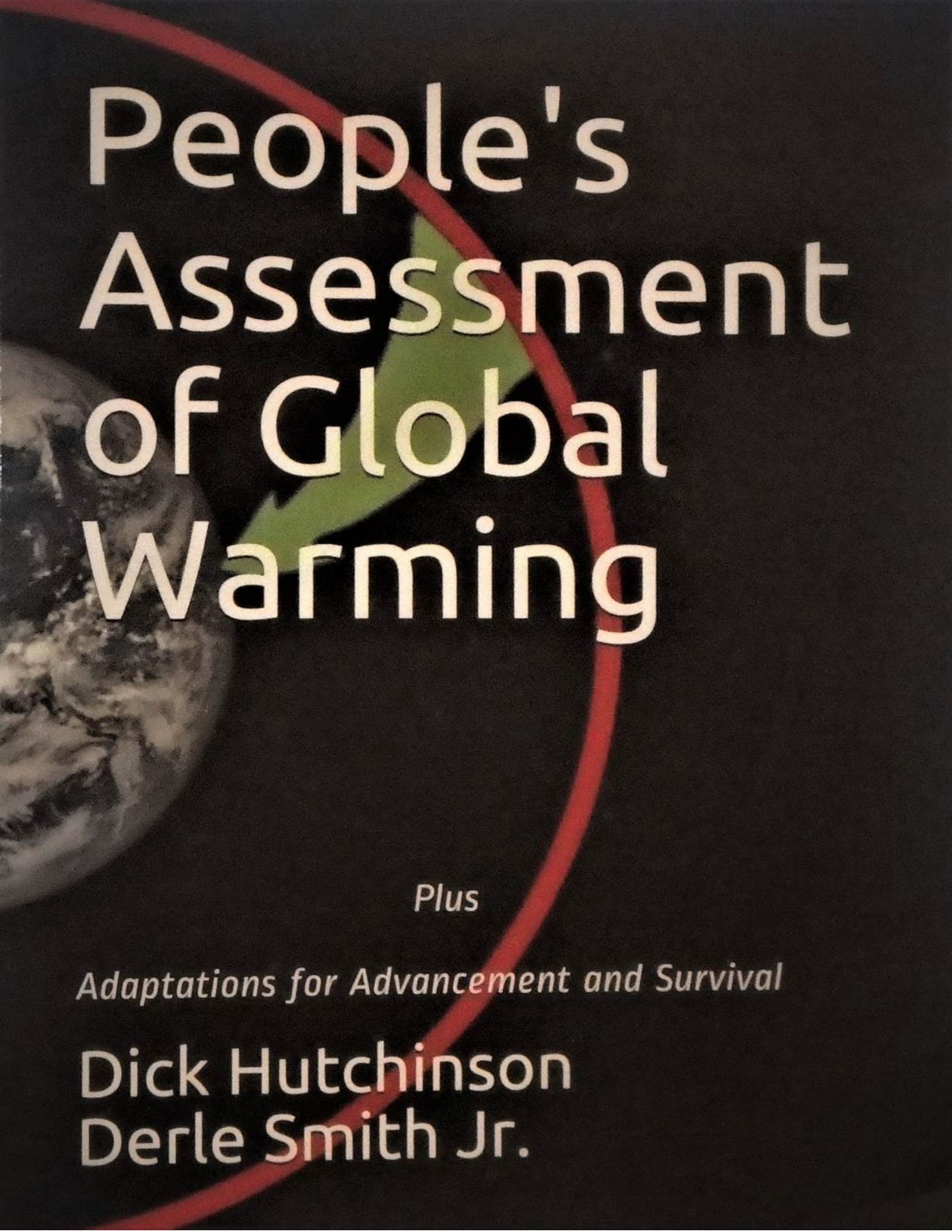


The background of the cover is dark. On the left, a portion of a globe showing clouds and land is visible. A large, thick green arrow points diagonally upwards from the bottom left towards the top right. Overlaid on this is a large red circle with a diagonal slash through it, resembling a prohibition or 'no' symbol.

People's Assessment of Global Warming

Plus

Adaptations for Advancement and Survival

Dick Hutchinson
Derle Smith Jr.

