The Heritage Foundation

SPECIAL REPORT
No. 293 | NOVEMBER 12, 2024

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CENTER FOR ENERGY, CLIMATE, AND ENVIRONMENT

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This paper, in its entirety, can be found at **https://report.heritage.org/sr293**

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Human Health and Welfare Effects from Increased Greenhouse Gases and Warming

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Claims that global warming will have net negative effects on human health are not supported by scientific evidence. Moderate warming and increased atmospheric concentrations of carbon-dioxide levels could provide net benefits for human welfare, agriculture, and the biosphere by reducing cold-related deaths, increasing the amount of arable land, extending the length of growing seasons, and invigorating plant life. The harmful effects of restricting access to fossil fuel energy and subsequently causing energy costs to increase would likely outweigh any potential benefits from slightly delaying any rise in temperatures. Climate change is likely to have less impact on health and welfare than polices that would deprive the poor living in emerging economies of the benefits of abundant and inexpensive energy.

The potential for an increase in the health and welfare effects of increasing carbon-dioxide concentrations and the concomitant warming of the climate has become an increasing focus of those concerned about climate change. Some claim that climate change is responsible for an increase in virtually everything that adversely affects human life and that it may also lead to a rapid deterioration of human health and welfare. During the past three decades, a politically-driven pseudo-science has invaded research in toxicology and epidemiology through governmental funding and environmental pressure. These efforts were intended to promote government regulatory activity, including expansion of regulatory controls.

In this *Special Report*, claims regarding the effects of climate change, rising air temperatures, and increasing carbon-dioxide concentrations will be identified and investigated. The results will show that a slight warming of the planet may make it more habitable and hospitable, that concerns about increases in disease proliferation due to climate change are vastly overstated, and that the expansion of abundant and inexpensive energy through the development of affordable and reliable energy has produced nearly two centuries of human progress and welfare. In particular, some of the policies intended to curb anthropogenically induced climate change may restrict access to affordable and reliable energy and are thus—ironically—*harmful* to low-income individuals across the world.

Effects of Rising Air Temperatures on Human Health

The Intergovernmental Panel on Climate Change (IPCC) claims that human health is in danger because the average air temperature of the planet may increase up to 4°C (7.2°F), based on the most extreme emissions scenarios (Shared Socio-Economic Pathway [SSP5-8.5])[1] and the concomitant climate changes that would result from it. During the decades that the IPCC has been issuing reports on the state of the Earth's climate, it has repeatedly warned that carbon dioxide (CO_2) and other greenhouse gases (i.e., methane, nitrous oxide, and chlorofluorocarbons, but not water vapor) will increase the Earth's air temperature by at least 1.5°C (2.7°F).[2]

In particular, the IPCC predicts that:

- Extreme heat coupled with poor air quality will increase complications arising from underlying heart and respiratory conditions such as asthma, renal failure, and premature birth, and as air temperatures rise, more heat-related illnesses and death will occur in both urban and rural areas.

- More frequent and/or intense extreme weather events will threaten lives and public health and also will significantly disrupt the response of health and social services.

- Wildfire risk will increase dramatically across much of the central and western portions of North America, leading to an increased threat to human life and also causing severe air pollution across most of the continent.

- Heavy downpours have increased in both frequency and intensity and are likely to increase further, increasing the risk of both flash floods as well as regional flooding from enhanced streamflow. This will enhance the exposure to water-borne illnesses, including those linked to sewage contamination of drinking water. Recreational waters are likely to experience more outbreaks of aquatic pathogens, including Vibrio bacteria and harmful algal blooms.

- As a result of rising air temperatures and expanding habitat, illnesses transported by ticks and mosquitoes, such as Lyme disease, West Nile virus, and malaria are likely to increase and spread to new areas in North America.[3]

How plausible is it that any of these climate changes are likely to be triggered by a gradual rise in Earth's surface temperature? Climate variability is reduced as the air temperature warms since the equator-to-pole temperature gradient is reduced.[4] This occurs since the air at the poles will warm faster than air at the equator because:

- Colder air warms more with the same energy input than warmer air warms;

- Water vapor (tropical) has a higher specific heat than dry (polar) air;

- The change in surface reflectance (albedo) is greater in polar regions due to the melting of highly reflective ice and snow, thereby uncovering the darker underlying soils;

- Sea ice provides a layer of insulation between unfrozen water and the much colder air above it;

- The lack of polar convection keeps warming closer to the surface; and

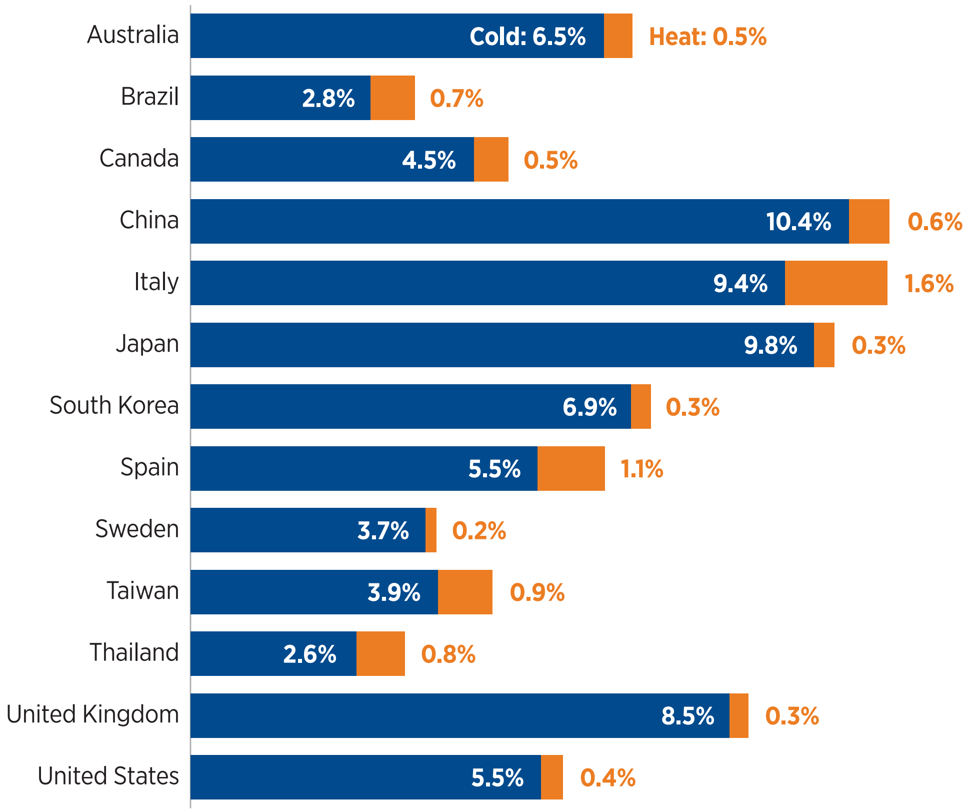
- Evaporation stores energy as latent heat, which then is transported poleward through the global circulation.[5]

In addition, polar warming is enhanced in the winter and is less in the summer, which leads a greater reduction of the equator-to-pole air temperature in the cold season. Consequently, rather than causing any of the concomitant climate changes listed above, additional carbon dioxide and warming may improve the habitability of the planet as a whole by reducing the harshness of cold latitudes, increasing the arability of land, and lengthening the growing season.

