

***The Weather Makers: How Man Is Changing the Climate and What It Means for Life on Earth.* Tim Flannery. New York: Grove Press, 2005.**

**The Slow Awakening**

“For the last 10,000 years, Earth’s thermostat has been set to an average surface temperature of around 57° F.” [5]

This has enabled social organization to develop. {5}

“CO<sub>2</sub> plays a critical role in maintaining the balance necessary to all life.” [5]

**PART ONE: GAIA’S TOOLS**

**One: Gaia**

Alfred Russel Wallace’s phrase, ‘the Great Aerial Ocean’ is better than ‘atmosphere’ “because it conjures in the mind’s eye the current, eddies, and layers that create the weather far above our heads, and that are all that stand between us and infinite space.” [12]

Thirty pounds of air are required daily by an adult human. [13]

Lovelock’s Gaia hypothesis... [13-15]

Events enabling climatic regulation: [15ff]

- Evolution of shell-forming plankton (ca. 300 million years ago);
- Simultaneous spread of forests;
- Spread of coral reefs (55 million years ago);
- Spread of grasses, which produce fires, which check forests (608 million years ago); and
- Spread of elephants across planet (20 million years ago) also held forests in check.

Importance of worldview – “... a Gaian worldview predisposes its adherents to sustainable ways of living.” [17]

But a “reductionist worldview” is ascendant, and this is what has brought about our present state. [17]

**Two. The Great Aerial Ocean**

Greenhouse gasses —————> global warming—————> climate change [19]

“Climate is the sum of all weather over a certain period, for a region or for the planet as a whole.” [20]

CO<sub>2</sub> molecules account for fewer than 4 of every 10,000 molecules in the atmosphere – key role in regulating temperature, preventing both freezing and overheating. [22]

Dynamism of the atmosphere – The CO<sub>2</sub> I exhale is dispersed around the earth. “Because of its dynamism, the atmosphere is on intimate terms with every aspect of our earth... No volcano belches, no ocean churns – indeed, no creature breathes – without the great aerial ocean registering it.” [22]

Telekinesis = ‘movements at a distance without a material connection.’ [23]

Changes manifest themselves simultaneously in different regions: allows “storms, droughts, floods, and wind patterns to alter on a global level, and to do more or less at the same time.” [23]

Greenhouse gases = “a collection of disparate molecules that share the ability to block long wavelengths of energy” (e.g., heat energy).

Were CO<sub>2</sub> 1% of Earth’s atmosphere, the surface temperature would reach boiling. [24]

Human ignorance – “... as recently as 30 years ago less than half of greenhouse gases had been identified and scientists were still divided about whether Earth was warming or cooling.” [24]

The Keeling curve (1958-2000), recording CO<sub>2</sub> levels at Mt. Mauna Loa – reveals annual seasonal change, but with a progressive upward curve. [25]

This was “the first definitive sign that the great aerial ocean might prove to be the Achilles heel of our fossil-fuel-addicted civilization.” [25-26]

### **THREE: The Gaseous Greenhouse**

“CO<sub>2</sub> acts as a trigger for that potent greenhouse gas, water vapor.” It heats the atmosphere enough to allow it to take up and return moisture: Positive Feedback Loop. [28]

CO<sub>2</sub> in long-lived – ca. 56% of all the CO<sub>2</sub> liberated by burning fossil fuels is still aloft. This known proportion allows calculation of a ‘carbon budget.’ [28]

1800 – 280 ppm of CO<sub>2</sub> in the atmosphere

2007 – 380 ppm of CO<sub>2</sub> in the atmosphere [28]

Ice cores reveal levels of 160 ppm in very cold eras, but 280 ppm had never been exceeded. [29]

Coal fired power plants: “nineteenth-century technology makes twenty-first century gadgets whirr. [30]

4 tons of CO<sub>2</sub> is created for every ton of anthracite consumed. [30]

Methane (1.5 ppm of the atmosphere): its concentration has doubled in the past 200 years. [30]

Methane is 60X more powerful than CO<sub>2</sub> in capturing heat energy, but lasts less long. [30]

Methane “abounds in swamps, farts, and belches.” [30]

Since it is sometimes released suddenly in large quantities, it plays a large role in creating positive feedback loops. [30]

Nitrous oxide is rare, but 270X more efficient than CO<sub>2</sub> in trapping heat energy and lasts 150 years in the atmosphere. [30]

There is 20% more nitrous oxide in the atmosphere than in 1800. [31]

Human-created HFC and CFC chemicals are 10,000X more efficient than CO<sub>2</sub> in trapping heat energy. [31]

The movements of carbon “are extraordinarily complex and are governed by temperature, the availability of other elements, and the activities of species such as ourselves.” [31]

Photosynthesis is the “self-sustaining cycle that forms the basis of life on Earth.” [31]

Ca. 1 trillion tons of carbon are tied up in living things, with a far greater amount buried underground and in the oceans. [31]

‘Carbon sinks’ are where carbon goes when it leaves the atmosphere.

Carbon released by burning fossil fuels has a unique chemical signature and thus can be tracked. [32]

New, vigorous forests are better carbon sinks than old forests. [33]

Oceans have absorbed 48% of carbon released in the last two centuries, largely in the North Sea (our planet’s ‘carbon kidney’). [33]

Changes in ocean circulation caused by climate change may reduce the North Sea’s effectiveness. Cold water holds more carbon than warm – and more acidic water also absorbs less carbon, and the oceans are becoming more acidic.

Sea creatures also absorb carbon, but they are also vulnerable to acidity. [35]

In 2100, the oceans are predicted to absorb 10% less carbon than in 2000. [35]

#### **FOUR: The Sages and the Onion Skin**

Alfred Russel Wallace’s *Man’s Place in the Universe* “is full of insights that resonate with an environmentally aware twenty-first century. [37]

Central thesis: “the foul effusions of the Industrial Revolution threatened humanity.” [37]

In 1661 John Evelyn called London ‘the suburbs of Hell’ because of the vile effusions of coal-burning fires. [37]

John Graunt (1662) posited lung disease as the leading cause of death in London. [37-38]

John Baptiste Fourier (18<sup>th</sup> century) understood that the atmosphere acted like glass in a hothouse, letting solar energy in and then trapping the heat. [39]

Svante Arrhenius (ca. 1900) calculated that a reduction in CO<sub>2</sub> could have caused the Ice Ages. He also projected that burning coal could lead to warming. [40]

Guy Callendar (1938) posited actual warming, due to burning fossil fuels. [40-41]

Milutin Milankovich (1941) published a book identifying three principal cycles driving Earth’s climatic variability: (1) Earth’s elliptical orbit carries it closer to, and further from, the sun (100,000 years); (2) tilt of the Earth’s axis (42,000 years); and (3) the wobble of the Earth on its axis (22,000 years).