Cover: Image of Earth from North America Space Agency (NASA),
Deep Space Climate Observatory, July 6, 2015

PEOPLE'S ASSESSMENT OF GLOBAL WARMING

Plus

Adaptations for Advancement and Survival

Dick Hutchinson (Chemical Engineer)

Derle Smith Jr. (Astrophysicist)

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DEDICATION

To the people of earth willing to work together to overcome
global warming while advancing civilization

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PROLOGUE

The engineers, scientists and others who wrote and contributed to this report have the same stake in global warming as you do – we are all concerned about the impacts of global warming on ourselves, our children, and future generations. We are not climate experts and have no axes to grind and receive no special-interest support.

The authors and contributors took an engineering problem-solving approach in developing this report. That is, we focused on finding solutions to the problem of global warming rather than debating the existence of the problem. Nevertheless, problems that are not understood often cannot be solved. Therefore, our first challenge was to gain an understanding of the global warming problem. We quickly found that the problem has great scope and complexity touching essentially all aspects of the earth’s natural systems as well as many social/political aspects of Modern Civilization.

As a result, we divided the report into two parts. Part I, *People’s Assessment of Global Warming*, addresses the physical aspects of global warming, including a definition of the problem, and suggests practical actions to solve the problem. While developing Part I we saw social/political issues inherent in Modern Civilization that could defeat otherwise successful actions to overcome global warming. As a result, we continued our analysis to identify the underlying causes of the issues and to identify adaptations needed to successfully solve the global warming problem. In addition, these adaptations could provide social/political benefits to advance civilization. These results are presented in Part II, *Adaptations for Advancement and Survival*. Bottom line: while global warming poses an unprecedented physical challenge to the survival of Modern Civilization, it also offers unprecedented opportunity to advance civilization, driven by necessity.

We mentioned taking an engineering problem-solving approach. This entailed understanding the global warming problem well enough to develop practical, effective solutions. Engineers focus on finding solutions that are “good enough” to solve a particular problem. “Perfect solutions” are not sought because they may not exist or be identifiable if they do exist, and because the excessive time spent on seeking perfection often results in doing nothing. Global warming is occurring now and cannot be stopped without coordinated international action, which is now lacking. This report recommends specific actions to fill this void.

We assessed the many aspects of global warming to understand the big picture with a focus on unbiased facts and observations rather than on speculation. Our goal is to share what we have learned in a way that is both understandable and believable. If people understand the issues of global warming, then they can draw their own conclusions, reach valid consensus, inform political leaders, and, together, take appropriate and effective action.

Part I. People's Assessment of Global Warming

Introduction. Part I is divided into four sections. Section 1 addresses “Earth’s Natural Climate Cycles” in order to understand how current global warming relates to and differs from temperature swings that have occurred naturally. Section 2, “The Story of Carbon,” explains how carbon plays a leading role in global warming as well as our dependence on fossil fuels to power Modern Civilization. Section 3 looks at “Global Warming Observations and Problem Definition” in order to see how and why the earth is becoming warmer and what the effects are. Finally, Section 4, “Taking Action” proposes three international projects to address and overcome global warming.

To foster understanding, we minimize the use of technical terms and begin each section with an overview. Part I focuses on the key aspects of global warming, including what is known and not known. The earth is a complex system where everything interacts with multiple other things. While we separate global warming into its different parts, there are many interactions between these parts. To help grasp these interactions, we provide a summary at the end of each section and encourage the reader to review the summaries of all preceding sections before starting to read the next section. This repetition can help our minds to combine the many factors in order to achieve a broader and deeper understanding.

Section 1. Earth's Natural Climate Cycles

Overview. *Our ability to see into the past was greatly advanced by scientists who drilled down through both the Antarctic and Greenland ice sheets. From the layered ice-core samples, they determined the year, local temperature, and atmospheric carbon dioxide concentration of each sample.*

The results showed repetitive climate cycles every 100 thousand years that took the earth from warm conditions like that of today to ice-age conditions where much of Canada and Russia and the northern parts of US and Europe and Asia were buried in ice. Ice-age periods were five times as prevalent as the warm intervals.

