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Review

Climate change and society

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Abstract: This paper examines our understanding of climate change, as well as the reluctance of industrial societies to deal with the drivers, especially the burning of the fossil fuels, before the future consequences become catastrophic. We describe how the energy balance of the Earth, oceans, land and Arctic sea ice are maintained, and how climate is warming and changing with increases in the three most important greenhouse gases: carbon dioxide from burning fossil fuels, water vapor from evaporation off a warmer ocean, and methane from several sources. We discuss the Earth's water cycle and the role of evaporation, latent heat and condensation in driving storms, transporting energy poleward and giving increasing precipitation extremes, floods, droughts and fires. We review the increasing challenge of meeting human demand for water as water tables are falling globally from increased pumping, and winter snowpack storage is shrinking. We discuss rising sea level, the challenges of long-term carbon storage and the lessons from the past four ice age cycles. The text is written for scientific and public audiences, both global and in the US, so metric and US units are given. The social, moral and ethical choices are mapped by contrasting the Earth-centered indigenous worldview needed for our survival with the industrial mindset that is willing to destroy a stable climate to keep the profits of the current economy growing. We review the long history of the misuse of human power, the rise of science and technology without a guiding moral framework, and how neoliberal capitalism by default makes choices that are driving rapid climate change. We outline how deceit by the matrix of corporations and fossil fuel interests that we call the Fossil Empire has prevented government regulation for decades and accelerated the climate crisis.

Keywords: climate change; greenhouse gases; water cycle; sea level rise; ice ages; blue river declaration; fossil empire; moral choices

1. Introduction

I have worked as a professional scientist for 50 years, but I also realized 50 years ago that science alone is not enough to deal with pressing global issues, as it lacks a moral framework—it lacks wisdom. So I decided it was also my responsibility as a scientist to develop the skills to map out what drives the social framework and the social assumptions. Traditionally this was not the scientist's responsibility; it was left to those in power, who typically also lack the necessary understanding. For a long time I have been convinced [1] that scientists have a clear responsibility for global issues, since these are connected to the use and misuse of both our science and technology, as well as the misuse of human power.

My title is "Climate Change and Society" and I will cover both explicitly, but in very different ways. Climate change is driven primarily by burning fossil fuels to power our industrial society. Fossil carbon that was sequestered long ago from the atmosphere and biosphere over a hundred million years is now being burnt and returned rapidly to the atmosphere as CO_2, a greenhouse gas. With several feedbacks that amplify, the resulting climate change and a parallel species extinction crisis have brought human society and the Earth to an existential crisis.

A selective set of climate change issues will be described in Section 2, starting with the climate energy balance of the Earth and the role of the greenhouse gases in Section 2.1, followed by a water cycle analysis in Section 2.2. Then in section 2.3 I will discuss sea level rise, the challenges of long-term carbon storage and what we have learnt from the last four ice age cycles. I will say little about the extinction crisis which is the response of the Earth's ecosystem to both climate change and human exploitation. We are able to model with uncertainties the future of the physical climate system, but modeling the future of ecosystem species, both microscopic and macroscopic, is still very difficult.

We are in an extraordinary situation where we have the technical skills to transform our energy system from fossil fuels to an efficient society powered by renewable energy sources. This would stabilize the climate system. However, global society and the web of financial, economic, political and social interests have not acted at all swiftly in the past three decades since June 1992, when 154 nations signed the United Nations Framework Convention on Climate Change (UNFCCC) [2]. In fact, global society on its present path will sacrifice our children and grandchildren and a substantial fraction of the natural world, simply to preserve the short-term profits and the financial interests of the matrix of wealthy corporations and individuals that support the fossil fuel industry. I will name this power matrix, with dark humor, the "Fossil Empire" (Section 3.3).

This raises an immediate issue. The scientific aspects of climate change are well known and some will be cited, but the public writings and comments by the Fossil Empire are at their core deliberately deceptive or misleading. Citing fraudulent material is pointless. My strategy as a scientist is to map out explicitly the conflicting choices for civilization, which are rarely discussed openly, and clarify how and why the Fossil Empire is free to destroy so much of life on Earth for profit. I will reference several recent detailed discussions by others.

In Section 3.1, I will start with a very different frame of reference for our social assumptions, the October 2011 Blue River Declaration [3]: "A truly adaptive civilization will align its ethics with the ways of the Earth. A civilization that ignores the deep constraints of its world will find itself in exactly the situation we face now, on the threshold of making the planet inhospitable to humankind and other species. The questions of our time are thus: What is our best current understanding of the nature of the world? What does that understanding tell us about how we might create a concordance between ecological and moral principles, and thus imagine an ethic that is of, rather than against, the Earth? In our time, science, religious traditions, Earth's many cultures, and artistic insights are all converging on a shared understanding of the nature of the world: The Earth is our home. It will always be our only source of shelter, sustenance, and inspiration. There is no other place for us to go. It follows that the world is worthy of reverence, awe, and care."

Clearly, ten years later, industrial societies have not made this transition to align their ethics with the ways of the Earth, and the climate crisis is deepening. There are pervasive issues here extending back many centuries that are linked to our concepts of human power, control, and the rise of science. I will examine these in Section 3.2 by presenting a contrasting frame, which I call the "Modern industrial mindset." I will discuss its origins, the current role of science and technology, and the abuse of human power and control.

I will confront the deceit issues in Section 3.3 by citing a recent book by Dr. Michael Mann [4], a scientist of great integrity, who was ruthlessly but unsuccessfully attacked for a decade by the Fossil Empire, because he was the lead author on a now famous paper [5]. This paper, cited by the Summary for Policy Makers in the 2001 Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report [6], showed clearly the rapid and exceptional warming of the climate in the past century. Dr. Mann's book outlines in detail both his own experience and the changing multiple levels of fraud and deceit from the Fossil Empire.

2. Climate change science

The climate of the Earth is changing because the Earth is not in energy balance. The mean temperature of the Earth is a balance between heating by the sun and the cooling of the Earth to space. The visible and infrared energy coming from the sun has only a small fluctuation with the 22-yr solar cycle. However, thermal or infrared cooling of the Earth to space is reduced by the atmospheric greenhouse gases (GHGs). As GHGs increase, the Earth warms. The initial driver of the GHG increase is the burning of fossil fuels, which were exploited to power our industrial societies in the last century. The fossil fuels consist of ancient carbon stored underground for hundreds of millions of years. The second driver is that as the Earth warms, more water vapor evaporates into the atmosphere, and because water vapor is a strong greenhouse gas, the Earth warms more. Then in addition, melting of snow and ice reduce the reflection of sunlight, so the Earth warms further.

2.1. The climate energy balance of the Earth

2.1.1. Earth

The Earth's climate is forced at the top-of-the-atmosphere by the short-wave radiation coming from the sun. Some of this energy (about 31%) is reflected directly back to space; this reflectivity of the whole globe is called the planetary albedo. Per unit area, clouds, snow and ice reflect a lot of the sun's energy (60–80%), so any reduction in the fractional coverage of clouds, snow or ice increases significantly how much of the sun's energy can heat the planet (Figure 1).

Figure 1. The sun heats the Earth: clouds and ice reflect sunlight. (4 January 2012, NASA Suomi NPP).

Figure 2. Winter reflection by snow, Pittsford, Vermont.