Effect of Extreme Air Temperatures. Extreme air temperatures—hot or cold—can kill. In the most comprehensive and authoritative study on the impact of air temperature on health across the planet, Gasparrini and his colleagues[6] tallied deaths in 384 locations across 13 countries from 1985 to 2012 to assess the impact of anomalous (extreme) temperatures (both hot and cold) on death rates. Their results are depicted in Chart 1.

CHART 1

Percent of Mortality Attributable to Hot and Cold Temperatures for 13 Select Nations



NOTE: Study periods vary by country. For most, the study period was from the 1980s through the 2010s.
SOURCE: Antonio Gasparrini et al., "Mortality Risk Attributable to High and Low Ambient Temperature: A Multicountry Observational Study," *The Lancet*, Vol. 386, No. 9991 (May 20, 2015), pp. 369–375, https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(14)62114-0/ (accessed July 2, 2024).

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As this chart shows, by a wide margin, the Gasparrini et al. study illustrates that cold extremes kill far more people that heatwaves—and by a wide margin. They concluded:

> Our findings show that temperature is responsible for advancing a substantial fraction of deaths...7.71% of the mortality.... Most of the mortality burden was caused by days colder than the optimum temperature (7.29%) compared with days warmer than the optimum temperature (0.42%).[7]

So cold produced 17 times the number of heat deaths. Gasparrini and his colleagues also reported a "statistically significant decrease in the relative risk for heat-related mortality in 2006 compared with 1993 in the majority of countries included in the analysis."[8] Mortality risk due to heat stress appeared to decrease over time in several countries, with relative risks associated with high air temperatures being significantly lower in 2006 compared with 1993. Temporal changes were difficult to assess in Australia and South Korea due to low statistical power, and there was little evidence of variation in the United Kingdom.

In the United States, the risk seemed to be completely abated in 2006 for summer air temperatures below the 99th percentile, but some significant risk persisted for higher temperatures in all countries. An updated study in 2023 that examined deaths attributable to cold and hot days in 854 cities in Europe confirmed the earlier study by Gasparrini and his colleagues: Cold outbreaks produced 203,000 excess deaths while heatwaves led to only 20,000 excess deaths between 2000 and 2019.[9]

Causes of Cold Deaths Versus Heat Deaths. It is challenging to attribute deaths directly to extreme temperatures. Much of this difficulty lies in the fact that such deaths may be not directly attributable to air temperature per se, but rather to conditions created by the heat or cold. Moreover, temperature-related deaths vary in the time it takes for death to occur depending on pre-existing medical and physical conditions of the individual and the severity of the air temperature and/or humidity anomality.

For example, wet and cold conditions or the direct exposure to cold water leads to death more quickly than wet and hot conditions because the body has the ability to provide evaporative cooling or to shelter itself from the effects of abnormal warmth. Heat deaths can occur due to poor housing conditions, neglect of the infirm and debilitated, and the occasional heat stress incurred by otherwise healthy individuals. Thus, many such deaths are avoidable, or at least can be minimized, with increasing affluency.

In particular, cold-related deaths do not usually result from hypothermia but, in most cases, from medical events triggered by the cold and they are recorded as deaths that occur during cold outbreaks. Cold-related morbidity and mortality—strokes; heart attacks; blood clots; direct effects of cold conditions that cause surface blood vessels to contract and possibly clot; and cold temperature effects resulting in lung tissue susceptibility to infections, airway spasm, and congestion—are the result of cold temperatures that cause blood vessel constriction and decreased circulation and blood flow. Hypothermic deaths are the result of the body's inability to maintain core temperature.[10] Death rates are about 10 percent higher in winter, and January is the deadliest month of the year in the Northern Hemisphere.[11]

By contrast, heat-related deaths are usually caused by stress, dehydration, and failure of evaporative and radiative heat loss that cause an increase of core temperatures to 41.1°C (106°F) and above. Death from the heat is a physiological stress state and an extreme rise in body core temperature. Research on death from extreme temperatures is limited by low autopsy rates on the aged or infirmed.

Blood Viscosity. The reason cold outbreaks are often more deadly than heatwaves—as the Gasparrini et al. study suggests—lies in how the human body attempts to deal with exposure to extreme temperatures. Exposure to cold conditions causes surface blood vessels to contract, which results in a condition known as *sludged blood*.[12] Sludged blood occurs when the viscosity of blood increases significantly due to contraction of the peripheral blood vessels. Sludged blood causes problems in circulation among vital organs, significantly reduced blood flow, clotting, and a clogging of arteries—all of which may be fatal as strokes, myocardial ischemia or infarction, or pulmonary embolisms.

Contraction of lung and airway blood vessels is also a factor in respiratory illnesses, and cold air can trigger airway spasms in people with underlying asthma or airway diseases such as bronchitis and emphysema.[13] Blood vessel contraction and decreased blood flow may lead to blood sludging and blood clots, but they also cause a reduction in the delivery of oxygen to the affected tissues, resulting in a loss of tissue integrity and susceptibility to infection and tissue deterioration. The effect of cold conditions on blood vessels is amplified in people whose blood vessel capacity and resiliency has declined with age.

While reduced blood flow and sludged blood may harm tissues of the extremities, blood vessel constriction to preserve core temperature during cold conditions also can induce blood flow issues in the vessels associated with the lungs, heart, and brain. A reduction in blood flow is called *ischemia*, while a complete loss of blood flow is called an *infarction*; an infarction in the brain is a stroke, an infarction in the lung is a pulmonary embolism, and an infarction of the heart is a heart attack. These infarctions can be deadly, or at least inflict potentially serious harm. Infarctions of the liver, spleen, kidneys, or intestines may also initiate illness, although they are not as deadly owing to the delayed response of the organ failure and because the damage usually is limited to just a portion of the organ.

Cardiac and Respiratory Implications. Most cold-weather deaths result from the inability of the body to tolerate either the degree or the duration of cold exposure. Cardiac arrhythmia may result due to an ischemia (a restriction in blood supply), an obstruction, or an occlusion (a complete blockage of blood to the heart) brought on by the body's attempt to preserve core temperature or its inability to adequately compensate for the cold conditions. Colder temperatures cause more premature deaths from cardiovascular causes than any effects of heat stress.[14] Moreover, hemorrhagic strokes (brain bleed) were found to be more prevalent in colder conditions resulting from vascular compromise from sludging.[15] In fact, Siberia (in Russia) is emblematic, as it exhibits one of the highest ischemic (obstructive) stroke incidence rates in the world.[16]

Respiratory diseases increase in prevalence in colder periods, and respiratory infections and reactive airway diseases (asthma and its variants) are aggravated by cold ambient air. Although they often are irritation or allergy-based diseases, asthma, bronchitis, and emphysema outbreaks are accentuated during colder weather since cold air triggers the reactive airways of asthmatics and people with chronic lung disease. This results in respiratory distress and reduced oxygen and the sufferer is forced to seek confined environments that lead to increased exposure to indoor allergens and an increased transmission of respiratory infections.[17]

Although pollen production from grasses, weeds, bushes, and trees causes asthmatic outbreaks in the early spring months, it is the onset of plant growth—not inherently warmer temperatures—that leads to these seasonal outbreaks. A consistently negative influence of colder temperatures is associated with both the incidence and severity of respiratory illnesses,[18] although the cold season wave of influenza and other respiratory illnesses confound the problem.[19]

Diurnal Effects on Health

Diurnal (daily) temperature range (DTR) studies show that an increased daily temperature range (between the daily high and low air temperatures) is more prevalent in the winter months, which increases the frequency of heart attacks and respiratory illnesses.[20] The initial assumption is that the human body does not tolerate extreme temperatures very well and does not respond quickly to air temperature changes. Thus, it might logically follow that large changes in air temperature during a short time period (e.g., the diurnal temperature range) would be detrimental to the human body in general.[21] However, the opposite might be true during longer heatwaves and cold spells since a respite from these extreme temperatures, no matter how brief, might be sufficient to allow the body to recover, thereby making the extreme temperatures more palatable.