The time scale for climate cycles was very long from a human perspective, requiring 6 to 12 thousand years to transition from ice-age conditions to warm conditions or from warm conditions to ice-age conditions. Our hunter-gatherer predecessors and other creatures had time to move north or south and to adjust to these gradual changes. Conversely, ice-age conditions would be devastating for modern civilization with our immobile infrastructure and high population levels.

Milankovitch cycles affect the amount and location of the sun's energy striking the earth and are a key trigger of the Earth's climate cycles. Feedback loops involving carbon dioxide and other factors that amplify these cycles cause the major changes in temperatures between warm and cold conditions. The feedback loops form a complex interrelated system that is not fully understood.

The current warm interval has persisted for 10 thousand years at relatively stable temperatures. It is the only such stable warm interval during the past 800 thousand years. These unique conditions are fortunate for civilization, which relies on a stable environment to sustain infrastructure and population levels. Even during this stable period, there were small changes in earth's temperatures that led to warmer and cooler climate periods such as the Roman Warm Period and the Dark Age Cool Period.

Thus, two levels of climate variations are at work in nature – the massive climate cycles that occur over thousands of years between ice ages and warm intervals, and the less extreme and shorter climate periods that occur over hundreds of years. Together, the climate cycles and climate periods present a complex climate system that is highly unstable and variable.

Please read on to gain a better understanding of earth's natural climate cycles.

Earth's changing climate. Most people are aware that civilization was preceded by an ice age that ended some 12,000 years ago. The polishing of stones by the glaciers can be seen on the tops of some mountains in New England. As the glaciers melted, they left piles of gravel, “moraine,” in some valleys as well as large boulders scattered about. The weight and force of the glaciers formed lakes, including the Great Lakes in North America. But what happened before the last ice age?

Our ability to see into the past was greatly advanced by the amazing discoveries of scientists who drilled down as much as 3,000 meters (9,800 feet) through the Antarctic ice sheet. Collecting the deepest ice cores required a semi-permanent scientific camp and a long, multi-year campaign. By analyzing the ice core samples in laboratories, they were able to relate the ratios of hydrogen isotopes in the annual layers of ice to variations in temperatures when the ice was deposited. These temperature variations are shown in Figure 1.1 in relation to pre-industrial average temperatures during the current warm interval and going back in time for 800 thousand years.

