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Greenhouse Gases: True, but Not the Whole Truth

Christopher A. Haines – Permadigms - cahaines26@gmail.com

Abstract: A brief history of climatological science sets the stage for understanding the rise of the greenhouse gas thesis. That science is true as far as it goes, justifying our confidence, but it is an incomplete assessment of climatic systems. We have spent 40 years accepting the "pot lid" as the cause of the pot boiling over. That the "sun-warmed surface" impacts climate has been known for nearly 200 years. But greenhouse science failed to incorporate that and other scientific findings on urbanism, water cycles, and land management practices. To remedy this, I propose a broad climatic paradigm to address the actual cause of warming and provide a far more hopeful future with ample opportunities to resolve over-heating more completely, locally, and in a matter of months, years, or maybe decades, instead of centuries. Lastly, I discuss the significance of paradigm change, a new approach, and an expanded curriculum as challenges to sustainability education.

Keywords:
Climate Change, Greenhouse gases, Urban heat islands, Sun-Warmed surface, Regeneration, Water cycle.

***Christopher A. Haines**, AIA, NCARB, LFA, is an Architect, urbanist, and educator in metro Boston. After an early career in energy efficiency, with a significant portion in Australia, he expanded into leading-edge sustainable design and urbanism. He has spent the last five years studying natural ecology and is currently writing a book on Heat Planet.*

*"If you want to make small changes, you can change the way you **DO** things.
If you want to make MAJOR changes, you have to change the way you **SEE** things."*
Gabe Brown attributed to Don Campbell.

Air Temp 90^{0}F, Under Bushes 68^{0}F, Pavement (30 ft away) 128^{0}F, (Sacks, 2016)

Humans, at least westerners, value solutions over questions. When we believe that we know the answer, we stop questioning. I propose that this is what has happened with the science of greenhouse gases.

Greenhouse science only studied the impact of carbon dioxide. It is true as far as it goes, justifying our confidence, but it is an incomplete assessment of climatic systems, leaving us with an incorrect understanding of our predicament. Due to the definition of the "problem," the "solution" has a depressingly long timeframe. Meanwhile, we fail to consider and thus exacerbate root causes of climate that could cool the planet more rapidly. The irony is that climatological science knows this, and answers are available (Dewdney, 2018; Henson, 2019; Rohli & Vega, 2012), but they view what they know through the lens of greenhouse gases appearing unable to draw alternative conclusions. I will begin with a brief history of climatology's science and politics to explain the rise of the greenhouse gas thesis, consider an alternative paradigm with the benefits it provides, and discuss the significance of the dominant paradigm as a challenge to sustainability education.

The History of Greenhouse Gas Science.

The history of greenhouse gas science might be said to start with the ability to measure temperature, and thus Daniel Fahrenheit (1686 – 1736), a Polish-born, Dutch physicist, who invented the alcohol thermometer in 1709, and the mercury thermometer, and his temperature scale in 1714, (Gribbin, 2002). Anders Celsius followed with his temperature scale in 1742 (Gribbin, 2002).

Joseph Black (1728 – 1799), born in Bordeaux of Scottish ancestry, made critical contributions as an eminent chemist in Glasgow and Edinburgh (Gribbin, 2002). As a student, he invented an analytical balance that was far more accurate than others at the time (Gribbin, 2002). His subsequent significant discovery was carbon dioxide, and that air was a mixture of gases. Later, turning his interests to physics, he discovered latent and specific heat, demonstrating the difference between temperature and heat (Gribbin, 2002).

Joseph Fourier (1768 – 1830), a French physicist and mathematician, began to weave these threads together in the 1820s when he recognized that the earth must shed heat to maintain its energy balance (Henson, 2019). It accomplishes this by emitting warming infrared waves to the atmosphere. Fourier thus showed that the heat source that warms the atmosphere is infrared radiation from the earth's "sun-warmed surface" (Henson, 2019).

But Fourier's made another discovery that superseded the first. He realized that the atmosphere must hold that heat, or temperatures would drop below freezing when the sun went down. While he did not understand the heat-trapping mechanism, he was aware of studies on the heat-trapping qualities of glass boxes and compared the atmosphere to a 'hothouse,' birthing the concept of the 'greenhouse effect, (Henson, 2019).

After a preliminary paper by Eunice Foote in 1856 (Henson, 2019), in 1862, John Tyndall (1820 – 1893), an Irish physicist, discovered the answer to Fourier's question (Henson, 2019). Some atmospheric gases, including water vapor and carbon dioxide, allow short-wavelength insolation to pass through to earth but prevent long-wavelength infrared rays from escaping to space. High absorptivity and emissivity define these "greenhouse gases"; the more wavelengths it can absorb, the higher its impact as a greenhouse gas (Henson, 2019). So they act like jugglers passing balls back and forth, trapping heat in the troposphere and reflecting it to earth.

