WARMING OF THE CLIMATE SYSTEM IS UNEQUIVOCAL —
ACTING URGENTLY TO CHANGE COURSE AT ALL LEVELS OF SOCIETY

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ABSTRACT

In the past 150 years, about one billion people, the developed world, have achieved great affluence powered by oil and coal. China and India are rapidly joining the developed world. Doing so will more than triple the population powered by the same fossil fuels. World oil is already about half gone, but the world has enough coal to power Chinese and Indian aspirations. UN agencies comprising thousands of the world's foremost climatologists have studied the consequences, and concluded that unless civilization changes course, by reducing emissions of green house gases (GHGs) by 2050 to levels well below half the levels in 2000, a melting disaster will occur in a century or so. But observations published in 2008 reinforce fears that the world's great ice sheets may soon slide into the sea catastrophically, without melting. GHGs in the atmosphere now have already initiated the process, and pursuit of affluence is producing GHGs at an ever greater rate. Consequences of business as usual would be that sea level would rise by 48 feet, and potentially as much as 263 feet (the elevation of the highest point in Florida is only 345 feet); a substantial fraction of the world's land would be flooded; drought would afflict an equatorial belt; storms in regions closer to the poles would become more intense; and there would be more epidemics. Hundreds of millions may have to flee, starve, or die from thirst or disease. In 2003 President Bush announced the ten-year FutureGen project to develop carbon capture and store technology required for sequestering GHG emissions from coal-fired powerplants. Funding was announced in 2007 December. But a month later U.S. Secretary of Energy Samuel W Bodman revealed plans to pull the $1.8 billion funding. Mobilizing to change course by following precedents of World War II and Apollo will replace assured disaster with unprecedented humanitarian benefits. Billions of unemployed and under-employed may be assigned to the task. Egregious disparities between rich and poor will be greatly reduced. Experience shows that affluence will cause population runaway to moderate. Billions will acquire self respect, a sense of accomplishment, and pride from participating as a team protecting the planet for future generations. War will be incompatible with progress. Changing course is within reach right now. Current technology is sufficient. New technology will contribute to well being beyond 2050. The only issue is whether humanity can begin to work together in peace. By precedent, human nature will compel people to do everything in their power to avoid sacrificing their descendants. Our future is in the lives of our descendants; the lives of our descendants are in our hands.

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OPENING

TIPS ON READING, PRINTING, AND PUBLISHING

Reading Handouts: Only the cover, Abstract, and Executive Summary are printed as handouts. The Executive Summary (comprising these tips, an abridgment, and the subset of references that the complete paper cites) contains many hyperlinks to details in the full paper, which begins with a Table of Contents missing in the Executive Summary.

Reading Cross-Referenced Text — Following Hyperlinks and Paths: Page numbers in the Table of Contents, and citations colored blue in electronic copies, are hyperlinks (mostly to waypoints of details outside the Abridgment). Clicking a hyperlink causes the waypoint to appear instantly on the screen. In the vicinity of a waypoint, a reader can return to the hyperlink by holding Alt while pressing and releasing the Left Arrow, or can reach another waypoint by clicking another hyperlink, and so forth. The first hyperlink clicked is the ***origin***, the final waypoint reached is the ***destination***, and the succession of waypoints reached is the ***path***. A reader can ***retrace*** the path, **from destination to origin**, by holding Alt while pressing and releasing **Left** Arrow the required number of times. A reader can ***again trace*** the path, **from origin to destination**, by holding Alt while pressing and releasing **Right** Arrow the required number of times.

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Adobe Acrobat Format: On some Web sites, files that were written in Microsoft Word format are stored converted Acrobat format, and most Word capabilities described above no longer work. Acrobat files can be recognized by the name extension .pdf instead of .doc. A pdf file offers different ways to do much of what is described above. Word hyperlinks retain their blue color, but lose the hyperlink property. To branch to a hyperlink, click on the search icon, shown as a binocular, write in the pdf search dialog box two or more words from the hyperlink, and click Search. Click a different page number to branch to the waypoint. To return, click the page number of the hyperlink. If Microsoft Windows is the operating system, text can be copied to the Windows clip board and pasted in a Windows application such as Word. To select text, click Acrobat's Select tool, which is just to the left of the camera icon, and then hold the mouse's left button while passing the mouse's pointer over the text. Pressing Ctrl+c copies the text. Move the mouse pointer to the other Windows application, put the mouse pointer where the text is to be pasted, and press Ctrl+v. Ctrl+c and Ctrl+v are Windows keyboard shortcuts for Cut and Paste. Unfortunately,

each pasted sentence becomes a paragraph, so it is necessary to reformat paragraphs having more than one sentence.

PREFACE — FROM IPCC AND SIGMA XI PANELS TO DREAM AND TIMETABLE FOR ACTION

"The **Intergovernmental Panel on Climate Change** (**IPCC**) is a scientific body tasked to evaluate the risk of climate change caused by human activity. The panel was established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP), two organizations of the United Nations."[1,2]

UN-Sigma Xi Panel: 'Three years ago, Sigma Xi was invited by the United Nations Department of Economic and Social Affairs to convene an international panel of scientists to prepare a report outlining the best measures for mitigating and adapting to global climate change. Chaired by Sigma Xi Past-President Peter H. Raven, director of the Missouri Botanical Garden, the 18-member Scientific Expert Group on Climate Change and Sustainable Development held its first meeting at the Sigma Xi Center in Research Triangle Park, North Carolina, in December of 2004 and presented its final report in New York on February 27, 2007. The non-profit United Nations Foundation co-sponsored the study. "This report gives very clear recommendations," Raven said, "for what the international community and nations themselves must do to mitigate and adapt to climate change." The following is an executive summary, and the full report can be found at www.sigmaxi.org.'[3]

The two panels establish the reality of climate change, its consequences, and enumerate elements and recommendations for a solution. They do not give detailed plans. The purpose of this article is provide detailed plans for mitigating climate change and converting to emission-free sources of energy, thereby eliminating the basic cause of climate change.

Purpose: This article's purpose is to formulate a world plan for plan for dealing with world problems, as expressed by conclusions of the UN panels. The IPCC concluded, "Warming of the climate system is unequivocal …".[4] The UN-Sigma Xi panel concluded, "Humanity must act collectively and urgently to change course through leadership at all levels of society. There is no more time for delay."[3] This article's title is a contraction of these quotations.

Expertise: This article uses wording of experts in the many disciplines represented. Authors resort to their own wording only when unable to find pertinent expert wording.

Scope and Organization: In keeping with the Sigma Xi conclusion, the article deals with what humanity must do at all levels of society (. At world level, it proposes two new UN panels. At national level, it uses the U.S. as an example for developed nations. At intra-national level, it adopts the organization used by the U.S. Department of Energy (DOE). DOE organizes all energy consumption into four end-user sectors: Residential, Commercial, Industrial, and Transportation. The article collects numerous contributions in all four sectors, down to the level owners of homes and automobiles. Material at the lowest levels may not be appropriate for newspapers or magazines, but seems appropriate for the Web.

Dream: This article extends dream of Post-WW II Europeans whose "dream was to produce, once and for all, an end to war on the continent, and an end to poverty."[5 page 25] The article extends the dream from "the continent" to "the world".

Timetable for Action: The IPCC responded to doubts expressed by some world leaders and a small fraction of scientists. The world seems to be accepting the IPCC conclusion. Continuing the debate would be pointless, and the time spent would risk making much of the world unlivable in centuries, or much earlier given "When the Larsen B ice shelf collapsed in March 2002, polar scientists realized that their timetable for action on global warming would be measured in months and years, not decades."[6]

ABRIDGMENT

Allan R Klumpp♣

Climate Change Processes: CO_2 and other greenhouse gases (GHGs) that humans have already put in the atmosphere will be raising atmospheric temperature for centuries, unless this global warming process is interrupted by a mitigation process for extracting primarily long-lived CO_2. A commonly cited mitigation process is replanting forests, which humans have been burned for heat, harvested for construction, or cleared for agriculture.

Glacial earthquakes and collapse of the West Antarctica Larsen B Ice Shelf in 2002 March show that ice sheets are already sliding toward the ocean and, instead of melting over the centuries, can collapse into the ocean in a much shorter time.[6,7] For more, see Glacial Earthquakes and Collapse of Larsen B Ice Shelf. Mitigation may take centuries. Is it still possible for mitigation to win the race against the already melting and collapsing ice? Not winning the race would affect civilization for as long as it exists.

Consequences of losing the race, so Greenland and West Antarctica ice caps enter the ocean, are: Sea level would rise by over 14.5 m (48 ft), while "10 percent of the world's population and 13 percent of the world's urban population" live in "settlements along coastal areas that are less than 10 metres above sea level"[8] and would then be 15 to 48 ft below sea level. "[T]wo percent of the world's land area"[8] would be flooded. Drought would afflict an equatorial belt. Storms in more-polar regions would become more intense. There would be more epidemics. Over 600 million would flee, starve, or die from drowning, thirst, or disease. See Climate Change — Long-Term Processes — How and When Disaster May Strike.

Tiny Orbit Variations Produce Glacial Cycles; Anthropogenic CO2 Is More effective: Orbital effects have increased Earth's heat by at most the product of obliquity and eccentricity effects = 1.06 x 1.1025 = 1.17 (17% in the last 41,000 years). But during industrialization, humans have raised atmospheric CO_2 at an ever-increasing rate, for about 35% increase in 150 years. "If the Earth had no atmosphere, the mean global surface temperature would be approximately 50 degrees Centigrade [90 deg Fahrenheit] colder!"[9] CO_2 has risen to 26% higher than at any time in the past four glacial cycles[10] (400,000 years). The atmosphere and ocean are thinner and more fragile than anyone would guess; neither is unlimited either as a repository for waste or as a resource for food. For details, see Earth's Natural Climate Control System — So Finely Balanced That Imperceptible Geometric Changes Drive Glacial Cycles and Atmospheric Scale Height and Ocean Depth.

Proposed Steps for Getting Started: (1) On a nation-by-nation basis, convert as fast as possible, to emission-free energy by means that do not depend on new technology or UN agencies; (2) concurrently replant forests to extract atmospheric CO_2; (3) mobilize the world for working together via UN Agencies, see International Actions — Two New UN Agencies — Climate Change Mitigation and International Sustainable Energy; (4) gradually change from a nation-by-nation basis to a UN-managed basis in order to take advantage of efficiencies of scale, and to meet the need for new facilities to flow seamlessly across international boundaries; (5) wherever war is underway, exercise whatever incentives are needed to

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motivate peacemaking so that facilities can be built and benefits can begin, see Conflicts and Their Consequences — A Neutrality Policy.

Early IPCC report(s) list several ways to mitigate climate change. The most effective and practical is to replant world forests, which remove CO_2 by photosynthesis. Oceans also extract CO_2 from the atmosphere, but produce carbonic acid, which is harmful to fish and other ocean life, so reforestation is preferable.

Affluence and Oil: The developed world has gained unprecedented affluence. In six decades since World War II, Japan ascended from the vanquished, joining the affluent. Japan's rise was financed largely by trade with and outsourcing from already affluent nations. China and India aspire to achieve the same end by the same means, and appear likely to succeed. Nations established by dissolution of the Soviet Union in 1991 seem on course toward re-establishing themselves.

Affluence has been powered largely by oil. U.S. production of oil peaked sometime between 1970 and 1980. Peak production is widely regarded as the halfway point of the supply. World production is now close to the peak. The population of U.S., Europe, and Japan totals roughly one billion. Nations now striving to gain or regain affluence will make world population seeking oil more than triple what it was. How long will oil last?

Switching from Oil to Coal: With about 5%, of world population, the U.S. emits about 25% of world GHGs. China, recognizing that oil cannot support world aspirations for long, is turning to coal. China "built 114,000 megawatts of fossil-fuel-based generating capacity last year alone, almost all coal-fired, and is on course to complete 95,000 megawatts more this year."[11] That is equivalent to two typical fission power plants per week. Emissions per unit energy, far exceeding those that would be produced by oil, are released into the atmosphere. China is also building nuclear-fission capacity, but 37 times less quickly, ibid. In 2007 China passed the U.S., becoming the world's foremost GHG emitter. Tourists say China's air pollution is becoming catastrophic.

To make it possible to burn some of Earth's abundant coal emission-free, the possibility of CO_2 Capture and Sequestration (CCS) has been studied for decades.[12,13] To this end, President Bush announced early in 2003 a 10-year project, named FutureGen, to develop the needed technology. For almost five years, FutureGen was not funded. Then in 2007 December, Congress announced FutureGen's location and funding, but in January U.S. Energy Secretary Samuel W. Bodman announced funding was being pulled. For details, see Sequestering CO_2 from Coal.