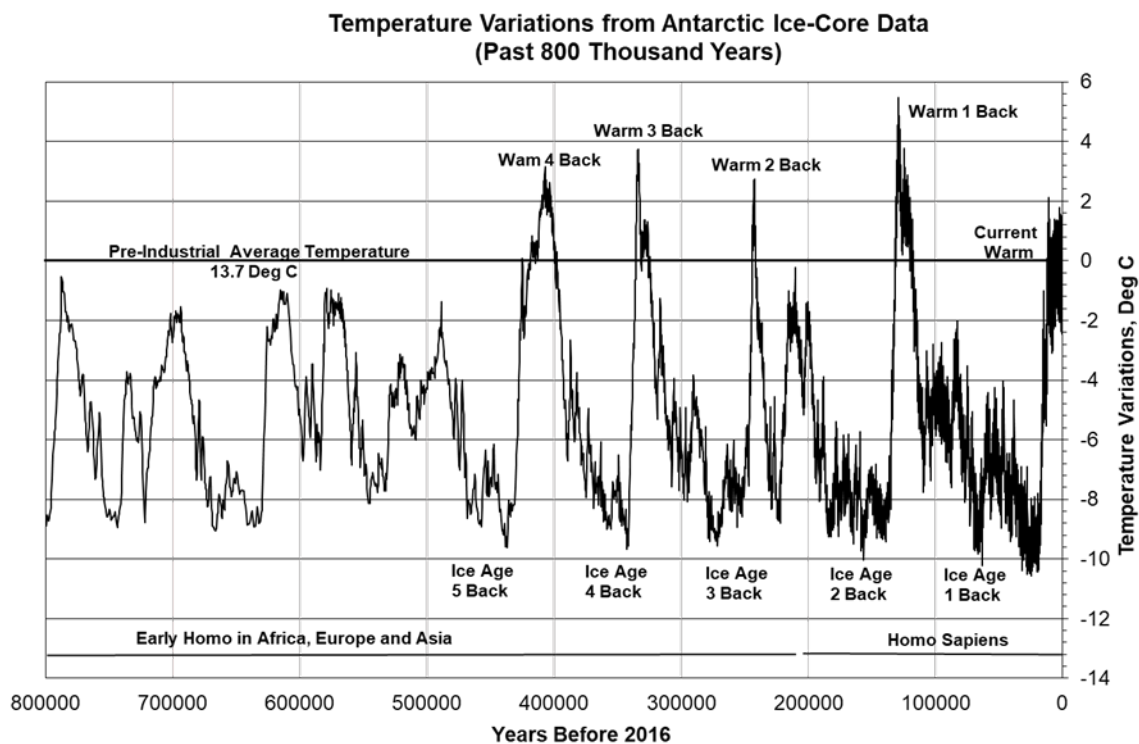


Figure 1.1 This chart depicts temperature variation data from Antarctic ice cores, the Dome C record, over the past 800 thousand years. The temperature variations are overlaid on the known pre-industrial average global temperature of 13.7° C and show the years when Antarctic temperatures were above or below that temperature. The Dome C record was produced by the European Project for Ice Coring in Antarctica.

The high-temperature peaks are the warm intervals such as the one we are in now. The low-temperature valleys are the ice ages. (The technical terms for warm intervals and ice ages are “inter-glacial periods” and “glacial periods.”) The bold line represents pre-industrial average temperatures of the current warm interval – *normal* temperatures for Modern Civilization with a *global* average of 13.7° C. The warm intervals over the

past 800 thousand years occurred periodically about every 100 thousand years. Cyclic temperature variations are most extreme at the poles where the ice-core data was taken. As a result, the temperature variations above and below the pre-industrial average temperature shown in Figure 1.1 would be less moving from the poles towards the equator.

You can also see that the relative duration of the warm intervals is much shorter than that of the ice ages by comparing the width of the peaks above the bold line to the width of the valleys below the bold line. Based on the ice-core data, the total duration of our current warm interval plus the prior four warm intervals was around 53 thousand years. The total duration of the last four ice ages was 290 thousand years. The earth was in ice-age conditions 5.5 times as long as in warm conditions ($290/53$) over the past 400 thousand years. Furthermore, the warm intervals from 400 to 800 thousand years ago barely reached our *normal* temperature. So, what people think of as normal conditions on earth are not really so normal – much colder conditions were the norm.

Temperatures in the prior four warm intervals tended to spike upward and then to drop right back toward ice-age conditions. *Stable* temperatures did not occur during these warm intervals – temperatures were either rising or falling.

To better see the transition between warm and cold conditions, Figure 1.2 focuses on the current and prior warm intervals and the in-between ice age. Temperatures rose rapidly in the one-back warm interval, then

