming trends of UHIs and roads. The results of Table 3 indicate the importance of coming up with solar city area estimates. These numbers are ballpark agreement with Table 2 authors' showing "conflicting significance" with IPCC estimates (Row 1) and CO_2 doubling theory as they must. Using the estimates, we were also able to provide (last row), a corrective action "what if" scenario for albedo increase to 0.5 in cities and roads.

Table 3 Results of GW Temperature Budget Change With City Surface Areas and Albedos

Year	Solar Surface Area of Cities (Appendix A)	Albedo Roads	Albedo Cities	Global Weighted Albedo (Appendix B)	Temperature Budget*	UHI Radiative Forcing
IPCC	0.046%	0.04	0.12	28.92	0.33 °F	0.075 W/m^2
1950	1.20%*	0.04	0.12	29%	0.2°F	0
2019	2.95% *	0.04	0.12	28.72	0.65°F	4.15 W/m^2
2019	2.95% *	0.5	0.5	29.45	-0.53°F	-1.73 W/m^2

*where Temperature Budget is given by: P_{Total}= 1361W/m2 {0.25 x (1-Albedo)} =σT^4

We note the model finds only a 0.28% global albedo changes would need to have occurred since 1950. Such a small change would likely be hard to verify from satellites due to cloud coverage. Since city urban areas are not very well known and certainly, the solar heating surface area is even more complex to estimate, it is likely that a more complex albedo weighted model would be unhelpful without detailed area data. However, from our estimates for this review we find:

- The IPCC (first row) would underestimate the radiative forcing based on their area estimates
- Actual shift from 1950 may be 0.45°F (0.65-0.2) due to Cities & Road increases, which is about 25.2% responsible for global warming (see Table 4) in agreement with authors [17-23] "Conflicting significance".
- A "what if" corrective action results shows if we can change city albedos to 0.5 and roads, total shift is 1.2°F ={0.65-(-0.53)}. This almost equates to the observed global warming.

This UHI albedo radiative forcing model provided above for cities and roads (in support of other authors [17-23]) indicate that IPCC global warming goals are insufficient at the present time.

5. Review of Some Atmospheric Humidity Data and UHI Atmospheric Humidity Forcing Issues from Cities

It is well known that overall, water vapor in the atmosphere has increased over land and ocean since the 1970s as indicated by a rise in specific humidity [28,29], while the relative humidity is dropping [29,29]. Some highlights of this type of data are illustrated in Table 3. We also include in the next to last row some indication showing road growth from 2009 and 2012, a factor growth of five in just the 4 year period identified for low albedo surface area changes. As well in the last row showing, we see a factor of 3.75 growth in road and building materials from 1950 to 2006 to support the high rate of city growth occurring in general.

Table 4 Specific Humidity, Relative Humidity, and Warm Mixed Asphalt changes

Source	Change	Period of Change
Specific Humidity Change [28]	Specific Humidity Change Land & Ocean about the same Increase of 0.45 g kg^{-1}	1960-2013
Total Atmosphere Water [29]	18.4-19.3kg/m2 NECP R2 25.5-26.6 kg/m2 RSS	1980-2017 1990-2017
Relative Humidity Change [28]	Δ%RH (land)~1% decrease Δ%RH (ocean)~0.5% decrease	1960-2013
Albedo Change [28]	ΔAlbedo (land)~4 units Units not defined (possibly reflectivity %)	2003-2012
US Warm Mixed Asphalt [30]	16.8 to 86.7 Million Tons ΔWMA=69.9 Million Tons	2009-2012
USGS, Building Materials Roads	Building and roads building	1950-2006

& Buildings [31]	materials 800 to 3000 x 10^6 Metric Tons Δ=2200 x 10^6 Metric Tons	

The IPCC and it authors have asserted that two-thirds of global warming trends are caused by increase moisture content in the atmosphere [1,32-37] due to ocean evaporation feedback. Here CO_2 creates initial warming raising ocean temperatures with warmer air that holds more water vapor (i.e. per the Clausius-Clapeyron relation).

In this section we review, the sources to the actual increase in specific humidity. That is, where does the moisture originate from? Is it all ocean feedback or in part humidity forcing related to UHI?

- Instead of mainly ocean feedback scenario, we should consider that impermeable surfaces of cities and roads create HHS with Highly Evaporating Hot Surfaces (HEHS) which also can contribute to increases in specific humidity.