This “solved the riddle of the ice ages,” but it remained obscure and with little impact. [42]  
Sunspot activity varies on a shorter cycle (11 years) and a longer cycle (centuries). [43]

Scientists do not understand why, but increased sunspot activity seems to coincide with warming on Earth. [43]

“... the fossil record is characterized by sudden shifts from one steady, long-lasting climatic state to another.” [44]

## **FIVE: Time’s Gateways**

Divisions between geologic eras are ‘time’s gateways,’ when life encountered setbacks or exceptional opportunities. [46]

Three change agents are sufficiently powerful to open such a gateway: “shifting of continents; (2) cosmic collisions; (3) climate-driving forces such as greenhouse gases. [46]

These “drive evolution using the same mechanisms – death and opportunity.” [46]

Three types of time division: small, medium, large. [46-48]

1. Small: brief and local – e.g., formation of intercontinental land bridge allows plants and animals to migrate;
2. Medium: separating geological periods – result from factors operating on a global level (e.g., greenhouse gases) – extinction of species, followed by slow evolution of new life forms’
3. Large: Massive upheaval, when as much as 95% of species vanish – which has occurred on only 5 occasions, the separation of eras.

The last time was 65 million years ago and resulted from an asteroid collision which injected materials into the atmosphere which changed climate. [48]

Analysts of ocean cores find 3 climatic aberrations (55, 34, and 23 million years ago) that cannot be explained by cosmological/geological factors. [50]

55 million years ago, the earth heated by 9°-18° F. The oceans had turned acidic, causing massive extinctions. Land evidence of abrupt changes in rainfall, and migration of flora and fauna from Asia into North America and Europe (made possible by Arctic land bridges made accessible by warming). [51]

The warming had been caused by a massive infusion of carbon into the atmosphere – perhaps from submarine volcanic activity in the Norwegian Sea. [52]

It took 20,000 years for Earth to reabsorb this carbon. [53]

“Back then the warming closed a geological period, while we might, through our activities, bring an end to an entire era.” [53]

## **SIX: Born in the Deep Freeze**

A time ca. 100,000 years ago when there were ca. 2,000 fertile adult humans, who were all that stood between us and extinction. Due to ice age. [55]

But by 60,000 years ago, climate had warmed, and humans wandered from Africa into Europe and Asia. [55]

Long period of stasis between 60,000 and 10,000 years ago seeks explanation in “the climate that minted our species.” [55]

430,000 years ago was the last time the Milankovich cycles brought Earth into a position similar to today. [58]

Ice cores reveal an exceptionally long warm period at that time. [58]

From 20,000 to 10,000 years ago, Earth’s temperature increased by 9°F – at a rate of 2°F per thousand years. We currently face a change 30X faster – “and because living things need time to adjust, speed is every bit as important as scale when it comes to climate change.” [59]

“... the transition from the ice age to the warmth of today was no gentle segue, but instead the wildest of roller-coaster rides, whose high and low points had the sharpness of sawteeth.” [61]

These oscillations “drew Earth jerkily yet inexorably toward its present state.” [61]

Until 10,000 years ago, extreme cold had made it impossible to grow crops – thus, humans remained hunters and gatherers. [62]

## **SEVEN: Making the Long Summer**

Though agriculture commenced in the Fertile Crescent ca. 10,500 years ago, it has been in the ‘long summer’ of the last 8,000 years that we acquired our major crops/animals, built cities, developed irrigation, writing and coinage. These developments occurred many times in different parts of the world. [63]

The similarities between cities in diverse places makes it seem “as if the human mind had sheltered a template for the city all along, and was just waiting until conditions permitted to manifest it.” [64]

Paul Crutzen marked 1800 AD as the advent of the Anthropocene – “when methane and CO<sub>2</sub> brewed up by the gargantuan machines of the Industrial Revolution first began to influence Earth’s climate.” [64]

Bill Ruddiman argues that human had “wrested control of methane emissions from nature” beginning 8,000 years ago. [65]

The beginnings of agriculture tipped the balance. [65]

The climate stability created by humans over these 8,000 years was delicate and vulnerable to the Milankovich cycles. [66]

Brian Fagan believes that ca. 3,800 BC, rainfall declined due to a Milankovich shift in Earth's orbit, with resultant famine driving wanderers into a few strategic locations, whence developed, e.g., Mesopotamian civilization. The city, e.g., as "a key human adaptation to drier climatic conditions." [67]

Ruddiman also sees correlation between CO<sub>2</sub> levels and plagues (e.g., 14<sup>th</sup> century) which "were global in their reach and killed so many people that forests were able to grow back on deserted farmland, which absorbed CO<sub>2</sub> and lowered temperatures. [67]

"Ruddiman's thesis implies that, by adding sufficient greenhouse gases to keep the earth 'just right' to delay another ice age yet not overheating the planet, the ancients performed an act of chemical wizardry." [67]

We were then "part of Gaia's balance rather than a destroyer of it." [68]

"... today there are unmistakable signs that the Anthropocene is turning ugly." [68]

### **EIGHT: Digging up the Dead**

Australian aborigines have "a distinctive way of seeing the world." Big Bill Neidjie tells of the impact of mining, and "describes the great cycle that runs from disturbing the eternal living dreaming of the ancestors to the catastrophe awaiting unborn generations." [69-70]

If you touch, / you might get cyclone, heavy raid or flood. / Not just here, / you might kill someone in another place. / Might be kill him in another country. / You cannot touch him. [69]

"... he has intuited the hidden links between mining, climate change, and human well-being that scientists have groped toward as they seek to understand the greenhouse effect." [70]

"... we need to learn a little of the history, nature, and power of that black stone, coal, and of its slippery ally, oil." [70]

"... when we burn fossil fuels, we release carbon that has been out of circulation for eons. Digging up the dead in this way is a particularly bad thing for the living to do." [70]

In 2002, burning fossil fuels released 23 billion tons of CO<sub>2</sub> into the atmosphere (41% coal; 39% oil; 20% gas). [70]

Coal is the most carbon intensive of the three, then oil, then gas. [70]

Coal is also the least efficient. [71]

"Coal is our planet's most abundant and widely distributed fossil fuel." [71]

Much anthracite lived during the Carboniferous Period, 360-290 million years ago. [72]

In the early 14<sup>th</sup> century, Edward I so detested coal that he banned it. There are records of coal burners being tortured, hanged, or decapitated. But England's forests were being exhausted and the price of timber rose, and the English became the first to burn coal on a large scale. [73]

Invention of the steam engine transformed coal into a transport fuel. [74]

“... more coal is burned today than at any time in the past.” [74]

“The trouble with oil, however, is that there is far less of it than coal, its distribution is patchier, and it's harder to find.” [75]

Oil is the product of ocean life, primarily plankton. [75]

“... the creation of oil reserves is the result of pure chance – the right rocks being cooked in the right way for the correct time, usually in a dome-shaped structure where a ‘crust’ overlies a porous oil-rich level that prevents the oil's escape.” [76]

“The twentieth century opened on a world that was home to little more than a billion people and closed on a world of 6 billion, and every one of those 6 billion is using on average four times as much energy as their forefathers did 100 year before.” [77]

Ca. 100 tons of ancient plant life creates one gallon of gasoline. Over each year of our industrial age, several centuries' worth of ancient sunlight has been required to keep our economy going. [77]

The figure for 1997: “Four hundred and twenty-two years' worth of blazing light from a Carboniferous sun – and we have burned it in a single year.”