U.S. Planning Fission Powerplants of Two Types: "Some 17 companies and consortia are pursuing licenses for more than 30 nuclear power plants. The U.S. Nuclear Regulatory Commission will begin reviewing the first wave of applications in 2007."[14] See also U.S. Plans New Conventional Fission Power Plants. Longer term, U.S. is planning breeder reactors for greatly expanding the potential of nuclear power, rendering waste incapable of being used in bombs, reprocessing spent fuel at existing fission power plants, and greatly reducing demands for disposal at Yucca Mountain,[15,16] see Liquid Metal-Cooled Fast Breeder Reactors.

Converting to Emission-Free Energy: Only two sources of energy are sufficient to meet the 2050 world need for 30 Terawatts of new emission-free power, the equivalent of

30,000 typical nuclear fission powerplants. Only 441 exist today, almost all of which burn U235. The world supply of U235 is sufficient for only 1,000 fission powerplants for 40 years.[17 page 60] Therefore, U238-based fission can be a major contributor only in the long term, see Liquid Metal-Cooled Fast Breeder Reactors.

Wind power can produce 70 Terawatts, over twice world need[18]. Some German wind turbines produce 6 Megawatts each[19]. Their blade diameter is 113 meters, larger than a U.S. football field, including end zones. Average efficiency of wind turbines is about 25%. Allowing for average efficiency, meeting the 2050 world need using only German wind turbines would take 20 million of them, a daunting number. Wind turbines can be located on land that is also used for agriculture, without detracting from its agricultural potential[20]. **No doubt U.S. great plains could host wind farms meeting all U.S. energy needs, while feeding the nation!**[20]

Solar power potential exceeds needs by thousands of times but costs far more than wind power. No doubt world deserts could meet world needs entirely from the Sun.

MOX: **M**ixed **ox**ide is being pursued by several nations as a way to consume current wastes from fission powerplants and render byproducts unsuitable for bombs, but. "Recycle of plutonium and re-enriched uranium from spent fuel will only increase energy yield about 15 % each in LWRs (Light Water Reactors).[21 page 834] It is also more expensive than using fresh fuel. Thus in the very long term using fast reactors is the only way to realize significant benefits. Today LWR recycle is being touted as a way to make waste disposal easier: an arguable proposition."[15 2008-02-15] See Energy from Disposal of Nuclear Weapons.

Solar Power — Land Cost Comparisons: Different methods for generating solar power differ greatly in land cost. Efficiency of Photosynthesis is only one or two percent, so the unit land cost of biofuels is enormous. Efficiency of solar photovoltaic panels is typically 17 percent, so unit land cost is less than one eighth that of biofuels. Efficiency of solar-thermal power (using the Sun's heat to produce power by fluid-driven turbines, such as in power towers) is about 30 percent, so unit land cost is about half that of solar photovoltaic. Wind turbines can generate over twice the world's needs while the land they occupy is used at the same time for growing crops, so land cost can be next to nothing.

Pumped Storage installations for generating power, in the absence of wind and sun, are needed by the hundreds. Over 140 exist today.[22] Pumped storage uses high- and low-elevation reservoirs. When surplus power is available, it is used to pump water from the low to the high reservoir. During slack periods, water drives turbines by descending from the high to the low reservoir. Reservoirs must be designed to avoid being disabled by freezing.

Expanded Electric Transmission Grids: World grids must be greatly expanded or built from scratch in order to meet world needs at locations remote from generating plants. Residential, Commercial and Industrial sectors can be made substantially self powered by means of local solar thermal and photovoltaic means. But emission-free electrical power is needed for local insufficiency and for charging batteries of plug-in hybrids. Electric grids in the developed world need substantial expansion.

The U.S. and other Developed Nations Can Greatly Cut Emissions Now: The U.S. can cut its emissions nearly in half using only existing technologies in the Residential, Commercial, Industrial, and Transportation sectors, without depending on UN agencies or

other nations. See Residential, Commercial, and Industrial Sectors — Cutting U.S. Emissions by Up to 35.8% and Transportation Sector — Cutting U.S. Emissions by Up to 11.72%.

Emissions Can Be Cut Significantly Immediately by Emission-Free Heating and Cooling,[23] see Residential, Commercial, and Industrial Sectors — Cutting U.S. Emissions by Up to 35.8%.

"Heating and cooling account for about 56% of the energy use in a typical U.S. home, making it the largest energy expense for most homes."[24] Despite cost, solar power has great potential by means of solar-thermal power for space and water heating and solar-photovoltaic for electricity. Buildings with unshaded south-facing roofs or walls may be heated and cooled largely by solar and/or geothermal energy. Lighting can be made entirely fluorescent.

Government incentives promote Solar heating and cooling for new homes and for retrofitting existing homes and industrial buildings. With common rebates, solar power in new buildings can pay for itself in a few years, and in existing buildings in a decade or so.

Transportation Using Existing and Proposed Methods can Cut Total U.S. Emissions Up to Almost 12%: **Automobiles** can be replaced by lower-emission hybrids, or by even more-effective soon-available plug-in hybrids. Plug-in hybrids (PIHEVs), need to emit GHGs only when driven beyond about 40 miles per day. Plug-in power already costs much less than gasoline, and reduces emissions. In the long term, plug-in power will be emission-free, from the grid. **Train travel** can replace flying. **Trains** can be electrified, using grid power, emission-free in the long run. **Long-distance freight** can be switched to trains, reducing emissions immediately, and eliminating emissions when trains are powered by emission-free electricity. **Buses** and **Trucks** can be PIHEVs, and trucks can be restricted to short hauls. **Transport aircraft** can, in the long term, be emission free, see Liquid-Hydrogen Propelled Aircraft. Chauncey Starr's SuperCables, can simultaneously deliver electricity loss-free by superconductivity, while delivering liquid hydrogen to airports, etc, as the cryogen.[25,26]

New Technologies described under Developing Technologies for Eliminating Remaining Emissions — Research Projects can further reduce the climate-change threat for descendants beyond grandchildren. Projects include **Nuclear Fusion Power**, to supply almost unlimited energy using hydrogen from water or fossil fuels; **Sequestering CO2 from Coal** to make burning coal emission free; **Liquid Metal-Cooled Fast Breeder Reactors** to reprocess existing transuranic waste products of fission power, rendering waste unsuitable for weapons while providing additional energy, and to harness U238 for nuclear fission power, increasing fission energy's potential by a factor of up to 100; **Liquid-Hydrogen-Propelled Aircraft** to make air travel emission free, eliminating what may be the world's last major source of fossil-fuel emissions; **Clean-Burning Diesel Engines** to compete in efficiency with today's ordinary gasoline-electric hybrids such as the Prius and Honda Civic; and **Electric-Drive Hybrid Vehicles** exemplified by the eagerly anticipated (2010) GM Chevy Volt, possibly the best hybrid-electric concept, which extends range by means of a small fossil-fuel engine whose only function is charging batteries, and does not need to run when batteries do not need charging, for much more see Electric-Drive Hybrid Vehicles.

Precedents and Today's Challenge: During World War II, In six years allied nations converted major industries from civilian to war products and overcame axis nations who had an apparently invincible head start.

In less than 12 years after President Kennedy established the goal, the U.S. landed six human missions on the moon, with no fatalities in outer space, and recovered preeminence in technology.

Only "the apparent reluctance of some influential circles in our own country to take global warming and climate change seriously"[9] page 14 can cause us to miss the opportunity to do what's right for future generations, unless we lose the race to prevent ice caps from sliding into the ocean without melting, see above. Today's campaign for ignoring early symptoms resembles 20th century disinformation describing smoking as harmless and not addictive.

In 42 years, the world can mobilize, mitigate climate change, and convert to emission-free energy. Today's challenge is political, **getting organized, mobilized, and willing to work together in peace**, not technical. A dozen generations would curse us for failing, but countless generations will praise us for meeting today's challenge.

ORGANIZING TO FIT THE UNPRECEDENTED SCALE OF THE PROBLEM

The following list and figure illustrate the scale of Earth's problem. Commonly mentioned mitigation and energy actions are listed in diminishing order of effectiveness.

A. **Replant Earth's Forests Internationally**: Widespread harvesting and burning of forests must be reversed.
B. **Convert to Wind and Solar Power Internationally**: A combination of up to 20 million wind turbines of 6 megawatt capacity and solar thermal and photovoltaic power of up to the power of 30 thousand typical fission power plants can eliminate burning fossil fuels, see Figure 1 below, Where the World's Emission-Free Power Must Be by 2050.
C. **Generate All Electric Power Emission Free**: In order to supply energy for residential, commercial, industrial, and transportation sectors that cannot be generated emission-free locally, electric power must be emission free.
D. **Expand and Create Electric Grids**: The preceding item may require some developed nations to double their grid capacity, and developing nations to start from scratch.
E. **Power Automobiles and Local Buses and Trucks Nearly Emission Free**: Plug-in hybrids whose daily mileage is within battery capacity can run emission free except on occasional long trips.
F. **Replace incandescent bulbs with compact fluorescents**: Replacing incandescent bulbs with CFLs saves money and significantly reduces emissions, but is not major.
G. **Why Switch from Gasoline to Corn-Based Ethanol**? Analyses show that it takes more energy to grow and harvest the corn, and distill the ethanol, than is produced by burning the ethanol. It may support companies like ADM, but it's a loser.

Unprecedented Scale: Producing some combination of 20 million wind turbines and solar powerplants equivalent to 30,000 fission powerplants by 2050 is a challenge beyond any mankind has faced. Few are still skeptical about the need, but many are skeptical about whether humanity can do it. UN panels have warned the task must be accomplished.

Progress To Date: Figure 1 illustrates the New 2050 Emission-Free Power Need and where the world is now. Installed world Wind Capacity is 74 GW, 0.25% of the 2050 world need. In 2005, solar thermal capacity was 111.0 GW, another 0.37%. Capacity of the 22 biggest photovoltaic stations is 0.394 GW. If remaining photovoltaic power makes photovoltaic match thermal, then wind and solar total 1% of the need. The world's existing 441 fission powerplants provide an additional 1.5% for a total of about 2.5%. At the current rate of five or ten years to reach the current wind and solar-power total, it would take centuries to reach the 2050 need. See also Where the World Stands at the End of 2007.

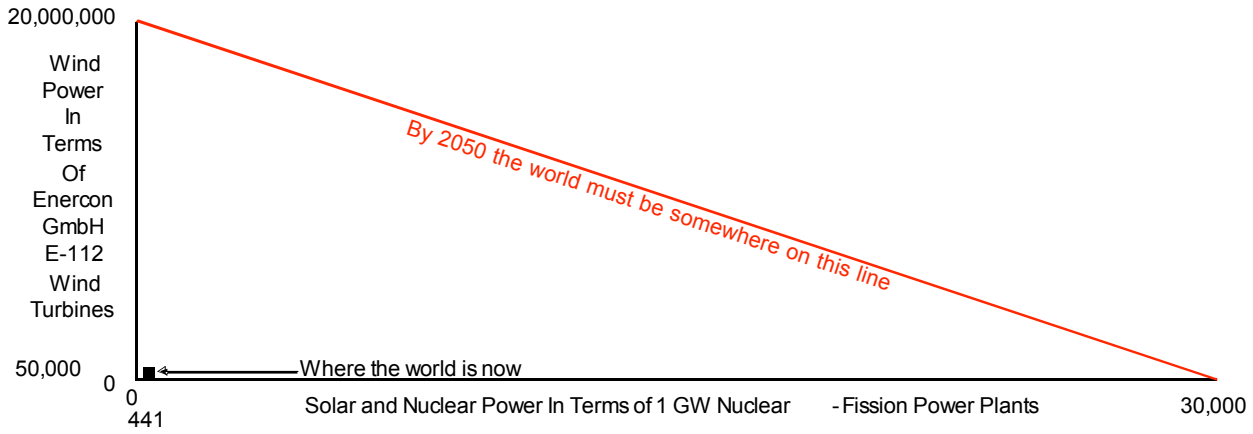


Figure 1. **Where the World's Emission-Free Power Must Be by 2050**

Business As Usual: If we continue burning fossil fuels at ever greater rates, proven reserves will last about 43 years, Figure 3. When fossil fuels run out, Paleozoic CO_2 is restored, and the world we know stops existing. Knowing this, humanity will change course.