In review of IPCC documentation, there is no reference to UHI and roads contributing to the observed increase in atmospheric greenhouse moisture gas. To investigation atmospheric humidity contribution to global warming, we looked at the evaporation rate as a metric. We investigate the rate of evaporation growth since 1950 from cities' HHS and compared to the ocean evaporation rate increase since 1950 in Appendix D.

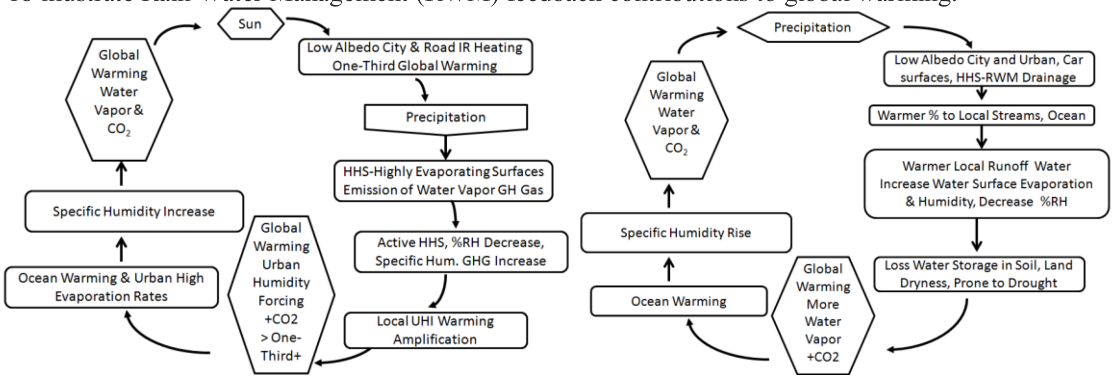
- What we estimated was that the evaporation rate increased of UHI, (mostly due to increase in surface area since 1950), compared to Ocean evaporation rate increase (mostly due to increase in water temperature increase since 1950) shows a 29% increase of cities evaporation rate compared to the ocean. This indicates that cities and roads HHS are also a likely source contributor to humidity forcing especially in light of the fact that UHI are a source of warming from albedo forcing effects.

*5.1 Concept Assessment of Urban Local **Greenhouse** Amplification Effect from Hydro-Hotspots*

Atmospheric moisture source is a complex issue from warm air effects that increase moisture greenhouse gas. This is also true of active HHS during precipitation periods which one might expect could help to trap city heat and increase infrared radiation during these periods. For example, (using the Clausius-Clapeyron relation) if the ambient condition when it rains is 25°C/98%RH and the HHS surface temperature is 60°C (1000Watt/m^2, albedo=0.3, prior to rain cooling) then the local relative humidity at the hotspot surface is reduced from 98%RH to 15.6%RH. This can increases temporarily locally specific humidity atmospheric concentration building up and could trap UHI heat effectively amplifying IR radiation that can contribute to warming anomalies due to city surface albedo problems. This conceptual type of assessment helps to understand how UHI have complex albedo forcing issues related to humidity.

5.2 Review of Highly Evaporation Surfaces and Rainwater Management HHS Feedback Mechanisms

In this section we briefly review UHI related global warming issues by summarizing issues with the aid of Figures 1a and 1b. Figure 1a which shows Hydro-HotSpots (HHS) from Highly Evaporating Surfaces (HES) feedback and Figure 1b illustrate Rain Water Management (RWM) feedback contributions to global warming.



(a) (b)

Figure 1 a) HHS- HES feedback view of contribution to global warming, b) HHS Rainwater Management (RWM) high temperature water cycling in Climate Change

Figure 1a shows HHS-HEHS feedback that may be summarized:

- Low albedo cities and roads emitting infrared radiation (IR), increased warming (approx. 1/3)
- Precipitation occurs, followed by evaporation of HHS-HES moisture, lower %RH increase specific humidity Greenhouse gas in warmed city area

- Local heat amplification, less local cooling with increased specific humidity amplifies heat index
- Local warming radiates heat increasing Global warming (with the 1/3 estimate)
- Evaporation increases in cities and ocean primarily from UHI and roads creates lower %RH and higher specific humidity globally along with CO_2 increase creating more humidity issues

Figure 1b Shows HHS-RWM feedback that may be summarized:

- Higher temperature storm water is collected off of HHS buildings, streets and hot cars
- A large percentage is drained to nearby rivers, lakes or ocean
- Warmer air allows for increase in specific humidity
- The impermeable city building and roads have replaced vegetative land creating lost area that would have stored cooler water in soil keeping the land moist with less generated heat compared to HHS runoff.
- This increases land dryness and can mean less land evaporation and more ocean rain since precipitation often follows evaporation areas as discussed below.
- The RWM is often warmer from HHS activity raising storm water temperatures from hot city buildings and street cycling each year billions of gallons of rainwater to local streams, lakes and ocean contributing to local surface water temperature increases depending on location. These runoffs affect atmospheric warming trends and GH gases.