2.1.2. Land

Vegetation over land has an albedo of only 10–15% for forests and 15–20% for grasslands, so vegetated surfaces absorb most of the sun's energy. However, with snow covering low vegetation, the albedo increases to 50–70% (Figure 2), but not for forests above the snow. Locally in winter, this large reflection of sunlight by snow cover helps lock in cold winter temperatures [7]. Plants use only 1–2% of the sun's energy for photosynthesis to grow in the warm season. A little heat is conducted into the soil in summer, but most of the sun's energy is used to evaporate water, some from wet leaves but most as transpiration by plants. Vapor is lost through leaf pores (stomata) as plants take in CO_2 for photosynthesis. Some energy is radiated back to the atmosphere as long-wave infrared radiation, and some is lost directly to the air by turbulence and convection. Sandy deserts have little water to evaporate, so they get hotter than vegetated surfaces, despite having a higher surface albedo (20–40%).

Figure 3. Oceans and clouds: Sunlight heats the ocean, evaporation cools it, rising water vapor forms clouds which reflect some sunlight.

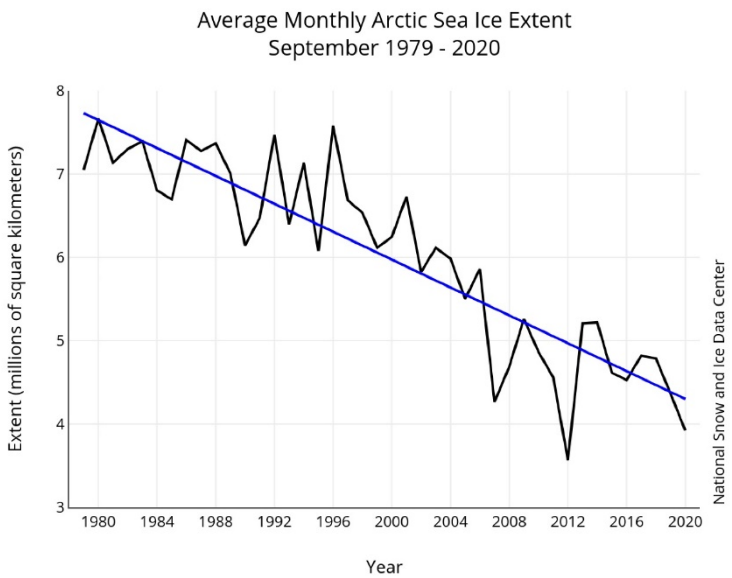

Figure 4. September sea-ice extent from 1979 to 2020 shows the decline. The (linear) September rate of sea ice decline since 1979 has increased to 13% per decade. Image Credit: National Snow and Ice Data Center, University of Colorado, Boulder.

2.1.3. Oceans

The oceans have a very low albedo (8%), so 92% of the sun's energy that reaches the surface enters the ocean, and most is absorbed within a few tens of meters. If there is a lot of plankton, the water is less clear, and the sun's heat does not penetrate as deeply. This heat from the sun is then mixed down further by turbulence (driven by the surface waves) into an upper ocean 'mixed' layer that may be 50-200m deep. The ocean is cooled mainly by the evaporation of water at the surface that increases as the wind gets stronger or the air gets drier. Just as over land, there is long-wave radiative heat loss from the ocean surface; and some heat transfer from water to air.

Figure 3 shows the non-precipitating shallow cumulus clouds that cover most of the tropics. Here the direct losses of heat from ocean surface to the air are small. In contrast the surface fluxes of heat can be very large if cold winter air blows off the continent over warm ocean currents like the Gulf Stream. As water evaporates from the ocean, leaving the salts behind, the ocean mixed layer increases in salinity. Over longer timescales, the ocean circulations transfer heat and salinity from the surface mixed layer down into the deep ocean.

2.1.4. Arctic sea ice

The very large difference between the albedo of the open ocean and of sea ice plays a critical role in the Earth's climate. In recent decades, as the Arctic has warmed, the melting of the Arctic sea ice in summer means that more sunlight is absorbed by the open ocean as less is reflected by sea ice. Figure 4 shows that the September minimum sea ice extent has decreased about 13% per year in the last thirty years. This gives a positive feedback that has accelerated the warming of the Arctic. There is a second positive feedback because water evaporates from the open ocean much faster than from sea ice. The extra water vapor in the atmosphere is a powerful greenhouse gas that also reduces the cooling of the Arctic to space. The increase of evaporation from the ocean has a third impact. Storminess increases, and stronger winds can break up more ice. In decades past, the Arctic sea ice was much thicker multi-year ice that had survived for several years. Now the sea ice is thinner, much of it formed only the previous winter, so it melts more readily in summer [8]. Other processes are contributing to the warming of the Arctic. Soot from airborne pollution from cities or fires darkens the ice [9], which reduces the albedo and accelerates melting. As the Arctic warms, shrubs are growing in the Arctic tundra regions, and this also darkens the surface (Figure 2) and accelerates the regional warming.

2.1.5. Energy balance of the Earth and the greenhouse gases

Solar energy heats the Earth, and the Earth cools to space by infrared radiation, which increases with temperature. To reach balance, the Earth warms up until it can radiate to space the energy that it gains from the sun. This is where the greenhouse gases (GHGs) are important. The GHGs are the gases that strongly absorb the Earth's thermal infrared radiation, so they effectively blanket the Earth (by radiating energy back down to the surface) and reduce the cooling of the Earth to space (because the radiation to space comes from higher in the atmosphere, where it is cooler). The primary GHGs are water vapor, carbon dioxide, methane, nitrous oxide, and ozone (H_2O, CO_2, CH_4, N_2O, O_3), but there are many other industrially produced gases (like the hydrofluorocarbons, HCFCs). All these GHGs are smaller constituents of the atmosphere, although they have modes of rotation and vibration that absorb the Earth's thermal radiation strongly. Most of the atmosphere is nitrogen and oxygen, but these simple diatomic molecules are too tightly bound to absorb this thermal radiation. The GHGs are critical to giving the Earth the warm climate that supports life – without them the Earth on average would be about 32^{o}C (57^{o}F) cooler, and the most of the oceans would be frozen. We will discuss below only the first three of the greenhouse gases: H_2O, CO_2 and CH_4. An excellent review of radiative forcing processes is the IPCC Fifth Assessment Report, Chapter 8 [10].

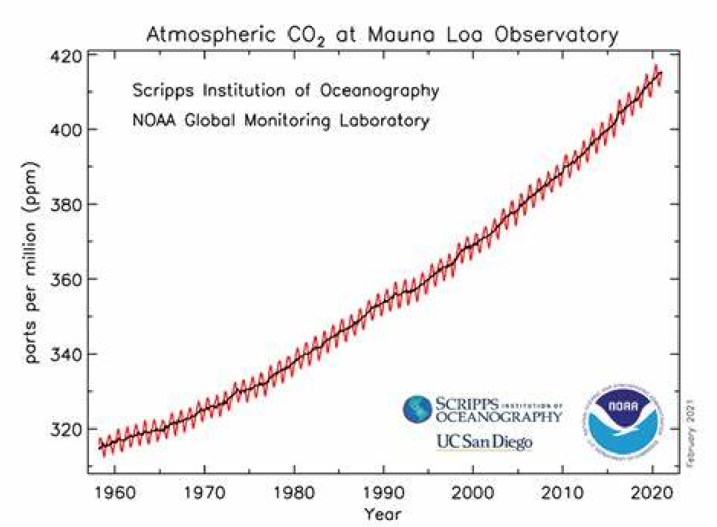

Figure 5. Increase of atmospheric CO_2 from 1958-2020 at Hawaiian observatory. Credit: NOAA/ESRL/Scripps.