Svante Arrhenius (1859 – 1927), a Swedish chemist, was interested in the causes of ice ages. He calculated that halving greenhouse gas levels would produce an ice age. Then, reversing that example, in 1896, Arrhenius recognized that burning coal and petroleum products for energy production could raise the world's temperatures (Cowie, 2013; Flannery, 2005; Henson, 2019). He calculated that doubling CO_2 in the atmosphere would produce a temperature rise of 5^0C (9^0F) (Henson, 2019). His studies began the increasingly specialized and sophisticated focus on what would later be called "the carbon problem" (Revelle, 1965).

Guy Stewart Callendar (1898 – 1964), a British steam engineer, moved the scientific understanding of greenhouse gases forward when he calculated the impact of putting CO_2 into the atmosphere, recognizing that the last five years had been the hottest on record (Rich, 2019). In 1938 Callendar published an article, "The Artificial Production of Carbon Dioxide and its Influence on Temperature, (Berman, 2011). Berman claims that with that article, Callendar established the modern theory of climate change. Callendar also correctly calculated the background level of CO2 and the temperature impacts of increased levels (Berman, 2011). Thus by the early twentieth century, science knew the potential dangers of excess greenhouse gases.

Roger Revelle, the Scripps Institution of Oceanography Director, obtained funding in 1958 for his colleague Charles Keeling to monitor CO_2 at Mauna Loa in Hawaii and the South Pole (Keeling,1998). That data led to the development of the 'Keeling curve,' a sawtooth rise in CO_2 that varied with the seasons in the northern hemisphere, falling during the growing season and rising during the fall, winter, and spring months (Keeling,1998). The rise follows the northern hemisphere's seasons because the southern hemisphere has a smaller landmass supporting photosynthesis. The two processes might maintain stability without added emissions or with increased photosynthesis, but the data shows a clear rise year over year.

The White House was notified of this growing understanding of greenhouse gases in November 1965 when Revelle, as a lead author with C.D. Keeling, W. Broecker, H. Craig, and J. Smagorinsky, produced 'Atmospheric Carbon Dioxide' for the Environmental Pollution Panel of the President's Advisory Committee, (Revelle et al., 1965). This report laid out the fundamental physics of the 'Carbon Problem,' which reviewed carbon sources, carbon partition between the atmosphere, the oceans, the biosphere, and the effects of carbon growth concentrations in these sinks. The report forecast a 25% increase in CO_2 by 2000 (Revelle et al., 1965).

In April 1979, the Jasons, a “mysterious coterie of elite scientists” (Rich, 2019, p.15), published “The Long-Term Impact of Atmospheric Carbon Dioxide on Climate.” (MacDonald et al., 1979). This report was a comprehensive update of previous accounts, but the Jasons’ status gave it extra impact (Rich, 2019). That led the Carter administration to commission the National Academy of Science to review the report. Rich (2019, p. 33) states, “They would review the available science and decide whether the White House should take seriously Gordon McDonald’s prediction of climate apocalypse.”

A distinguished team of scientists led by Jule Charney of MIT conducted the review (Rich, 2019). With the publication of the Charney Report “Carbon Dioxide and Climate: A Scientific Assessment” (Charney et al., 1979) in July, science codified and canonized greenhouse gases as the cause of climate change, and the government was on board with this interpretation. “within the highest levels of the federal government, the scientific community, and the oil and gas industry—within the commonwealth of people who had begun to concern themselves with the future habitability of the planet—the Charney report almost immediately assumed the authority of settled fact.” (Rich, 2019, p. 36).

But the road forward was not smooth. Oreskes & Conway (2010) document how a handful of scientists spread doubt and misinformation about climate change, apparently to take pressure off of the fossil fuel industry. Rich (2019) documents the political maneuvering that served to kick the can down the road on meaningful changes, up to and including the first IPCC meeting in 1988.

The modeling of atmospheric carbon and climate was made more sophisticated by the IPCC a decade later, but they did not change the structure. The 2021 IPCC AR6 report (IPCC, 2021) is a massive 3949 pages. However, at the bottom of each page is a notation "Do Not Cite, Quote or Distribute." The horse is out of the barn, so I will note that in chapter two, pages 27 and 28, and in chapter seven, pages 44 and 45 are a total of about two pages of discussion of land management. That appears to be the total content concerning land management in the report (Lewis, 2021). Most of that discussion concerns albedo, which I will discuss below. That fact confirms the genealogy of the current IPCC process with its parentage in Svante Arrhenius, Callendar, the Jason's, Charney, and the other works. When your tool is a hammer, everything looks like a nail.

<u>Evaluating the Greenhouse Gas Thesis.</u>

The Jason report was written by some of the best scientific minds of the day, using the latest science and data. However, its specifically limited scope was affectively a continuing response to Svante Arrhenius’ warning. "This report addresses the questions of the sources of atmospheric carbon dioxide, considers distribution of the present carbon dioxide among the atmospheric, oceanic and biospheric reservoir and assesses the impact on climate as reflected by the average ground temperature at each latitude of significant increases in atmospheric carbon dioxide." (MacDonald et al., 1979, p.1).