6. Modeling Global Warming for Alternatives to IPCC Forcing Estimates

Typical CO_2, doubling theories [1, 32-35] asserts that one-third of global warming is roughly due to CO_2 and two-thirds likely due to increases in atmospheric greenhouse moisture from ocean evaporation feedback. However, if we consider one-third warming comes instead from UHI, then clearly adjustments would be needed. For example, one could estimate that this leaves only 1/3 due to increase in ocean moisture (instead of two-thirds). This scenario is modeled in Appendix C. Table 5 summarized the results for a possible alternate estimates (to IPCC [1]) contributions with UHI albedo forcing effects substantially included. Note in CO_2 theory the doubling temperature is found to drop down (Appendix C) to 1.37°C. The results (ignoring other greenhouse gases) are from 1951 to 2019. All estimates are detailed in Appendix C.

Table 5 Calculated Forced Effects Causing Global Warming from 1950 to 2019

Forced Effect	**Contributing Change**	**Temperature Increase**	**Radiative Forcing (W/m^2)**	**Percentage**
Albedo (Cities & Roads)	0.29 to 0.287	0.43°F (0.24°C)	1.05	25.2%
Water Vapor	183 PPM increase	0.638°F (0.355°C)	1.55	37.3%
CO_2	100 PPM increase	0.638°F (0.355°C)	1.55	37.3%
Greenhouse Gas Increase	1.46%=60.8%-59.32%	(~0.63 °C, H_2O + CO_2)		
Totals	283PPM	1.71°F (0,95°C)	4.15	100%

We note that the percent of moisture greenhouse gas is about 74.6% leaving CO_2 greenhouse gas controlling about 37.3% of the global warming effect as estimate in this updated to the doubling theory. This is as estimated in Appendix C. In this estimate 37% of global warming by CO_2 is responsible for the 0.355°C rise (Column 3), is controlled by the upper troposphere effect and in the lower troposphere 37% is due to moisture greenhouse gas and 25% due to UHI albedo effects. We suggest in this review, that the IPCC should re-asses their CO_2 doubling estimates in order to take into account UHI effects and provide new estimates as exemplified. Historically, UHI warming effects are conflicted with CO_2 doubling theory (Table 2) and indicating concerns.

7. Review of Some Data Information on Rainwater Management (RWM) Trends

Another important aspect not addressed by the IPCC is high temperature storm water runoff. Rainwater management is an important factor in UHI as it too can influence global warming trends and should be included in its goals. It can also impact where it rains! Rain sometimes follows local evapotranspiration. Apart from precipitation, evapotranspiration is the major component in the hydrologic budget.

When it rains in a city, much of the land in urban areas is covered by pavement or asphalt. These impermeable surfaces in urban cities commonly estimated around 55% runoff, with 30% for evapotranspiration, 10% shallow soil infiltration, 5% deep soil infiltration. Water temperatures from runoffs are often hotter due to HHS. For example,

- The New York Environment Report, in 2014 reported [38], "Every year, old sewers flooded by storm water release more than 27 billion gallons of untreated sewage into New York Harbor."

- Fry et al. [39] reported that in February of 2019 California estimated that 18 trillion gallons of rain in February alone had most of the water going to the Pacific Ocean. The article goes on to point out the LA dept. of water captured 22 billion gallons of water during recent storm.
- In August 2001, rains over Cedar Rapids, Iowa, led to a 10.5C rise in the nearby stream within one hour, which led to a fish kill. Similar events have been documented across the American Midwest, as well as Oregon and California [40]
- Sydney Paper reported [41]: "Every year around 132 billion gallons of storm water – enough to fill Sydney Harbor – runs from Sydney to the sea."