“The past is a truly capacious land, whose stored riches are fabulous when compared with the meager daily ration of solar radiation we receive.” [78]

“1986 makes the year that humans reached Earth's carrying capacity, and ever since we have been running the environmental equivalent of a deficit budget, which is sustained only by plundering our capital base.” [78-79]

At current rate, by 2050, we will be using 2 planets' worth of resources – if they can be found. [79]

## **PART TWO: ONE IN TEN THOUSAND**

### **NINE: The Unraveling World**

“Global warming changes climate in jerks, during which climate patterns jump from one stable state to another.” These changes manifest themselves simultaneously across the globe. [83]

Julia Cole posits “magic gates “climate leaps) in 1976 and 1998.

1976: sudden and sustained increase in sea surface temperature of 1° F and an 0.8% decline in ocean salinity. [84]

Between 1945-1955, tropical Pacific surface temperature commonly dipped below 66.5° F; since '76, it has rarely been below 77° F. [84]

This Pacific region is a great regulator of climate (e.g., El Niños, tropical precipitation, jet stream position). [84]

1998: A severe El Niño event seems to have permanently altered global climate, and established El Niño dominance over La Niña. This single event raised global temperature by 0.5° F. [86]

A build-up of warm water in the central western Pacific concentrates and amplifies the small rises in temperature caused by greenhouse gases. [86]

Since '98, Pacific waters have remained warmer and the jet stream has shifted toward the North Pole. [86]

Camille Parmesan and Gary Yohe researched natural history observation (naturalists, birdwatchers, captains' logs, etc.) and asked two questions: "Is an underlying trend evident in all of the regions, habitats, and organisms documented? And if so, is that trend in the general direction one would expect, given what we know of climate change?" [87]

Little evidence was found of any trend prior to 1950; since then a strong global pattern has emerged: poleward shift in species' distribution (4 miles per decade), a retreat up mountainsides (20 feet per decade), an advance of Spring activity (2.3 days per decade). [88]

"... it's as if the researchers had caught CO<sub>2</sub> in the act of driving nature poleward with a lash." [88]

As species relocate, human environmental changes inevitably obstruct migration. [88]

Since the world's most fertile regions are now "occupied by human-modified environments," numerous extinctions are likely. [89]

The common murre has begun to lay its eggs an average of 24 days earlier each decade. Plants flower earlier; butterflies and migrating birds appear earlier. [89]

The capacity of species to adapt varies widely. As some shift rapidly and others are left behind, the connectedness among species is disrupted. [89]

"... all around the world the delicate web of life is being torn apart." [90]

In lakes and rainforests, ecosystems are being seriously disrupted. [91-92]

"At the ends of the earth... climate change is occurring now at *twice* the rate seen anywhere else." [94]

### **TEN: Peril at the Poles**

Subantarctic seas are some of the richest on Earth. The semi-frozen edge between salt water and floating ice promotes remarkable growth of plankton, the base of the food chain. [96]

Angus Atkinson compared data on krill population: (a) 1926-1939 and (b) 1976-2003. [96]

- (a) Krill population was stable.
- (b) Krill population declining 40% per decade.

And "penguins, albatrosses, seals and whales... are prone to krill shortages."

Research indicates sea ice was stable from 1840-1950, but has since decreased 20%. [97]

Emperor Penguin population is half what it was 30 years ago; Adelie penguins have declined 70%. [98]

Southern Alaskan winters are 4°-5° F warmer than 30 years ago.



40 million trees in southern Alaska have been killed by the spruce bark beetle. Cold winters had usually controlled the beetle population. [98]

If current trends persist, forests will encroach northward, depriving migratory birds of their nesting habitat. [99]

The Perry caribou population (Greenland) declined from 26,000 in 1961 to 1,000 in 1997. Autumn rains ice over the lichens that are the creature's winter food supply. [100]

Diminished arctic sea ice harms the seal population, which in turn deprives polar bears of food. [101]

Polar bears are on average 15% skinnier than they were a few decades ago. [101]

The ivory gull has declined by 90% in Canada in the last 20 years. [102]

In the 1960s both the Soviets and Americans considered efforts to destroy the Arctic ice cap purposefully. The Soviets proposed pumping water from the Bering Sea; Americans considered nuclear weapons. [102-103]

This is now being accomplished inadvertently. If current trends continue, this century will see a summer in which the Arctic is "a vast, dark, turbulent sea" – without ice. [103]

These polar trends will also involve loss of albedo (reflection of sunlight), with darker forest, sea absorbing more of the sun's heat. [103]

"... after persisting for millions of years the north polar cryosphere will have vanished forever." [103]

### **ELEVEN: 2050 – The Great Stumpy Reef?**

None of the ocean's ecosystems is more beautiful than the coral reef, and none more endangered. [104]

"The citizens of five nations live entirely on coral atolls, while fringing reefs are all that stand between the invading sea and tens of millions more." [105]

One quarter of all ocean creatures spends part of their life cycle in coral reefs. [105]

Overfishing threatens coral reefs, as their stability depends on the diversity of fishes and other creatures they shelter. [106]

Agricultural and urban runoff also threatens reefs. Even Australia's protected Great Barrier Reef is being seriously degraded. [106]

Indonesian fires during the 1998 and 2002 El Niños produces toxins that seriously damaged reefs. [107]

And high temperatures bleach coral reefs, even where they are far from human interference. [107]

Coral reefs involve a 'partnership' between a polyp, which gains its hue from an algae that lodges in it. The polyp provides a home and some nourishment to the algae, which provide the polyp with food from photosynthesis. [108]

Rising temperatures impair the algae's ability to photosynthesis – polyp and algae consequently split off, and the polyps starve. [108]

42% of the Great Barrier Reef bleached in 1998; 18% permanently. [108-109]

The 2002 El Niño affected 60% of the reef. [109]

"Australians emit more CO<sub>2</sub> per capita than any people on Earth," yet the government's 2004 energy policy places coal at the center of the nation's energy system. [109]

Scientists project that a 5° F temperature increase would cause "'total devastation'" to the world's coral reefs. [109]

It takes oceans three decades to catch up with atmospheric heat, so "it may well be that four-fifths of the Great Barrier Reef is one vast zone of the living dead." [110]

### **TWELVE: A Warning from the Golden Toad**

Numerous changes among birds, reptiles, and amphibians noticed in Costa Rica following the 'magic gate' of 1976. [114-115]

Following the dry season of 1987, many reptiles, frogs and other fauna have become rarer by the year. [117]

The number of mistless days each dry season, coalescing into runs of mistless days, had increased since 1976, passing a critical threshold in 1987. [118]

Without mist, "the forest dried out sufficiently to trigger a landslide of catastrophic changes that swept before it mountain birds, orioles, golden toads, and other amphibians alike." [118]

The mist was absent because cloud cover had elevated, driven by the abrupt rise in sea temperatures that heralded the magic gate of 1976. [118]

"... the dismantling of ecosystems and irreparable genetic loss." [118]

"The golden toad was the first documented victim of global warming." [119]

Steve Richards "has documented a series of amphibian declines in the mossy mountain rain forests of eastern Australia." Beginning in the late 1970s.