In an analysis using data from 95 cities across the United States, total mortality (when adjusted to include only non-accidental deaths) increased by an average of 0.27 percent for each 1°C (1.8°F) change in DTR.[22] When cities outside the United States were included, total non-accidental mortality increased by 0.31 percent for each 1°C (1.8°F) change in DTR.[23] Seasonal trends are more difficult to ascertain, owing to both variations in the definition of "season" (i.e., calendar versus climatological variations) and different methods of analysis.[24]

Overall, the existing literature suggests that variability in daily high temperature leads to enhanced morbidity and mortality, regardless of the mean air temperature condition.[25] However, the interpretation of DTR and its causal influence on morbidity and mortality is difficult to both quantify and interpret. This is because DTR is driven by changes in the opposite extreme temperature to the seasonal average (i.e., cold in summer and warmth in winter); that is, summer's DTR is more dependent on the daily minimum air temperature while DTR in the winter depends more on the daily maximum air temperature.[26]

With the prospect of a warming climate, what are the prospects for changes in DTR and how will that affect human health? Recent assessments of changes in DTR resulting from human impacts, including the influence of greenhouse gases, aerosols, and the urban heat island effect, show that the DTR has *decreased*, particularly since the latter half of the 20th century.[27] This decrease in DTR results from a warming in minimum air temperature with a lesser warming in maximum air temperature and amounts to about 0.5°C (0.9°F) in mid-latitudes.

Climate models suggest this reduction of DTR is the result of an increase in daytime cloudiness, which minimizes maximum air temperatures.[28] Climate models, however, tend to underestimate the observed increases in the minimum air temperature but overestimate the observed increases in maximum air temperature, which leads to an overestimate of future prognostications of the DTR.[29] Simply put, a milder climate results in less morbidity and mortality.

The Effect of Vector-Borne Diseases

Some raise concerns that climate change will lead to an expanded geographic range and, thus, a proliferation of vector-borne diseases. These include diseases that are spread due to mosquitos, mites, flies, fleas, chiggers, and ticks, and include dengue fever, Rocky Mountain spotted fever, malaria, West Nile virus, and yellow fever. One of the most prevalent claims in this discussion is that these are all "tropical" diseases, and that they will spread poleward as the planet warms.

Even if the most dramatic increase in air temperature prognostications from current climate models occurred, the range in mosquitos, fleas, ticks and other carriers would not significantly change because they are all acclimated to non-tropical environments. In Finland, for example, malaria has been endemic for more than two centuries, although modern agricultural and health practices have greatly reduced its infection rate.[30] The Anopheles mosquito is a vector of the parasite Plasmodia, which causes malaria in birds, reptiles, and mammals,[31] and it has been home in Finland for years.[32] Most of these carriers of vector-borne diseases are ectothermic insects; that is, they lay eggs and hibernate during the cold winter, only to emerge as the air temperature warms.

Since these vectors are present largely during the summer months, people concerned about climate change would argue that the threat should increase with increasing air temperature. But since many of these vector-borne diseases are found in middle- and upper-latitude locations (for example, dengue fever, malaria, and yellow fever) and their vectors are, too—the *Aedes aegypti*, *Albopictus* (tiger), and *Anopheles* mosquitos, for example—an increase in these diseases would be tied to the extension of the vector's active season (e.g., the increase in warm air temperatures) and not to a spread of either the vector or the disease poleward. This is accentuated by the fact that some vector-borne diseases are actually prevalent in moderate climates; these include Rocky Mountain spotted fever and Lyme disease.

A number of examples provide compelling evidence that such diseases are relatively independent from changes in global air temperature. Bubonic plague (spread by flea-borne bacteria, *Yersinia pestis*), which led to the Black Death in Asia, Europe, and Africa in the 14th century, is an example of a vector-borne epidemic of the past.[33] It thrived in the relatively colder period of the Little Ice Age (circa 1350–1850) and was nearly eradicated due to pest control and modern sanitation. Typhus, spread by lice, is given credit for halting Napoleon's *Grande Armée* invasion of Russia in 1812.[34]

Other diseases are decidedly mid-latitude phenomena and are not associated with the tropics. Rocky Mountain spotted fever is a hemorrhagic rickettsia (transmitted by the bacteria *Rickettsia rickettsii* and spread through ticks).[35] It is endemic to the Rocky Mountain region of North America and not found naturally in tropical regions. Similarly, Lyme disease occurs regularly in temperate regions of the Northern Hemisphere, including Canada and the United States, as well as much of Europe and Asia north of the Himalayas.[36] Other middle- and upper-latitude vector-borne diseases exist.[37] Some of the more common vectors are discussed below.

Malaria. Malaria is often predicted to migrate poleward and to intensify in the tropics as a result of changes in air temperature, humidity, and rainfall.[38] The female *Anopheles* mosquito is responsible for the spread of the malaria parasite *Plasmodia,* which is a neither a bacterium nor a virus but a protozoon. The *Plasmodia* grow and reproduce in the mosquito and subsequently invade its salivary glands. When the mosquito feeds on a mammal, the protozoon is transmitted to the host, killing red blood cells and invading other tissues. Ironically, colder conditions actually accentuate the disease since people are forced indoors where temperatures are warmer and the mosquito can continue to feed on humans and other animals present indoors.

Five different strains of malaria exist. The worst and most prevalent and virulent is *Plasmodia falciparum,* which causes half of the infections and nearly all of the deaths attributed to malaria.[39] The *Plasmodia* protozoon is so specialized at survival that it exhibits both sexual and asexual forms of reproduction. Malaria invades the red blood cells and causes a prostrating, horrific, and disabling illness, usually characterized by respiratory distress and often culminating in death by encephalitis.

Although malaria is prominent in Africa, which has 90 percent of cases and more than 500,000 deaths every year, no links between air temperature and the increase in malaria outbreaks have been established.[40] However, the World Health Organization noted that COVID-19 exacerbated the spread of malaria and that

> [c]limate variability is expected to have indirect effects on malaria trends through, for example, reduced access to essential malaria services and disruptions to the supply chain of insecticide-treated nets, medicines and vaccines. Population displacement due to climate-induced factors may also lead to increased malaria as individuals without immunity migrate to endemic areas.[41]

As mentioned earlier, malaria is endemic to moderate climates and is found in both high latitudes and high altitudes where air temperatures are much colder than the tropics. The female *Anopheles* mosquito is a resilient and tough blood sucker that can survive colder temperatures in its search for warm-blooded humans or mammals. While they are vector-borne disease carriers, that is simply a byproduct of their nature; the *Anopheles* mosquito is driven by its feeding on warm blood.