The Charney group was assembled to review the Jason report. In the Foreword, Verner E. Suomi, Chairman of the Climate Research Board, states: “It seemed feasible, however, to start with a single basic question: If we were indeed certain that atmospheric carbon dioxide would increase on a known schedule, how well could we project the climatic consequences?” (Charney et al., 1979, p. viii). That was the focus of the Charney Report.

Within that context, they stated their scope as a broad concern for the topic:

1. “To identify the principal premises on which our current understanding of the question is based.
2. To access quantitatively the adequacy and uncertainty of our knowledge of these factors and processes, and
3. To summarize in concise and objective terms our best present understanding of the carbon dioxide/climate issue for the benefit of policymakers.” (Charney et al., 1979, p. ix)

They specifically state: “we limited our considerations to the direct climatic effects of steadily rising atmospheric concentrations of rising CO_2 increase” (Charney et al., 1979, p. 1). Rich summarized: “Charney’s group had considered everything known about oceans, sun, sea, air and fossil fuels and had distilled it into a single number: three” (degree rise with a doubling of CO_2 concentrations) (Rich, 2019, p. 37).

In all fairness to the authors, it appears from side comments that they knew the climate was more complicated, but they were not projecting about climate. The report titles state their objectives, “The Long-Term Impact of Atmospheric Carbon Dioxide on Climate.” and “Carbon Dioxide and Climate: A Scientific Assessment." Their charge was a precise mathematical evaluation of CO_2’s impact. Accepting their charge, I think we can state that they did a good job.

The failure of greenhouse gas science is not that they are wrong, they are not, but that their scope is too narrow. Greenhouse gases trap heat, so their increase <u>exacerbates</u> warming but does not generate it. And the parallel rise of GHG levels and temperatures are <u>correlations</u> <u>until</u> one has proved that no other climatic variables have changed. But those reports never considered other variables. This is true on two fronts. They did not consider other factors as possible contributors to climate change, and they interpreted all climatic changes as a result of increased greenhouse gas levels.

Michael Kravcik states: "It is astounding, then, that while scientific publications and conferences emphasize the impacts of global warming on the circulation of water in nature, almost all of them are totally silent on the influences the water cycle has on climate changes." (Kravcik et al., 2008, p. 87). And David Ellison, with 22 co-authors, makes their case for the failures of the carbon-centric model. "…Forests and trees must be recognized as prime regulators within the <u>water, energy and carbon cycles</u>…Our call to action targets a reversal of paradigms, from <u>a carbon-centric model</u> to one that treats the hydrologic and climate-cooling effects of trees and forests as the first order of priority…” (Ellison et al., 2017, p. 52).

We are the recipients of sophisticated modeling of one climatic variable, with secondary inputs, in a very complex system. Is it possible that the IPCC's continued underestimation of the rate of warming is related to this oversimplification? That water cycles, land management variables, and the "sun-warmed surface" discovered by Fourier impact climate is the topic of the remainder of this article.

The Earth's Sun-Warmed Surface.

Responding to Svante Arrhenius' warning, climate science fixated on the impact of atmospheric constituents as the sole cause of climate change. While that warning was valid, they have failed to respond to other warnings issued since (Brown, 2018; Ellison et al., 2017; Kravcik et al., 2008) and are ignoring other scientific discoveries (Gribbin, 2002; Howard, 1818,1820). To investigate a nature-based proposal, we need to return to the history of science.

We begin in early nineteenth-century England with Luke Howard (1772 – 1864). Even as a child, Howard was fascinated by clouds and weather, spending hours watching the sky (Hamblyn, 2001). On an evening in December 1802, by then a chemist by profession, he walked onto the Askesian Society stage, a science club in London, and presented "On the Transformation of Clouds" (Hamblyn, 2001). An hour later, he walked into history, creating the classification system for clouds that we still use today. He became instantly famous and Goethe wrote poetry in his praise (Hamblyn, 2001).

Howard's fascination with weather later produced several years of temperature measurements in and around London, which he published as "the Climate of London" (Howard, 1818), with the second volume in 1820 and the second edition in 1833. With this, Howard was the first to identify and analyze urban heat islands - the increased temperatures created within densely populated but sparsely-vegetated built environments compared to their rural surroundings. "It is probable, therefore, that the sun in summer actually warms the air of the city more than it does that of the country around." (Howard, 1820, p. 106). That the same physics apply year-round is obscured in that quote due to Howard's original supposition, on which the selection is based.

Howard documented an increased mean annual temperature difference in London of 1.57^{0}F (Howard, 1820: 106). He determined that increased urban temperatures were due to decreased vegetation reducing cooling, heat generation, and capture by the concentration of buildings and their proximate geometry and thermal pollution (Howard, 1818, 1820). While the modern science of heat islands is more sophisticated (Garland, 2011), Howard hit all the essential points.