Humanitarian Benefits of meeting today's challenge will be enormous. Billions of unemployed and under-employed may be assigned to the task. Egregious disparities between rich and poor will be greatly reduced. Experience shows that affluence will cause population runaway to moderate. Billions will acquire self respect, a sense of accomplishment, and pride from participating as a team protecting the planet for future generations. War will be incompatible with progress. See also Immediate Humanitarian Benefits from Accepting the Climate-Change-Energy Challenge.

CLIMATE CHANGE — LONG-TERM PROCESSES — HOW AND WHEN DISASTER MAY STRIKE

Although our current goal is to cut in half the our production of $C0_2$ and other GHGs, the coal-fired power plants that China is currently building at a rate equivalent to one typical nuclear-fission powerplant every four days[11] are contributing to the net increase in the rate at which humans are putting GHGs into the atmosphere. "[O]nce Carbon dioxide gas is released into our atmosphere, it stays there for century."[9 page 14] "Both past and future anthropogenic carbon dioxide (CO_2) emissions will continue to contribute to warming and sea level rise for more than a millennium …"[27] page 13. Lifetimes are 12 years for methane (CH_4) and 114 years for nitrous oxide[4] Table 6.7. So CO_2 produced by our ancestors, and what we are producing now, are driving a global warming process that, unless mitigated, will imperil our descendants for many generations. As a dramatic change in the last few years, glacial melting at twice predicted rates has been observed[28].

A second process, mitigating climate change, must win the race with the global warming process in order to avoid a global catastrophe. To win that race, humans everywhere must be educated regarding the consequences of our current behavior, and about available remedies. Humanity must be mobilized to initiate world reforestation, the most effective approach for extracting atmospheric CO_2. Oceans, once "equivalent in size"[29] "are already beginning to saturate in their ability to take up atmospheric [CO_2] … ."[29,9 page 14]

A "tipping point" is the common term for a "runaway instability" in the parlance of a control-systems engineer. The following quotation, from the Washington Post[30] is the fourth of "about 307,000" responses from Googling "James Hansen Tipping Point".

> *This "tipping point" scenario has begun to consume many prominent researchers in the United States and abroad, because the answer could determine how drastically countries need to reduce their greenhouse gas emissions in the coming years. While scientists remain uncertain when such a point might occur, many say it is urgent that policymakers cut global carbon dioxide emissions in half over the next 50 years or risk the triggering of changes that would be irreversible.*
>
> *There are three specific events that these scientists describe as especially worrisome and potentially imminent, although the time frames are a matter of dispute: widespread coral bleaching that could damage the world's fisheries within three decades; dramatic sea level rise by the end of the century that would take tens of thousands of years to reverse; and, within 200 years, a shutdown of the ocean current that moderates temperatures in northern Europe.*
>
> *The debate has been intensifying because Earth is warming much faster than some researchers had predicted. James E. Hansen, who directs NASA's Goddard Institute of Space Studies, last week confirmed that 2005 was the warmest year on record, surpassing 1998. Earth's average temperature has risen nearly 1 degree Fahrenheit over the past 30 years, he noted, and another increase of about 4 degrees over the next century would "imply changes that constitute practically a different planet."*

"It's not something you can adapt to," Hansen said in an interview. "We can't let it go on another 10 years like this. We've got to do something."

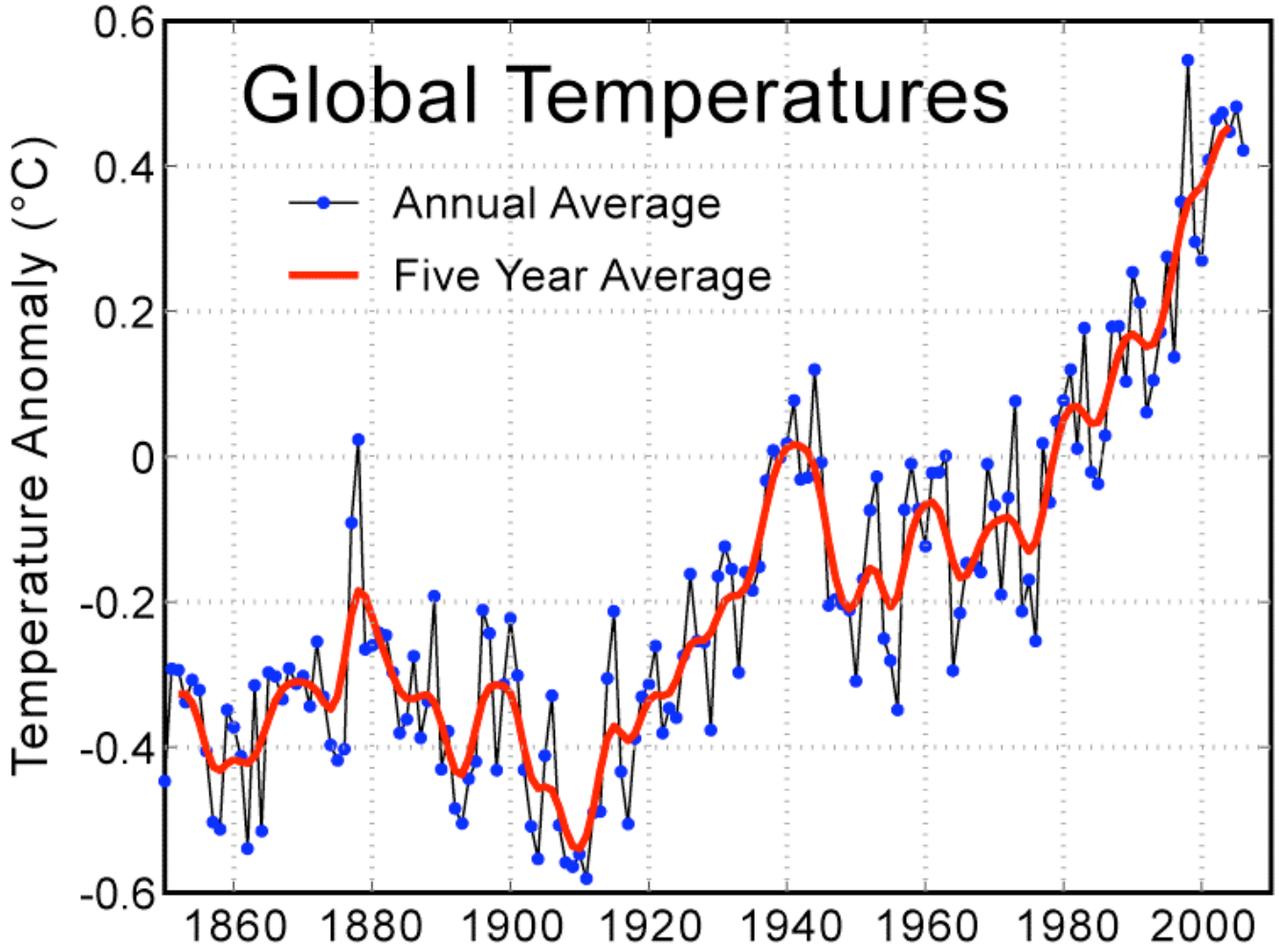
Princeton University geosciences and international affairs professor Michael Oppenheimer, who also advises the advocacy group Environmental Defense, said one of the greatest dangers lies in the disintegration of the Greenland or West Antarctic ice sheets, which together hold about 20 percent of the fresh water on the planet. If either of the two sheets disintegrates, sea level could rise nearly 20 feet in the course of a couple of centuries, swamping the southern third of Florida and Manhattan up to the middle of Greenwich Village.

While both the Greenland and the Antarctic ice sheets as a whole are gaining some mass in their cold interiors because of increasing snowfall, they are losing ice along their peripheries. That indicates that scientists may have underestimated the rate of disintegration they face in the future, Oppenheimer said. Greenland's current net ice loss is equivalent to an annual 0.008 inch sea level rise.

The effects of the collapse of either ice sheet would be "huge," Oppenheimer said. "Once you lost one of these ice sheets, there's really no putting it back for thousands of years, if ever."

"Abundant liquid water newly discovered underneath the world's great ice sheets could intensify the destabilizing effects of global warming on the sheets. Then, even without melting, the sheets may slide into the sea and raise sea level catastrophically … When the Larsen B ice shelf collapsed in March 2002, polar scientists realized that their timetable for action on global warming would be measured in months and years, not decades.".[6]

GLOBAL TEMPERATURE DURING THE INDUSTRIAL REVOLUTION



Source: {Refs 31 & 32}

Figure 2. Global Temperatures Since Beginning Industrial Revolution (1850 to 2006)

POTENTIAL SEA LEVEL RISE FROM VARIOUS GLACIERS AND ICE CAPS

Location	Volume (km^3)	Sea-Level Rise (m)	Sea-Level Rise (ft)
East Antarctic ice sheet	26,039,200	64.80	212.6
West Antarctic ice sheet	3,262,000	8.06	26.4
Antarctic Peninsula	227,100	.46	1.51
Greenland	2,620,000	6.55	21.49
All other ice caps, ice fields, and valley glaciers	180,000	.45	1.48
Total	32,328,300	80.32	263.5

Source: {Ref 33}, column for sea-level rise in feet added.
Table 1. Estimated Potential Max Sea-Level Rise

PAST TEMPERATURE RUNAWAYS

Past runaways have dramatically changed the temperature in as little as a decade. While melting the Greenland and West Antarctic ice caps would raise sea level over 40 feet, melting all glaciers on Earth would raise sea level 263 feet[33]. The elevation of the highest point on Manhattan Island is 265 feet; the highest point in Florida is 345 feet.

Even without runaway temperature, widespread prolonged drought is predicted for an equator-centered belt. Millions may starve from crop failure. Although single events like Katrina can rarely be blamed with certainty on climate change, further from the equator Katrina-like storms and tornados are predicted to be more intense, and some say to occur more frequently. Property damage would soar. Epidemics would proliferate from contamination of drinking water.

No estimate of remaining coal has been found indicating it will last for more than a few centuries. If actual fossil fuels are only twice proven reserves, and we continue business as usual, all fossil fuels will be gone in a century or so, and the world we know will no longer exist, see World Resources: Green Power, Green Energy, & Fossil Fuel Energy.

MELTING THE PERMAFROST

"Permafrost is the (until now) permanently frozen soil of the tundra, and as the ice crystals in it melt, it reflects less light and turns darker, absorbing more light, and that melts more permafrost. Helium dating of trapped bubbles in the permafrost shows that we're melting permafrost now that hasn't been melted in 40,000 years. And there's enough CO_2 and methane (another greenhouse gas) trapped in the permafrost to have the greenhouse gas levels not go up by a factor of two but by a factor of 10. … The world was there at least once before, most recently in the Permian era 250 million years ago. There was a massive release of isotopically light carbon from unknown causes, and CO_2 levels rose by a factor of 10. … Temperatures spiked for on the order of tens of thousands of years, and the fossil fuel record snows that about 90 percent of the species on the planet went extinct. We do not know if this will happen again. We do know that there is only one way to find out."[34,35]

GLACIAL EARTHQUAKES AND COLLAPSE OF LARSEN B ICE SHELF

Glacial earthquakes and collapse of the West Antarctica Larsen B Ice Shelf in 2002 March show that ice sheets are already sliding toward the ocean and, instead of melting over the centuries, can collapse into the ocean in a much shorter time.

> *'Some glaciers and ice streams periodically lurch forward with sufficient force to generate emissions of elastic waves that are recorded on seismometers worldwide. Such glacial earthquakes on Greenland show a strong seasonality as well as a doubling of their rate of occurrence over the past 5 years. These temporal patterns suggest a link to the hydrological cycle and are indicative of a dynamic glacial response to changing climate conditions. … These "glacial earthquakes" are*

characterized by emissions of globally observable low-frequency waves that are incompatible with standard earthquake models for tectonic stress release but can be successfully modeled as large and sudden glacial-sliding motions. … Seismic waves are generated in the solid earth by the forces exerted by the sliding ice mass as it accelerates down slope and subsequently decelerates. The observed duration of sliding is typically 30 to 60 s. All detected events of this type are associated with mountain glaciers in Alaska or with glaciers and ice streams along the edges of the Antarctic and Greenland ice sheets. The Greenland events are most numerous, and we present new data indicating a strong seasonality and an increasing frequency of occurrence for these events since at least 2002. … For the period January 1993 to October 2005, we have found 182 earthquakes on Greenland by analysis of continuous records from globally distributed seismic stations. … None of these earthquakes are reported in standard seismicity catalogs. We have modeled seismograms for 136 of the best-recorded events to confirm their glacial-sliding source mechanism and obtain improved locations. … This analysis yields an estimate of the twice-time-integrated active force couple at the earthquake source, a quantity that can be interpreted as the product of sliding mass and sliding distance. … All events have long-period seismic magnitudes in the range 4.6 to 5.1, corresponding to a product of sliding mass and sliding distance of 0.1 to 2.0 x 10^{14} kg m. The locations resulting from our seismogram modeling have an uncertainty of approximately 20 km. All 136 earthquakes analyzed can be spatially associated with major outlet glaciers of the Greenland Ice Sheet.'[7]

WARNINGS FROM THE 2007 UN BALI CONFERENCE IN NUSA DUA, INDONESIA — DIVERSE RESPONSES

'This year's studies by the Intergovernmental Panel of Climate Change concluded that centuries of warming, rising seas and species extinctions would probably result unless there were sharp curbs in climate-warming emissions within a few decades.