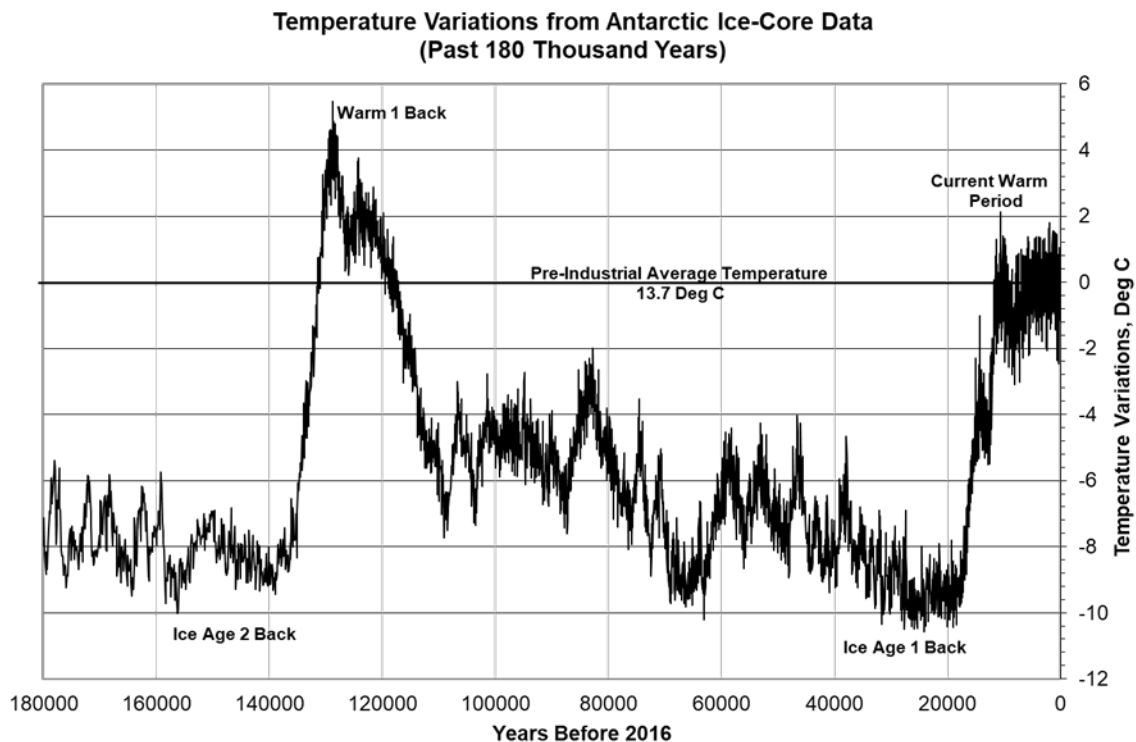


Figure 1.2. This chart depicts temperature variation data from ice cores in the Antarctic, the Dome C record, over the past 180 thousand years. The temperature changes are overlaid on the known pre-industrial average global temperature of 13.7° C and show the years when Antarctic temperatures were above or below that temperature.

they dropped off and peaked again before falling into the last ice age. Even during the past ice age, that lasted 90 thousand years, temperatures continued to move up and down with an overall downward trend. Coming into the current warm interval, temperatures rose quickly and then dropped somewhat before rising again to pre-industrial average temperatures.

The temperatures in Figures 1.1 and 1.2 appear to rise rapidly at the end of an ice age and then to fall rapidly at the end of a warm interval. However, the time scales in Figures 1.1 and 1.2 are very long. Just how fast did these temperatures rise and fall during a period of one-hundred years? The average rise in temperatures over the past 400 thousand years – in going from prior ice ages to subsequent warm intervals – was 0.16°C per 100 years and involved total temperature rises of 10 to 13°C . The average fall in temperature going from warm intervals back to the prior ice ages was 0.06°C over 100 years. The total times required for these transitions varied from six to twelve thousand years with the warming transitions occurring faster than cooling transitions. Thus, the changes in temperatures associated with Earth's natural cycles occurred *very slowly* from a human perspective.

Ice core data is also available from the Greenland ice sheet, which provides a perspective on natural climate cycles in the northern hemisphere. Greenland Ice Sheet Project Two drilled through 3,053 meters (10,000 feet) of ice over a period of five years before hitting bedrock. The resulting temperature variation data is shown in Figure 1.3. The data goes back 50 thousand years to when the ice had completely disappeared,