Joseph Fourier (1768 – 1830), mentioned earlier, first recognized in the 1820s that infrared radiation from the earth's "sun-warmed surface" is the heat source that warms the atmosphere (Henson, 2019). That discovery implies that changes to the earth's surface, such as those Howard had documented, impact the climate. How can science talk seriously about reflected heat if they have not addressed the source of that heat?

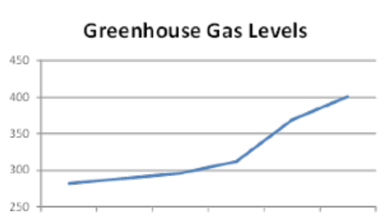
> "The atmosphere…. absorbs infrared radiation rising from the earth's sun-warmed surface" (R. Henson, 2019, p. 30. American Meteorological Society)

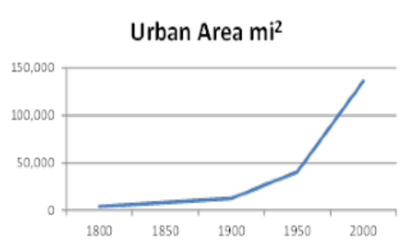
William Thomson (1824 – 1907), known as Lord Kelvin, and Rudolf Clausius (1822 –1888), a German physicist and mathematician, are credited with developing the first law of thermodynamics, the conservation of energy, independently, around 1850 (Gribbin, 2002). The first law states that energy can neither be created nor destroyed, but it can change form (Gribbin, 2002).

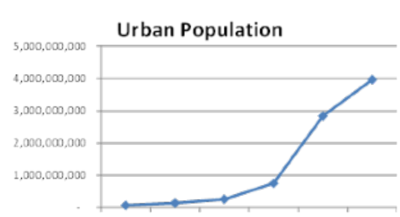
Solar energy, a high-frequency electromagnetic wave, is converted into different forms of energy depending on the interface it strikes. In living plants, it provides the energy for photosynthesis by converting solar energy into chemical bonds, producing growth (Schneider & Sagan, 2005). Some energy converts to heat, but the majority powers the pressure differentials that cause water to transpire from leaves, creating cooling (Schneider & Sagan, 2005). In non-living materials, solar energy causes molecules to jiggle, which we recognize as heat, where energy inputs cause faster jiggling and higher temperatures. (Schneider & Sagan, 2005). You can experience these differences yourself by walking barefoot on a summer day through a forest or across a meadow, desert, or parking lot.

Howard's discoveries document the characteristics that increase heat output from the earth's "sun-warmed surface." That urban influences have increased should be evident in the drastically increased differentials of modern heat islands, compared to Howard's findings of 1.57^{0}F. Today heat islands readily produce 1 to 5^{0}C (2 to 9^{0}F) (Rohli & Vega, 2012, p. 292) above surrounding areas. Kim (2014, p. 1085) documents central areas of Columbus, Ohio at least 11.0^{0}C (19.8^{0}F) warmer than outlying areas. These increased urban temperatures are many times the average increase we face from greenhouse gases.

And in addition to increased urban temperature intensities, urbanism has also increased significantly. While greenhouse gas levels rose from 282 to 369 ppm or 30.85% from 1800 to 2000, urban footprints and population increased more than 100 times faster: 3345% and 3836%, respectively (Richie & Roser, 2018).







Additionally, even though the north side of buildings; (in the northern

1 story House @ 1800 SF: Walls ≈ floor/roof area, doubling the building site surface area.
5 story commercial building. @ 2500 sf/floor: Walls ≈ 4x floor/roof area.
50 story commercial Building. @ 10,000 sf/floor: Walls ≈ 20x floor/roof area

hemisphere) remains in the shade most of the year, exterior surfaces of tall buildings can be ten or more times the building footprint (See sidebar). The destruction of vegetation and expansion of development has **changed** the earth's surface!

It should be clear that the physics don't change at the city line. And this has two implications. Firstly, we have assumed that a rural area represents a "zero point" temperature for that region, and the heat island indicates the increased temperature above that zero point. But if the same physics raises the temperature, even to a lesser degree in suburban and rural areas, we underestimate the increase in temperatures created by the heat island because we have no zero point.

Secondly, if rural and suburban areas also generate heat, again, even if to a lesser degree than cities, the problem is not limited to the world's cities. Hundreds of millions of acres of bare ground in agriculture generate heat from solar energy. Vick (2016) documented cooling in the Canadian Prairie Provinces due to a reversal of those trends. Additional bare ground from deforestation, aridification, wildfires, receding glaciers, open-pit mining, and mountain top removal, millions of miles of roadways, paving and parking lots, and vast expanses of housing and other buildings in rural and suburban areas also generate heat from sunlight.