'"Logic requires that we listen to the science," said Stavros Dimas, the European Union's environmental commissioner. "I would expect others to follow that logic."'[36]

'[O]fficials from the United Nations, backed by the European Union and many developing countries, offered a draft plan for talks over the next two years, including a statement that dangerous warming can be avoided only if industrialized countries cut emissions by 2020 to levels 25 to 40 percent below those of 1990.

'But … the United States held firmly opposed to such language.' ibid Actions of some of today's leaders reflect alarming ignorance of what our generation has learned, and ancient people could only hypothesize. Alignment of stone structures at Stonehenge and elsewhere show that ancients had an appreciation for the effects of Earth's diurnal and orbital geometry beyond the understanding of some of our leaders today.

Ban Ki-moon, the United Nations secretary general said countries have a choice between a comprehensive agreement and "oblivion". Ibid

From these reports and later ones, the prospect for emission-free power from coal has been on and off for many years, and as of 2008-01-30 was being turned off, see Sequestering CO_2 from Coal.

Al Gore in his Nobel Peace Prize lecture said, "There is hopeful news as well: we have the ability to solve this crisis and avoid the worst — not all — of its consequences, if we act boldly, decisively, and quickly."[37]

Earth's Natural Climate Control System — So Finely Balanced That Imperceptible Geometric Changes Drive Glacial Cycles

Most of the time, starting at least many hundreds of thousands of years ago, Earth has been substantially covered by glaciers. About every 100,000 years, Earth has an interglacial hiatus — glaciers recede to cover primarily polar regions. Earth has been in a hiatus for about 12,000 years, during which our civilization has arisen. Glacial coverage may have delayed building a world civilization.

About three quarters of Earth's land is in the northern hemisphere. Land is more responsive than ocean to variations in heating from the Sun Therefore, the northern hemisphere drives Earth's glacial cycles.

Earth rotates about its north-south pole, causing diurnal events: day, night, sunrise and sunset. Earth orbits the Sun about the Ecliptic pole, causing annual events, including the four seasons, spring and fall equinoxes, summer and winter solstices, and perihelion and aphelion. Imperceptible geometrical variations cause the glacial cycle.[38]

The hiatus of 100,000 years ago lasted only about 12,000 years. But the orbital geometry of the current hiatus resembles more closely the hiatus of 200,000 years ago, which lasted about 35,000 years. So scientists think that the current hiatus is not due to end soon, regardless of human emissions.

Geometrical variations causing the glacial cycle are described below.

Spring and Fall Equinoxes

Equinoxes are the instants at which Earth's equatorial plane and the ecliptic plane coincide. On the day of the spring equinox, night and day are approximately equal in length, and night is getting shorter. On the day of the fall equinox, night and day are again approximately equal in length, but night is getting longer. Night's length from sunset to sunrise, is not exactly equal to day's length largely because sunrise is defined as the instant at which the first point of light from the Sun can be seen at the eastern horizon, and sunset is defined as the instant at which the last point of light can be seen at the western horizon. These instants can be observed very precisely, so they are used.

Earth's equatorial pole sweeps out a cone about Earth's orbital (ecliptic) pole in a cycle whose period is 25,772 years.[39] In each cycle, the times of spring and fall equinoxes vary by one year.

Equinox times can be quite precisely measured and predicted. In 1992, spring equinox occurred March 20 at 08:48 Universal Time (UT), and fall equinox September 22 18:43 UT.[40] In 2020, spring equinox will occur March 20 03:49 UT, and fall equinox September 22 13:30 UT.[40]

Summer and Winter Solstices

Solstices are the instants at which the angle between the Earth and ecliptic poles is maximum. Summer solstice is when the Earth's northern hemisphere is toward the Sun, and winter solstice is when the Earth's northern hemisphere is away from the Sun..

Like equinoxes, solstice times vary by one year due to precession of the Earth's pole about the ecliptic pole every 25,772 years. Also, solstice times can be precisely measured and predicted. In 1992, summer solstice occurred June 21 at 03:14 UT, and winter solstice December 21 14:43 UT.[40] In 2020, Summer solstice will occur June 20 21:43 UT, and winter solstice December 21 10:02 UT.[40]

Perihelion and Aphelion

Perihelion time is the instant at which Earth is closest to the Sun, and aphelion time is the instant at which Earth is farthest from the Sun.

Unlike equinox and solstice times, perihelion and aphelion times cannot be precisely measured and predicted. In 1992, perihelion occurred January 3 about 15:00 UT and aphelion July 3 about 12:00 UT.[40] In 2020, perihelion will occur January 5 about 08:00 and aphelion July 4 about 12:00 UT.[40]

With perihelion time currently about two weeks after winter solstice, heating from the Sun is close to maximum during northern hemisphere's winter.

Both the solstice time and the eccentricity of Earth's orbit can affect the timing of maximum heating during northern hemisphere's winter. If only the solstice variations were considered, the roles of the northern and southern hemispheres would be interchanged twice every 25,772 years. Variations in the obliquity must also be considered, as noted above in the statement that the current interglacial hiatus is not expected to end soon, regardless of human emissions.

Inclination of Earth's Equatorial with Respect to Its Orbital Plane (Obliquity)

Inclination of Earth's equator with respect to the ecliptic is currently about 23.5 deg, and ranges from 22.1 to 24.5 deg in a cycle of about 41,000 years.[41] Variations in obliquity have a great effect on glaciation.

The Sun's heat load on the northern hemisphere is approximately proportional to the sine of obliquity. So heat load due to obliquity variation cannot have increased by more than is the ratio sine(23.5 deg) / sine(22.1 deg) = 1.06 in the past 41,000 years.

Ellipticity of the Earth's Orbit (Eccentricity)

Eccentricity of Earth's orbit, currently only 1.67%, ranges from zero to 5% in a cycle of about 100,000 years.[42] The period for eccentricity variations is approximately the interval between one interglacial hiatus and the next. But with eccentricity period not a multiple of the obliquity period or the period for Earth's pole to sweep out a cone about the ecliptic pole, the geometry varies from one hiatus to the next, making hiatus duration vary even in the absence of anthropogenic effects.

The Sun's heat load on Earth is inversely proportional to the square of the distance from Sun to Earth. This distance is the semi-major axis of the Earth's orbit divided by 1+e, where e is the eccentricity. So heat load due to eccentricity cannot have increased by more than the ratio $(1.05 / 1.0)^2 = 1.1025$ in the past 100,000 years.

Summary of Orbital and Human Heat Load Effects

Orbital effects have increased Earth's heat by at most the product of obliquity and eccentricity effects = 1.06 x 1.1025 = 1.17 (17% in the last 41,000 years). But during industrialization, humans have raised atmospheric CO_2 at an ever-increasing rate, for about 35% increase in 150 years. "If the Earth had no atmosphere, the mean global surface temperature would be approximately 50 degrees Centigrade [90 deg Fahrenheit] colder!"[9]

"The global atmospheric concentration of carbon dioxide has increased from a pre-industrial value of about 280 ppm to 379 ppm in 2005."[27] This is a variation of slightly over 35%, twice the maximum variation due to orbital effects.

Atmospheric Scale Height

A typical chicken egg has a major diameter of 60 mm and a shell thickness of 0.45 mm. On this scale, with Earth's radius being 6,378 km, an egg shell extends from Earth's surface to an altitude of 96 km = 59 miles. The atmospheric scale height is 8.5 km[43] = 5.3 miles, so only 1/e ~37% of the atmosphere is above that height. (The pressure on a spherical surface at some height in the atmosphere above a spherical Earth is just sufficient to support the weight of the portion of the atmosphere above that surface.)

By comparison, transport aircraft fly at altitudes up to 41,000 ft, about 8 miles.

Conclusion: Much more than half of Earth's atmosphere lies below the height of a transport airplane, which is about one-eighth the thickness of an eggshell, at Earth's scale. The atmosphere is very thin and not very robust.

Ocean Depth

"The deepest point in the ocean is generally believed to be in the Marianas Trench in the Western Pacific Ocean at approximately 36,160 feet (11,021 m), according to the Rand McNally Atlas (1977)."[44]

Warnings have been widespread for at least several decades that the oceans are being over fished. In recent years, prices for fish have been much higher compared to the costs of

other foods, and some species are less often available in markets, apparently due to their diminished populations in oceans.

Conclusion: Like the atmosphere, but more extreme, ocean depth is much less than one-eighth the thickness of an eggshell, at Earth's scale. Oceans are not an inexhaustible resource for feeding humans or for storing human waste.

A civilization that can control its climate processes can save the planet.

CUTTING U.S. EMISSIONS UP TO 47.5% WITHOUT WAITING FOR AGENCIES OR NEW TECHNOLOGIES

Among all the ways U.S. energy is produced and used, only two lack an obvious way for eliminating emissions by eliminating consumption without waiting for new technologies to be developed by research projects: (1)

The U.S. can cut emissions by up to 47.5% without waiting for UN Sustainable Energy or for new technologies for eliminating remaining emissions. Only cuts in transportation related to aircraft must wait, see Liquid-Hydrogen Propelled Aircraft. Do similar possibilities apply to other developed nations?

Developing nations, like China and India, can follow the example of developed nations as soon as possible without interrupting progress for decade(s).

This section uses the U.S. as an example of how emissions of end-use sectors can be cut for a total reduction of more than half of U.S. emissions. The end-use sectors, defined by the U.S. Department of Energy, Energy Information Administration, are Residential, Commercial, Industrial, and Transportation.

Voluntary emission-cutting measures can taken by individuals in each sector. Government incentives such as rebates, tax exemptions, and tax deductions may successfully promote these measures.

Accounting for U.S. Total Reductions: See Arguments for Cutting Emissions of Residential, Commercial, and Industrial Sectors and Arguments for Cutting Emissions of Transportation Sector. Total emissions cuts are 35.8% and 11.72% of U.S. total, or a grand total of the 47.5% shown above.

U.S. PLANS NEW CONVENTIONAL FISSION POWER PLANTS

"Concerns about rising electricity demand and clean air are among the factors driving interest in new nuclear plants. Nuclear energy is the only electricity source that can generate electricity 24/7 reliably, efficiently and with no greenhouse-gas emissions."[14] see **U.S. Planning Fission Powerplants of Two Types**.

U.S. ENERGY CONSUMPTION BY END-USE SECTOR — 2006

The following table, from[45] shows the U.S. energy consumption by end-use by four sectors. Three, Residential, Commercial, and Industrial include combined-heat-and-power (CHP), and two, Commercial and Industrial include electricity-only plants. All four sectors include electrical system energy losses.

End-Use Sector	Residential	Commercial	Industrial	Transportation	Totals
Trillion BTU	21,054	18,001	32,426	28,401	99,882
Percent of U.S. Total	21.1	18.0	32.5	28.4	100.0

Table 2. U.S. Energy Consumption by End-Use Sector In 2006

Residential, Commercial, and Industrial Sectors — Cutting U.S. Emissions by Up to 35.8%

Discovering Ways and Means for Cutting Energy and Emissions

Residential, Commercial and Industrial sectors use energy and produce emissions for building heating, cooling, and lighting. Means for cutting energy consumption and emissions for buildings apply to all three sectors. The Industrial Sector produces emissions for many additional purposes; ways and means for cutting such emissions are not obvious.

A national poll, possibly as part of a census, could identify countless ways and means for cutting emissions. Poll results could support writing legislation to provide incentives for reducing emissions. Incentives have often included rebates, tax exemptions, and tax deductions. Knowledge derived by polls could be invaluable in selecting emission-reduction measures that are practical and cost effective.

Arguments for Cutting Emissions of Residential, Commercial, and Industrial Sectors

The measures described below, promoted by government incentives, including rebates and tax exemptions and deductions, argue that heating and cooling energy and emissions by up to 50% for each of the three sectors. Similar incentives and measures for the remainder of the industrial sector argue that similar results can be achieved, thereby cutting total emissions of the three sectors by 50%.