2.1.6. CO_2 greenhouse

CO_2 is currently the critical greenhouse gas driving climate change, even though there is much less CO_2 than H_2O in the air [11]. Atmospheric CO_2 is growing rapidly as we burn fossil fuels that have been stored underground for hundreds of millions of years. The concentration of CO_2 has increased 48% in the past 100 years from about 280 to 415 parts per million (ppm). Figure 5 shows the rise at the mountain-top Mauna Loa Observatory in Hawaii since March 1958, when Charles David Keeling [12] started detailed observations. The yearly oscillations are because CO_2 goes up in the northern hemisphere winter when plant respiration dominates giving a net release of CO_2; and down in the summer when photosynthesis dominates and takes up CO_2. In the natural Earth system, before the human impact became large, these were close to being in balance over the annual cycle. However, now the input of CO_2 from burning fossil fuels and other industrial processes is large, and the biosphere and oceans can only take up about half of the human input. Consequently atmospheric CO_2 is increasing every year because this human waste product has a long lifetime in the air—a century or more. Some CO_2 is dissolving in the oceans, which are becoming less alkaline. Some of this ocean CO_2 will be returned to the atmosphere centuries from now, once we have strictly controlled the burning of fossil fuels, exhausted the reserves, or climate catastrophes have triggered the collapse of our industrial society.

2.1.7. Water vapor (H_2O) greenhouse

Water vapor, which varies strongly across the Earth with surface evaporation and atmospheric transports, is the strongest GHG. The Earth's water cycle (Section 2.2) is close to balance on monthly timescales, so atmospheric water vapor increases with temperature on these relatively short timescales. Basically water, evaporated from the surface, rains out in a few weeks and the latent heating from the condensation of water in the atmosphere (which falls out as precipitation) balances the radiative cooling of the atmosphere. This quick response means that the water vapor greenhouse effect has a rather large positive feedback to the climate system temperature: if temperature rises, more evaporation gives more water vapor in the air, and this traps more of the Earth's thermal radiation. The water vapor greenhouse roughly triples the warming by the CO_2 greenhouse.

2.1.8. Methane (CH_4) greenhouse

The third most important atmospheric GHG is methane (CH_4), which has many different sources: some from human activity and some of natural origin. The atmospheric concentration of CH_4 in 2020 is 1880 ppb (1.88ppm) and it has doubled since 1920. This is 220 times lower than atmospheric CO_2 in 2020, shown in Figure 5. However, CH_4 is a much more powerful GHG than CO_2 although its lifetime in the atmosphere is shorter because it can be oxidized to CO_2. Estimates are that over 20 years, CH_4 has about 84 times the GHG impact of the same concentration of CO_2 (see Table 8.7 in [10]).

Global data for the many sources of CH_4 are limited. Many sources are clearly anthropogenic. Leakage of natural gas from gas and oil well infrastructure is poorly regulated, and in-situ aircraft measurements show methane leakage is actually much greater than industry estimates of fugitive emissions [13,14]. A second human source comes from fermentation of sewage and other waste products. A detailed measurement and modeling study of the downstream emissions from the large Eastern Ontario waste treatment facility [15] shows that the methane emissions from this plant are as much as methane emissions from 100,000 dairy cows (Ray Desjardins, personal communication). The agricultural source from enteric fermentation in ruminants (cattle, sheep and goats) has been quantified, and emissions from ruminant husbandry are much larger than emissions from other animal sources of protein such as pork, poultry or eggs [16].

There are two natural sources of CH_4 that may be increasing in a warming world. Over land, large deposits of carbon stored in wet soils can decompose to CH_4, and even larger deposits are frozen in permafrost. Where permafrost is melting, the decomposition of carbon to methane in wet soils will increase, but global estimates are uncertain as soil microbes may break down the methane before it is released to the air. There are also large ancient methane hydrate deposits at depth in the cold oceans. Direct global sampling is very limited, and if more CH_4 is released from these deposits, we do not know how much will be oxidized to CO_2 by ocean microbes before reaching the surface.

2.1.9. Earth's energy imbalance

Because of increasing GHGs in the atmosphere, the Earth at present has a net energy gain [17] of about 1–2 Wm^{-2}. A small part of this energy imbalance goes to melting ice, but more than 90% of the Earth's energy imbalance is being stored in the oceans. Warming oceans are driving stronger storms and raising sea level. The Earth will warm until this imbalance can be radiated back to space. The large thermal inertia of the oceans means there are lags of 50–100 years. Furthermore, the climate system has instabilities and feedbacks [17] that are only partially understood, so there are still uncertainties in our projections for the future climate of the Earth.

2.2. *Earth's water cycle*

The Earth's water cycle is central not only to the Earth's climate, but to all aspects of life on this planet. It is one key component that humanity must understand and where necessary adapt. Water has two roles in the physical climate system and the energy balance of the Earth. The high albedo of snow, ice and clouds is important in reflecting sunlight and cooling the planet. In addition, water vapor is a powerful greenhouse gas, which reduces the cooling of the Earth to space in the infrared. Water vapor in the atmosphere increases rapidly with temperature. The greenhouse gases keep the global mean surface temperature well above freezing. The years 1961–1990 are often taken as a reference baseline, when the global mean surface temperature was 14°C (57°F). Without the greenhouse gases, the Earth would be almost completely frozen, with a mean temperature around −18°C (0°F).

Every degree the Earth warms relative to freezing reduces the snow and ice which reflect sunlight, and increases the atmospheric water vapor, a greenhouse gas. Both these processes are called positive feedbacks because they heat the Earth more as the temperature rises.

2.2.1. Role of latent heat transport

Equally important is the so-called latent energy associated with the phase changes of water. In the tropics, as the sun heats the ocean, the net solar energy flux at the surface is about 180Wm^{-2}. Most of this energy (150 Wm^{-2}) evaporates ocean water, over 5 mm day^{-1}, since it takes about 29 Wm^{-2} to evaporate each mm of water [18]. The infrared cooling of the surface is small because there is so much water vapor in the atmosphere in the tropics. This surface evaporation, which increases strongly with temperature, places a cap on ocean temperatures in the tropics at around 30°C (86°F) in the present climate. Most of the tropics are covered in shallow clouds, as shown earlier in Figure 3. The water vapor rises into clouds where it condenses, releasing this large latent heat back to the atmosphere. In these shallow clouds that do not precipitate, the droplets are transported upwards and evaporate again at the cloud tops, cooling and moistening the warm sinking air [18].

Figure 6. Radar image of Hurricane Irma as it struck St Thomas in USVI on 6 September, 2017 at 2pm AST.