It is of course very difficult to tell the global thermodynamic influences of higher temperature water cycling. However, Australia might be a good extreme example, on the Sydney-Melbourne South-East side, the Tasman Sea is about 1 to 2 deciles range warmer (NOAA Sea Map [42]) than the South -West coast of Australia and about 5 deciles range warmer that the far south west coast. This might in part be an example of cyclic ocean heating. We tend to think of the ocean as an infinite temperature sink, but over 70 years of cycling, it can take a toll and perhaps this is somewhat of what we are seeing on the Sydney – Melbourne side and costal issues.

7.1 Review of Some Data Information on Rainwater Management (RWM) Causing Dry Day Increases

As an example of the importance in losing wet land (water storage), Cao et. al. [43] did a study on wet land reduction in China and correlation to drought with the following conclusion

- "The wetland distributions and areas of the five provinces of southwestern China in the 1970s, 1990, 2000 and 2008 show that the total reduction of wetland area was 3553.21 km^2 in the five provinces of southwestern China from 1970 to 2008, accounting for about 17% of the ground area, and thus the average annual reduction area is about 88.83 km^2. The reduction rate was comparatively fast from 2000 to 2008 with an average annual reduction of 329.31 km^2. The changes to the wetland area show a negative correlation with temperature (i.e. wetland decrease, increase in temperature), and a positive correlation with precipitation (i.e. wetland decrease, precipitation decrease)." [43]

Hirshi et al. [44] did the following study

- "We analyzed observational indices based on measurements at 275 meteorological stations in central and southeastern Europe, and on publicly available gridded observations. We find a relationship between soil-moisture deficit, as expressed by the standardized precipitation index, and summer hot extremes in southeastern Europe. This relationship is stronger for the high end of the distribution of temperature extremes. We compare our results with simulations of current climate models and find that the models correctly represent the soil-moisture impacts on temperature extremes in southeastern Europe, but overestimate them in central Europe."

In Hirshi et. al. study [44] they observed a negative linear relationship between wet land decrease and dry days increase.

Wetland issues are recognized by the IPCC in Chapter 2 (2019), "warming trends over dry lands are twice the global average (Lickley and Solomon 2018) [52]. However, there is little connection to UHI rainwater runoff being dumped into oceans and this in part causing some of the dry lands.

8. Conclusions and Suggestions

From our review of data and its analysis presented, it is our opinion that the IPCC goals focused solely on CO_2 reduction appears not to be enough to stop global warming trends from occurring. Our conclusion is that albedo reduction of UHI is needed to help stop global warming anomalies. This will also reduce HHS contribution to atmospheric moisture issues. Of course, we also feel more studies are needed to assess these impacts such as better estimates of global UHI solar surface areas. In this review we exemplified CO_2 doubling theory which one would anticipate that the doubling temperature would be reduced given any additional source of UHI global warming. The results indicated a drop from 2.36 to about 1.37^{o}C found in the doubling temperature in our suggested model. Since the doubling temperature significantly drops as one might expect upon recognizes UHI warming influences, one might anticipate concerns in CO_2 doubling theory. Below we provide suggestions and corrective actions related to Albedo and HHS reduction that includes:

- Creating new IPCC goals to include and recognize albedo forcing issue of UHI and roads

- Recommending changes for albedo of roads and cities to reducing HHS and the area effect dramatically, i.e. paint roads and building with reflective colors (have minimally albedo requirements, 0.25 – 0.5)
- Mandating future albedo design requirements of city and roads
- Roads to be more HHS eco-friendly
- Reduce driving speeds during rain to reduce evaporation rates can also reduce KE molecules
- Change to electric cars with HHS - cooler hoods
- Requiring all cars to be silver or white
- Thoroughly assess and making goals for rain water management issues including evapotranspiration and rainwater runoff allowed temperatures released into streams, rivers, lakes and oceans
- Requiring negative population growth to reduce increase HHS-HES surfaces and fossil fuel use
- Improve HHS-HES irrigation to soil
- Improving vegetation in runoff areas
- Adopting Low Impact Development in city planning and improvements for design approach aiming to mimic naturalized water balances with semi-permeable surfaces
- Requiring severe HHS-RWM changes to reduce runoff into the ocean worldwide that can cause loss of wet lands and local increase in dry days and increase in evaporation rates
- Providing new studies on albedo and humidity forcing from UHI to better understand their effects, address conflicts with CO_2 theory. Providing updated UHI radiative forcing contribution to GW. Provide a modern microclimate doubling experiment if possible to verify doubling claims.