Climatology recognizes the part played by land management in the climate and attempts to address it. To quantify the heat generation potential of land areas, they utilize albedo or reflectivity values. These are convenient because airplanes can be fitted with sensors to map albedo levels over large areas. Albedo quantifies reflected energy, but unfortunately, it does not tell you what happens to the non-reflected energy. This matters because the albedo of a forest and brick are about the same at 15%, and urban areas are only slightly higher. So while Schneider & Sagan (2005) have documented a forest profile of 15% energy reflected, 18% converted to heat, 1% utilized for growth, but 66% used to transpire water and create cooling, the 85% of the energy not reflected from brick, or urban area is converted entirely into heat. The brick gets hot! That is the source of heat islands (Howard, 1818; Garland, 2011). Albedo is not a valid measure of heat generation.

So while greenhouse gas science focused on atmospheric constituents, ignoring land surfaces, and climatology inaccurately measured land's heat generation, we have created what is effectively a global heat island – A Heat Planet. This condition has resulted from the destruction of natural vegetation, solar energy converting to heat in bare soil and abiotic materials, vast energy consumption, and forest fires, generating thermal pollution. Greenhouse gases exacerbate this warming, so reducing emissions is important, but addressing heat generation is required.

A hopeful Future:

The Heat Planet thesis proposes that the root cause of warming the planet is the generation of heat. While requiring a paradigm change, this perspective provides a far more hopeful future, with a world of opportunities to resolve over-heating at the root cause, more completely, locally, and in a matter of months, years, or maybe decades, instead of centuries.

Sunlight's conversion into heat instead of non-thermal forms of energy, such as photosynthesis, or evapotranspiration is the most significant heat source. The other important source of heat is the combustion of fuels, the largest source of greenhouse gases. So by focusing on heat, we must address combustion, resolving greenhouse from a different perspective. Everything is connected.

While greenhouse gases trap heat, less heat generation would reduce the amount trapped and thus the greenhouse effect. And by eliminating the source, not just the reflected portion, we reduce the heating more completely. Turning down the stove does more than remove the pot lid. We still need to reduce emissions, but addressing the root cause must be the priority.

And the climates we live in are local. The opening photo of this article (Sacks, 2016) documents a 60 ^{0}F differential in temperature in about 30 feet, between the moist shade under the bush to the asphalt road. This differential represents the difference between a morning frost and a hot summer day. Where Kim (2014:1085) documents central areas of Columbus, Ohio at least 11.0^{0}C (19.8^{0}F) hotter, he also documents outlying areas up to 15.0^{0}C (26.0^{0}F) cooler than the city center. Canberra, ACT. Australia, a city of about 400,000, designed as a "Garden City," is about 7.0^{0}C (12.6^{0}F) cooler than urban areas two miles away (Jehne, 2015). These discrepancies demonstrate the local character of temperatures.

But this local quality of climate has another impact. While activists are bemoaning the lack of progress at COP 26 in Glasgow, local activism is rising (Shankman, 2021b). The local quality of this perspective puts more power in the hands of local activists to make changes in their region. The problems at the UN may not go away, but perhaps they matter a little bit less if they can make real progress at the local level.

And “local climate” can be exact. There is a whole science of micro-climates that creates comfortable outdoor conditions for social use, regardless of climate and season, by organizing spatial orientation of the sun, wind, moisture, and surfaces (Brown, 2010; Erell et al., 2015). That these attempts can be successful demonstrates what is possible.

We have heat islands, but also cool islands. Oases in the desert are cool islands resulting from the impact of water in an otherwise dry environment. Water is the critical element in creating cool environments (Kravcik et al., 2008). That barefoot walk confirms that and provides the information you need to recognize changes that could cool your local area reasonably quickly.

De-paving removes a heat-generating material that will not generate heat tomorrow. Planting that space into a meadow will begin transpiring water and creating cooling in the coming weeks or months. Vine-covered arbors provide shade in one season. The impact of planting trees will start slowly but be significant within a decade. Miyawaki forests, named after their Japanese inventor, are very dense, fast-growing solutions to increasing biodiversity and alleviating climate problems and are ideal for even a few thousand square feet (Lewis, 2020). If the space is not large, the impact will not be large, but it will have an effect. Many people recognize these benefits in terms of livability, even without seeing them as a cause of climate change (Perez & Perini, 2018). Now you know that they are.

Sea level rise will still be a global phenomenon, although cooling may slow that process. But a portion of sea-level rise is the result of water loss from the land (Kravcik et al., 2008; Jehne, 2015), so restoring water cycles, recharging aquifers, and regenerative land practices will have a beneficial impact. Low-lying cities such as Miami may still require adaptation measures.

Opportunities

Sunlight converts into heat instead of other energy forms in bare soil (Brown, 2018), in poor-soil with reduced fertility and water holding capacity including lawns, (Kravcik et al., 2008), in deforested or aridified areas and mining sites (Schneider & Sagan, 2005), and of course in the whole of the built environment (Garland, 2011).