When clouds get deep, their droplets grow and precipitate, which releases the large latent heat of water vapor back to heat the atmosphere, and this energy drives storms. Figure 6 is a radar image, taken from Puerto Rico (center left) of Hurricane Irma as it hit the north shore of St Thomas in the Virgin Islands, (marked with red crosses) on 6 September, 2017. Irma was an exceptionally strong Category 5 storm with 290 kmph (180 mph) winds in the eyewall as it struck the north shore of the island. The hurricane spiral bands are getting their energy from the condensation of the water vapor evaporated from the warm tropical ocean. I was watching the radar closely as my daughter's family are huddled desperately fearful in a small, battered hotel near the southern shore. Their stories of surviving Irma, evacuating to Puerto Rico and then being hit two weeks later by Hurricane Maria have been published [19, 20].

2.2.2. Poleward transports

Some water vapor is transported out of the tropics to supply energy for storms in the mid-latitudes. This is a large energy transport from the tropics towards the poles, which get much less energy from the sun than the tropics. The warm ocean currents, such as the Gulf Stream, also transport a lot of energy poleward. Together these energy transports drive the mid-latitude cyclonic storm systems and at the same time reduce the gradient of temperature and moisture between equator and poles. In essence, the sun's heat evaporates water from the surface; the vapor rises (and some moves poleward) and condenses in the atmosphere, releasing its latent heat as precipitation falls out without re-evaporating. This heating from condensation balances the cooling of the atmosphere by infrared radiation to space. In this way the net radiative cooling of the atmosphere, the surface evaporation and precipitation are coupled together.

The details are complex, and global models are needed to compute the transports of cloud systems, their precipitation, reflection of solar radiation and absorption of infrared radiation, as well as fluxes from the underlying ocean. However, from the perspective of the Earth's climate, this means that the water cycle and net radiative cooling of the planet to space are coupled together, and this coupling changes as the Earth gets warmer [18]. This is because infrared radiative cooling increases almost linearly with temperature, but not as fast as the increase with temperature of water vapor in the atmosphere, which is linked to the almost exponential increase of the saturation vapor pressure with temperature. As a result, our models predict more intense precipitation and storms as the climate warms [21].

In the Northern Hemisphere the Arctic region is warming twice as fast as the subtropics because the Arctic sea ice, which reflects sunlight, is melting (Figure 4). Consequently the north-south temperature gradient is decreasing in the northern hemisphere mid-latitudes, which reduces the strength of the westerly jet stream. Often there are now larger north-south amplitude waves in the jet stream that move slowly, from west to east, and this changes the northern mid-latitude climate [22].

2.2.3. Precipitation extremes and distribution

Precipitation extremes are important for human civilization because they determine flooding and drought. Generally we expect precipitation extremes to increase, because of the steep increase of the saturation vapor pressure with temperature. We see this increase in heavy precipitation across the

U.S over 50 years (1958–2012), with a peak increase of 71% in the north-east [23]. One study suggested that precipitation events now last longer, which suggests slower travel speeds linked to changes in the global circulation [24]. In the tropics there have been several remarkable slow-moving hurricanes that have done extensive damage. Hurricane Harvey was nearly stationary just south of Houston Texas for 4 days in late August 2017, and about 1000mm (40 ins) of rain fell on the city. Slowly moving Hurricane Florence with 635mm (25 ins) of rain produced record flooding in North Carolina in mid-September 2018. A USGS report indicated nine river gauges reported floods exceeding their 1-in-500 year expected return intervals, based on the historic record. In 2019, Category 5 Hurricane Dorian broke the wind-speed record set by Irma in 2017 (Figure 6) for an open Atlantic hurricane, and stayed stationary over Grand Bahama for 24 hours, causing the most catastrophic damage in Bahamian history.

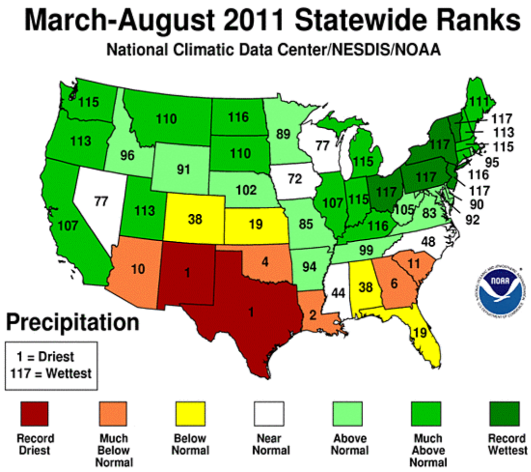

Figure 7. Statewide ranks of precipitation for March-August 2011 (NCDC/NOAA).

Because global rainfall is constrained by the radiative cooling of the planet, heavy rain in one location means less rainfall elsewhere. Similarly more stationary storm patterns bring flooding to some regions and drought elsewhere. An example in Figure 7 is the ranking of precipitation for the six months March to August 2011 for the US states for the 117 years that data were available. The dark red states of Texas and New Mexico, labeled 1, had the driest six months on record, while the dark green states from Ohio to Vermont, labeled 117, were the wettest on record. Clearly most storms for this period tracked across the northern US, not the south. Within this six months Vermont had two record floods. In the spring, heavy rain fell on a melting winter snow pack. Floods in both Vermont and New York, which border Lake Champlain, pushed the lake above flood stage for 67 days, reaching a new record flood level on May 6. In late August, after a relatively wet summer, tropical storm Irene move up the east coast across Vermont and also produced record flooding that cut off 13 towns [25].

This extreme drought in Texas in 2011 drove record wildfires covering 0.4 million hectares (Mha), the harbinger of the extreme wildfires that would come globally by the end of the decade in regions of drought. In 2020, California had fires covering 1.66 Mha (4.1 million acres), the Australian bushfires for the season 2019-2020 scorched a staggering 18.6 Mha and the vast Siberian fires in 2020 burnt through 20 Mha (49 million acres) of the Russian landscape.

Figure 8. Forests after rain with fast evaporation from wet canopy.

2.2.4. Precipitation over land

Vegetation can provide a buffer over land in moderate precipitation events. Vegetation cover intercepts precipitation, so that some is evaporated quickly back to the atmosphere, as shown in Figure 8. Generally a vegetative surface is more porous and may have surface organic litter, which increases recharge of ground water and aquifers, and reduces surface runoff. In tropical forests, the rooting systems transport water down in the rainy season and back from deep soil reservoirs in the dry season, so that they have a dependable water source, even if there is insufficient rain to meet evaporative needs for six months. Their survival depends on this local efficient management of water. Maintaining evaporation also stabilizes temperature year-round.

2.2.5. Human demand

In contrast, the human system approach to freshwater issues is to try to supply human demand, which in many regions already exceeds local supplies—and continues to grow. Rivers are dammed to supply towns and agriculture and to provide hydroelectric power. However, reservoirs of open water in dry climates experience substantial losses from evaporation and over time fill with silt. For crop irrigation, deep aquifers are also pumped. But the water in deep aquifers is only replaced on timescales of centuries, so globally water tables are dropping [26]. In many tropical regions, runoff water from roofs is stored in tanks to last through long dry seasons. This is a useful reference point for human water use: matching annual use to precipitation on the roof. An annual rainfall of 760mm (30 inches) on a 100 m^2 (1080 ft^2) roof supplies 76000 liters (20000 gals) of water. This corresponds to 210 liters or 55 gals per day, which is typical of per capita indoor household use in the US. Many drier regions have less annual rainfall.