Summary: With the three sectors accounting for 71.6% of U.S. energy consumption, a 50% reduction is 35.8% of the U.S. total.

Heating and Cooling

"Heating and cooling account for about 56% of the energy use in a typical U.S. home, making it the largest energy expense for most homes."[24] With the Residential sector representing 21% of U.S. energy consumption in 2006, emission-free residential heating, ventilation and air conditioning (HVAC) will reduce national emissions by 12%. If similar reductions can be made in Commercial and Industrial sectors, emission-free HVAC can reduce U.S. emissions by 40%.

Insulation: Effective insulation can effectively block a building's heat loss in winter and block unwanted heat gain in summer. A good measure of effectiveness is that a building has a thermal time constant of 40 hours, that is, the rate of change of inside temperature is one fortieth of the difference between inside and outside temperatures per hour.[46] "Insulate the attic, basement, and crawl space, about 20 percent of energy costs come from heat loss in those areas."[47]

Insulating Attics — Ice Dams: Attic heat can cause ice dams to form in the overhang and gutter area. Ice dams can damage roofing and cause water to leak into walls at the upper boundaries of overhangs. Googling "attic heating ice dam" produces about 55,700 responses, the first ten of which include numerous ways to thwart ice-dam formation, including heated cables and gutters.[48 to 51] Thwarting ice dam formation generally takes energy, but if it reduces even more the energy needed for heating, it may be cost effective. It appears the optimum approach can be determined only case by case.

Scaling laws: Scaling laws favor large buildings, especially for heating. That is, doubling dimensions of a building quadruples the area exposed to the weather, but increases the interior volume by a factor of eight. Large apartment buildings may have enough heat generated from appliances and indoor activities to substantially reduce or eliminate the need for heating. and exposed area may be small enough to reduce or eliminate forced cooling.

Large commercial and industrial buildings may have enough roof area to supply all needed heat by solar thermal facilities, and all needed electric power by photovoltaic facilities.

Windows: In sun-facing walls or roofs, windows or skylights with clear double-glazing can capture about 75% of the incident solar energy, and with infra-red-opaque coatings minimize heat loss at night. On mild overcast days incident light may provide sufficient heat.

Solar-Thermal Collectors: Flat-plate collectors[52] Chapter 6 typically comprise a black absorber plate and one or more cover plates for minimizing heat loss to the atmosphere by convection and radiation. On the back side of the absorber plate are numerous fluid conduit tubes which conduct the heat to water used for transferring the heat to a water tank by means of a heat exchanger. Figure 6.18.1 shows test data, with collector efficiency ranging from just over 15% to just over 70%.

Concentrating Collectors: A concentrating collector has "an optical device between the source of radiation and the energy-absorbing surface"[52] Chapter 7. The purpose is to "deliver energy at temperatures higher than those possible with flat plane collectors."

Solar-Photovoltaic Panels: Buildings can be heated indirectly from electricity captured by photovoltaic panels, but area used by panels would be over four times as effective with clear windows.

Geothermal Energy: Possible sources are the ground around or under a building, and well water.[46] The geothermal energy source can also be a sink for storing heat. Sources can be used for both heating and cooling. A heat exchanger pumps heat from the source/sink to the building in winter, and heat from the building to the source/sink in summer. It takes energy to run the heat exchanger, which can be obtained emission-free from solar-photovoltaic panels, shingles, etc.

Clothing: Warm winter clothing and cool summer clothing can cut HVAC emissions.

Miscellaneous: "1 Keep original windows intact. … Weatherstrip them. 2. Use light paint colors for your house's exterior [to] reflect heat better … . 3. Insulate the attic, basement, and crawl space [see **Insulation**.] 4 Reuse old materials … . 5 Install fireplace draft stoppers, attic door covers, and dryer vent seals that open only when your dryer is in use. An open dampener in a fireplace can increase energy costs by 30 percent, and attic doors and dryer vent ducts are notorious energy sieves. 6. Plant trees. Evergreen trees on the north and west sides of your house can block winter winds, and leafy trees on the south and west provide shade from the summer sun. Using old photos of your house, try to match the historic landscaping. 7. Have an energy audit done by your local utility company, or visit Home Energy Saver (http://hes.lbl.gov). Audits can help pinpoint problem areas and

measure energy savings after you improve your home's efficiency. 8. In summer, open the windows and use fans and dehumidifiers, which consume less energy than air-conditioning. Many old houses were designed with good cross ventilation; take advantage of your home's layout. 9. Keep doors airtight by weatherstripping, caulking, and painting them regularly. Recent studies suggest that installing a storm door is not necessarily cost effective. 10. restore porches and awnings. Porches, awnings, and shutters were intended for shade and insulations. To save energy, draw shades on w inter nights and summer days."[47] 11. On a cold day, search the inside of outside walls for leaks of cold air, especially around electric outlets and switches. Air leaks can constitute a substantial fraction of a house's heat loss. They can often be plugged by stuffing fiberglass insulation into the passageway.[46]

Peak-Power Insufficiency — Backing Up Emission-Free Heating: A building closer than 45 degrees to Earth's north or south pole must have very effective insulation for insolation (exposure to sunlight) to be sufficient for heating. That is, solar heating to the extent necessary to heat a cold house as fast as a furnace burning oil or gas may be very costly, and the Sun may not be shining when the building must be heated. Effective insulation can hold a building's temperature so that wearing a sweater early in the morning eliminates the need to immediately restore daytime temperature.

Even with sunshine, it may not be feasible to do without fossil-fuel backup heating. Consider matching the heating rate of a furnace by means of windows. A gas furnace of a typical U.S. home produces 100,000 BTUs per hour. This power is 29.3 kilowatts. With solar power density at Earth surface of one kilowatt per square meter, and 75% of the power passing through double-pane clear glass, it would take about 40 square meters of window area normal to the direction to the Sun to match the heating rate of the furnace. If the Sun's direction were 60 degrees off normal, the window area would need to be doubled, to about 80 square meters, over 800 square feet. This window area compares with the upper floor area of a typical two-story U.S. house.

An alternative to extremes in insulation and window area is to store solar heat for rapidly raising temperature, see below.

Storing Heat Energy: Heat energy, when no geothermal source/sink is available, can be stored in insulated water tank(s) within the building. Stored heat can be accessed as if it were geothermal energy. Although it is possible to use stored electric energy to cool the house by heating tanked water, it may be more efficient to use electric energy to run air conditioning.

Avoiding Freezing in Power Outages: Photovoltaic electric power can easily run the gas valve of a gas fireplace directly. It can also run the fan of a gas furnace, possibly with the help of a battery used for making heating immune to loss of power from the Sun and power grid. This is critical for avoiding freezing when away from home in winter.

Regardless of whether a building is solar heated, effective insulation is desirable. A building is more comfortable with good insulation, and insulation's cost is recovered by lowering the cost of heating.

LIGHTING

Fluorescent Bulbs: Normal and compact fluorescent (CFL) reduce electric power by about a factor of four compared to incandescent bulbs, perhaps making power from photovoltaic panels feasible. When powered from the grid, CFLs are cost effective, although their emissions reduction is small compared to what is needed.

LED Lighting: Light Emitting Diodes are advertised as producing no art-damaging ultraviolet, and twice as much light per unit power as CFLs, but merchants on the Web were found asking ten times CFL prices for equivalent LEDs.

ELECTRIC POWER

Electric power can be generated by photovoltaic solar panels whose efficiency is about 17%, or by photovoltaic shingles or sheets. Consultants have expressed concern about efficiency and reliability of shingles and sheets.

Storing Electric Energy: Electric energy can be stored in batteries, so that it can be used later when other energy sources are unavailable or peak power is insufficient (see below). Currently, ordinary lead-acid batteries minimize the unit cost for storing electric energy, let's hope that changes. Currently, lithium-ion batteries minimize the weight and volume for storing electric energy, let's hope prices fall.

TRANSPORTATION SECTOR — CUTTING U.S. EMISSIONS BY UP TO 11.72%

The following table, from[53] shows the U.S. energy consumption by mode for the Transportation Sector. There is a slight conflict in total energy use for this Sector in 2006 compared to the table under U.S. Energy Consumption by End-Use Sector — 2006 even though both tables came from the same DOE Administration. The table cited here shows the transportation sector used 24,906.7 trillion BTUs whereas the previous table shows 28,401. As a consequence, the table below shows transportation's share is about 29.4% of U.S. energy, whereas by the previous table, transportation's share is about 28.4%.

Mode	Highwy	Air	Water	Rail	Lubri-cants	Pipeline Fuel Natural Gas	Mili-tary	Totals
Trillion BTU	22815.4	2993.7	1369.1	609.7	202.8	663.9	752.3	29406.7
% Transptn Totl	77.59	10.18	4.656	2.073	0.6896	2.258	2.558	100.001
% of U.S. Total	22.84	2.997	1.371	0.610	0.2030	0.665	0.753	29.4416

Table 3. U.S. Transportation Sector Energy Consumption in 2006

ARGUMENTS FOR CUTTING EMISSIONS OF TRANSPORTATION SECTOR

Arguments for reductions in transportation emissions are, by mode:

1. **Highway**: By (1) switching from Sport Utility Vehicles to hybrid coupes, sedans, and station wagons; (2) switching from long-distance buses to trains; and (3) switching long-distance freight from trucks to rail; highway emissions may be cut 50%.

2. **Air**: Making rail travel more appealing and less costly, and providing incentives for using trains, may reduce air travel and emissions by 10%.

3. **Water**: Shipping of international freight by water is preferable to air. Therefore prospects for reducing water travel significantly appear dim.

4. **Rail**: For both passengers and freight, rail is the preferred mode. Rail emissions may be held to current levels by switching from diesel to electric power while switching electric power from fossil fuels to wind and solar.

5. **Lubricants**: No significant change in lubricant emissions appears obviously possible.

6. **Pipeline Gas**: With increases in local solar-thermal heating, gas consumption and pipeline emissions may be held despite increases in total energy consumption.

7. **Military**: With the Iraq war ending and new wars viewed unfavorably, military emissions may be maintained.

Summary: The sum of a Highway cut of 50%, 11.42% of the U.S. total; plus an Air cut of 10%, 0.3% of the U.S. total, is 11.72% of the U.S. total for transportation.

Emission Rates of Current Transportation Means

The following table of emission costs and cost rates is collected from several sources. Load factor would affect per-passenger emissions substantially; per-passenger emissions of a half-empty airplane, train, or bus would be much higher than for a full one. Emission per seat is as great as per passenger only if all seats are filled.

Regarding load factors, the Mayors' report[54] uses the term "per seat" for the transcontinental flight, giving the airplane an unfair advantage compared to modes where load factor is taken into account. The American Bus Association (ABA) report[55] is quite well documented, but load factor seems to be accounted for only for motor coach and van pool, so ABA data may give the other three modes shown below unfair, but not necessarily equal, advantages.

Emissions for electric intercity rail,[55] "account for all carbon dioxide produced by electricity generation" which apparently is why there is no distinction between electric and diesel. However, when electric energy becomes emission-free (wind power or solar power), rail transportation will be emission free. But travel by conventional and plug-in hybrids will be emission free only within the battery-only range, a possibility that can apply to buses and trucks as well as passenger cars.

Activity	CO2 emissions A: Pounds B: gm per passngr-mile	Ref
Burning one gallon of gasoline	20 A	54
Train, diesel versus electric	5 to 50% of 20 mpg car A	56
Transcontinental flight (JFK-LAX) per seat	1,158 A	54
Transcontinental hybrid (2827 Mi N.Y.C. to L.A.)	1,414 A	Arithmtic
Domestic Air Travel (Scheduled between U.S. cities)	243 B	55
Car Average Trip (US fleet average 22.9 mpg)	235 B	55
Intercity Rail (electric or diesel long distance)	179 B	55

Van Pool (ride sharing for a group)	101 B	55
Motor Coach (passenger compartment above baggage)	56 B	55
20 mile commute at 20 miles per gallon at 20 MPG	20 A	54
20 mile commute, 40 MPG [hybrid Prius or Civic HEV]	10 A	54
20 mile commute, 100 MPG [plug-in hybrid (PHEV)]	4 [+ ? for electricity] A	54

Table 4. U.S. Transportation — Selected Emission Costs and Cost Rates

INTERNATIONAL ACTIONS — TWO NEW UN AGENCIES — CLIMATE CHANGE MITIGATION AND INTERNATIONAL SUSTAINABLE ENERGY

Building the wind- and solar-power facilities to meet the New 2050 Emission-Free Power need will be the largest challenge mankind has ever faced. But we have been warned that we must do so: "Humanity must act collectively and urgently to change course through leadership at all levels of society. There is no more time for delay."[3] Humanity can ignore this warning at its peril. Or it can accept the challenge, which will bring unprecedented humanitarian benefits, see Immediate Humanitarian Benefits from Accepting the Climate-Change-Energy Challenge.