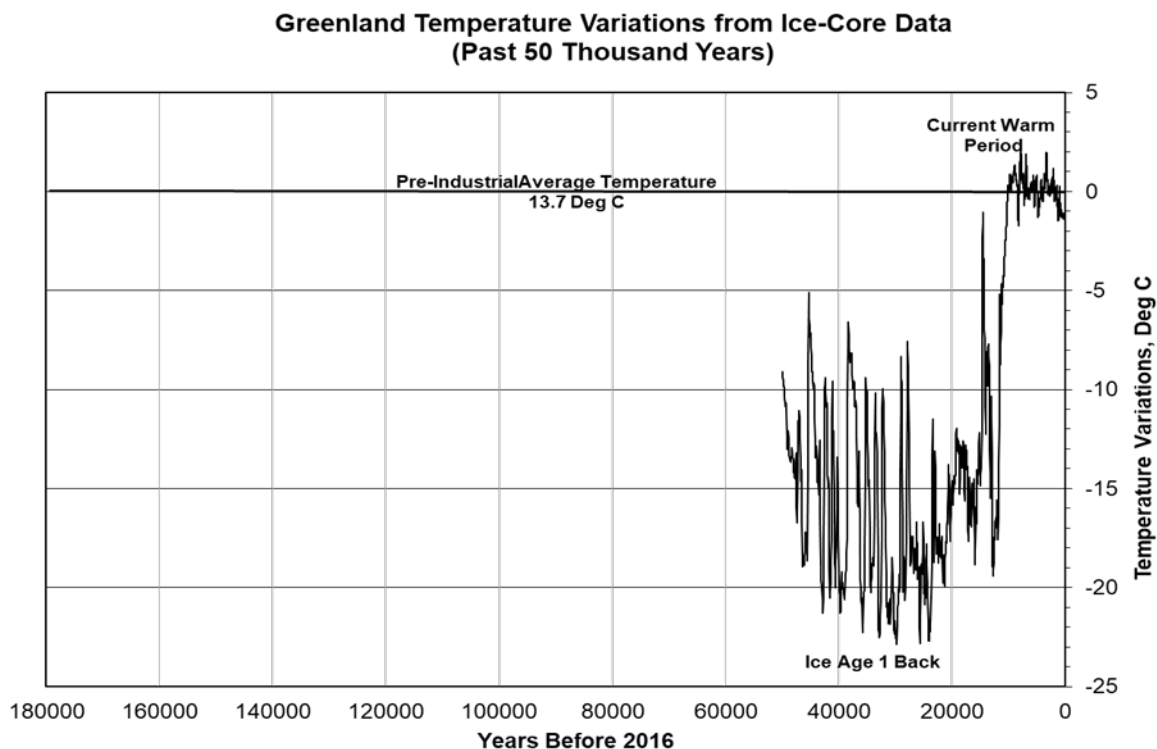


Figure 1.3. This chart depicts temperature variation data from ice cores in the Greenland Ice Sheet Project Two over the past 50 thousand years. The temperature changes are overlaid on the known pre-industrial average global temperature of 13.7°C and show the years when Arctic temperatures were above or below that temperature. Current temperatures are now 1 deg. C above pre-industrial average temperatures but is not seen on this figure because ice-core data is not that recent.

presumably melted, prior to that time. The data is shown for the same time scale of 180 thousand years used in Figure 1.2 so that the two plots can be compared. Note that Greenland temperatures rose by around 20° C from the end of the last ice age to the current warm interval. Temperatures in the Antarctic rose by around 10° C during this same period (see Figure 1.2). Thus, temperature variations between the last ice age and current warm interval were twice as much in Greenland than in the Antarctic. During this period Greenland temperatures rose at a rate of 0.46° C per 100 years.

The fact that most of the earth's land is in the northern hemisphere and that a correspondingly greater portion of the oceans are in the southern hemisphere likely explains this difference. Land does not capture and hold very much of the sun's energy. (Recall how the sand on a beach becomes very hot in the day and then cools quickly as the sun sets.) Conversely, oceans can absorb and store huge quantities of the sun's energy because of their depth, clarity, heat capacity, and mixing. As a result, oceans tend to buffer temperature changes – temperature change between day and night on the ocean is much less than on a desert. Thus, greater temperature variations occur in the northern hemisphere, where most of the land is, and where most of the people live, rather than in the southern hemisphere with its vast oceans.

Causes of natural climate cycles. Minor changes in energy received from the sun occur in a cyclic manner. These are called Milankovitch cycles, after the person who first recognized and analyzed them. As the Earth rotates around the sun, its orbit varies from circular to elliptical, the tilt of its axis varies, and the direction of its axis varies relative to the sun. These changes in movement and orientation are due primarily to interactions with the gravitational fields of the planets Jupiter and Saturn. They alter the amount and location of solar radiation reaching the Earth.

These variations in solar energy and the periodic changes in cold and warm intervals on Earth appear to match so well that scientists are convinced that the Milankovitch cycles do initiate the dramatic swings in the Earth's climate. However, these changes in solar energy are not nearly large enough to be responsible on their own for the large temperature changes between ice ages and warm intervals. Rather, it is felt that the Milankovitch cycles trigger climate change that is reinforced by feedback loops as described below. In addition, the earth's environment may reach points of instability at the extremes of its climate cycles that, when triggered, initiate a change in temperature direction.