The key lesson from natural systems is that the best water storage is groundwater. Good practice for all urban water management is to maximize infiltration, rather than accelerate runoff. Slowing runoff and maximizing infiltration are often critical issues for land management and agriculture (except where soils need drainage), since doing so reduces topsoil losses and also increases groundwater storage. This becomes even more essential in a warmer climate, as rainfall rates rise with temperature, extreme precipitation events become more frequent, and periods of drought may also become more common. Maintaining a shrub or forest land cover is generally a good solution. Ironically, hydrologists have sometimes been ambivalent towards forests historically, precisely because they reduce the runoff for human use.

The cold season storage of water as snow and ice in mountain snowpacks is important in many regions, as spring and summer melt then supplies water for human use though summer dry seasons. This supply is vulnerable to a warming climate. As the freezing level moves to increasingly higher elevations, snowpack storage may be reduced because more winter precipitation falls as rain and less as snow. Spring melt will come earlier, leaving less water storage into the summer.

There is little human society can do about global and regional changes in the water cycle, except adapt more intelligently to them—and of course reduce the drivers of climate change. Water is a renewable resource, but local and global supplies are finite, and many regions have a strong annual cycle of rainfall. As in many areas of our society, more can be gained cheaply by using water more efficiently (and recycling it) than by trying to meet virtually unlimited human demand. However, a good strategy for land-use planning would be to build, contour and plant to maximize ground storage of water.

2.3. Long-term issues

Climate has several timescales: current short-term extreme events and ongoing decadal shifts. Sea level rise is already causing flooding of low-lying islands with storm surges and high tides, and extensive coastal areas will be see flooding later this century. Many carbon cycle processes have slower components because they are coupled, for example, to forest growth as well as human management. There are also important lessons on climate going back through the ice ages of the past million years, long before the current human impact.

2.3.1. Sea level rise this century

Sea level is rising for two reasons. The energy imbalance of the Earth is mostly stored in the oceans, and sea level rises with the thermal expansion from this ocean heating. The second process involves melting of grounded ice. The water released flows down into the ocean, which raises sea level. The melting of floating sea ice does not raise sea level. Satellites directly measure the height of sea level, and global mean seal level from 1993 to 2020 has been rising about 3.3 millimeters per year, which is only 33cm per century or a little over one foot. Currently about a third of this rise comes from melting of grounded ice. However, models suggest that as the global temperature rises, the melting of glaciers into the ocean from Greenland and Antarctica will increase substantially, and the sea level rise this century might be much larger, depending on GHG emission rates.

As sea level rises, low-lying islands become flooded and uninhabitable, and salt water also intrudes into low-lying lands. Coastal floods come with high tides and storms, and storm intensities are increasing as the oceans warm. A separate issue is that coastal flooding depends on the relative rise of sea level. Some inhabited coastal land is sinking, from both natural causes and human causes, such as the pumping of ground water [27]. Globally, there are complex continuing changes in elevation with ongoing uplift where thick ice sheets melted at the end of the last ice-age, and new uplift where ice sheets and glaciers are now melting.

2.3.2. Long-term carbon storage

We will not discuss the carbon budget of the Earth in detail. As discussed in Section 2.2, the growth of vegetation by photosynthesis is coupled to transpiration and the water budget. The long-term storage of carbon in trees and in the ground is one important way to reduce the atmospheric CO_2 released from burning fossil fuels. But this balance depends on the complex biosphere carbon cycle and Earth system processes that are impacted by both climate change and extensive human intervention. Unfortunately human society typically exploits the biosphere with little understanding of how this fully coupled complex system responds as it adapts to a globally changing climate.

In broad terms, higher atmospheric CO_2 changes plant photosynthesis. At middle and higher latitudes, warmer temperatures and a longer growing season increase gross primary productivity (GPP), which means more uptake of carbon by vegetation that is beneficial in reducing climate change. However in the tropical forests, GPP appears to be decreasing, because of increased water stress at higher temperatures [28]. So the Amazon forest that was a sink for carbon may be losing this role. A related factor is that when trees grow faster they usually die younger. In addition, the felling of the Amazon forest for agriculture and development continues, and has been increasing in the last few years. This puts carbon back into the atmosphere and also impacts the regional climate, as evaporation from crops falls off in the dry season.

2.3.3. Ice-age message

The ice-age records of the past million years show that some strong positive feedbacks exist in the Earth system on long timescales, long before human civilization. For simplicity, Figure 9 goes back just 400,000 years through four ice age cycles. On timescales between forty and a hundred thousand years, changes in the inclination of the Earth's axis and the geometry of the Earth's orbit around the sun give small changes in the solar radiation reaching the Earth (15–20% at 60°N in June). These small radiative changes are amplified by the climate system because of changes in the ice sheets and in the greenhouse gases on long timescales to give variations of temperature at the poles of order 10°C (18°F).

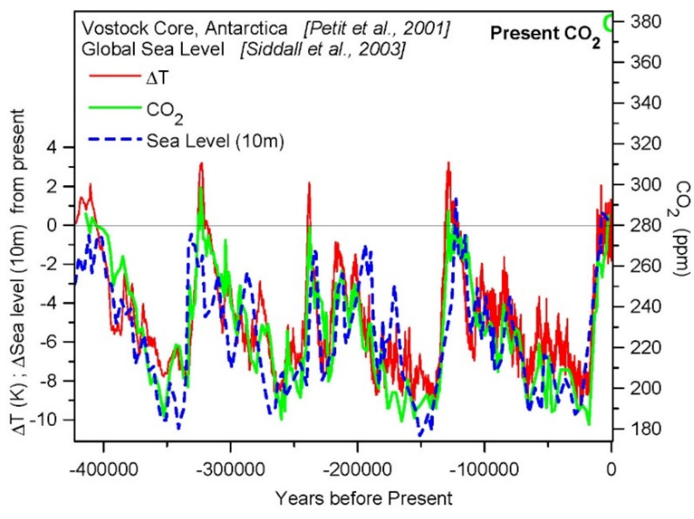

Figure 9. Changes through the ice ages of Antarctic polar temperature, atmospheric CO_2 and sea level (in 10 m) [29,30]. Graph was drawn in 2003 and "Present CO_2" has risen to 415 ppm.

During glacial maxima, ice sheets grew to more than double their present size, reflecting much more sunlight and lowering sea level by as much as 100 m (330 ft). Ice-age cycles appear to have ended during periods of higher solar radiation in summer at northern latitudes; with ice-sheet collapse taking only a few thousand years, and sea level rising again about 100m. On these ice-age timescales, as temperature dropped, CO_2 fell from 280 to 180 ppm, with the weathering of rocks and transports of carbon into the deep ocean; and methane fell from 700 to 350 ppb (not shown). Solar forcing was the driver (not the burning of fossil fuels!), but changes in the three GHGs (H_2O, CO_2, CH_4) greatly amplified the global climate change just as they are doing now.