E.g., the gastric brooding frog. [119]

In the early 1990s, frogs began to disappear from Australian rain forests, which were undisturbed other than by warming. [121]

Almost a third of the world's 6,000-odd amphibian species were judged to be threatened with extinction in 2004. [121]

American researchers studying toads in the Northwest U.S. found that ultraviolet light retards the embryonic development of toads, leaving them vulnerable to a fungal disease. [121]

The toad embryos were more exposed to ultraviolet light because their nursery ponds were shallower, due to persistent El Niño conditions since 1976 brought less winter rain to the Pacific Northwest. [121]

"... joined the long list of species in free fall toward extinction." [122]

### **THIRTEEN: Liquid Gold – Changes in Rainfall**

Warming will increase rainfall (1% increase for every 1° F) but this increase is not evenly distributed in time and space. [123]

Some regions will experience problematic increases in rainfall, but there are also regions that will be tipped into perpetual rainfall deficit. [124]

There is evidence of shift to a new drier climate, in Africa's Sahel region. [124]

This change resulted from rising sea-surface temperatures in the Indian Ocean, which resulted from an accumulation of greenhouse gases. [125]

Global dimming cuts down on the amount of sunlight reaching Earth's surface, resulting from particles emitted by power plants, automobiles, and factories. This has further weakened the monsoon. [126]

A significant part of the conflict in Darfur results from the desperation experienced by nomads and farmers and the conflict between them for scarce resources. [126]

The West has focused on religion and politics, misunderstanding the root cause: evident environmental catastrophe. [126]

Dust blowing from the Sahel could influence the climate of the entire planet. About half the global dust in the air today originates in Africa. [126-127]

The planet's dust loading has increased by a third. [127]

A 15% decrease in rainfall in Australia has profoundly impacted agriculture. Winter rainfall has actually declined by more than that, while Summer rainfall has increased; both facts are problematic. [128]

The increased Summer rains have brought underground salt to the surface, killing everything it touches. [129]

"... the worst case of dry-land salinity in the world." [129]

Severe decline in water supply, endangering Perth and Sydney. [129-131]

The American West is experiencing the driest conditions in 700 years. [131]

This is consistent with what would be expected by global warming modeling. [132]

Over the last 50 years, there has been a steady decline in snowfall, which is a major source of water supply, hydropower, and fish habitat. [133]

And snow is less tightly packed, so it melts earlier (3 weeks sooner than in 1948), leaving less water for the height of summer, when it is most needed. [133]

Cities on the U.S. West "are tethered to ever dwindling water supplies." [133]

5,000 years ago, when the Southwest was just a little warmer and drier than today, "the Indian cultures that had flourished across the region all but vanished." [134]

### **FOURTEEN: An Energetic Onion Skin**

In 2003 climate scientists discovered that the tropopause (edge between troposphere and stratosphere) had risen by several hundred meters. This is where much of our weather is generated; if it is changed, both weather patterns and extreme weather are likely to change. [135]

This was caused by a combination of ozone-destroying chemicals and greenhouse gases. [136]

“By warming the troposphere, we both change the weather patterns globally and increase the likelihood of extreme weather events.” [136]

Events in the past decade as the troposphere has warmed: The most powerful El Niño ever ('97-'98); most devastating hurricane in 200 years (Mitch, '98); hottest European summer on record (2003); the first South Atlantic hurricane ever (2002); and one of the worst storm seasons ever experienced in Florida (2004). [136]

Change in hurricane tracks since 1950, becoming less frequent in some regions and more frequent in others. They appear to be becoming more frequent in North America. [137]

Because warm air holds more water vapor, “the incidence of severe floods is rising and expected to rise further.” [138]

“Because extreme weather events by their very nature are rare, it can be a long time before sufficient data accumulates to detect a trend.” [138]

1990s = warmest decade in central England since records began in the 1660s.

The U.K. has also experienced a significant increase in severe winter storms. [139]

The European summer of 2003 was “so hot that, statistically speaking, such an outlandish event should occur no more often than every 46,000 years.” [139]

One year later the temperature hit 123.8°F in Egypt. [139]

Post 1950 North America: decreased temperature gradient from north to south, altered temperature contrast between land and sea, reduced daytime temperature range. [139]

The U.S. “already has the most varied weather of any country, and is likely to bear a higher cost from global warming than any other large nation.” [140]

India appears as yet to have been little affected. [140]

All continents are shrinking as the heated oceans expand. [141]

## **FIFTEEN: Playing at Canute**

“Nestled deep within the human psyche lies a primal fear of the awful powers of water.” (Gilgamesh, Genesis). [142]

Yet humans have always sought to live close to water. [142]

⅔ of the human population today lives within 50 miles of the coast – “... yet in our subconscious we understand that the waters can rise over the land, making all of our hard-won real estate count for naught.” [143]

15,000 years ago, the oceans stood at least 300 feet lower than today. [143]

Melting glaciers alone raised global sea levels by 243 feet. About 8,000 years ago, the sea reached its present level and stabilized. [143]

In Bangladesh, 10 million people live within 3 feet of sea level. [143]

The Greenland ice cap is a true remnant of the ice age. It contains enough water to raise global sea levels by 23 feet. [144]

Ice covering the North Pole Sea has contracted (summer) by 20% since 1979, and is thinning. [144]

Melting polar ice does not directly raise sea level, but does significantly diminish albedo. [144]

“... warm water occupies more space than cold.” [146]

Antarctica provides “the most alarming news of melting ice.” [147]

Collapse of the Larsen B ice shelf in 2002 was unexpected. [147]

It had been initiated by warming waters. [148]

Largest expanse of sea ice is the West Antarctic ice sheet. [148]

The sheet itself and the glaciers whose flow it blocks “constitute enough water to raise global sea levels by 20 to 23 feet.” [148]

If Earth ever becomes ice-free, sea level would rise around 220 feet. [148]

A 10-20 foot rise could occur in the next century or two. [149]

### **PART THREE: THE SCIENCE OF PREDICTION**

#### **SIXTEEN: Model Worlds**

Lee Kump: “We have made the natural world our laboratory, but the experiment is inadvertent...” [153]

It is more likely that we are underestimating, than overstating, the effects of global warming. [153]

In modeling, “Clouds cloud the issue, so to speak, because no one has yet developed a theory of cloud formation and dissipation.” [155]

Human-induced climate change is altering sea level pressure as well as temperature, and newly discovered factors such as this need continually to be factored into modeling. [156]

Between the 1940s and 1970s global temperature declined, despite an increase of greenhouse gases. This was caused by aerosols. [158]

Aerosols generated by burning coal kill around 60,000 people annually in the United States. [159]

In response to acid rain, scrubbers were required on coal-burning power plants, reducing aerosols – and thus diminishing the factor that had been masking the effect of greenhouse gases on temperature. [159-160]

After the 1991 eruption of Pinatubo (Philippines), modeling predicted 0.3°C of global cooling, which is exactly what happened. [160]

Model predictions: Poles will warm more rapidly than elsewhere; land temperatures will rise more rapidly than global average; more rain; extreme weather events will increase in frequency and intensity; nights will be warmer relative to days; trend toward semipermanent El Niño conditions. [160]

The key uncertainty remains whether doubling of CO<sub>2</sub> will lead to 2° C (3.6° F) or 5° C (9° F) increase in warming. [160-161].