Both agencies may be established by the United Nations, as were the two panels that have made such great contributions.

Why Scope Must Be International: Voluntary nation-by-nation reforestation and conversion to emission-free energy may be appealing, but both must freely cross national boundaries. Worldwide voluntary action is unlikely, many nations will follow the example of nations that participated in creating the Kyoto Accords, but declined to abide by them.

MOBILIZING PUBLIC SUPPORT — SIMCASTS, CONTRACTORS, COMMUNICATIONS, AND DYNAMIC LEADERSHIP

To mobilize the world UN agencies may apply methods that were successful in meeting the most-nearly comparable previous challenges. Here are examples, with some lessons learned.

- Preparing to fight the Nazis in World War II. In World War II, newscasts of early allied defeats left no doubt that the axis threat was real, and that allied nations had to mobilize immediately. Newscasts would come too late to help in averting consequent climate change, but consequences are already understood by world climatologists using simulators to trace the effects of GHGs and various mitigation scenarios. Simcasts (simulator forecasts) can predict perils that would be faced by future generations. Transforming simulation results into moving pictures is a well developed art. Simcasts will be dramatic and persuasive, a great aid in convincing the public and world leaders that, like WWII, the threat is real, and immediate mobilization is paramount.

- Building the U.S. Interstate Highway System and the Autobahns. Private contractors working competitively are often efficient in carrying out major projects.

- Communicating within sessions of the European Union entails Simultaneous translation of proceedings to as many as twenty, languages at considerable cost. "The EU employs some 4,000 full-time interpreters and translators, not to mention the translating titan called E-C Systran, a software program that can pump out 2,000 pages of translation per hour."[5] Appendix II, pages 285-6. By contrast, communicating with pilots in the international air traffic control system is entirely in English.

- Project Apollo, safely flying humans to the moon and back. President Kennedy, a dynamic leader, declaring a major objective, fully disclosing the difficulties, as well as the benefits, mobilized public support of a major project.

CLIMATE CHANGE MITIGATION AGENCY

This agency mitigates the world-wide consequences of climate change.

Regarding carbon dioxide, oceans, and forests, because "the oceans are already beginning to saturate in their ability to take up atmospheric carbon dioxide at the current rate" and "the land is the only other major sink for this greenhouse gas"[9] page 14, re-forestation is the most effective means for purging CO_2.

Paper companies such as Georgia-Pacific and others have been re-foresting for generations to maintain raw materials for paper, and may be engaged to re-forest their nations and to train inexperienced teams in other nations.

Funding may be obtained from member nations according to their GHG emissions in a model year such as 2007. New permanent forests do not produce revenue, so the revenue needed must be collected from those who produce or would be harmed by emissions.

MITIGATION MEASURES POSSIBLE IMMEDIATELY

Primary source of these measures is {Ref 57}.

A. **Forestation**: Replant lost forests and plant new forests. Photosynthesis is the most-effective GHG extraction method.

B. **Stop Deforestation**: Make deforestation illegal, or subject to tax.

C. **Oceans**: Oceans naturally extract CO_2, but depositing CO_2 in oceans raises acidity, and can harm or kill plant and animal life.

D. **Glacial Melt**: Can glacial melt irrigate drought-stricken farms and refill aquifers?

E. **Tax Credits**: Provide tax credits for reducing emissions.

F. **Carbon Tax**: Impose taxes for emitting CO_2 or CH_4.

MITIGATION MEASURES ENTAILING TECHNOLOGY DEVELOPMENT

BIO ENGINEERING

Plants may be developed to replace food crops and extract GHG(s) copiously, especially where it's dry and windy.

CLIMATE ENGINEERING INCLUDING ALBEDO ADJUSTMENT

In 1991, Mt Pinatabo erupted, setting an example of how the consequences of atmospheric carbon dioxide might be avoided. Quotations below are from {Refs 58, 59}.

"Nobel Prize-winning scientist Paul Crutzen, professor emeritus at Utrecht University in the Netherlands, has set the scientific community afire with a proposal to address global warming, should it be demonstrated to endanger the planet.

"Crutzen, who won a Nobel Prize in 1995 for his work regarding atmospheric ozone depletion, demonstrated in the August issue of *Climate Change* that sulfur dioxide can be released into the Earth's extreme upper atmosphere to deflect incoming solar radiation and lower the Earth's temperature.

"Crutzen's proposal was inspired in part by sulfur dioxide releases in the 1991 Mt. Pinatubo volcanic eruption, which lowered global temperatures by 0.5 degrees Celsius for a full year. That cooling negated slightly more than half of the Earth's total temperature gain over the entire previous century."

Crutzen writes that the necessary albedo adjustment can be achieved "by a continuous deployment of about 1-2 Tg S per year for a total [annual] price of US $25-50 billion, or about $25-50 per capita in the affluent world [and 500,000 premature deaths]". "According to the World Health Organization, the pollution particles affect health and lead to more than 500,000 premature deaths per year worldwide".

INTERNATIONAL SUSTAINABLE ENERGY AGENCY

This agency oversees the conversion of the world's power industries (coal, oil, gas, and electricity) to emission-free energy sources. The agency may be modeled after the U.S. Defense Advanced Research Projects Agency (DARPA).

Much of this conversion can be accomplished with existing technology, and can be undertaken immediately, without waiting for any new technology to be developed. Tasks that must await development of new technology are described under Developing Technologies for Eliminating Remaining Emissions — Research Projects.

An international agency is needed because construction projects, wind farms and solar-energy facilities, must freely transcend national boundaries. Also, benefits must be distributed across national boundaries, where abrupt changes in standards may occur. Among benefits will be the reduction in disparities between rich and poor nations and groups, and enhancing prospects for world peace. "Sustainable energy will not truly succeed if major segments of the earth's population remain hungry or economically destitute."[21] pages 81-2.

For-profit development of sustainable energy does not seem to be reducing disparities, see the table in {Ref 60}, which shows wind capacity by country, with India the only country not in the OECD {Ref 61}. Iberdrola, Spain's second largest electricity group, most of whose renewable energy capacity is from wind has "38,000 MW of renewable-energy capacity in the pipeline, including 6,000 in Spain and a similar amount in Britain [and] 19,200 MW … in the United States"[62].

Financing may be needed only for construction; revenues may maintain the agency indefinitely.

The size of the immediate tasks that may be assigned to this agency should be clear from the following sections.

Energy transmission facilities such as electric power grids, and pipelines to transport hydrogen to on-demand users and hydrogen storage facilities whenever they become practical as a result of cited research projects or otherwise. For the U.S., grid capacity must be increased by a factor greater than 4-1/2, see Immediately Begin Updating and Building Electric Power grids. Hydrogen piping must start from scratch.

The Energy Challenge — Stop Generating Greenhouse Gases, Convert to Emission-Free Energy

World power capacity today is about 13 Terawatts, 30 year growth extrapolated to 2050 is 36 Terawatts, the New 2050 Emission-Free Power is 30 Terawatts. This level will reduce 2050 emissions to just under half of today's emissions and to 20% of what 2050 emissions would be if the world made no change in course.

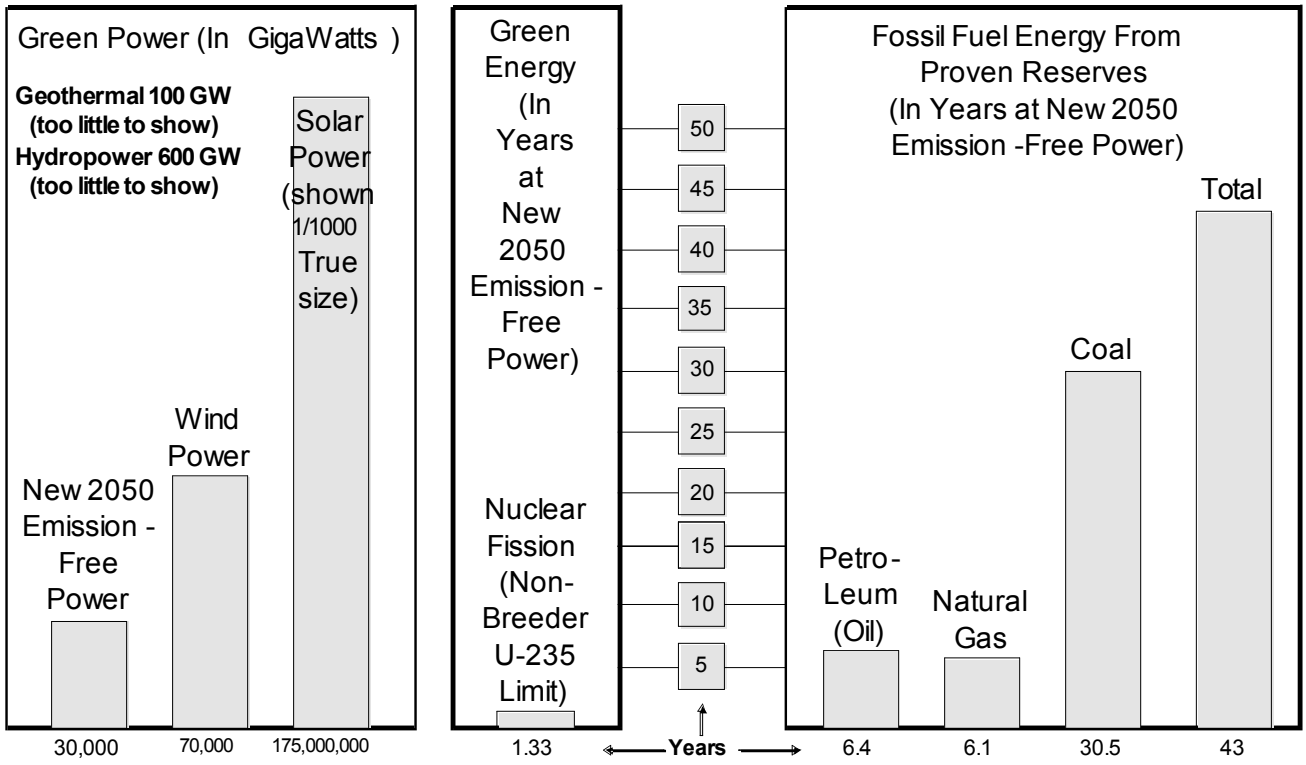
New 2050 Emission-Free Power is equivalent to the power from 30,000 nuclear fission power plants, or 20 million Enercon GmbH E-112, wind turbines. The world currently has 441 nuclear fission power plants. Each turbine's rotor diameter is 113 meters, which is larger than a football field, including end zones, the world's largest (2004 December[19]). Each turbine has a capacity of 6 MW, but the average efficiency of wind turbines is about 25%.

World Resources: Green Power, Green Energy, & Fossil Fuel Energy

The following bar chart shows that only two sources of emission-free power are sufficient to supply the New 2050 Emission-Free Power. Wind power potential is over twice the need, and solar power potential is over five thousand times the need. The sun can meet 2050's energy needs in about 90 minutes. No doubt world deserts can supply the equivalent of 30,000 typical fission powerplants with a comfortable margin.

Consider three quotations[63]; (1) "Earth's ultimate recoverable resource of oil, estimated at 3 trillion barrels, … the Sun supplies to Earth in 1.5 days."; (2) "An estimated 100 TW of solar [power] go into photosynthesis,"; and (3) "Although plants have covered Earth in green in their quest to capture solar photons, their overall conversion efficiency is too low to readily satisfy the human demand for energy." Thus solar power impinging on Earth (see bar chart below) is 1,750 times estimated photosynthesis power, the maximum obtainable from plants.

On the other hand, the bar chart shows that proven reserves of fossil fuels are good for only 43 years of the New 2050 Emission-Free Power. Although no estimate of actual coal resources has been found, if fossil fuel resources (coal, oil, and gas) were actually twice proven reserves, they would be depleted in about a century.



Sources: (A) New 2050 Emission-Free Power[17] page 69; (B) Nuclear Fission Non-Breeder U-235 Limit: ibid page 60; (C) *Wind Power*[18]; (D) Solar Power: computed from well-known solar constant = 1,370 W per m^2 and Earth's radius = 6,378 km[64] page 192; (E) *Sustainable Energy*[21] Tables 2.3 page 60 and 2.1, page 53.