The reason malaria is no longer endemic in the United States is because a long and successful campaign against its habitat was undertaken by the U.S. Army Corps of Engineers (USACE). The Swamp Land Act of 1849 authorized the USACE to drain and cultivate lowland wetlands throughout all of Louisiana in an effort to reduce malaria infestation. The Swamp Lands Act of 1850 extended the 1849 act to include all public lands in the eastern United States, and the Swamp Lands Act of 1860 extended the 1850 act to include Minnesota and Oregon.[42]

Dr. Paul Reiter is an internationally recognized expert in entomology at the Pasteur Institute in Paris with a specialty in the vector-borne diseases of malaria and dengue fever. He asserts that the claim that CO_2-driven warming will result in an increase in incidents of malaria ignores other important factors in the propagation of the disease.[43] He notes that malaria increased substantially during the Little Ice Age, when air temperatures reached a global low and then declined during the modern warming in the latter 19th and 20th centuries. He avers that economic factors and agricultural/land use practices coupled with pest control (i.e., mosquito control) measures have a more important effect on the prevalence of malaria than a rise in global air temperatures.[44] He writes in *Malaria Journal*:

> Simplistic reasoning on the future prevalence of malaria is ill-founded; malaria is not limited by climate in most temperate regions, nor in the tropics, and in nearly all cases, "new" malaria at high altitudes is well below the maximum altitudinal limits for transmission. Future changes in climate may alter the prevalence and incidence of the disease, but obsessive emphasis on "global warming" as a dominant parameter is indefensible; the principal determinants are linked to ecological and societal change, politics and economics.[45]

Reiter summarized his U.S. Senate testimony in 2006 by making four important points regarding climate change–induced effects on the spread of malaria:

1. Malaria is not an exclusively tropical disease;

2. The transmission dynamics of the disease are complex; the interplay of climate, ecology, mosquito biology, mosquito behavior, and many other factors defies simplistic analysis;

3. It is facile to attribute current resurgence of the disease to climate change or to use models based on temperature to "predict" future prevalence; and

4. Environmental activists use the "big talk" of science to create a simple but false paradigm and malaria specialists who protest this are generally ignored or labelled as "sceptics."[46]

The reality is that *Anopheles* and other species of mosquitos are not tropical but are far-ranging and that climate change plays a very small role in determining the habitat of the vector and the vector-borne disease. The ultimate direction of that impact on human health is still unclear.

Yellow Fever. Yellow fever is a virus transmitted primarily by the *Aedes aegypti* mosquito in Africa and by the *Haemagogus* genus of mosquitoes in South America. Yellow fever is relatively benign, infrequently lethal, and today, is well-prevented by a vaccine. In severe cases, damage to the liver and other organs occurs, producing jaundice (and the traditional "yellow" skin color). At present, the disease is confined largely to tropical Africa and South America.[47]

Again, a key issue to examine is the extent to which climate change can impact the prevalence and proliferation of the disease. Although it seems reasonable to expect the geographic distribution of yellow fever to expand with warmer temperatures, little evidence exists that its geographic area is expanding with the recent warming or that it will expand with additional warming. Note that *Aedes aegypti* is the same mosquito that serves as the vector for dengue fever, chikungunya, Zika fever, and Mayaro, and although its original habitat was Africa, its domain has spread to many tropical, subtropical, and mid-latitude climates throughout the world.

A study conducted in Brazil concluded that when various climate change warming scenarios were studied, a decrease in both the number of cases and the duration of the outbreak would be expected, for both the "extreme" climate scenario of SSP5-8.5 (RCP8.5) and even for the "mild" climate change scenario of SSP3-4.5 (RCP4.5).[48] Their conclusion was based on a calculation that the increase in air temperature would increase beyond the temperature range suitable for survival of the vector *Haemagogus*.

Increased precipitation, however, accentuates the development of yellow fever (due to the prevalence of standing water in outdoor containers), and in the United States, warm and wet conditions usually accompany El Niño events. An El Niño accompanied the yellow fever epidemic in 1878 as well as six of the remaining eight major yellow fever outbreaks ("major" meaning more than 1,000 deaths).[49] However, Dr. Kevin Lafferty of the Western Ecological Research Center of the U.S. Geological Survey in Santa Barbara, California, notes that although this appears to be a case in which climate dictates the yellow fever vector, his more detailed analysis shows otherwise.[50]

In particular, the nine yellow fever epidemics were more likely to follow the year *after* an El Niño event, and separate analyses of individual cities (e.g., Charleston, New Orleans, and Philadelphia) indicated no correlation between yellow fever outbreaks and El Niño events. Lafferty found that "while some comparisons indicated that climate was statistically associated with historical yellow fever epidemics in the United States, El Niño did not explain a substantial proportion [of] the variance in epidemics."[51] Writing in *Ecology*, he concludes:

> There are several reasons climate change may not always lead to a net increase in the geographic distribution [of] infectious diseases. Firstly, most species, including infectious diseases, have upper and lower limits to their temperature tolerance. This means that changes in climate should often lead to shifts, not expansions, in habitat suitability. Furthermore, while a reduction in habitat suitability should reduce a species' range, an increase in habitat suitability does not necessarily result in an increase in geographic distribution. This is because other factors besides climate, such as barriers to dispersal, competition, and predation, affect the realized niche. For infectious diseases that depend on other species for vectoring or as intermediate hosts, habitat degradation can prevent transmission even if climate is suitable. In particular, because disease control efforts have successfully reduced or eliminated the transmission of previously widespread infectious diseases from developed countries, human activities will prevent the expansion of some infectious diseases even if climate becomes more suitable. For these reasons, it seems plausible that the geographic distribution of some infectious diseases may actually experience a net decline with climate change. For these reasons, it seems plausible that the geographic distribution of some infectious diseases may actually experience a net decline with climate change.[52]

Dengue Fever. Dengue fever is rapidly expanding its range in Europe. It is spread by the female *Aedes albopictus* mosquito into Europe, but a more effective vector is the female *Aedes aegypti*. Its spread is linked closely to the spread of yellow fever as both are viruses of the same family and genus (*Flaviviridae Flavivirus*) and both infect only primates (including humans). Originally, both are transmitted by forest-dwelling mosquitoes living near urban and suburban areas. Both cause hemorrhagic illness in humans with potentially fatal complications. Although primarily tropical in origin, both yellow and dengue fever have a history of transmission into Europe and other middle-latitude regions through the global movement of goods and people.[53]

In particular, dengue fever is a widespread viral illness and is quite possibly the most important viral disease globally. Although often asymptomatic, the incidence of dengue fever has increased dramatically and produces a significant number of deaths annually. Dengue hemorrhagic shock syndrome is the most severe and lethal version of the disease with more than about 5,000 dengue-related deaths annually.[54]

Dr. Reiter, who was an employee of the Dengue Branch of the Center for Disease Control for 22 years, argues that the recent resurgence of dengue fever "is a major cause for concern, but it is facile to attribute this resurgence to climate change.... [T]he principal determinants are politics, economics, and human activities."[55] Although some authors suggest the spatial extent of dengue fever will expand due to a variety of ongoing environmental and social phenomena,[56] a more recent study by Mercier and colleagues concluded that "if temperature is the key environmental factor limiting transmission, then transmission of [chikungunya], but not [dengue fever] is feasible in much of Europe" as it is limited to air temperatures above 28°C (82.4°F).[57]

Tick-Borne Diseases. Similar to the viruses and bacteria transmitted by mosquitos, diseases spread by ticks, such as encephalitis and Lyme disease, are purported to increase with increasing air temperatures.[58] However, ticks and their concomitant diseases are already present in middle latitudes, and they are acclimatized to areas with significant cool periods. Tick behavior is seasonal; thus, additional warming will not affect the range of the vector.