Due to the vast acreage, our largest opportunity to reduce heat generation is drastically reducing bare soil and increasing fertility and transpiration by converting agriculture to regenerative practices (Brown, 2018). Soil has eroded over many centuries (Montgomery, 2007; Ophuls, 2012) but has been increasingly damaged by industrial agriculture over the last century (Howard, 1943; Montgomery, 2007; Rabhi, 2006). Likewise, the concern for soil health and for reversing destructive practices has an extensive history. Early writers including King (1911), Howard (1943), and Faulkner (1943) warrant mention, along with extensive writings by Louis Bromfield during the 1930s and 1940s.

Much of modern science was inspired by the work of Allan Savory (1988), where Schwartz (2013) and White (2014) deserve mention. Montgomery & Bikle (2016) look at the soil on a garden scale from a health perspective, with critical implications. Toby Hemenway (2009, 2015) and many others provide a permaculture perspective, generally also at a gardening scale. Gabe Brown (2018) has perhaps best summarized the science and practice of soil regeneration and demonstrates incredible results on his ranch in Bismarck, North Dakota. While he works at a farm scale, his ideas can be translated to garden scale and applied everywhere there are gardens, even cities (Cockrall-King, 2012).

While the implications of soil health go well beyond the issue of heat generation, they are critical for reducing warming. In the Canadian Prairie Provinces, Vick's (2016) study found maximum summer temperatures falling 2^0C (3.6^0F), with rising rainfall and humidity, coinciding with a reduction of fallow land from 15 million to 2 million hectares. These findings document the climatic value of reducing/eliminating bare soil.

While there is still fallow ground in agriculture, our most significant source of bare soil is probably that between crop rows. Rows are typically cultivated, or worse, spayed with biocide to keep down weeds. Planting diverse cover crops between the rows would turn these monoculture crops into biodiverse cultures and have significant ecological benefits (Brown, 2018; Fukuoka, 2009). In 2017/2018, American agriculture worked 183.38 million acres (74.21 million hectares) of corn, soybeans, and cotton, crops with high percentages of bare soil. Worldwide those figures are 862.35 million acres (348.98 million hectares) (USDA, 2019). While Vick's changes occurred over 40 years, you could reproduce them in one season if you could get all the farmers and ranchers on board. With a focused effort, perhaps significant changes could occur within a decade.

Fred Pearce (2006) declared water as the defining crisis of the twenty-first century, but he certainly isn't alone in that. It is the one element that can create an oasis in a desert and is disappearing due to our misunderstanding. In addition to Kravcik's (2008) New Water Paradigm, Alice Outwater (1996) provides the story behind the systems that maintain clean and healthy water resources, and Glennon (2012) points out some of the manifestations of our misunderstanding of water's true nature.

Restoring soil health goes in lock-step with restoring small water cycles (Ellison, 2017; Kravcik et al., 2008; Schwartz, 2016), critical for water retention, cooling and carbon sequestration. Brown (2018) describes his soil's transformation from a permeability of one-half inch per hour to one inch in nine seconds and the second inch in sixteen additional seconds. Soil with that capacity will remain productive through a draught, remaining cool, and only experience erosion or flooding under very severe circumstances.

In addition to agricultural land, we also have aridified land that has ceased to be productive (Bingham, 1996). While quantification is elusive, Ghosh (2020) indicates it may be hundreds of thousands of square miles. We can also employ regenerative practices on that land (Brown 2018; Kravcik et al., 2008; Todd, 2019). The transformation of Dixie Creek in Nevada (Evans, & Griggs, 2015 - photos of the same site, 1989 and 2010) results from enlightened grazing practices. Once established, beaver would reverse aridification and refill aquifers (Goldfarb, 2018).

Trees and forests are also critical to the planet's health (Ellison, 2017; Maloof, 2016; Maser, 1994). And the stakes rise if the Biotic Pump theory is correct (Hance, 2012). It claims that forests create and control ocean-to-land winds, bringing moisture to terrestrial life. That puts a new price on deforestation. Either way, trees are critical cooling machines, and forests are the lungs of the planet (Ellison, 2017).

Recognizing that forests serve as lungs, should we be talking about oxygen? The oxygen cycle is very complicated, but the oxygen percentage has generally increased from about 18% to the present 21% over the last 35 to 40 million years (Ward, 2006). But as we consume oxygen by combustion, and destroy the sources of production, is a decrease in atmospheric oxygen the next 'unintended consequence' we face (Lane, 2002; Ward, 2006)? Regardless, we need to reverse deforestation and increase tree planting. We cannot continue to destroy trees and forests without consequences (Smil, 2013).

Fungi and their symbiotic relationships with trees are critical to forest health (Howard, 1943; Phillips, 2017; Sheldrake, 2020). Fungal networks beneath forest floors may be the largest living structures in the world. But even if they are not, they are critical to soil health in ways we are still discovering.