Appendix A: ***Solar City Surface Area Estimates***

One of the main criteria needed for UHI albedo modeling are estimates of solar surface areas covered by cities and roads. The effect of area increase by a factor of 3 in 2019 Column 2 compared to 6 in Table A1 is somewhat supported by Zhou et al. [27] (2015) that found UHI changes the climate in area 2–4 times larger than its own area. We have used an average factor of 3. Certainly, estimating solar city areas of cities globally from 1950 to 2019 is a difficult task. Therefore, we use this estimate of Zhou et al [27] is only one way this estimate can be justified.

Table A1 Values used to estimate the Solar Surface area in cities

Year	Urban Area Percent	Buildings % Coverage	Surface area & Height factor	Solar surface Area %	50% Illumination
1950	0.62	0.50	7	2.48	1.2
2019	1.10	0.50	10	6.05	3.0

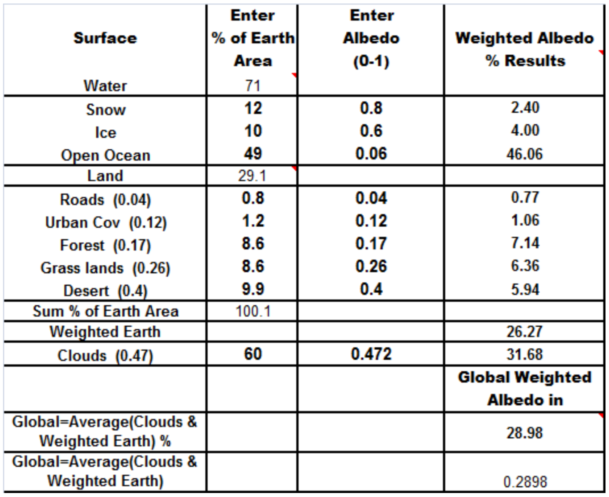
To further justify the rough factor of 3, we use a 2010, estimates from a GRUMP [24] 2005 study (and its critics [45] of the study) indicate just the surface area relative to the Earth's coverage is somewhere between 0.85% and 2.7%. Another 2010 study indicates its much lower to 0.3% [46]. We will take a round number of 1% coverage of the Earth surface area in 2010. The growth rate of cities is taken from the U.S. Census of 0.8% per year [47]. We are interested in Global Warming trends from 1950 to 2019. The extrapolation using this growth rate is shown in Column 2 of 1. We then need to make a rough estimate that buildings occupied 50% of the urban land (Column 3). Finally we add a multiplication factor to assume each building sides equates to 7 times the bottom surface area in 1950. As well since buildings have become taller [44] we increase the height factor from 7 to 10 times in 2019 (Column 4). The estimates are shown in Table A1 for example the 1950 estimate is 0.62x0.5+0.62x.5x7=2.48 (column 5) and then we take 50% illumination factor (Column 6). This agrees more or less with Decheng et al. [27].

Appendix B: ***Simplified Weighted Albedo Model 1950 & 2020***

Below is a simplified author's Albedo model to estimate the Earth's total albedo decrease with increase in city and road solar areas and a decrease in grass lands. Note in our albedo modeling we hold ice and snow changes constant, that is the Earth weighted Albedo since 1950 is only a function of changes to roads and cities. This allows us to focus on causes and not effects. The goal of the simplified global albedo model is to illustrate the sensitivity of global albedo change from 1950 to 2019 in order to show global UHI cause feasibility. The simplistic model allows for later refinement and aids one's ability to argue the importance of UHI cause issue on a global scale.

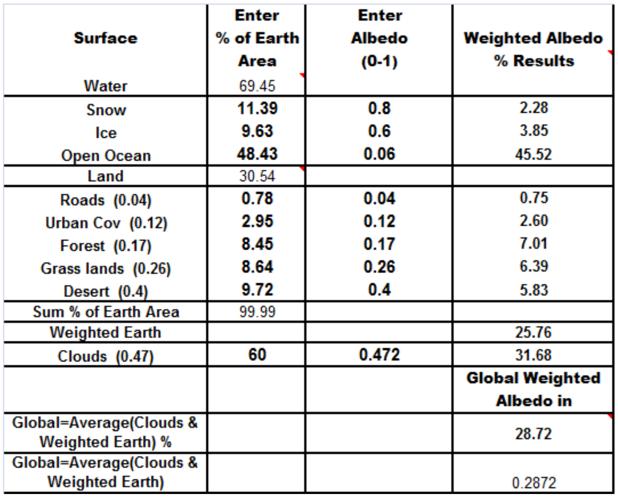
Results of the simplified model are exemplified in Table B1-B3 with the full estimates provided in Table 3.