Even the lower figures would be catastrophic, but the uncertainty is often used to discredit proposals for action. [161]

Global dimming is a key variable. The amount of sunlight actually reaching earth has diminished. [161]

In the days after 9/11 when jets were grounded, the absence of contrails led to increased daytime temperatures. [162]

Without this factor, warming would be far more intense. [162]

“Earth’s climate system... is so ridden with positive feedback loops that our usual concepts of causes and effect no longer hold.” [162]

“... what we have are seemingly insignificant initial occurrences – such as an increase of atmospheric CO<sub>2</sub> -- that lead to runaway change. [162]

“From the perspective of a human lifetime, global warming is slow.” [163]

By 2050, “there will be no more climatic ‘acts of God,’ only human-made climate disasters.” [164]

The longer the time frame, and the more global the scope, predictions are more reliable. [165]

## **SEVENTEEN: The Commitment and Approaching Extreme Danger**

“The full impact of the greenhouse gases already in the atmosphere will not be felt until around 2050.” [166]

“Half the energy generated since the Industrial Revolution has been consumed in just the last twenty years.” [167]

Since we are generally more affluent than our forebears, we are better able to bear the costs of changing our ways. [167]

We are committed: CO<sub>2</sub> already in atmosphere; amplifying positive feedback loops; global dimming; the speed at which human economies can decarbonizes. [167]

The last is “the only impact over which we have control.” [168]

Consensus: 70% reduction in CO<sub>2</sub> emissions from 1990 levels by midcentury is required to stabilize Earth’s climate. [168]

“... it’s too late to avoid changing our world, but we still have time, if good policy is implemented, to avoid disaster.” [169]

The *rate* of change is significant, because “life is flexible, and if given sufficient time, it can adapt to the most extreme conditions.” [169]

“But the question of what constitutes dangerous climate change raises another question – dangerous to whom?” [169]

The fate of hundreds of thousands of species and billions of people is at stake. [170]

### **EIGHTEEN: Leveling the Mountains**

“Nothing in predictive climate science is more certain than the extinction of many of the world’s mountain-dwelling species.” [172]

As the world warms, species retreat to higher, cooler regions. [172]

“... there are few mountains anywhere on Earth high enough to provide alpine refuge.” [173]

The world’s mountains “nurture a staggering variety of life – from iconic species such as pandas and mountain gorillas to humble lichens and insects.” [173]

Mountain-dwelling species have withdrawn an average of twenty feet per decade upslope. [174]

Many ancient species are clinging to the last few hundred yards – many are survivors from cooler, moister eras 20 million years ago. [174]

“Plants grown experimentally in CO<sub>2</sub>-enriched environments tend to have reduced nutritional value.” [175]

“Throughout the world, every continent, as well as many islands, has mountain ranges that are the last refuge of species of remarkable beauty and diversity.” [177]

One species that will benefit from warming is the parasites that cause malaria. “As rainfall increases, the mosquitoes that carry the parasite will spread, the malarial season will lengthen, and the disease will proliferate.” [177]

### **NINETEEN: How Can They Keep on Moving?**

“Species have survived past shifts of climate change because mountains have been tall enough, continents extensive enough, and the change gradual enough for them to migrate.” [178]

The deciduous forests around Montreal were only native to Florida 14,000 years ago. [178-179]  
Human-modified landscapes now stand in the way. [179]

“... there is not an ecosystem of Earth that will be unaffected by climate change.” [180]

South Africa’s succulent karoo flora (2,500 species found nowhere else), all bound by ocean and mountains: They have nowhere to go. [180]

In Australia, land clearing makes migration impossible for many species of flora. [181]

“In the past when abrupt shifts of climate occurred, trees, birds, insects – indeed entire biotas – would migrate the length of continents as they tracked conditions suitable for them. In the modern world... such movements are not possible.” [181]

Wintering habitat for migratory snowbirds in North American will be significantly reduced.  
Salmon will diminish because of waning streams. [181]

On smaller landmasses (islands) the situation is even more dire. [182]

Many Pacific island birds, trees, insects will all diminish or disappear. [182]

“... it appears that at least one out of every five living things on this planet is committed to extinction by the existing level of greenhouse gases.” [183]

Action now could save two species for every one that is doomed. [183]

## **TWENTY: Boiling the Abyss**

“The structure of the world’s oceans is critical to our climate.” Three layers, separated by temperature: (1) top 300 feet; (2) down to half a mile; (3) the lightless depths (where the temperature ranges from 23°F to 39°F), exported primarily from Antarctica. [185]

As CO<sub>2</sub> is absorbed, acidity increased, limiting creatures’ capacity to form shells. [186]

“... by the time the first signs of this shift are felt, it will be far, far too late.” [186]

“... the deep oceans are one of the most wondrous and extensive realms on our planet.” [186]

“... it’s almost a parallel universe brimming with evolutionary possibilities.” [186]

“... lessons from the past indicate that even this vast realm may fall victim to climate change.” [186]

Methane explosion 55 million years ago warmed the ocean depths to such a degree that life was almost annihilated. [187]

It would take centuries for the depths to warm. [188]

## **TWENTY-ONE: The Pack of Jokers**

“Earth’s systems sometimes snap, and a new world order is suddenly created, to which the survivors must adapt or perish.” [189]



The main tipping points: (1) slowing/collapse of the Gulf Stream; (2) demise of the Amazon rain forests; (3) release of gas hydrates from the sea floor. [189-190]

There is geological evidence that each has happened – and thus *can* happen [190]

#### Scenario 1: Collapse of the Gulf Stream

A Pentagon-commissioned study concluded that such a collapse (resulting from freshwater from melting ice accumulating in the North Atlantic) would lead to persistent drought in critical agricultural regions – and cooling in North America and Europe, waning in Australia, South America, and Africa. [190]

This is likely to occasion conflict, with probable proliferation of nuclear weapons. [191]

Nations would refuse to cooperate; there would be widespread starvation, and mass emigration “as regions as diverse as Scandinavia, Bangladesh, and the Caribbean become incapable of supporting their populations.” [191]

Scramble for resources would lead to new alliances, and the potential for war would heighten. [191]

The Pentagon report made many suggestions (e.g., sequestration of O<sub>2</sub>) but failed so much as to mention the option of reducing the use of fossil fuels! [192]

The first map of the Gulf Stream was printed by Benjamin Franklin. [192]

The flow rate of the Gulf Stream is 100X as great as the Amazon. [192]

In the North, the Gulf Stream is far warmer than surrounding waters; its source of heat is tropical sunlight, and the current is a highly efficient way to transport it. [192-193]

In the north Atlantic, the Gulf Stream’s release of heat warms Europe as much as if the continent’s sunlight increased by a third. [193]