Last but certainly not least, we need to rebuild wetlands, marshes, and shallows. These intersections of soil and water create the most ecologically productive natural systems, and beavers will do the work for us if we let them (Goldfarb, 2018). Beaver are famous for creating havoc for landowners, and those problems can be real. However, we need to recognize the real benefits of water reappearing on the surface and find ways to alleviate those issues. Where groundwater levels have been dropping for decades, the weight of water from a beaver pond presses water into the ground and raises water tables (Goldfarb, 2018). And the biodiversity that appears in and around beaver ponds can catalyze ecological regeneration (Goldfarb, 2018).

Although not necessarily politically easy, these highly beneficial and technically straightforward changes to land care practices might produce enough cooling to minimize or eliminate the need for more complicated changes to our cities. However, people and organizations are working to green cities, not because they understand this paradigm, but because more urban trees and regenerated water cycles make cities cooler, healthier, and happier places for inhabitants (Perez & Perini, 2018). We can improve our cities by increasing vegetation and greenery (Garland, 2011). And ecological justice is a required component. (Plumer & Popovich, 2020).

The most common means of greening cities are street trees and the private gardens that blend in with them, which frequently account for most of a city's greenery (Perez & Perini, 2018). Jill Jonnes (2016) provides a fascinating history of street trees in American cities, along with the pests and diseases that we imported with them. But moving beyond conventional tree planting and layouts, Perez & Perini (2018) discuss ways streets can become something more. These 'green streets' create natural corridors that accommodate air and water flows (McHarg, 1971), connect ecological features, and catalyze community involvement. Greening buildings that face these 'green streets' can increase the benefits and biodiversity (Perez & Perini, 2018). Green roofs are gaining popularity, and while their loading can make them structurally challenging (Huntington & Mickadeit, 1981), creative solutions frequently exist. Vertical greening systems often face resistance, but it seems to diminish when people can see and feel real examples and have their questions answered (Perez & Perini, 2018).

Beyond street trees and "Green Streets," the most critical change needed in cities is restoring water cycles to increase cooling (Howard, 1818; Garland, 2011). Water must be able to sink in where it falls, increasing cooling and rainfall (Kravcik et al., 2008; Schwartz, 2016). However, with most of the urban surface paved and extensive infrastructure in place to remove 'wastewater,' inertia against change makes restoring water cycles in cities quite difficult. However, some municipalities, such as NYC, Chicago, Philadelphia, Portland, Seattle, Tokyo, and Bangkok, have made changes on their own when they recognize that it is less costly to prevent wastewater surges than it is to expand drainage networks (Perez & Perini, 2018).

Charles Waldheim (2016) identified opportunities for urban revisioning in decayed industrialism, but other sources for ecological reconfigurations also exist (Calthorpe, 2011; McHarg, 1971). Restoring water flows through cities that have been destroyed or covered over provides opportunities to reignite the biodiversity that existed with that water system and recreate natural connections that made those places special (Goldfarb, 2018). Greening cities (McHarg, 1971; Perez & Perini, 2018; Waldheim, 2016) while recognizing their complexity (West, 2018) would be the best means of improving their livability, reducing crime, and increasing ecojustice, and building community. Perez & Perini (2018) provide examples in New York City, Portland, Seattle, and Chicago.

Addressing building surfaces' heat capture raises the level of complexity, but is possible. Shading systems with low heat capacity materials such as fabrics could help. Increasing building surface reflectivity, or better yet, emissivity (Ahmad et al. 2019; Cook, Ed. 1989), could also help. Reducing the heat capacity of a building's exterior surface could coincide with increased energy efficiency but needs to address all technical criteria carefully. Recladding building exteriors, even with PV panels, though expensive, could have long-term benefits. Could the exterior surfaces of our city's buildings become our energy generation systems, replacing other generation facilities, and leaving greater land area for greenery? The details of the technical complexities involved here go beyond the scope of this article.

Efficiency is more critical than net-zero. This is true in the context of heat planet with thermal pollution, and it is true in minimizing emissions from the whole system. But Friedemann (2016) argues it is also true to buy time for the economy, and Dan Young (2017) argues that energy generation increases climate instability. A discussion of the second law of thermodynamics also falls outside of this articles' scope.

We need to accept energy efficiency standards that reflect the perspective of Passive House, along with the more general requirements of Living Building Challenge. Passive House turned building services on its head by generating an energy budget from the building's size and requiring a building envelop that provides acceptable thermal conditions within that budget. Admittedly, the Passive House approach is based on relatively small skin-dominated buildings and provides challenges when applied to larger load-dominated commercial buildings, but its focus on efficiency has merit. When you meet Passive House standards, net-zero is a slam dunk.