Tick encephalitis occurs mostly in Europe and Asia. The disease is spread by a virus transmitted by the bite of *Ixodes Ricinus*. Although encephalitis is rarely lethal—about 1 percent of persons who contract the disease die from it—it can lead to other disease sequellae such as myelitis, cranial neuritis, and meningitis. About one-third of those who contract encephalitis experience lasting symptoms, primarily of a neuropsychiatric nature.

Lyme disease is the most common tick-borne disease and is a multifarious infection that has both acute and chronic components.[59] After a bite from the nymph form of the deer tick injects the *Borrelia burgdorferi* bacteria into the victim, a unique rash (erythema migrans) is subsequently accompanied by fever, headaches, arthritis, and a general myositis/tendinitis (joint and muscle inflammation). In some cases, this then is followed by encephalitis and meningitis (brain infection) as well as facial paralysis (Bell's palsy) with weakness and pain arising from arthritis and myositis.

The disease was originally identified in Lyme, Connecticut—whence its name originates—and is endemic to deciduous forested areas of the northeastern, mid-Atlantic, and north-central states.[60] Thus, it is unlikely that climate change would play a major role in the geographical spread of Lyme disease since both the bacteria and the tick vector are already acclimatized to middle latitudes. In a discussion of changes in the spatial distribution of tick-borne encephalitis and Lyme disease, Sarah E. Randolph of the University of Oxford concluded:

> [R]eal changes in the natural dynamics of the major American and European tick-borne zoonoses appear to have occurred towards the end of the 20th century, largely precipitated by human impact on the habitat and wildlife hosts of ticks. Purely climatic factors may have played some part, but this is only apparent at the northern extreme of [Ixodes Ricinus] distribution.... [W]ithin their ranges, the frequency of contact between humans and ticks is the common principal determinant of any temporal variation in human infection rates by these tick-borne pathogens.[61]

In a later article, she wrote:

> While nobody would deny the sensitivity of ticks and tick-borne disease systems to climatic factors, that largely determine their geographical distributions, the evidence is that climate change has not been the most significant factor driving the recent temporal patterns in the epidemiology of tick-borne diseases.[62]

Some studies suggest that increasing air temperatures will extend the time during which the tick vector is active.[63] However, research suggests that although European mean spring, spring–autumn, and winter temperatures have increased gradually during the period 1960 to 2000, changes in the local climate cannot explain the temporal and spatial patterns of changes in tick-borne diseases. Instead, biotic factors, such as increases in deer abundance and changing habitat behavior as well as socio-political factors, are more likely responsible for the observed changes in tick-borne disease than is climate change.[64]

Altogether, malaria, yellow fever, dengue fever, tick encephalitis, Lyme disease, and other vector-borne diseases either are currently or have been present in middle latitudes. Thus, their vector range is already defined and their geography would not be amplified by an increase in mean air temperature, given the variability in air temperature that already exists. Clearly, other factors such as biotic (e.g., deer abundance, standing water availability for mosquitoes) or socio-political factors (e.g., draining swamps or widespread use of pesticides) are influencing the geographical spread of these diseases in Europe more than the marginal air temperature changes some attribute to human greenhouse gases. Consequently, it is not reasonable to assert that vector-borne diseases will spread poleward into middle latitudes as a result of a warming planet since most vector-borne diseases are not influenced by a mild warming, and their vector range is not affected within their active temperature ranges.

The Linear No-Threshold Theory and Its Relationship to Net Zero

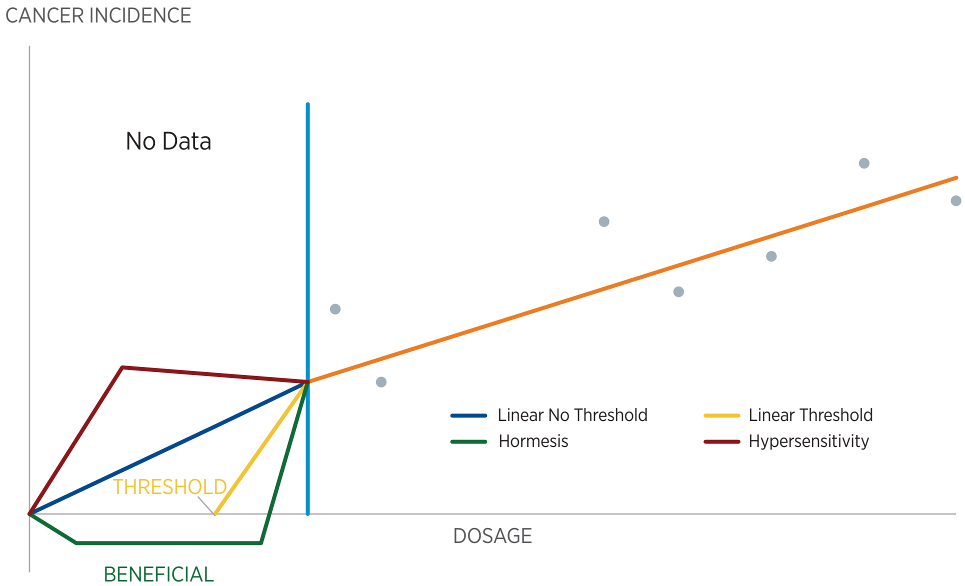
In cancer risk assessments, assumptions must be made between dosage and potential risk since it is not possible to test the response of all possible dosages given the expense and time required. One such assumption, made regularly when determining the potential environmental hazard, is the Linear No-Threshold (LNT) toxicology. Simply put, the LNT assumption is that if a chemical or something else (originally, nuclear radiation) can be determined to be dangerous at *any* dosage, then it also is dangerous at *all* dosages, no matter how small. The "linear" part indicates that all additional risk is presumed to increase the risk of harm in a linear fashion while the "no-threshold" part indicates there is no level below which the risk is alleviated.[65] Taken to an illogical extreme, anything that can be proven to be a danger at any level must be banned at all levels.