As the Gulf Stream releases heat, its’ water sinks, “forming a great midoceanic waterfall,” which is both the powerhouse and Achilles heel of all ocean currents. [193]

It has been destabilized before, coinciding with climate shifts – caused by infusion of fresh water (from ice melts) which prevents its waters from sinking. [193]

There is an emerging trend of decreasing salinity in the North Atlantic waters: “at all depths the tropical Atlantic is becoming saltier, while the north and south polar Atlantic are becoming fresher” – due to a 5-10% acceleration of the world’s evaporation and precipitation rates. Ironically, the saltier tropic water will speed up the Gulf Stream, transferring heat to the Poles, melting ice to freshen the north Atlantic, “collapsing the system altogether.” [194]

Greenland ice core samples indicate past collapse of the Gulf Stream is as little as a decade. [194]

#### Scenario 2: Collapse of the Amazon Rain Forests

The reserve of carbon in Earth’s soil dwarfs the amount in living vegetation. Just a small change in temperature can turn soil from an absorber of CO<sub>2</sub> into an emitter; such change is caused by bacterial decomposition, which accelerates with heat. [196]

“... the plants of the Amazon effectively create their own rainfall, for so vast is the volume of water transpired by them that it forms clouds that are blown ever eastward, where the moisture falls as rain, only to be transpired again and again.” [197]

CO<sub>2</sub> does add things to plant transpiration, decreasing it because increased CO<sub>2</sub> leads plants to open their stomata less often. [197]

With less transpiration, less rain – which will intensify the decline due to El Niño-like climate conditions. [197]

El Niño “transforms the world’s landmasses from carbon sinks into carbon sources.” By 2100 Amazon basin rainfall is projected to decrease from 0.2” per day to 0.08” per day; almost zero in northeastern Amazonia. [197]

Decreased rainfall combined with higher temperatures will stress plants to the point that the rain forest will collapse – reducing an enormous amount of the world’s carbon storage. [198]

“... a sparse cover of semi-desert plants might be possible;” [198]

Positive feedback loop: caused by global warming, this scenario will greatly hasten climate change. [199]

### Scenario 3: Methane Release from the Sea Floor

Clathrates is Latin for “caged,” and refers to the structure of ice crystals that trap molecules of methane in tiny ‘cages’; they contain enormous amounts of gas under high pressure [199]

Massive volumes of clathrates lie in the world’s sea bed – holding “perhaps twice as much in energy as all other fossil fuels combined.” [199]

The material is kept solid by pressure and cold. [199]

“It’s illustrative of the endless ingenuity of life that some marine worms survive by feeding on the methane in clathrates.” [199]

“... both worms and the fossil fuel industry can see a future in this paradoxical material.” [199]

Decrease of pressure and/or increase of temperature would lead to release of enormous amounts of methane. [200]

Permo-Triassic extinction event: 245 million years ago, ca 90% of species living on Earth became extinct. Extinction of mammal-like creatures opened the way for dominance of the dinosaurs. [200]

Some posit an asteroid collision as cause. A second hypothesis posits a massive outpouring from Siberian Trap volcanoes releasing billions of tons of CO<sub>2</sub>. [200]

Temperature increased 11° F initially, alongside widespread acid rain, which released yet more carbon, further increasing temperature. [200]

This “triggered the release of huge volumes of methane from the tundra and clathrates on the sea floor.” [200]

Methane and CO<sub>2</sub> are also stored in the permafrost, which are even more likely to be released by climate change than the clathrates. [200]

The oxygen content of the atmosphere fell from 21% 280 million years ago (same as today) – to 15% 260 million years ago – to 10% at the time of the Permo-Triassic extinction. [201]

Clathrates are also important to sea floor stability. A sudden decline could lead to ‘slumping’ and “the generation of tsunamis of unprecedented power.” [201]

Gulf Stream shutdown is a negative feedback loop – temporarily and dramatically reversing the warming trend (like cutting off a gangrenous limb); the other two scenarios are positive feedback loops. [201]

“... as when firing a gun, the possibility of human control is there only at the beginning of the process – before we trip the trigger.” [201]

In the U.S., 55% of total domestic energy budget is for home heating and air conditioning. As warming occurs, the demand for air conditioning will increase, causing further burning of fossil fuels: a powerful positive feedback loop. [202]

“... in order to cool our homes, we end up cooking our planet.” [202]

## **TWENTY-TWO: Out with a Whimper?**

Two foundations of civilization: (1) ability to grow enough food to support the large number of people engaged in other tasks; and (2) our ability to live in cities, clusters of people large enough to support great institutions. [203]

Cities are central to civilization, yet highly vulnerable to the stresses brought about by climate change. Their basic needs are food, water, and power – which could be threatened by climate change. [204]

Jared Diamond has argued that “exhaustion of the resource base is a key reason even large, complex, literate societies such as the Maya failed.” [205]

Climate change would alter the location and volume of water and food sources. [205]

A cycle of drought and flood has led to Australia being constituted of very small settlements and large cities, without middle-sized towns. [205]

The small, rural towns lose much of their population to cities in time of drought; cities survive by tying into the global economy. [206]

Water will be the first critical resource to be affected, because it is difficult to transport. [206]

Cities are more like plants than animals: immobile and dependent on intricate networks to supply water, food, and energy. [207]

Like forests, many cities will ‘die.’ [207]

“... the overall biological productivity of our planet is decreasing.” [207]

“... a cosseted, wealthy few may survive climate change by retreating to some refuge, but the vast majority will inevitably perish.” [208]

Talk of “adaptation” thus acquires “a genocidal meaning.” [208]

“... climate change may well, by destroying our cities, bring about the end of our civilization.” [209]

People will persist in villages and towns. [209]

“If humans pursue a business-as-usual course for the first half of this century, I believe the collapse of civilization due to climate change becomes inevitable.” [209]

#### **PART FOUR: PEOPLE IN GREENHOUSES**

##### **TWENTY-THREE: A Close-Run Thing**

Ozone hole response as “a full dress rehearsal for Kyoto.” [213]

In 1973, James Lovelock measured CFCs in the atmosphere, and a DuPont chemist calculated that this measurement corresponded to “almost all of the CFCs ever made. The stuff simply did not go away.” [216-217]

Chlorine levels in the atmosphere had reached 5X their historic background level. [217]

“As a result of the hole they punched in the ozone layer, people living south of 40° are experiencing a spectacular rise in the incidence of skin cancer.” [218]

25 years ago, the chances of getting melanoma in the U.S. was 1 in 250; now it is 1 in 84. [218]

There is a 0.5% increase in cataracts for every 1% decrease in ozone concentration. [218]

Increase in UV exposure damages the immune system. A general sickening results in stricken communities, such as the Inuit. [218]

Marine species are especially vulnerable to UV increase. [218]

Crop yields also decrease. [219]

Bromine and chlorine are relatively interchangeable. CFCs came to prominence over BFCs largely because bromine is slightly more expensive. It also causes far more severe atmospheric damage. Had BFCs flourished, the results would have been catastrophic. [219]

Televised images of the ozone hole influenced people throughout the world to demand action. [219]

Had the 1987 Montreal Protocol not been enacted, actual damage has been about 10% of what it would have been. [220]

“... the Montreal; Protocol marks a significant development in human societal development, for it represents the first ever victory by humanity over a global pollution problem.” [220]

##### **TWENTY-FOUR: The Road to Kyoto**

Economics and politics have caused the bitter contestation over Kyoto. [222]

A “furious struggle” among potential winners and losers in the energy sector. [223]

Non-ratifying nations: U.S., Australia, Monaco, and Lichtenstein. [223]

“If we are to stabilize our climate, Kyoto’s target needs to be strengthened twelve times over.” [224]

Australia’s per capita greenhouse emissions are 25% higher than the U.S. [225]

## **TWENTY-FIVE: Cost, Cost, Cost**

U.S. and Australia refuse to ratify Kyoto because of prohibitive cost – yet no careful analysis has been made of the costs of ratification vs. nonratification. [232]

Wildly varying estimates produced by an array of specific interest groups. [233]

Past experience is the best way to evaluate these estimates.