Scientists have identified several technical problems in relating the Milankovitch cycles precisely to the ice core and deep-sea core data. For example, the cyclic period for climate change was around 41 thousand years prior to one million years ago and then changed to a period of around 100 thousand years beginning one million years ago. The reason for this change is not known. Scientists have noted instances when a climate cycle began before it was triggered by a Milankovitch cycle, and the strong warm interval 4 back occurred when the Milankovitch cycles were at their minimum levels. So, while the Milankovitch cycles certainly play a key role in Earth's natural climate cycles, there is still much more to learn.

Earth's feedback loops. Increased temperature raises the amount of water vapor in the air. Since water vapor is a greenhouse gas, increases in water vapor also increase temperatures. Increasing the temperature of the oceans reduces the amount carbon dioxide (CO₂) they can hold, so the oceans release CO₂ into the air as they warm up. CO₂ is also a greenhouse gas that increases the Earth's temperature as its concentration increases. These self-reinforcing changes are referred to as "feedback loops."

As temperatures rise and polar ice melts, much of the sun's energy that was reflected off of the sea ice is now absorbed by the dark open seas and land, thereby adding to global warming. Rising temperatures in the Arctic can also release large quantities of methane, another greenhouse gas, by thawing permafrost and by warming methane clathrate deposited on the sea floor.

Dust is another feedback loop. The amount of dust in the ice core record increased dramatically during the ice-ages when land-based vegetation decreased and allowed loose dust to be carried by the wind. In warming intervals, the land was more heavily vegetated, and the dust was trapped. The dust carried into the oceans supplied minerals that enhanced the growth of phytoplankton. Phytoplankton removed more CO₂ from the ocean which, in turn, was replaced by CO₂ drawn from the atmosphere, causing the climate to cool down further. When the atmospheric CO₂ fell to a critical point, about 200 parts per million (ppm), the arid conditions and further die-back of forests and grasslands caused more dust to deposit on the northern ice sheets. The dust-covered ice-sheets absorbed considerably more energy from the sun and underwent rapid melting, which favored global warming.

Changes to the sea's currents, including the Gulf Stream, are yet another feedback loop. These huge rivers in the seas distribute energy between northern and southern oceans and greatly impact the Earth's climate. Climate Scientists believe that the climate cycles alter the sea's currents, which, in turn, greatly influence the earth's climate.

It takes time for all of these feedbacks to take full effect because they "feed" on each other, ultimately ratcheting the temperature up more and more. They are all reversible in going from warm back to cold conditions. Together, these feedback loops form an enormously complex interrelated system. Our ability fully to identify, understand, quantify, and predict these complex, interrelated changes is far from complete.

The natural cycles of atmospheric CO₂ concentration expressed in parts per million (ppm) are shown over the past 800 thousand years in Figure 1.4. Scientists measured CO₂ concentrations in air bubbles trapped in the layers of ice in the Antarctic ice cores. The figure includes the natural temperature cycles from Figure 1.1 shown in grey. Clearly, the Earth's temperatures and the CO₂ concentrations cycled up and down together. Vast quantities of CO₂ are dissolved in the oceans. The solubility of CO₂ in water *decreases* as temperatures *increase*. The situation is analogous to an opened soda that warms up and quickly loses its bite because the CO₂ vaporizes out. Thus, as temperatures rise, the CO₂ in the oceans is released and adds to the atmospheric concentration of CO₂. Since CO₂ is a greenhouse gas, increasing amounts result in further warming – thus, the feedback loop effect. The total rise in CO₂ from an ice age to a warm interval during the past 400 thousand years ranged from 80 and 100 ppm.

The relationship between CO₂ and temperature can be better seen in Figure 1.5 that focuses on the current and prior warm interval going back 180 thousand years. The temperature and CO₂ concentrations clearly rise and fall together. In transitioning from past ice ages to warm intervals, CO₂ rose by an average of 100 ppm over 10,000 years, corresponding to a rate of rise of 1 ppm per 100 years. This slow increase in CO₂ was in keeping with the slow pace of temperature rise of 0.16° C over 100 years.