However, the anthropogenic increase in atmospheric CO_2 that is driving the present climate shift is much faster than any of the natural Earth system processes seen in the ice-age cycles. We are witnessing a large amplification, as declining ice cover reflects less sunlight, and the increasing water vapor greenhouse traps more of the global long-wave heat radiation. But the Earth's temperature and atmospheric CO_2 are now much higher than during the ice ages, so it is hard to predict exactly what will happen to the Earth. It has been millions of years since the Earth's atmosphere had 400-500 ppm CO_2 (which we are again reaching), and then the Earth may have had no ice caps, as well as a very different climate and vegetation. This is why Hansen [17] has suggested that atmospheric CO_2 should be brought back down below 350 ppm as soon as possible. Figure 9 shows that this is still well above the highest interglacial values.

3. Social framing

As outlined in the introduction, discussing the social framing of climate change is very different from discussing the science. The social assumptions of societies across the world differ. For a low-lying island nation in the Pacific, rising sea level is an imminent threat. For an oil company in the US, action on climate change is a threat to its business and profits. This section will spell out some of the key issues and differing perspectives on the Earth, and on our financial, economic and political structures, and how our concepts of human power and control differ from the indigenous mindset. The focus will be on industrial nations that are responsible for climate change, and especially on the US. We will end by using my experience in the state of Vermont to illustrate how the transition to renewable power is possible.

3.1. Blue river declaration

The Blue River Declaration [3] was quoted in the Introduction. The first lines say: "A truly adaptive civilization will align its ethics with the ways of the Earth. A civilization that ignores the deep constraints of its world will find itself in exactly the situation we face now, on the threshold of making the planet inhospitable to humankind and other species."

This is a succinct definition of our global predicament in the face of climate change driven by burning fossil fuels. However, it is not the frame of reference for industrial societies that are guided by money and power, instead of ethics. The Blue River Declaration continues "The Earth is our home. It will always be our only source of shelter, sustenance, and inspiration. There is no other place for us to go. It follows that the world is worthy of reverence, awe, and care."

This is the framework of indigenous peoples who live embedded in the natural world and treat it with reverence, care and wisdom. Understanding this ethical framework is critically important for modern society [31], because our technology cannot replace the Earth and its coupled living infrastructure. However, this understanding clearly conflicts with the framework of industrial societies that mine the Earth for minerals and fossil fuels needed for economic growth and strip forests for crops and livestock. With a growing human population and an economic system tied to growth, the carrying capacity of the Earth is approaching, along with the climate crisis.

3.2. Modern industrial mindset

As a contrast to an ethical framework aligned with the ways of the Earth, we will review the modern industrial mindset. Our industrialization developed with the rise of science and technology, and it has been powered by the fossil fuels—initially with steam engines fueled by coal. But the mindset that has given us such power has an important history that is rarely discussed.

3.2.1. Origin of the western mindset

The key concept that humans have power and control over the natural world is an ancient one that can be found in some translations of the Old Testament. It was not, however, part of the holistic teachings of the indigenous Aramaic prophet Yeshua (whom we know as Jesus) [32]. His indigenous teachings were not framed in terms of human power, but in the understanding that the Creator was within all Creation. Our task as humans was to join with Him and the Creation, so we could see the truth of the web of life that would set us free to act on behalf of the Creator—not human self-interest.

When his wife converted to Christianity, Emperor Constantine summoned the Christian Bishops from across his empire to the Council of Nicea in 325 AD, and explicitly told them to reject the Aramaic gospels in favor of the Greek Gospels. The Greeks, despite their polytheism, believed in the power of rulers over the people and people over nature. Christianity as the Roman Catholic Church was essentially reframed in simple doctrinal terms within the power framework of the Roman Empire. Many Jewish and Assyrian Christians, who understood the original Aramaic gospels, perished as heretics over the next two centuries. In time the persecution of the Jewish Christians shifted into the persecution of the Jews. For those of the Judeo-Christian faith, it is critical to understand this background of how the indigenous teachings of Yeshua were suppressed, because these teachings are now one of the keys to the survival of the living Earth. One good way to connect deeply to the living Earth system and the Creation is to sit quietly in the natural world and surrender until you become connected. This is not easy for the modern western mindset because of the contrary belief of "fight, fight and never surrender".

In Western Europe throughout the medieval period, the Catholic clergy controlled society, until Western Christianity started to fracture into Catholicism and Protestantism, starting with Martin Luther in 1521. The Protestant groups looked back to the Old Testament view of human power over the natural world. In the next few centuries, the European colonial powers, backed by Christianity, crushed the indigenous people's worldview, probably unaware that it was the perspective of their indigenous teacher Yeshua. They also embraced white (male) supremacy and slavery, based on a belief in the inferiority of black people.

At the same time that Christianity fragmented, science started the long process of becoming independent of religion, which took centuries. Observations of the heavens, the Copernican heliocentric model in 1543, Kepler's laws of elliptical planetary motion and Galileo's observations of the moons of Jupiter in 1610 all conflicted with and in time replaced church doctrine. Isaac Newton's treatise on classical mechanics (Mathematical Principles of Natural Philosophy 1687) is viewed as a marker for the independent rise of science, even though his practice of alchemy and understanding of the occult was later shunned by scientists. However, as science developed, it has continued within the power framework of human superiority over nature, which is contributing directly to the climate and extinction crises.

In recent times, the view of some Protestant and Evangelical Christian groups that humanity is charged with subduing the earth has meshed well with capitalism [33]. A second evangelical belief that the end-times are coming by 2050 can make climate change concerns seem irrelevant. Indeed some believe God, not man, is responsible for the climate.

3.2.2. Current role of science and technology and capitalism

Much of our present human world is driven by science and technology. Science is a good frame for understanding the technological world we made and for exploring the complexity of the living natural world. But science is not useful for addressing social values and making moral choices. The historic framing of science was that understanding came from collecting facts, but without the direct indigenous understanding of the web of life, there is no basis for wisdom. The Indian sage Sri Aurobindo in 1920 phrased this rather starkly: "Science gathers facts and thinks it knows, but wisdom as she walks hears the echo of her solitary tread on the shore of an infinite ocean."

In this void, choices are made implicitly by society's guiding economic frame, which is capitalism. For decades the free-market ideology of capitalism has been neoliberalism, a political framework based on privatization, deregulation, globalization, free-trade, austerity and reductions in government spending. Simplified, neoliberalism is a façade with the goal of increasing short-term profits for the private sector within a consumer growth economy under tight political control. Immense wealth has been created for some, and the human population has increased until our global impact is reaching the Earth's carrying capacity. Now climate and extinction catastrophes are rapidly approaching, simply because this economic system does not accept responsibility to pay for future costs unless mandated. In principal this could be corrected within the neoliberal framework by placing a rising price on burning fossil fuels, since we have estimates of the vast future damage to society from climate change. This economic trigger would help drive the shift to renewable sources of energy and amplify downstream savings. Clearly without including a realistic estimate for future costs, burning fossil fuels is an unregulated misuse of technology.

However neoliberalism is also a mindset that has manipulated the thinking of both politicians, businesses and the public. A recent book [34] discusses how neoliberalism has encouraged the individual sense of entitlement and the uncaring part of their human psychology over the reality of our interdependent relationships with each other, and our connections with external realities like climate change. This helps businesses encourage individual consumption, and talk about environmental issues without any sense of collective responsibility. The broader neoliberal mindset has a natural overlap with the mindset of the Fossil Empire, which will be discussed in section 3.3.