Table B1: Albedo=0.29 [49], 1950



Surface	Enter % of Earth Area	Enter Albedo (0-1)	Weighted Albedo % Results
Water	71		
Snow	12	0.8	2.40
Ice	10	0.6	4.00
Open Ocean	49	0.06	46.06
Land	29.1		
Roads (0.04)	0.8	0.04	0.77
Urban Cov (0.12)	1.2	0.12	1.06
Forest (0.17)	8.6	0.17	7.14
Grass lands (0.26)	8.6	0.26	6.36
Desert (0.4)	9.9	0.4	5.94
Sum % of Earth Area	100.1		
Weighted Earth			26.27
Clouds (0.47)	60	0.472	31.68
			Global Weighted Albedo in
Global=Average(Clouds & Weighted Earth) %			28.98
Global=Average(Clouds & Weighted Earth)			0.2898

Table B2: Albedo=0.287, 2019



Surface	Enter % of Earth Area	Enter Albedo (0-1)	Weighted Albedo % Results
Water	69.45		
Snow	11.39	0.8	2.28
Ice	9.63	0.6	3.85
Open Ocean	48.43	0.06	45.52
Land	30.54		
Roads (0.04)	0.78	0.04	0.75
Urban Cov (0.12)	2.95	0.12	2.60
Forest (0.17)	8.45	0.17	7.01
Grass lands (0.26)	8.64	0.26	6.39
Desert (0.4)	9.72	0.4	5.83
Sum % of Earth Area	99.99		
Weighted Earth			25.76
Clouds (0.47)	60	0.472	31.68
			Global Weighted Albedo in
Global=Average(Clouds & Weighted Earth) %			28.72
Global=Average(Clouds & Weighted Earth)			0.2872

Equation B1 is the weighted albedo by area,

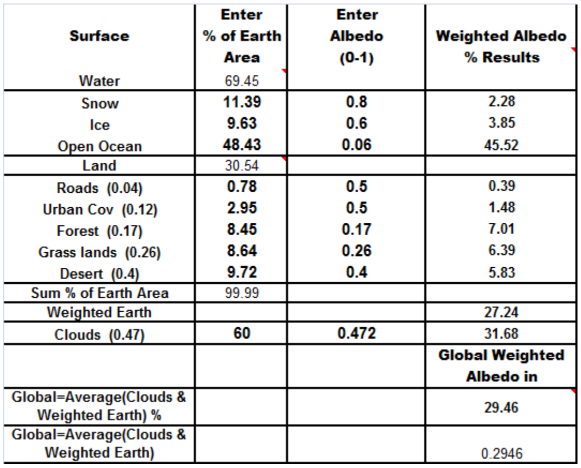
$$Earth\ Weighted\ \ Albedo = \sum_i \{\%\,Earth\ Area_i\ x\,(1 - Surface\,Item\ Albedo_i)\} \qquad \text{(B1)}$$

Equation B2 is the average weighted albedo with clouds.

$$Global\,Weighted\ Albedo = Average\{((1 - Clouds\ Albedo)\,x\,\%\ Coverage) + (1 - Earth\ Weighted\ Albedo)\} \qquad \text{(B2)}$$

Below we show a "what if" scenario illustrating if roads and urban coverage could have an increase albedo to 0.5.

Table B3: Albedo=0.294, "what if"



Surface	Enter % of Earth Area	Enter Albedo (0-1)	Weighted Albedo % Results
Water	69.45		
Snow	11.39	0.8	2.28
Ice	9.63	0.6	3.85
Open Ocean	48.43	0.06	45.52
Land	30.54		
Roads (0.04)	0.78	0.5	0.39
Urban Cov (0.12)	2.95	0.5	1.48
Forest (0.17)	8.45	0.17	7.01
Grass lands (0.26)	8.64	0.26	6.39
Desert (0.4)	9.72	0.4	5.83
Sum % of Earth Area	99.99		
Weighted Earth			27.24
Clouds (0.47)	60	0.472	31.68
			Global Weighted Albedo in
Global=Average(Clouds & Weighted Earth) %			29.46
Global=Average(Clouds & Weighted Earth)			0.2946