The LNT concept was spawned from the consideration of nuclear energy in the United States.[66] During the past 70 years, nuclear energy has gone from exhibiting considerable potential for the production of available low-cost energy to being too dangerous for wide-spread use through the production of radioactive waste and nuclear disasters, to finally being too expensive for wide-spread use owing to current environmental policy. Nuclear energy began as an unknown source of energy in the early 20th century that led to the proliferation of nuclear weapons. This "Ban the Bomb" mentality led to a policy of LNT, which has since become widespread in many medical areas and spawned probabilistic risk analysis.[67] In particular, LNT is based on the extrapolation of studies comparing patients subjected to high radiation doses delivered at a high dose rate to unobserved situations for low doses and low dose rates.[68]

Figure 1 offers a visual depiction of the concept of LNT theory with respect to cancer incidence, but can easily be generalized to other settings as well. As Figure 1 illustrates, LNT theory assumes that below the dosages used in epidemiological trials, the incidence of cancer risk decreases linearly to zero with no dosage (solid line), and zero when there is no dosage for cancer incidence. An alternative choice is the Linear Threshold Model (large-dash line) which assumes there is a threshold dosage below which the cancer risk becomes zero. Hormesis—a biological phenomenon characterized by opposite effects between low and high doses of stressors that can result in stimulatory and adaptive benefits to individuals within a population[69] (represented here by the small-dash line)—is another choice in which there is a dosage below which the exposure is actually beneficial, rather than

FIGURE 1

Epidemiological Risk Data, Observations



NOTE: Graphic is a conceptual diagram.
SOURCE: M. Mancuso et al., "The Radiation Bystander Effect and Its Potential Implications for Human Health," *Current Molecular Medicine, Vol. 12* (2012), pp. 613–624.

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harmful. The Hypersensitive Model (dot-dash line) assumes that dosages lower than those in the epidemiological trials will actually provide a higher cancer risk than observed at the lowest end of epidemiological trials.

Net Zero. In various discussions on climate change, the LNT theory is often employed, promoting a perspective that emphasizes stringent measures to minimize greenhouse gas emissions regardless of any actual data of attributable harm and costs involved. Such is the underlying concept behind *Net Zero*. Net Zero refers to a balance between the amount of greenhouse gases put into the atmosphere (through the combustion of fossil fuels, emissions from cattle feedlots and raising other ruminants, and the production of synthetic fertilizers, for example) and greenhouse gases removed from the atmosphere (through reduction in their sources, carbon sequestration, and natural uptake by forests and oceans).[70]

Underlying the concept of Net Zero is the LNT philosophy laid down more than three decades earlier: no net emissions of greenhouse gases are acceptable. There is no threshold that allows some net production of greenhouse gases such that at any level, the net emission of greenhouse gases at any non-zero level is detrimental to the environment and must, therefore, be stopped. The belief is that since urgent action must be taken to avoid any additional warming of the planet, greenhouse gases must be removed from the atmosphere.[71] When "emissions released by human action are taking a catastrophic toll on our planet and propelling us further into an irreversible climate crisis," no threshold is acceptable.[72]

Carbon Neutral and Gross Zero. It should be noted that the concept of net zero differs from that of *carbon neutral*. Carbon neutrality usually is applied to businesses who use carbon offsets to neutralize existing emissions without a specific reduction trajectory or mandatory targets.[73] The ultimate goal of most who espouse net zero is *gross zero*. Net zero allows for the emission of greenhouse gases, provided they are removed from the atmosphere by either natural or geoengineering means. Gross zero is the effort to reach zero emissions in absolute numbers by removing all sources of greenhouse gas emissions regardless of how much greenhouse gases are removed even by natural means. The ultimate concept of both net and gross zero follows exactly the concept of LNT—there is no threshold of greenhouse gas emissions that are tolerable.

Linking LNT and Climate Change. *Atomic Insights* goes farther in linking the genetic effects of radiation (and LNT theory) to concerns about climate change.[74] The author of the piece, Rod Adams, notes that numerous similarities exist between "What We Know: The Reality, Risk and Response to Climate Change," authored by the American Association for the Advancement of Science in 2014,[75] and the "Genetics Committee Report Concerning Effects of Radioactivity on Heredity," produced by the National Academy of Sciences in 1956:

- Both reports were issued by credible, well-known scientific bodies and were sponsored by organizations with substantial financial interests in shaping public opinion and actions.
- Although uncertainties are noted, both assert the existence of dangerous risks on which humans must take immediate action to avoid.
- Both assert incontrovertible proof of the basic science behind their views.
- Both appeal to a consensus of scientists and nearly unanimous agreement among other qualified scientists.

- Both call for scientists to become activists to warn the public about the dire risks and the need for immediate action.

- Although both acknowledge that the topic (climate change or radioactivity) is a natural process that is exacerbated through human activity, both recommend strict limitations on the activity in the future.

- Both are or were a part of a major public relations campaign designed to change human behavior and perception.[76]

Adams gives several samples from both documents that illustrate the parallelism between the two articles and between climate change and radioactivity policies. He concludes "there is no logical or moral reason to impose too tight a limit on either one."[77] The fallacy of a no-threshold-for-greenhouse-gases policy becomes clearer when the history and fallacy of the LNT theory is critically examined.

Linear No-Threshold theory began in 1927 when H. J. Muller examined phenotypical damages in fruit flies resulting from x-ray exposure, for which he was awarded the Nobel Prize in 1946.[78] It was introduced in radiological risk studies in 1959 and subsequently into general cancer risk. Consequently, the U.S. National Academy of Science recommended use of the LNT model to the induction of radiation-related mutations in somatic cells and, subsequently, to the study of cancer initiation.[79] In low-energy radiation, The United Nations Scientific Committee on the Effects of Atomic Radiation based its radiological protection system on the assumption that the radiation-induced risk was directly proportional (i.e., linear) to the dosage, with no dose threshold below which no risk exists.[80]

About a decade after receiving the Nobel Prize, Muller admitted that he did not discover small mutations in fruit flies with the x-ray exposure for which he was heralded; rather, the high-energy radiation nearly obliterated large portions of their chromosomes. However, his Nobel Lecture argued that no safe radiation dose existed and that the LNT model must replace a threshold-dose-response model.[81]

A Better Rule. An obviously better rule than LNT (and to net zero and other greenhouse gas–reduction strategies) is that of Paracelsus, a Swiss physician and alchemist of the 16th century: "All things are poison and nothing is without poison; the dosage alone makes it so a thing is not a poison" (*Sola dosis facit venenum*).[82] Objective criteria for the proof of causation to be implied from an association or a correlation require:

- Temporal relation;
- Correlative strength;
- Dose-response correlation;
- Consistency (i.e., reproducibility);
- Plausibility; i.e., a reasonable scientific mechanism;
- Consideration of alternate explanation and confounding factors;
- Experimental evidence;
- Coherence (i.e., the association or correlation is compatible with existing theory and knowledge); and
- Specificity.[83]

When applied to low-dose radiation, these criteria do not support the LNT template as applied to low-dose radiation.[84] Consequently, LNT has recently come under attack as a scientific discussion and controversy.[85]

Despite this, the U.S. Environmental Protection Agency wrote: "Biophysical calculations and experiments demonstrate that a single track of ionizing radiation passing through a cell produces complex damage sites in DNA, unique to radiation, the repair of which is error-prone. Thus, no threshold for radiation-induced mutations is expected, and, indeed, none has been observed."[86]

This statement relies on an argument for biological plausibility that is, in fact, contradicted by a knowledge of cancer and its causes—DNA damage is not the explanation for cancer in the majority of types. Instead, modern oncology attributes cancer to the development of hyperploidy and multiploidy in cell lines due to telomeric dysfunction combined with failure of immune mechanisms to eliminate the malignant cell lines (i.e., why aging correlates well with cancer rates).