Figure 3. Green Power, Green Energy, and Fossil-Fuel Energy

The value of 30 terawatts for New 2050 Emission Free Power in Figure 3 is the upper end of the "10 and 30 terawatts" range specified in Reference 17, and one may wonder whether picking the upper end is justified. An even higher number would have to be picked in order to meet the UN specification, "A UNITED Nations meeting on climate change in Vienna has recognised recent scientific data that global emissions of greenhouse gases need to peak in the next 10 to 15 years and be reduced to very low levels well below half the levels in 2000 - by the middle of this century."[65] Even if 2050 emissions are computed based on extrapolating 1970-2000 annual world energy to 2050, the 30 emission-free terawatts is still not quite enough to satisfy the UN specification.

With proven reserves of coal good for only 30 years at new 2050 emission-free power, and nobody knowing how much coal beyond proven reserves exists, continuing business as usual by burning coal at an ever greater rate is surely not possible for more than another 200 years, ten generations, and one of the next ten generations will be the last.

ENERGY FROM DISPOSAL OF NUCLEAR WEAPONS

This section quotes several references pertaining to "Mixed oxide, or MOX fuel"[66]. The situation is that only four nations, the U.S. is not included, are using MOX, which could extend the fuel available for the world's current fission powerplants by a small amount. Here are supporting quotations, see also **MOX**.

ABSTRACT[67]

The process of nuclear disarmament frees a significant amount of weapons plutonium for other uses, which, if unutilized, represents a constant general threat. In France, Great Britain, Belgium, Russia, and Japan, reactor-grade plutonium is used in [mixed oxide (MOX)] fuel production. Making MOX-fuel for CANDU (Canada) and pressurized water reactors (PWR) (Europe) is under consideration in Russia. If this latter production is added, as many as 5 tons of Pu per year might be processed into new FAs [fuel assemblies] in Russia.

USING WARHEAD PLUTONIUM AS REACTOR FUEL *DOES NOT* MAKE IT UNUSABLE IN NUCLEAR BOMBS[68]

The nuclear industry and other advocates of using warhead plutonium in "mixed-oxide" (MOX) plutonium-uranium fuel often claim that the MOX option would make plutonium unusable in weapons. Such claims are inaccurate and irresponsible. Using warhead plutonium in MOX fuel neither "burns it up" nor renders it unusable in nuclear weapons. In fact, reactor-grade plutonium is even more desirable than weapon-grade in crude bomb designs that might be used by terrorists because reactor-grade makes initiation of the nuclear chain reaction easier.

THERMAL REACTORS[66]

Over 30 thermal reactors in Europe (Belgium, Switzerland, Germany and France) are using MOX and a further 20 have been licensed to do so. Most reactors use it as about one third of their core, but some will accept up to 50% MOX assemblies. In France, EDF aims to have all its 900 MWe series of reactors running with at least one-third MOX. Japan aims to have one third of its reactors using MOX by 2010, and has approved construction of a new reactor with a complete fuel loading of MOX.

HISTORY[69]

At the end of the Cold War, the United States and the former Soviet Union began dismantling nuclear weapons. As a result, both countries were left with large quantities of surplus weapons-grade highly enriched uranium and plutonium. In September 2000, the United States and Russia signed an agreement to reduce their respective stockpiles of surplus plutonium.

The Department of Energy (DOE) evaluated the different strategies to dispose of this material. Under DOE's Surplus Disposition Program, DOE plans to convert approximately 34 metric tons of surplus weapons-grade plutonium into mixed oxide (MOX) fuel to be used in commercial nuclear power plants. As part of the program, DOE selected Duke Cogema Stone & Webster (DCS) as the contractor to design, construct, and operate a facility to fabricate the MOX fuel.

LICENSING INFORMATION[69]

The NRC process for licensing an MFFF would be generally the same as that for licensing other fuel cycle facilities. On April 18, 2001, the NRC published a notice in the Federal Register *announcing that the NRC had accepted an application for*

authority to construct a MFFF from DCS. The notice also announced an opportunity for a hearing on the DCS application.

On March 30, 2005, the NRC issued a Construction Authorization (CA) to DCS for a MFFF to be located at the Savannah River Site in South Carolina. The NRC staff's technical basis for issuing the CA is set forth in NUREG-1821, "Final Safety Evaluation Report on the Construction Authorization Request for the Mixed Oxide Fuel Fabrication Facility at the Savannah River Site, South Carolina." The results of the staff's environmental review related to the issuance of the CA are contained in NUREG-1767, "Environmental Impact Statement on the Construction and Operation of a Mixed Oxide Fuel Fabrication Facility at the Savannah River Site, South Carolina - Final Report."

In a letter dated October 25, 2006, DCS requested the NRC's consent to change the corporate name for the CA for the MFFF to Shaw AREVA MOX Services (MOX Services). The NRC reviewed the request for a name change and issued an amendment to the CA to reflect the new corporate name on November 30, 2006.

On September 27, 2006, MOX Services submitted a license application (LA) and Integrated Safety Analysis Summary for a mixed oxide fuel fabrication facility at the Savannah River Site in South Carolina. In the process of performing the Acceptance/Acknowledgment review of the LA, the staff identified some parts of the submittal that required some modification in order to complete the initial review.

The preliminary review of the license application indicated that much of the information required by Part 70 (in particular 10 CFR 70.22 and 10 CFR Part 70, Subpart H) to be in an operating license application was contained in the Integrated Safety Analyses (ISA) Summary. The staff also believed that some of the information that was identified to be withheld as proprietary should be publicly available. A revised LA was submitted to the NRC on November 16, 2006. The NRC completed its Acceptance/Acknowledgment review and sent a letter to MOX Services on December 20, 2006, indicating that the application was acceptable for docketing (reference ML063530612). For more information, see the following pages:

PRODUCTION AND DISPOSITION[70]

Over 1500 metric tons of plutonium have been produced worldwide, some for weapons use, and most of the rest as a byproduct of electricity production. It is important to note that the plutonium produced as a byproduct in a nuclear power reactor is created in its many isotopic forms, including Pu-239, Pu-240, Pu-241, and Pu-242. This is known as "reactor-grade" plutonium. In contrast, "weapons-grade" plutonium contains almost pure (over 90 percent) Pu-239. Plutonium-239 is created in a reactor that is specially designed and operated to produce Pu-239 from uranium.

With the end of the Cold War, the United States and the former Soviet Union began dismantling thousands of nuclear weapons which has resulted in a surplus of highly enriched uranium and plutonium. To dispose of this surplus and protect against it falling into the wrong hands, the U.S. has plans to mix the plutonium

with uranium to make mixed oxide (MOX) fuel for power reactors. The intent of the MOX fuel program is to irradiate the so-called "weapons-grade" plutonium, converting it to "reactor-grade," which will make the plutonium no longer suitable for use in advanced nuclear weapons. There would be no reprocessing or subsequent reuse of the MOX spent fuel. The fuel would be disposed of in a waste repository along with other high-level nuclear waste.

CANADA'S ROLE[71]

When it comes to radiologically hazardous materials as weapons plutonium, there is no room for a "not in my backyard" syndrome, as the environmental and security consequences of any accident or misuse befalling such material in Russia (or elsewhere) would also impact on this country. Since no feasible options currently exist for the safe long-term storage of weapons plutonium, burning the material under proper international supervision in commercial power reactors remains a viable option. Given the suitability of the CANDU for this purpose, Canada should also actively explore the possibilities of selling CANDU reactors to the US and Russia to assist in the safe and efficient disposition of weapons plutonium. In this regard, the Canadian government needs to make an informed political decision to pursue the CANDU option in assisting the US and Russia safely dispose of their stockpiles of weapons plutonium. Having lived under the US nuclear umbrella for nearly 50 years, and being a strong proponent of nuclear arms control, Canada has an obligation to play a constructive role in helping the world deal with its burden of excess weapons plutonium.

WOULD MOX FUEL BE REPROCESSED?[72]

The United States does not currently reprocess nuclear fuel (a small quantity of used fuel was reprocessed at the West Valley site in the 1960s). Reprocessing of used fuel involves the chemical treatment of the fuel to separate unused uranium and plutonium from radioactive fission products. Theoretically, uranium could be recycled through an enrichment facility and some recovered plutonium could be used in new fuel assemblies. The DOE has stated that it has no capability and no plans to reprocess used reactor or MOX fuel.

QUESTIONS[73]

*Why are countries such as France and Japan pursuing MOX recycle? See also **MOX**.*

IMMEDIATELY ACCELERATE PRODUCTION OF WIND AND SOLAR POWER TO MEET 2050 NEEDS ON TIME

Primary Source Wind: Wind power is economically competitive. The potential is more than twice the need[18]. Wind turbines are not affected by darkness. By replacing solar power lost at night, wind turbines may support charging batteries of plug-in hybrid vehicles.

No doubt U.S. great plains could feed the nation while hosting wind farms meeting all U.S. energy needs! "'*I didn't really expect them to come all the way out here in northern Iowa to start a wind farm. But this is really great. Now we grow corn on the ground and generate power in the air — all on the same piece off property*" Delbert Watson, farmer near Clear Lake, Iowa, quoted in the Christian Science Monitor[20]. "Paul Sclavounos is

designing floating platforms that would be stable enough to support even very tall windmills and far enough offshore to mollify the view-protectors"[74] page 17. Do reduced transmission distances and losses make off-coast siting preferable for densely populated coastal regions?

Secondary Source Solar Thermal: Solar Thermal (power towers and parabolic troughs) minimize land area per unit of power[21] Fig 17.7, use the data for Solar Thermal Trough. One type of power tower is also called a Heliostat, in which a field of Sun-tracking mirrors surrounding the tower focus sunlight on a receiver tank at the top, ibid Fig 13.14. The tank holds a working fluid which, when heated, drives a turbine and generator to produce electricity. "[N]ine [parabolic] trough power plants in California's Mojave Desert provide the world's largest generating capacity of solar electricity, with a combined output of 354 megawatts" ibid Fig 13.15. What is the potential of Sahara, which accounts for over one-fourth of Africa's area, or the Libyan or Syrian Deserts?

Another type of power tower is called a Solar Chimney or Solar Updraft Tower[75&76]. Instead of using a steam turbine, it encloses many wind turbines at its base, and drives the turbines by heating air within the chimney to cause it to rise, sucking in cold air' which drives the turbines. It's an easy guess that most of the Sun's energy escapes as heat making this type valuable only where land is plentiful. "A 650-foot prototype … had a 32-month period of daily operation during which it ran for an average of 8.9 hours per day. … During this time it had a 0.53% solar to electricity efficiency, which could be increased to 1.3% in a 100 MW unit."[76]

"'We have enough suitable land in the [U.S.] Southwest for CSP [Concentrating Solar Power] to support over 6 million megawatts of capacity," according to Mark Mehos, the CSP program manager at the National Renewable Energy Laboratory (NREL) in Golden, Colorado.'[77] That would be 20 percent of the New 2050 Emission-Free Power, Figure 3, Green Power, Green Energy, and Fossil-Fuel Energy.

Tertiary Source Solar Voltaic: With Collectors on Sun-facing surfaces, buildings may meet their own energy needs and deliver electric power to the grid. Solar voltaic efficiency is currently only about half that of solar thermal, making land costs for power plants much higher, ibid table 17.7, and the amount of world solar photovoltaic power is hard to determine. Photovoltaic power seems to be practical mostly in corporation buildings and residences. Photovoltaic power in residences is valuable for backing up electric utilities, enabling heating and home appliances to operate during power outages. Battery backups for loss of sunshine are practical but expensive. The International Sustainable Energy Agency's role in photovoltaic power may be largely arranging subsidies for the benefit of society.

Pumped Storage: Since there are times when neither local wind nor sunlight is available, some way of storing energy for use during slack periods is required. With pumped storage, high- and low-elevation reservoirs are used. When surplus power is available, it pumps water from the low to the high reservoir. During slack periods, water drives turbines in descending to the low reservoir. Reservoirs must be designed to avoid being disabled by freezing. There are over 140 such plants in the world today[22].

Immediately Begin Updating and Building Electric Power grids

In developed nations, capacity of electric power grids must be raised to distribute increased GHG-free power, which is most conveniently distributed electrically. Plug-in

Hybrid Electric Vehicles (PHEVs) are a key example. Building heating and cooling and manufacturing are others. About 20% of U.S. energy is currently electric, and must be increased to perhaps 70 to 90% (depending upon the amount of building heating and cooling supplied in situ) which would require transmission capacity to increase by a factor of 3-1/2 to 4-1/2 plus a power-growth factor.