Eban Goodstein has analyzed past projections of regulatory costs as they relate to a variety of industries: “... in every case, when compared with the actual costs paid, the estimates were grossly inflated.” – regardless of whether industry itself or an independent assessor did the work. [234]

Economists cannot anticipate the innovative means of compliance that will be found; projections assume a business-as-usual approach that must absorb the costs. [234]

Goodstein further found that projected costs of environmental cleanup were almost always underestimated. [234]

Governments (U.S. and Australia) have made no analysis of the costs of doing nothing. Given the enormous expense of severe weather events, “the costs of doing nothing about climate change are so large that the failure to calculate it bankrupts the argument.” [235]

The cost of weather events in 1998 exceeded the cost of such events for the entire 1980s. [235]

Philosophical differences between America/Australia and Europe partially explain the former’s resistance to ratification of Kyoto. [237]

“America and Australia were created on the frontier and the citizens of both nations hold deep beliefs about the benefits of endless growth and expansion.” [237]

Immigration-driven population growth increases difficulty of compliance. [237]

“Kyoto questions the philosophies underpinning societies such as America and Australia, which cling to the myth of limitless growth.” [237]

Global warming also “creates an illusion of a comfortable, warm future that is deeply appealing.” – We are “an essentially tropical species... and cold has long been our greatest enemy.” [237]

“Our deep psychological resistance to thinking that ‘warm’ might be bad allows us to be deceived about the nature of climate change.” [238]

## **TWENTY-SIX: People in Greenhouses Shouldn’t Tell Lies**

The American energy sector has taken the lead in preventing the world from taking serious action to combat climate change. [239-240]

In the 1970s, “the United States was a world leader and innovator in energy conservation, photovoltaics, and wind technology, and yet today is simply a follower.” [239-240]

The “arena of public opinion and closed-door political maneuverings” is as much a part of the battleground as is the stock market – and there is a great deal of very clever industry propaganda. [240]

Industry also makes substantial political contributions. [241]

An industry lobby group, Global Climate Coalition, was established in 1989 by 50 oil/gas/coal/chemical corporations to “cast doubt on the theory of global warming.” [242]

The coalition has virtually disbanded, but it retains a website. Visiting it, Flannery is “struck by its resemblance to a dinosaur whose brain has been irretrievably damaged but which still staggers along, wreaking havoc as it wends its way to the grave.” [243]

There is now substantial division in industry over climate change, as many have come to see the potential dangers of doing nothing and the potential benefits of substantial action. [243]

In 2000, 36% of Fortune 500 CEOs favored ratification of Kyoto; only 26% opposed. [243]

But reactionary groups have also sprung up. [244]

“Skepticism is an indispensable element in scientific inquiry, but when the intention is to mislead rather than clarify, we have not skepticism but deceit.” [245]

Work of the Intergovernmental Panel on Climate Change has been slowed and toned down by industry proxies, because it operates by consensus. [245]

Thus, IPCC pronouncements represent lowest-common-denominator science, delivered at glacial speed. [246]

BP has broken ranks with industry, reduced its CO<sub>2</sub> emissions by 20% and profiting in the process, and is the world’s largest producer of photovoltaic cells. [246]

This must be understood in the broader context of British engagement of the issue, which begins with James Lovelock, who convinced Margaret Thatcher to take the issue seriously. [247]

By 2003, Britain’s CO<sub>2</sub> emissions had fallen 14% below 1990; during that period, national economic growth was 36%. [247]

“... each pound of carbon dug from the ground is, given current technology, an irretrievable step toward a hostile geologic age – one in which civilization will struggle to survive.” [248]

## **TWENTY-SEVEN: Engineering Solutions?**

“... truly planetary engineering.” [249]

One proposal is to fertilize the Southern Ocean with iron filings, which can stimulate growth in plankton. [250]

Very limited positive result, and the plankton grew at the expense of other species. [251]

Pumping compressed CO<sub>2</sub> directly into the ocean depths. [251]

Predicted high mortality rates for sea creatures due to acidity. [251]

Geosequestration: [252]

This is an energy-intensive process, and there is risk of catastrophic leaks. [253]

Governments and industry are presently debating how much risk is acceptable. [253]

“Imagine injecting twelve cubic miles of liquid CO<sub>2</sub> into the earth’s crust every day of the year for the next century or two.” [254]

“Politicians have been seduced by the coal industry’s spin.” [255]

“Soil carbon can be enhanced by following sustainable agricultural and animal husbandry practices, for this increases the vegetable mold (mostly carbon) in the soil.” [256]

Limitation of logging and reforestation can play a role. [256]

But “carbon in coal has been safely tucked away for hundreds of millions of years and would remain so for millions more had it not been dug up. Yet carbon locked away in forests or the soil is unlikely to remain out of circulation for more than a few centuries.” [256-257]

“... exchanging a gilt-edged guarantee for a junk bond.” [257]

Governments are throwing billions into such industry schemes as these. “Meanwhile, the competition from less carbon-dense fuels is looking simpler and cheaper by the day.” [257]

## **TWENTY-EIGHT: Last Steps on the Stairway to Heaven**

Some in industry propose ascending a metaphorical staircase of fuels, containing an ever diminishing amount of carbon:

Coal —————> Oil —————> Natural Gas —————> Hydrogen

“... gas appears to be the fuel of choice for the twenty-first century.” [259]

In the 1970s John Bockris coined the phrase “the hydrogen economy.” [260]

Two types of hydrogen fuel cells: (1) stationary cells used to produce electricity; and (2) those used in transport. [261]

The fundamental problem is that in any technology so far conceived, it takes more energy and emits more CO<sub>2</sub> to convert hydrogen to fuel and to transport it than would the direct use of oil or gas. [261-263]

“The only way that the hydrogen economy can help combat climate change is if the electricity grid is powered entirely from carbon-free sources.” [264]

## **PART FIVE: THE SOLUTION**

## **TWENTY-NINE: Bright as Sunlight, Light as Wind**

Decarbonizing the power grid is fundamental; with that achieved, the renewable power thus generated can be used to decarbonizes transport. [267]