Scientific evidence has emerged that refutes critical elements of the LNT model, most notably:

> Since the cell is able to repair a very high level of endogenous DNA damage without frequent mutagenic consequences, a further small increment of such

> DNA damage from low dose rate irradiation should, equally efficiently, be repaired. Mutation rates will only increase if due to a higher dose and dose rate the capacity for high fidelity DNA repair is exceeded.... [T]he mechanism which induces "radiation-induced, genomic instability" appears to involve a non-nuclear target and upregulation of oxidative stress, which also is the main mechanism of metabolic DNA damage. These experimental observations are not compatible with a single hit mechanism which is the basis for the microdosimetric justification of the linear-non threshold dose response hypothesis.[87]

It would be reasonable (and correct) to assert that biological effects differ for different levels of exposures, and certainly with ionizing radiation at the low-dose-rate level.[88] Claims of linearity and "no threshold" are contrary to the evidence, making the LNT assumption incorrect. More recent studies examining mutations in fruit flies confirm that the dose-response is characterized by a threshold, or even by hormesis. A threshold for radiation-induced mutations also has been observed in mice, human–hamster hybrid cells, and humans.[89]

Based on the preponderance of recent evidence, the LNT model is an unreasonable choice for extrapolation of risk in low-dose conditions.[90] Its use by the U.S. Environmental Protection Agency has been unreliable and potentially dangerous with regard to assessing radiation-biology interactions and even in general toxicological issues. Its use has led to a society so fearful of radiation and other cancer-potentials that unnecessary steps often are taken and public misunderstanding has led to the elevation of other potential risks (e.g., avoidance of possibly life-saving radiological exams).

Objectively evaluating and incorporating the latest scientific evidence on low-dose, dose-response relationships for application to the regulatory and policymaking process will:

- Ensure a solid scientific foundation for decision-making,
- Reduce unnecessary burdens elicited from inappropriate public scares and panics,
- Provide a needed platform to educate the public on the risks of and benefits from low-dose exposures, and
- Bring governmental policies into line with those recognized by the rest of the scientific community.

This requires pressure on the Nuclear Regulatory Commission through congressional and presidential pressure, education of physicians about low-dose radiation, and a concerted effort to educate the populace through the media and other journalists.[91]

Application of the same principles that govern LNT risk assessment regarding issues in radiology were subsequently applied to health and welfare issues implicated by increasing atmospheric greenhouse gas concentrations and the concomitant resultant effects of climate change.[92] Both efforts have resulted in inappropriate assessments and prioritizations of the risks posed by an increase in global average air temperature and the accompanying climate of the Earth. Instead, a careful assessment of those risks yields no evidence to support the argument that mild climate change will negatively impact human health and welfare; by contrast, higher carbon-dioxide concentrations and longer growing seasons unquestionably do benefit it.

The following section discusses the overarching benefits of affordable energy.

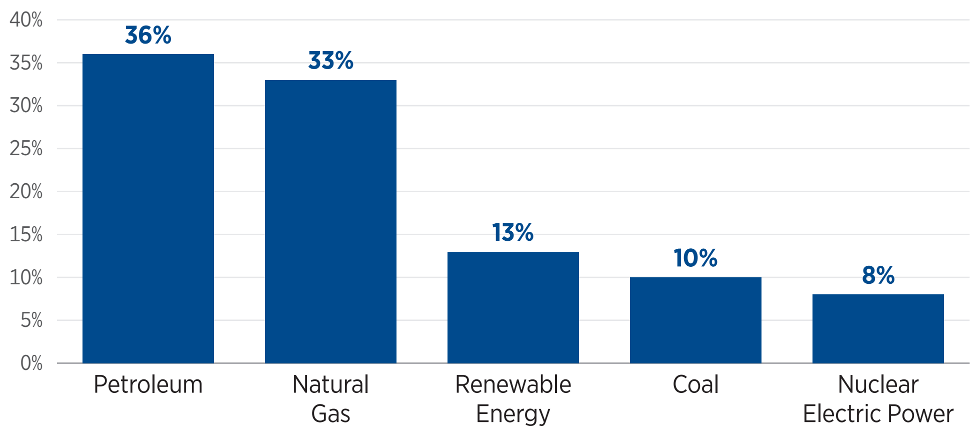
Improving Life Expectancy by Increasing Energy Availability

Efforts to curb global warming, predicated in part by many of the concerns described in the prior sections, hinge on limiting and ultimately eliminating carbon-dioxide emissions from certain forms of energy, as well as other industrial processes and goods of societal benefit. Affordable and reliable energy, however, is the key to the progress and prosperity that makes the quality of life of a modern person better than that of even the ruling class and plutocrats/oligarchs of previous centuries. Energy availability increases global income, availability of goods and services, literacy, leisure time, housing, nutrition, transportation, medical care, welfare, and its best metric—life expectancy at birth.

Life expectancy around the planet has increased dramatically in the past century, particularly because of availability and usage opportunities created by fossil fuel–generated energy, both mobile and fixed-source. Farming and agriculture have been revolutionized by the internal combustion engine and electrical appliances. Fossil fuels provide food stock for products like fertilizers, pesticides, plastics, and other materials that are important to human progress. Fixed and mobile energy sources are essential to farming because fossil fuels provide dense energy sources that can be transported and accomplish much work in a small footprint. No substitute exists for a good tractor in the field and no other alternatives exist, certainly not from

CHART 2

U.S. Primary Energy Consumption by Energy Source



NOTE: Data are current as of April 2023.
SOURCE: U.S. Energy Information Administration, "U.S. Energy Facts Explained," https://www.eia.gov/energyexplained/us-energy-facts/ (accessed July 1, 2024).

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solar or wind sources of energy, despite the demand for electric tractors and other electric farm vehicles.

Unfortunately, regulations designed to abate human-induced climate change often require the unnecessary restriction of energy supplies or make energy more expensive so less will be consumed. In the United States, solar energy, wind energy, biofuels, and other so-called "renewable energy" sources carry concomitant subsidies to make them viable for the producers, which, in turn, raises the cost for ratepayers and taxpayers. Energy sources that do not produce greenhouse gases but which are not solar, wind, or biofuels—namely, nuclear and hydroelectric—are eschewed. This guarantees that the quest to protect the planet from the alleged ravages of human-induced climate change will cause energy to become less available and more expensive.

Clearly, the human health care industry is highly dependent on reliable and inexpensive sources of energy. X-ray and other imaging machines, drug and other medical materials and appliances, surgical essentials, pharmaceutical manufacturing and distribution, as well as computers, monitors, lights, and other necessities rely on readily available energy. Imagine medical care in a civilization deprived of energy sources required to run a modern hospital or medical facility. The importance of energy is why many modern hospitals have back-up generators.