3.2.3. Abuse of human power and control

Power and control over the natural world now includes power and control over people, specifically the poor and underprivileged (who effectively replaced slaves). In other words, the rich and powerful corporations and individuals exploit both the Earth and the poor, both those living within the industrial nations and those living more sustainably in less developed countries. There are some laws limiting the abuse of humans, after centuries of abuse of slaves and women, but the struggle for ethical standards to limit the abuse of the Earth is only beginning.

As Pope Francis said: "Our increased power has not been linked with deeper moral values, and a true sense of our common home and common destiny" [35]. He pointed out that the exploitation of the Earth and the exploitation of the poor by the wealthy are now intertwined.

Power and wealth are indeed deeply linked in society. Capitalist economics focus primarily on maximizing current quarterly profits and on growing the consumer economy. Only a few socially responsible businesses, connected with their communities, promote a more just and sustainable world. Simply maximizing profit means minimizing costs, and that means exploiting people, and also dumping waste streams at the lowest possible cost. Unless mandated by society, capitalism typically places no value on the future, which is deeply unethical, since currently it means sacrificing our children, grandchildren and the Earth itself.

Mismanagement of industrial waste streams is a large problem. Society has partially regulated the current pollution of air and water to reduce sickness and death in local communities, although air quality inside buildings is largely unregulated. However the recent ex-president ordered the EPA to roll back automobile efficiency and GHG standards that were a decade old. Burning fossil fuels for energy puts billions of tons of carbon dioxide into the global atmosphere and oceans every year that had previously been stored underground for hundreds of millions of years. Since 1950, CO_2 has grown nearly 40% in the atmosphere, where it lasts as a GHG for decades to centuries. As the oceans warm, more water vapor, a powerful GHG, evaporates and triples the warming. The Arctic polar ice melts in summer and snow melts faster in winter and spring, so less sunlight is reflected.

Collectively these changes drive rapid change in both global and regional climate. The global downstream costs are huge, probably in the hundreds of trillions of US dollars. However, society has refused to place a rising cost on burning fossil fuels, primarily because of deceptive propaganda from the fossil fuel industries, who are concerned about reduced profits (Section 3.3). Dumping CO_2 on a massive scale into the atmosphere at little current economic cost is a clear ethical abuse of our technology, as it will destroy so much this century, both human lives and infrastructure, as well as the large-scale extinction of species. Adding a substantial escalating cost to burning fossil carbon could be transformative, if the money is used to build renewable energy systems.

As climate change accelerates, each year brings new and different disasters. Short-term repairs and fixes are essential, but the long-term drivers are harder for society to confront. Some social conservatives long for the stability (and mythology) of the past, and fear change so much that they turn to climate change denial. On the other hand, others think control should be possible using science and technology to geo-engineer the Earth, but this may be pointless if we do not phase out burning fossil fuels in the next decade or so.

3.3. Fossil empire

I chose the term Fossil Empire to discuss the role of the fossil fuel industry and its industrial allies in driving the climate and extinction crises that have come from burning fossil fuels. The Exxon senior scientist James Black identified and modeled correctly the impact of doubling CO_2 on global climate in 1978, more than 40 years ago. He speculated that "present thinking holds that man has a time window of five to 10 years before the need for hard decisions regarding changes in energy strategies might become critical" [36]. Exxon suppressed his report and started insidious campaigns to confuse the public and politicians that are still ongoing [37]. By 1989 the company had helped create the Global Climate Coalition (disbanded in 2002) to question the scientific basis for concern about climate change. It also helped to prevent the US from signing the international treaty on climate known as the Kyoto Protocol in 1998 to control greenhouse gases [36].

Historically for many decades, the US military and economic dominance had been closely tied to the control and access to global oil supplies [38]. The US kept the price of oil low until the OPEC oil embargo of 1973. The power of the US oil monopolies effectively ruled government policy for much of the past century, rather than the reverse. Exxon's strategy in the 1970s and 1980s continued this, and remarkably it is still true decades later. A clear example was the 2003 attack on Iraq, which despite lies from the US and the UK governments, was an attempt to get stable access to Iraq's oil production [38].

One of the central reasons why there has been so little progress in moving away from burning fossil fuels, despite IPCC Assessment Reports going back to 1990, has been the continued opposition of the fossil fuel companies, most of it hidden from the public [37]. Strategies for this deception have changed with time. In recent decades a conservative climate change counter-movement has developed both in the US [39] and a similar one in Europe [40] which merges the interests of the Fossil Empire and neoliberalism in delaying government and international action on climate change. One strategy uses media articles and advertising to suggest that individual and corporate actions are sufficient. Concealing their funding sources behind donor directed funds, like the Donors Trust, helps protects conservative organizations and businesses from criticism by those who understand the climate crisis. In parallel the direct bribery of conservative politicians is ongoing. A recent study [41] found that it cost the Fossil Empire only $61 million to bribe 139 Republicans in the US Congress to publically lie and deny climate change: an average of only $442,000 per politician.

For this paper I will summarize some ideas from the recent book, 'The New Climate War' [4], by Michael Mann, an excellent scientist.

3.3.1. The new climate war

As a young scientist, Dr. Michael Mann happened to be the lead author of an important paper [5] that used tree ring data from around the world to show the mean temperature change from the years 1000–1996 AD. This key figure was given the name "hockey stick", with the upturned blade showing the steep temperature rise in the past century after nine centuries of slow temperature decline. The Summary for Policy Makers in the 2001 IPCC Third Assessment Report included this figure to illustrate recent climate change, as its message was unambiguous to the public. The Fossil Empire reacted with horror, and with vengeance attacked and harassed Dr. Mann and his research for about ten years. He was exonerated by his institutions, and he has continued to examine in detail the patterns of deceit from the Fossil Empire. In the following paragraphs I will summarize some key points from his book [4].

For decades, the Fossil Empire, following Exxon's strategy since the 1970's, simply denied the reality of climate change, or denied that fossil fuel combustion was the primary driver; that is, they consistently lied to the public to protect their huge profits. Their central goal has been and continues to be to prevent any systematic government regulation and phase out of fossil fuels. Mann describes their policy as "inaction" and calls them "Inactivists". In the past decade as climate disasters of many different kinds have mounted around the world, simple denial looks obviously dishonest, so the Fossil Empire strategy has shifted to deflection. This strategy has been widely used to shift issues from corporate responsibility to one of individual personal responsibility. For example, drink companies were able to prevent bottle bills in most of the US, by shifting the issue to the responsibility of individuals to pick up their litter. So locally we pick up litter in spring, but we have global plastic pollution in the oceans, because there is no corporate obligation to manage this waste stream.

It is our collective and corporate way of life that is driving climate change, but the Fossil Empire can be freed of corporate culpability by deflecting the issue and saying that changing our individual behavior is the best way to solve it. Covertly selling this strategy has been an immense success, as it also opens a wide field for divide and rule, and finger pointing. Climate activists can be encouraged to argue over whether one should travel less, buy an electric car, install solar panels, eat a vegetarian diet, have fewer children or live a simpler life. The list is endless. This strategy has been very successful in deflecting attention from what needs to be done at a collective level to the individual level, where people can either feel they are taking useful steps, or instead perhaps feel guilty. Of course changes are needed at both a collective societal level and in individual actions and choices. In the US where I am writing, deflecting and reframing the climate issue in terms of individual freedom is easy. At the same time, conservative interests that oppose collective action to reduce fossil fuel use can also be encouraged by framing collective action as socialism.