Appendix C1: *Table 5 Greenhouse Gas Estimates*

Here we review the change in greenhouse gas from 1950 to 2019. We first note that the Earth's energy budget in 1950 due to the estimated global albedo of 0.29 is 241.58 Watts/m^2 (where P_{Total}= 1361W/m2 {0.25 x (1-0.29)}). In 1950 the average temperature was 57^{o}F. This yields 384.93 Watts/m^2 ($P=\sigma T^4$). This leaves 143.3Watts/m^2 of power emitted back by GH gases which is 59.34% of the 241.58 Watts/m^2. In 2019 Earth energy budget is 242.63 (P_{Total}= 1361W/m2 {0.25 x (1-0.2869)}, the average temperature is taken as 58.73^{o}F yielding 390.1 Watts/m^2 which leaves 147.47 Watts/m^2 above the Earth's energy budget or 60.8% emitted back by GreenHouse (GH) gases. The difference in the Earth's energy budget from albedo change from 1950 to 2019 is 1.05W/m^2.The difference of the emitted back radiation is 3.1 Watts/m^2 (note we took into account an albedo change in 2019 in the Earth's energy budget that makes this estimate lower than the 4.1 Watts/m^2 typical found) and the difference in the percent of emitted back Greenhouse gases is

$$1.46\%=147.47/242.63-143.3/241.58=60.8\%-59.32\% \qquad \text{(C-1)}$$

Therefore, this must be the percent of GH gases required to increase global temperatures to 1.14°F (0.317+0.317=0.634°C).

Using 312 PPM in 1951 and 412PPM of CO_2 in 2019 and an average of 25,000 PPM for water vapor in our atmosphere [46], the 1.48% GH gas increase is estimated as ½ of 1.48% from moisture and CO_2 as

$$25{,}000\text{PPM x } \tfrac{1}{2} \text{ of } 1.46\% = 183\text{PPM } (H_2O\uparrow) \tag{C-2}$$

$$\tfrac{1}{2} \text{ of } 1.46\% = 100 \text{ PPM } CO_2\uparrow \quad \text{(doubling theory)} \tag{C-3}$$

$$183\text{PPM } (H_2O\uparrow) + 100\text{PPM } (CO_2\uparrow) = 283\text{PPM} \tag{C-4}$$

We note that the percent of moisture greenhouse gas is about 64.6% leaving CO_2 greenhouse gas controlling about 35.4% of the global warming effect as estimate in this updated doubling theory. This is close to 1/3 estimate. That is, in this update, 1/3 of global warming by CO_2, the 0.317C rise it creates is controlled by the upper troposphere effect and in the lower troposphere 1/3 is due to moisture greenhouse gas and 1/3 due to UHI albedo effects.

Appendix C2: ***Table 5 Temperature Estimates***

Here we can use the 1950 to 2019 changes described above in Appendix C1 for albedo and greenhouse gas (moisture and CO2) to determine the portion of Global Warming temperature increase can be assigned to each forcing mechanism (ignoring other greenhouse gasses). The results are as follows.

- 37.3% CO_2, 1.55W/m^2 (1/2 of 3.1 W/m^2)
- 25.3% UHI albedo forcing 1.05W/m2
- 37.3% moisture 1.55W/m^2 (1/2 of 3.1 W/m^2)

Total 4.15 W/m^2

The full temperature summary from 1951 to December of 2019 is then

$$0.638^\circ\text{F } (0.355^\circ\text{C}) (H_2O\uparrow) + 0.638^\circ\text{F } (0.355^\circ\text{C}) (CO_2\uparrow) + 0.43^\circ\text{F } (0.24^\circ\text{C}) \text{ (Albedo)} = 1.71^\circ\text{F } (0.95^\circ\text{C}) \tag{C-5}$$

This yields the 2019 (December) global average temperature of *14.85C (58.73F).*

Appendix C3: ***Table 2 CO_2 Doubling Estimate with UHI warming effects included***

To estimate the CO_2 doubling temperature, we combine Appendix C1 and C2 results as follows:
The percentages assigned in Appendix C2 are

- 37.3% CO_2, 25.3%, UHI albedo forcing 37.3%, Moisture

Then UHI Albedo moisture forcing is taken as

- 25.3/(37.2+25.3) x 0.355 °C =0.144 °C

The total UHI Albedo effect with its influence on moisture is then responsible for