In the modern world, nothing operates without some influence from or an essential contribution of electricity. Eighty percent of modern energy is produced by burning petroleum, natural gas, or coal to turn the turbines inside electricity generators. (See Chart 2.) Running 24 hours a day and seven days a week, a traditional coal, natural gas, or nuclear plant requires about 12.5 acres per megawatt of electricity. By contrast, solar (43.5 acres per megawatt) and wind (70.6 acres per megawatt) arrays occupy vastly more land area and have a much larger negative impact on the local habitat and its environment.[93]

Human Life Expectancy

Fossil fuels are safe, inexpensive, and abundant. They have been, and continue to be, the key to the modern way of life that has dramatically and positively improved the prospects of human health and increased life expectancies across the planet. Two millennia ago, life expectancy during the Classical Age (i.e., the Greeks and the Romans) was less than 20 years of age—with half dying by the age of 10 due to high infant mortality, a low marriage age, and high fertility rates.[94] Note that life expectancies are averages and greatly affected by high infant mortality driven largely by epidemics and abandonment of unwanted newborns. Scheidel further notes that for those who survived to age 10, half lived to be older than age 50.[95]

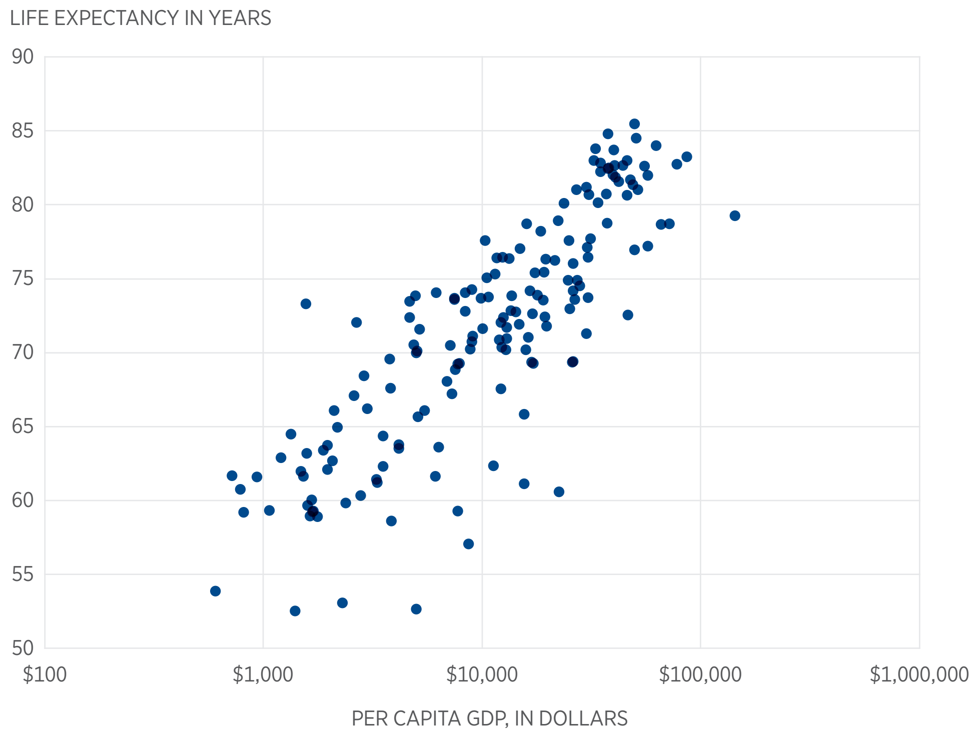
Historical economists Julian Simon[96] and Indur Goklany[97] both demonstrated the long-term trends of prosperity that led to improvements in human welfare and health, food availability, a decrease in famine and starvation, and access to good housing, safe water, and ample food. In constant dollars, the planet's citizens were provided access to a better life that directly resulted from an availability of affordable and abundant energy. Use of fossil fuels was an undeniable factor in that trend.

Epidemics and other calamities have caused frequent historical disasters that led to extensive human deaths that, along with infant mortality, kept the average lifespan below 35 years of age before the 19th century.[98] Although the Romans used coal, for example, the exploitation of the varied forms of fossil fuels and their widespread use during the past two centuries have led to societal modernization, thanks to the distribution of energy throughout cities and to the countryside by railroads, pipelines, the creation of an electricity grid, and then highways.

An interesting graph is the Preston Curve of life expectancy versus Gross Domestic Product (GDP) per capita.[99] (See Chart 3.) The benefit in the rise in GDP per capita by country is evident for the first $5,000 of GDP, adding

CHART 3

Life Expectancy and GDP Per Capita, 2021



SOURCE: Our World in Data, "Life Expectancy vs. GDP Per Capita, 2021," https://ourworldindata.org/grapher/life-expectancy-vs-gdp-per-capita?tab=table (accessed July 1, 2024).

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28 years to the average life expectancy (from 40 years to about 68 years). At that point, life expectancy is very close to what is commonly found in well-developed nations and increases by only about 10 years (from 68 to 78 years) with an increase of about $30,000 per capita. Availability of affordable energy is responsible for the dramatic rise in life expectancy with the first $5,000 of GDP. Nations that are still along the rising limb are all less developed because they are energy- and technology-deprived. Limited access to energy and technology directly impacts living conditions, nutrition, food and water quality, housing, and medical care.[100]

Life expectancy even in prosperous countries is enhanced by movement of the population to warmer climes. The "snowbird" phenomenon[101] occurs around the world, but is particularly prevalent in the United States and Canada. For non-tropical latitudes with populations in more prosperous countries with higher incomes, older and retiring citizens tend to move to and live in locations with less harsh winter locations.[102] This mobility is afforded by a more affluent population that has the ability to move and the money to afford it. A direct consequence is the increase in health conditions and longevity since colder conditions are associated with enhanced morbidity over warmer climes.[103] Increased technological developments have made both warmer and colder conditions more palatable.[104]

Human health and welfare are enhanced by good housing, transportation, nutrition, medical care, and education which, in turn, are driven by the availability of affordable energy. Fossil fuels have been indispensable to the progress of civilization, and policies to prevent energy availability or to make energy more expensive will cause deprivation for the more than half of the world that are called “emerging,” but, in reality, are simply living in conditions that are harsher than they would be if affordable energy were available. For example, indoor plumbing is a convenience of which more than half the world’s population is deprived,[105] clean water is available for only about 75 percent of the world’s population,[106] and while the availability of electricity has risen dramatically in the past few decades, still over 10 percent of the world’s population is without it.[107] Without fossil fuels, any advanced society would rapidly devolve to a horse-and-buggy, wood-burning survivalist society because renewable energy cannot possibly match the affordability or availability of fossil fuels.[108]

However, the main discussion here focuses on the impact of warming that is predicted to occur as a result of an increase in atmospheric CO_2 concentrations that will lead to a warming of 2°C (3.6°F), assuming the most plausible Shared Socio-Economic Pathway (SSP2-4.5).[109] Rather than leading to an increase in disease and a decline in human health, the authors propose that:

- Human welfare and health might benefit from a modest increase in temperature, as indicated by some IPCC statements and other environmental assessments;
- Human welfare and health are typically more adversely affected by decreases in global air temperature since colder conditions tend to result in higher mortality and morbidity than warmer conditions; and
- There is insufficient evidence to support claims that an increased range for vector-borne diseases would lead to significant harm.

Conclusion

Carbon dioxide and warmer conditions are unquestionably good for the development of both humans and plants. By contrast, all else being equal, a reduction in carbon dioxide and a return to colder conditions will harm the human race. Moreover, a mistaken assessment of the relative risk to worldwide health and welfare from mild change in climate to justify a transition to more costly sources of energy will lead to a reversal of the progress that has been made in improving the human condition during the past two centuries, thanks to the development and exploitation of fossil fuel sources of energy.

Fossil fuels have provided both stationary and mobile sources of energy that have proven to be essential to human progress in human health and welfare. No measurable health benefits would follow from reducing carbon-dioxide emissions, nor would efforts to prevent rising temperatures come anywhere near offsetting the benefits of abundant and affordable fossil fuels.

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