But just as genocide was only clearly defined as a crime after the fact, ecocide will only become a crime when we recognize the rights of life on Earth. The flagrant immorality and deceit of the Fossil Empire and its political supporters will haunt the hundreds of millions who will die this century in disasters from climate change.

3.4. Simple technical solutions

I will close this review of social issues by illustrating the simple beauty of well-managed technical solutions, based on my direct experience in Vermont with electrical power generation and plug-in transportation. Initially I moved to Vermont from academia in 1978 and built a passive solar post and beam home. The location was quite remote, with no electric power. It was much cheaper to install 200 W of solar panels and a bank of eight 6 V deep storage batteries than pay for a mile of electric power lines. This gave me basic 12 V power for lighting, and with an inverter, 120 V power for electronics and computers, as well as a washing machine. The well-insulated house faced south and had both a wood stove and wood-fired cooking stove that also supplied hot water for a tank upstairs by convection. Water flowed downhill from a spring to the house. I cut the wood for the two stoves and had no electric bill. I could run two computers and do climate research. I lived there for ten years, grew vegetables and developed an appreciation for the basic principles of simpler living.

However, in 1991 I moved to a house dating back to 1846 that needed extensive renovation for basic utilities, like wiring, heating and plumbing, as well as more insulation. I considered again installing my own solar panels, but there were too many large old trees surrounding the house. Fortunately, in the past decade, the State of Vermont and the local utility encouraged community solar arrays, integrated into the grid. For the first ten years, these pay retail electricity rates plus a bonus of a few cents per kWh for generating solar electricity. In 2015 and 2016, I purchased solar panels in a local community array, with a total solar electric output of 5.8 kW peak at a total investment cost of US $18,240. Each year these provide on average all my electrical demand. After adding the utility fixed costs, this solar generation credit covers about 80% of my electrical bill. The tax-free return, computed as annual solar credit over total investment, is 7.3%, averaged over the past 4 years. After the first ten years, this return will drop to an estimated 6% for the next ten years. This is clearly a good investment for me as well as the Earth. The federal tax credits went to the developer.

I had driven a Prius hybrid car for many years, simply because its gas consumption was close to 4.70 litres/100km (50 mpg), roughly half that of most gasoline cars or small trucks. Having solar electricity, we purchased a plug-in Prius Prime in late 2016 and have now driven it for 4 years. Its all-electric range is only about 48km (30 miles), a little more in summer and less in winter. Yet after driving 72,400 km (45,000 miles) in 4 years, it has averaged 1.57 litres/100km (150 mpg). This is highly significant, as it has reduced our fuel use by a further factor of three to only 17% of a typical small gasoline car. Much of our driving is local and therefore all-electric, but electrical energy recovery when slowing down or descending hills leads to greater efficiency in all driving. One long distance trip we made through mountainous terrain from Vermont through the Canadian Atlantic provinces to Nova Scotia illustrates the remarkable overall efficiency. We drove 3380km (2100 miles) in two weeks, plugging in overnight at 110 V for a 6 kWh recharge, and we averaged 2.87 litres/100km (82 mpg). Maintenance is much less than for gasoline cars (we will change sparkplugs at ten years), and the new lithium storage batteries now have long warranties. I also have an electric-assist bicycle for short trips where a car is not needed.

Figure 10. 2017 Prius Prime plug-in hybrid.

I use these examples to show that local investments, fully supported by the utility and state government, are simple, inexpensive, and profitable for all the parties involved. They illustrate two key transitions away from fossil fuels: to solar electricity, and the transition towards electric vehicles. Plug-in hybrids can reduce gasoline use by up to 80%. It is the hidden propaganda from the Fossil Empire that has limited rapid implementation of technologies to speed the transition away from fossil fuels in the US.

4. Conclusions

The climate crisis we face is an exceptional one for both humanity and the Earth itself, and it needs exceptional clarity for all audiences. It is an existential crisis for humanity and more broadly for life on Earth. We do not get a second chance if we continue to refuse to pay attention and act—as society has done for decades.

I have mapped out the key climate change issues for this century. The Earth is warming as the energy balance has been changed over land, oceans and ice sheets by the burning of fossil fuels to CO_2, a greenhouse gas, which slows the cooling of the planet to space. As the Earth warms, evaporation increases water vapor, a stronger GHG, and the northern ice sheets are melting, reflecting less sunlight. As a result, the Arctic warms faster than the tropics and this changes the mid-latitude circulations. Along with rising temperatures, this circulation change has altered the water cycle, and increased the frequency, intensity and duration of extreme events, hurricanes, floods, droughts and fires. Rising sea level from the warming oceans and melting ice sheets is a critical long-term issue for coastal regions and low-lying islands. Large uncertainty remains in the complex carbon cycle that is linked to photosynthesis and transpiration in the biosphere as the regional temperature, humidity and CO_2 of the climate system changes.

The social, moral and ethical issues have been mapped out by contrasting the Earth-centered indigenous world view that is needed for our survival with the industrial mind-set that is willing to destroy a stable climate to keep the profits of the current economy flowing. I briefly review the long history of the concept that humans have power and control over the natural world, and the misuse of this power by science and technology, as well as by industrial societies and capitalism. Neither science nor capitalism have a guiding moral or wisdom framework. Society's choices are largely based on the needs of neoliberal capitalism to expand and make profits, and exploit both people and the Earth in the process. So the climate crisis grows.

Capitalism places no value on the future unless society demands it. The cruelty of this to future generations is clear, and rebellions by perceptive youth are underway. However so far the Fossil Empire and its conservative neoliberal supporters have succeeded in controlling the political and public mindsets to slow the national and global phase-out of the fossil fuels. Their strategies have involved skillful webs of lies to conceal the urgency of what we face, and an effort to encourage the individual to feel responsible for changing behavior. Their attitude is that governments can make future promises but have little obligation to act on them. Scientists have started to speak out about the mythology of net-zero promises [42] while atmospheric CO_2 continues to rise. However most of the academic climate science community is effectively forced to stay out of politics by the political system which funds research. Forty-five years ago I objected to the fraud implicit in this separation [1]. There is little possibility of funding to address the central issues of corruption and deceit in the political and economic system that has driven the climate emergency for decades.

We showed how in Vermont with a favorable mindset and carefully managed incentives, the transition away from fossil fuels is relatively easy and inexpensive for electricity and light transportation. Indeed globally we have the technology to drive rapid change. However a huge effort is needed to change mindsets across the US to embrace change and the associated transition costs.

Manipulated by skillful propaganda, many are unhappy at the prospect of climate action driven by local and federal governments after decades of inaction. In the US it is especially difficult as the political right, which controls about half the States, largely believes webs of lies that debunk the climate crisis. It requires skillful leadership by elites, to explain the real consequences of delaying action, and large shifts in values and preferences towards an understanding of the indigenous mindset towards the Earth, which we have presented only in brief outline. We will see whether the current US administration is able to create and rapidly implement realistic visionary solutions. The Earth will manage the climate crisis, but the industrial nations have a clear choice: cooperate with the Earth or collapse is likely.

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Conflict of interest

I declare no conflict of interest in this paper.

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