- 0.24 °C + 0.144 °C =0.384 °C

This is to be subtracted off the final global warming temperature of 14.85 °C which gives 14.466 so that the CO2 doubling temperature can be found

$$13.9C\ (57F) + X_{\text{Doubling}}\ Ln\{414/311.8)/Ln2 = 14.466^\circ\text{C } (58.03F) \tag{C-5}$$

Solving, $X_{\text{Doubling}}=1.37^\circ\text{C}$

Such an evaluation indicates that the doubling temperature would drop down to 1.37°C from 2.36°C noted in Table 2. As the table indicates, this is in conflict with CO_2 doubling estimates and would indicate a necessity for new evaluations by the IPCC.

Appendix D: ***Evaporation Rate of Cities Vs. Ocean Feedback***

It is important to note the assess urban growth as a source of moisture greenhouse gas. Therefore, in this example, the evaporation rate increase of HHS simulated area in Cities (Ec) vs that of the Ocean (Eo), we make comparison between 1950 and 2019 relative to a possible average hydro-hotspot temperature of 50°C (using average range from

25^o-75^oC) for simulated area growth. We find that the evaporation rate increase is higher in cities compared to Oceans.

In this assessment, we will first ignore the evaporation wind effect. The comparisons for the effects are:

$$HHS_{effect-o}(1950)=\frac{E_O}{E_C}=\frac{A_O}{A_C}R(T_O,T_{HHS})\frac{E_{WO}}{E_{WC}}\frac{RH_C}{RH_O}=40.8x\frac{1}{6.69}x100x0.5=304.9 \qquad \text{(D-1)}$$

and

$$HHS_{effect-o}(2019)=\frac{E_O}{E_C}=\frac{A_O}{A_C}R(T_O,T_{HHS})\frac{E_{WO}}{E_{WC}}\frac{RH_C}{RH_O}=16.3x\frac{1}{6.28}x100x0.5=129.8 \qquad \text{(D-2)}$$

Where:
E_O,E_C=Evaporation Rate of Ocean, Evaporation Rate of Cities
AO, AC= Surface Area of Ocean, simulated proportional Area of City Surfaces growth rate (Ao/AC=49%/3%=16.3 in 2019, Ao/AC=49%/1.2%=40.8 in 1950)
To=Average ocean temperature, 16C, 1950, 17C 2019
T_{HHS}=average temperature of hydro-hotspots, 50C
R(T_O=16C,T_{HHS}=50C,1950) Temp. rate factor Ocean to City HHS ~6.69
R(T_O=17C,T_{HHS}=50C,2019) Temp. rate factor Ocean to City HHS ~6.28,
E_{WO}, E_{WC}= Percent of time surface exposed to water, E_{WO}=100%, E_{wc}=1%
RH_C, RH_O=Local relative humidity of ocean and RH of city near surface ~40/80

$$where\ R=\exp\{\frac{E_a}{K_B}(\frac{1}{T_{HHS}}-\frac{1}{T_O})\}$$ **Ea=0.45eV [51]**

From Eq. D-1 and D-2 we find the percent increase in evaporation rate from HHS relative to the ocean since 1950 (ignoring wind) as

$$\%2019\,Increase=\frac{304.9-129.8}{304.9}=57.4\% \qquad \text{(D-3)}$$

We might consider the wind effect in cities to have decreased by a maximum value of 50% due to tall building and growth, this would yield a 29% growth rate in evaporation compared to the ocean effect.

In summary, humidity forcing from HHS shows a strong evaporation growth rate compared to ocean changes in evaporation rate from 1950 to 2019. This supports reasonable strong feasibility that the 1.46% increase (Appendix C3) in greenhouse gas due to moisture contribution (Table 5) has contributions from UHI humidity forcing and ocean evaporation due to the Clausius-Clapeyron effect.

Conflict of Interest Statement: This review is unfunded and there are no conflicts of interest with this work.

Biography

Alec Feinberg is the founder of DfRSoft. He has a Ph.D. in Physics and is the principal author of the books, Design for Reliability and Thermodynamic Degradation Science: Physics of Failure, Accelerated Testing, Fatigue, and Reliability Applications. Alec has presented numerous technical papers and won the 2003 RAMS best tutorial award for the topic, "Thermodynamic Reliability Engineering." Alec has studied degradation systems for his entire professional career.

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