Two types of technology: (1) those that presently provide power intermittently; and (2) those that can provide a continuous output of power regardless of circumstance. [268]

Wind [type 1] now provides 21% of Denmark's electricity. When the Danes decided to back wind power, it was much more costly than carbon-based electricity generation. They could see the potential, however, and as the invested in the industry, costs came down. [268]

"... some 85 percent of capacity is owned by individuals as wind cooperatives, and so power lies in the hands of the people." [268]

If you take a regional approach, "it is fairly certain that the wind will be blowing somewhere." [269]

Three technologies directly exploit the sun's power: solar hot water systems, solar thermal devices, and photovoltaic cells. [270]

Solar hot water systems are simply, inexpensive, and reliable. [270]

Solar-thermal power stations concentrate the sun's rays onto small, highly efficient solar collectors, which then produce both electricity and heat. [270]

"... wind and solar thermal are perfect partners... for if the wind isn't blowing, there's a good chance that the sun will be shining." [270]

Photovoltaic cells generate electricity that must then be transformed into an alternating current of the correct voltage. [371]

In Japan and 15 other countries, households can sell excess power to the grid. [271]

"... there is no silver bullet for decarbonizing the grid: Rather, we will see a multiplicity of technologies used wherever favorable conditions prevail." [271]

## **THIRTY: Nuclear Lazarus?**

"Nuclear power already provides 18 percent of the world's electricity, with no CO<sub>2</sub> emissions." [273]

Memories of Chernobyl keep concerns about safety at a high level. [274]

Regarding waste: the waste stream has reached such proportions, that "even if Yucca Mountain were opened tomorrow, it would be filled at once and another dump would be needed." [274]

As reactors proliferate, the likelihood increases of nuclear weapons becoming available to those who want them. [275]

The potential of geothermal power is just opening up. [276-277]



“Trillions of dollars will need to be invested to make the transition to the carbon-free economy, and, once a certain path of investment is embarked upon, it will gather such momentum that it will be difficult to change directions.” [277-278]

If we pursue ‘decentralized’ sources such as wind and solar (rather than ‘centralized’ sources such as nuclear and hydrogen) “we will have opened a door to a world the likes of which have not been seen since the days of James Watt, when a single fuel powered transport, industrial, and domestic needs alike, the big difference being that the fuel will be generated not by large corporations, but by every one of us.” [278]

### **THIRTY-ONE: Of Hybrids, Minicats, and Contrails**

“Domine, defende nos / Contra has motores bas!” (A.D. Godley, “The Motor Bus”). [279]

Toyota and Honda “have brought a revolutionary new technology to market which halves fuel consumption and opens the way to astonishing future developments.” (i.e., hybrids) [280]

European developments include electric cars and compressed-air cars. [280]

The fuel oil that powers shipping is one of the foulest pollutants, and the volume of shipping has grown by 50% in just the last few years. [281]

Wind and solar power could make shipping carbon free. [282]

In the U.S., air traffic accounts for 10% of fuel use. [282]

### **THIRTY-TWO: The Last Act of God?**

“Some time this century, the day will arrive when the human influence on the climate will overwhelm all natural factors.” [284]

“... so immense are changes in the Arctic that the Inuit may be the first people to see their nation – the land and the way of life it supports – extinguished.” [287]

“There is no term so far as I know for the extinction of a sovereign state. Perhaps we will soon need to invent one.” [287]

This pertains, too, to the five sovereign atoll countries: Kiribati, Maldives, Marshall Islands, Tokelau, and Tuvalu. [287]

Canada and Russia “will reap 90 percent of the benefit that global warming brings to food crops.” [288]

Even conservative studies predict a tripling in the number of humans at risk of food shortage by the 2080s.” [288]

“... and it’s hard to avoid the idea that any solution to the climate change crisis must be based upon principles of natural justice.” [288]

### **THIRTY-THREE: 2084 – The Carbon Dictatorship**

“... the great game of climate modification that humanity is engaged in>’ [290]

Three possible outcomes: [291]

1. Great climate shifts destroy Earth's life-support systems and destabilize global civilization: A protracted darkest of ages – with nuclear weapons, without means to regulate their use. [291]
2. Humanity responds promptly to reduce emissions, and significant damage is avoided. [291]
3. Emissions are reduced sufficiently to avoid disaster, but serious damage to Earth's ecosystems results. Geoengineering projects are the only way to proceed. [291]

If scenario 3 results, there would be no alternative to establishment of some global authority: Earth Commission for Thermostatic Control. [292]

There would need to be global regulation of the oceans, the poles, agriculture, forestry, and other land uses. [292]

Such a commission would need to arbitrate between nations. [292]

An international court, with an international armed force to assure compliance. [293]

“... an Orwellian-style world government with its own currency, army, and control over every person and every inch of our planet.” [294]

Today no citizen of any developed nation has such mastery over their own lives as, e.g., Scottish highlanders. We have traded such freedom for stability. [294]

“If big coal, big oil, and their allied interests continue to prevent the world from taking action to combat climate change, we may soon have an Earth Commission for Thermostatic Control. The only way to avoid both tyranny and destruction is to act as America's Founding Fathers did, by swiftly heeding the call to action and by ceding just enough power to a higher authority to combat the threat. And this will be effective only if we act now, before the crisis becomes full blown.” [295]

#### **THIRTY-FOUR: Time's Up**

Delay of even a decade is too much. The few years left before the end of cheap oil are crucial to making the transition to a carbon-free economy, because not it can be done most easily and least expensively. [297]

Biomass is essentially young coal, so it seems a natural step for the coal industry to invest in this emerging technology. [297-298]

One of the long-term problems of exhausting fossil fuels is that this will deprive future humans of them when faced with potential ice ages consequent to the Milankovich cycles. [298]

Governments need to regulate emissions and efficiency, and to subsidize renewable sources of energy. [298-299]

Contraction and Convergence: grant every human person an equal 'right to pollute,' with trading options. [299]

Citizens of the developed countries would need to buy carbon credits from the world's poor. [299]

This would force reduction of emissions in the developed countries and facilitate development among the poor: convergence. [299]

“Action is needed now, and the only responsible thing you, as a concerned individual can do is to reduce your own emissions as far and as quickly as possible.” [301]

Further, “government is unlikely to do anything unless people demand it.” [301]

### **THIRTY-FIVE: Over to You**

“... there is no need to wait for government to act. You can do it for yourself.”

Green power option from power company; solar hot water; energy efficient appliances; insulation; hand tools, rather than power; walking and public transit. [303-305]

If enough people buy green power, etc., the price will plummet. [306]

### **Afterword**

Warm water intensifies hurricanes. In summer 2005, surface waters were exceptionally hot (87° F) when Katrina hit. [309]

“... there is growing evidence that global warming is changing the conditions in the atmosphere and oceans in ways that will make hurricanes even more destructive in the future.” [310]

“Both the warmer ocean and the increased water vapor increase the energy available for all manner of storms...” [311]

“... we are already seeing an increase in hurricane intensity and numbers far in advance of that suggested by computer modeling.” [312]

“... the total amount of energy released by humans worldwide has increased by 60 percent in the last two decades.” [312]