Lastly, we need to replace fuel-consuming systems with heat pumps that collect heat from the environment. Heat pumps are standard practice for Passive House and Living Building Challenge and are becoming common even for utility-sponsored energy efficiency programs (Shankman, 2021). The only heat they add is the electricity they consume, and good units are highly efficient. While the electricity can be renewable, unfortunately, "Renewable" energy is not the panacea we hoped (Friedemann, 2016). While less damaging than the combustion of fossil fuels, renewable energy also generates heat and contributes to climate disruption (Schneider & Sagan, 2005; Young, 2017). That is particularly true if energy (heat) generation displaces natural ecology. Photo-voltaic farms built over meadows or replacing forests move us in the wrong direction.

But in addition to building stock, the internal combustion engine, with combustion chamber temperatures of about 2500^0 F, is our primary means of propulsion. Additionally, our massive industrial energy consumption produces thermal pollution on a grand scale. We have also created a massive road network for these automobiles, four million miles of asphalt and concrete in the US, turning sunshine into heat (Friedemann, 2016). Roads were considered obsolete when rail was seen as the modern solution to inter-city travel in the second quarter of the nineteenth century (Cudahy, 1990). And many, or even most cities, had electric public transport in the late nineteenth century (Cudahy, 1990). We traded that in for vast expanses of roadways, private cars, and gridlock.

We have an ecological problem that is much bigger than greenhouse gases. While we still need to lower emissions, that in itself is insufficient. Fortunately, there are ample opportunities to reduce warming in our homes, neighborhoods, and regions. Perhaps we can have friendly 'competitions' with neighboring towns to make the most extensive improvements, or share our biggest successes and help others learn from our mistakes.

Implications for Sustainability Education

The heat planet paradigm has three significant implications for sustainability education. Firstly is the West's cultural disconnection from the natural environment. Unless human society recognizes and acts on the fact that the health of the natural world ultimately determines its future, nothing else will matter. If that connection is clear, there is room for progress on the other two points.

Secondly, Thomas Kuhn (1957, 1970) has written extensively on the power of entrenched paradigms to endure, and greenhouse gases are certainly an entrenched paradigm, even when faced with extensive scientific evidence to the contrary. Kuhn (1957) began this study with Copernicus's discovery that the earth rotated around the sun and not the other way around. The resistance of Ptolemaic astronomers was such that it took 150 years and Johannes Kepler to convince the scientific community that Copernicus was right.

But in his most famous work, “The Structure of Scientific Revolutions," Kuhn (1970) expanded his study into an investigation of scientific training and culture around paradigms and the problems of change. His finding can be summarized, while oversimplified, in a quote by Max Plank: “a new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it.”, (Kuhn, 1970, p.151).

This is an “Emperor's New Clothes” story. Those who are fully invested in the greenhouse gas thesis will, as Plank stated, probably never accept a new paradigm. That has been my experience. Those on the periphery (Centola, 2021) may be more likely to consider it. Several international communities looking at aspects of land management will recognize Heat Planet because it fits their understanding of the world (Sacks, 2021). Addressing the challenge of scientific culture will be critical for sustainability education. Plank's comment could be interpreted to indicate that education may need to start with the young.

And thirdly, Heat Planet adjusts the focus and expands and field of what is necessary for sustainability education. It must focus more on systems (Meadows, 2008) and be wide enough to address the issues identified above. Scholars must address topics from various positions, not just from one, however valuable that one would seem. The approach must be far-more generalist, not the specialized education that we now have. We have an enormous trove of material to work with from all that we have learned in the last century of specialization. The problem is not to go deeper with what is there but to build bridges between all the pieces, find relationships, make connections, and seek synergies that increase our understanding of the world (Haines, 2010).

In terms of content, we cannot arrive at the right answers if we are asking the wrong questions. For humans to be constructive agents in repairing earth's systems, we must understand how they developed (Margulis, 1998; Storer, 1953). This understanding requires education of living systems going back at least to the Cambrian explosion, and not just for biology majors. The biology, physics, and chemistry that created soil, the atmosphere, and the biome that lives within it are critical to a human future (Lovelock, 1979, 2016; Smil, 2002; Vernadsky, 1926/1998). We need to understand geology and hydrology to include water cycles into our thinking of soils. But even some events that we think of as geological are biologically based (Westbroek, 1991). And it is incredible to look at all we do not know about something as critical to life as water (Pollack, 2013).

There is much we do not know and will not know. We need to rethink our assumptions about development and human's place in the world. Written before understanding Heat Planet, I addressed an element of that adjustment from the perspective of life-long learning (Haines, 2018).

Howard began his consideration of heat generation in cities with the metabolic heat of the population and animals. He rapidly realized that was a minor component and dismissed it. However, he lived with a human population of just over one billion. With the understanding of Heat Planet and a population nearing eight billion, does that need to be revisited? What are the biological and physical limits to the human population, development, and technology in light of heat planet? Even the classic Limits to Growth (Meadows, 1975), with several updates, did not consider the impacts of heat. It is time we began.

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***Fig. 8* Photograph of the square and adjacent park in Třeboň, Czech Republic, taken with a thermal camera.** The differences in temperatures between the vegetation, facades and roofs of the houses is visible.