In large portions of third-world nations, no power grids exist yet, and energy needs are met currently without controlling emissions. Where wood is the primary source of energy, climate change consequences are double; burning wood emits GHGs, and cutting trees reduces photosynthesis needed to extract CO_2. GHG-free electric power could eliminate both consequences.

CONFLICTS AND THEIR CONSEQUENCES — A NEUTRALITY POLICY

Members of the two UN Agencies must neither participate in nor be endangered by conflicts between nations.

Just as U.S. reconstruction in Iraq has been thwarted by open fighting in Iraq, actions of the UN agencies are likely to be thwarted.

A UN neutrality policy could thwart progress in both nations engaged in a conflict. Such a policy could have thwarted progress in Israel and its Arab neighbors for 40 years. What about other international conflicts?

Would a neutrality policy's withholding of benefits provide sufficient incentive to cause nations to resolve conflicts quickly?

DEVELOPING TECHNOLOGIES FOR ELIMINATING REMAINING EMISSIONS — RESEARCH PROJECTS

Eliminating remaining emissions depends on successfully completing the following research projects, which are described in order of diminishing estimated payoff.

NUCLEAR FUSION POWER

The process that powers the sun can produce almost unlimited energy. But I concluded when I first studied this in the early 1970s, that it didn't have a chance to become productive in my lifetime. Now it is widely believed that it won't be productive in the first half of the 21st century. The French, who have won the world contract to build the next experimental fusion reactor, should contribute to making the day come.

SEQUESTERING CO_2 FROM COAL

"Coal is likely to remain an important source of energy in any conceivable future energy scenario."[13] "We have confidence that large-scale CO_2 injection projects can be operated safely, however no CO_2 storage project that is currently operating (Sleipner, Norway; Weyburn, Canada; In Salah, Algeria) has the necessary modeling, monitoring, and verification (MMV) capability to resolve outstanding technical issues, at scale. Each reservoir for large-scale sequestration will have unique characteristics that demand site-specific study, and a range of geologies should be investigated. We estimate that the number of at-scale CCS ['CO_2 Capture and Sequestration' or 'Carbon Capture and Storage'] projects needed is about 3 in the U.S. and about 10 worldwide to cover the range of likely accessible geologies for large scale storage. Data from each project should be thoroughly analyzed and shared. The cost per project (not including acquisition of CO_2) is about $15 million/year for a ten-year period." Ibid

"Today I am pleased to announce that the United States will sponsor a $1 billion, 10-year demonstration project to create the world's first coal-based, zero-emissions electricity and hydrogen power plant...", President Bush, 2003-02-27[78]. This project was named FutureGen, and the prospect has received considerable attention in the intervening years[79]. But FutureGen "today remains a collection of research projects. No FutureGen plant has been constructed, and no site for one has been chosen [but see 'Mattoon Ill.,' below]."[17 page 52] Nonetheless American Electric Power "… sees clean coal technology as more than ready". Ibid page 57. Norway's Sleipner CO_2 Injection Project is operational[12]. *Mattoon Ill., picked as site for $1.8b pollution-free coal-burning facility* "Officials have said the plant is expected to be operating by 2012. They hope to begin construction by July 2009. … Congress is giving the program $75 million this year, $33 million less than the Bush administration had wanted."[80] *ENERGY DEPT. PULLING SUPPORT FOR CLEAN POWER PLANT* "Frustrated by ballooning costs for an ambitious plan to build a virtually emissions-free power plant, the Energy Department told federal lawmakers that it planned to pull its support for the $1.8 billion project in Illinois, lawmakers said. … Senator Richard J. Durbin … Democrat of Illinois, accused Energy Secretary Samuel W. Bodman of "cruel deception" of Illinoisans by "creating false hope in a FutureGen project which he has no intention of funding or supporting."[81]

LIQUID METAL-COOLED FAST BREEDER REACTORS

LMFBRs can potentially increase fission power by a factor of up to 100.[17] page 59 This could make nuclear-fission a major contributor to world emission-free power, but not as soon as 2050. With the Global Nuclear Energy Partnership (GNEP), "The U.S. is moving from a once through fuel cycle to a new approach that includes recycling of spent nuclear fuel without separating out pure plutonium. This capability would employ advanced technologies to increase proliferation resistance, recover and reuse fuel resources, and reduce the amount of wastes requiring permanent geological disposal at Yucca Mountain. This work builds on the Department of Energy's Advanced Fuel Cycle Initiative, which has been researching innovative recycle concepts since 2000."[16] Sodium-cooled fast breeders are now preferred over the Lead-Bismuth Eutectic type described in Reference 82.[per 15] See U.S. Planning Fission Powerplants of Two Types.

LIQUID-HYDROGEN PROPELLED AIRCRAFT

References 83 thru 86 indicate that the technology for aircraft propelled by cryogenic liquid hydrogen was explored as early as 1945, and has been sufficiently thought out to portray a concept of such an aircraft that looks feasible. Chauncey Starr's SuperCables, can simultaneously deliver electricity loss free by superconductivity, while delivering liquid hydrogen to airports, etc, as the cryogen.[25,26]

While liquid hydrogen-propelled aircraft may not be feasible before mid century, their development would eliminate what may be the world's last major source of fossil-fuel emissions.

ELECTRIC-DRIVE HYBRID VEHICLES

CHEVY VOLT

Volt Advantages Unknown to Most People: Volt, whose manufacture is planned for 2010, has major advantages compared to an ordinary hybrid exemplified by the Toyota Prius, and hybrid versions of Toyota's Highlander, Honda's Civic and Accord, and others from numerous manufacturers. Volt is driven only by a battery-powered electric motor. Within battery range, (about 40 miles) no fossil fuel is burned. Most drivers drive less than 40 miles per day and can get by entirely on house current, by charging the battery at night. Monetary cost for charging is only about a third the cost for the equivalent gasoline or diesel, and emissions cost is also substantially less. Volt provides a small engine for recharging the battery, so range between charges is unlimited. Volt's engine does not drive the car directly, so unlike ordinary hybrids, there is no need for engine speed to track the speed of the car, and the engine can run near maximum efficiency any time it runs. There is a large improvement in efficiency due both to the smaller than ordinary engine, and to always running near maximum efficiency.

Potential Improvements: The Volt has only one electric motor. If it had one electric motor for each wheel, advantages would be; three mechanical differentials would be eliminated in favor of three electric motors; the car would be all-wheel drive; the computer could automatically apply torque to wheels according to their traction; and dynamic stability control could be almost instantaneous, and regenerative, like hybrid braking, (related

energy is captured and used for battery charging). Mitsubishi personnel have said they are planning a vehicle driven by electric motors on each wheel. The only drawback of an electric motor on each wheel is that it increases unsprung weight, a concern primarily for race cars. Regardless of the number of electric motors, cruise control could limit downhill speed regeneratively, offering the same advantage as regenerative braking. Is regenerative, speed-limiting cruise control already planned for Volt?

CLEAN-BURNING DIESEL ENGINES

"Improved engines and exhaust scrubbers, combined with a new fuel, will make energy-efficient diesels nearly as green as hybrids".[87] Making diesels Clean burning entails extensive changes to the engine and exhaust system, but does not appear to offer the same zero-emission prospect of plug-in or electric-drive hybrids described above. Is the clean-diesel concept cost effective?

HYDROGEN-POWERED AUTOMOBILES

Neither the GM Chevy Sequel nor the Honda Clarity, nor any other, is likely to soon become a large seller for at least three reasons: (1) they cannot be built profitably in large numbers because the fuel cell is too expensive; and (2) hydrogen will not be produced in large amounts for decades; and (3) hydrogen storage takes about four times the volume per unit energy as kerosene or gasoline, so limitations on fuel tank size confine the vehicles to an unacceptable range. Tank-size limitations exist even if hydrogen is stored as a liquid at near absolute zero temperature, see Liquid-Hydrogen Propelled Aircraft.

CLOSING

WHERE THE WORLD STANDS AT THE END OF 2007

Insignificant World Progress: Although ***potential*** emission-free power vastly exceeds 2050 needs, the installed amount is insignificant. Installed world Wind Capacity is 74,223 MW[60] 0.25% of the goal. In 2005, "The solar thermal collector capacity in operation worldwide equaled 111.0 GW_{th}",[88] 0.37% of the 2050 goal. The capacity of the world's 22 largest photovoltaic power stations totals 0.394 GW[89]. If the remaining photovoltaic power makes solar photovoltaic match solar thermal, wind and solar would total 1% of the goal, and the existing 441 fission powerplants bring the world total to 2.5% of the 2050 goal. At the current rate of five or ten years to reach the current wind and solar-power total, it would take centuries to reach the 2050 goal. For a graphical representation of this data, see Figure 1 Where the World's Emission-Free Power Must Be by 2050.

Other Data: Iberdrola, Spain's second largest electricity group has "38,000 MW of renewable-energy capacity in the pipeline, including 6,000 in Spain and a similar amount in Britain. [and] 19,200 MW … in the United States"[62]. World wind power capacity is 74,306 MW[90]. "Europe's first commercial concentrating solar power plant [11 MW] was inaugurated today [2007-03-30] near the sunny southern Spanish city of Seville", [91]. "Germany [is] home to what the companies involved [call] the world's largest solar electric power plant …12-Megawatt … near the Bavarian town of Arnstein"[92] 2006-09-05.

Glaciers Halved in Glacier Park: Dan Fagre, a scientist for U.S. Geological Survey, who has studied glaciers in the park for 15 years reports that there are "27 glaciers left in the park out of 150 a century ago, 90 percent of the ice volume [is] gone."[93]

Existing Technology Adequate: Existing technology is sufficient to substantially reduce emissions and consequent climate change while meeting the world's energy needs, see Cutting U.S. Emissions Up to 47.5% Without Waiting for Agencies or New Technologies.

IMMEDIATE HUMANITARIAN BENEFITS FROM ACCEPTING THE CLIMATE-CHANGE-ENERGY CHALLENGE

Humanitarian benefits from accepting the challenge begin immediately and do not stop when the threat of a climate disaster is eliminated. Benefits include:

1. Hundreds of millions if not billions of the world's unemployed and underemployed are given work.

2. Those who lacked hope gain self esteem and a sense of achievement.

3. People at all levels of society become a team devoted to eliminating a common threat.

4. Egregious economic disparities between the world's rich and poor are greatly reduced.

5. In keeping with past experience, as the affluence of spreads, people become more self reliant, birth rate drops, and population runaway stops.

6. Acting responsibly now passes down to future generations the well being that previous generations passed down to us.

7. War is widely recognized as a digression, which would thwart everyone's goals.

FINALE

> *Amid the misery and ruin left behind by the twentieth century's two lethal world wars, a group of Europeans set out to create a lasting peace on the continent and a shared economy. They did not aim low. Their dream was to produce, once and for all, an end to war on the continent, and an end to poverty.*[5 page 25]

Today, mitigating climate change while converting to emission-free energy, can make real on the planet, not just on the continent, both visions of the Europeans' dream. Human nature compels people to do everything in their power to avoid sacrificing their descendants. Our future is in our descendants' lives; our descendants' lives are in our hands.

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RANKING OF REFERENCES, MOST-IMPORTANT FIRST

A. 57: IPCC's reports are generally best overall because they either are or are backed up by the most complete reports with the most carefully stated confidence levels.

B. 3: The UN-Sigma Xi report is very close to the IPCC reports in content, but it states the demands that the situation places on humanity much more clearly and emphatically.

C. 9: Stuart Jordan's treatise is the most fascinating to read, the clearest, and most convincing treatise I've seen from any source, including IPCC's excellent reports, (including {Refs 4, 57 and 27} from 2001 and the first half of 2007) this report is in the same class as the UN-Sigma Xi Panel's[3]. No intelligent person who reads Jordan's treatise can fail to believe that climate change is happening, is damaging Earth at an increasing rate, and is threatening future generations. This treatise is a stunning accomplishment for a single individual.

D. 34: Nathan S Lewis's "talk", which he's been giving for five years, is on par with Jordan's treatise, but it is the only reference in which I have found anything about the alarming suspected consequences of melting Earth's permafrost.

E. 26: This NASA report, two of whose authors are two from Boeing, one is from NASA, and one is from MTU in Munich, shows that LH2-propelled transport aircraft can be made practical, especially at ranges longer than 3,000-nmi, even though LH2 requires about four times the storage volume per unit of energy as kerosene-like Jet-A fuel.

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