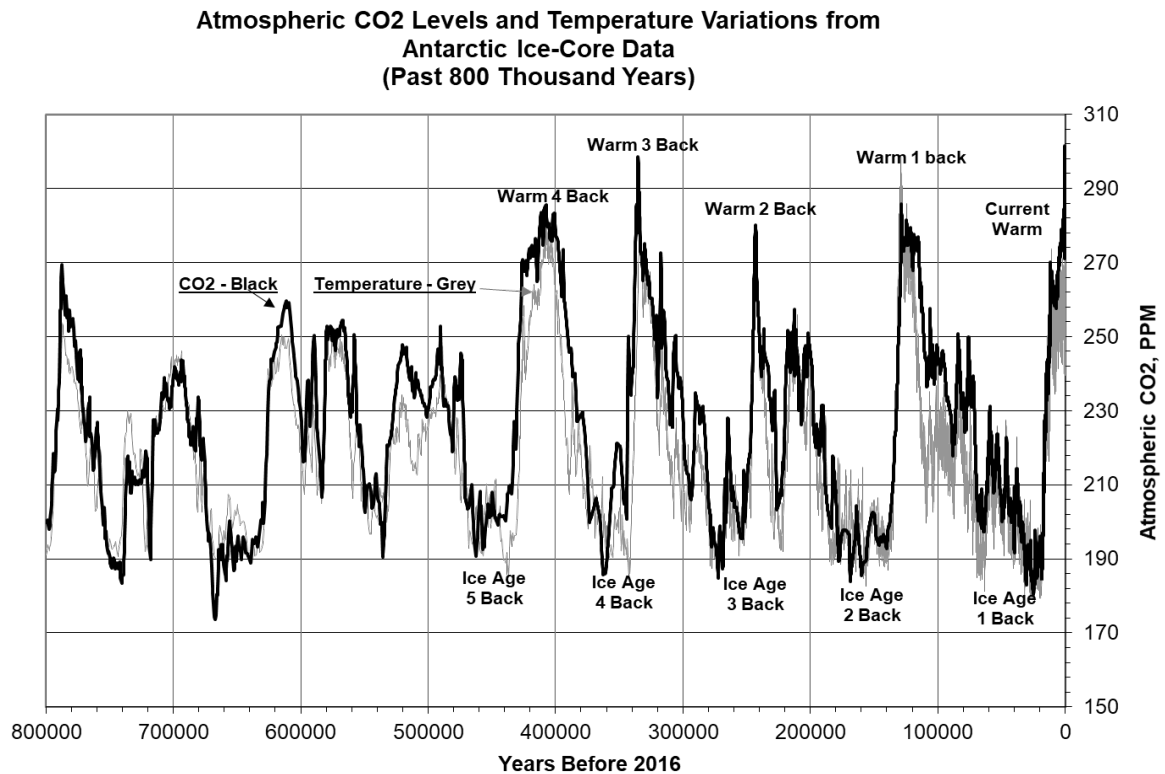


Figure 1.4. This chart depicts atmospheric changes in CO₂ from the ice cores in the Antarctic, the Dome C record, over the past 800 thousand years. The changes in CO₂, shown in black, are overlaid on the natural temperature cycles taken from Figure 1.1 and shown here in grey.

Impacts of Earth's natural climate cycles. The natural cycles between warm intervals and ice ages caused enormous changes in the Earth's climate and surface condition. By the end of the proceeding ice age, around 22 thousand years ago, Canada was almost completely covered by ice, as was the northern part of the US. Northern Europe was covered with ice sheets that extended to the British Isles, Germany, Poland and Russia as well as to northwestern Asia. The formation of ice towards the poles produced a drop in ocean levels of approximately 100 m (328 ft.) below today's levels. At these low levels, continental shelves and other submerged lands were exposed.

Clearly, ice-age conditions would be devastating for modern civilization and its extensive infrastructure and high population levels. Vast areas of the earth now productively populated would be buried in ice and other areas rendered excessively cold and dry.

During the warm intervals, much of the ice accumulated during the ice ages melted, raising ocean levels and increasing rainfall over the temperate zones. Warm spells over the past 400 thousand years did not raise ocean levels very much above today's levels. The seas would rise about 66 m (220 ft.) above current levels if all of the remaining ice were to melt. Warming periods 17 million years ago were sufficiently warm to melt at least half of this ice and to raise sea levels by approximately 40 m (130 ft.) over levels of today.

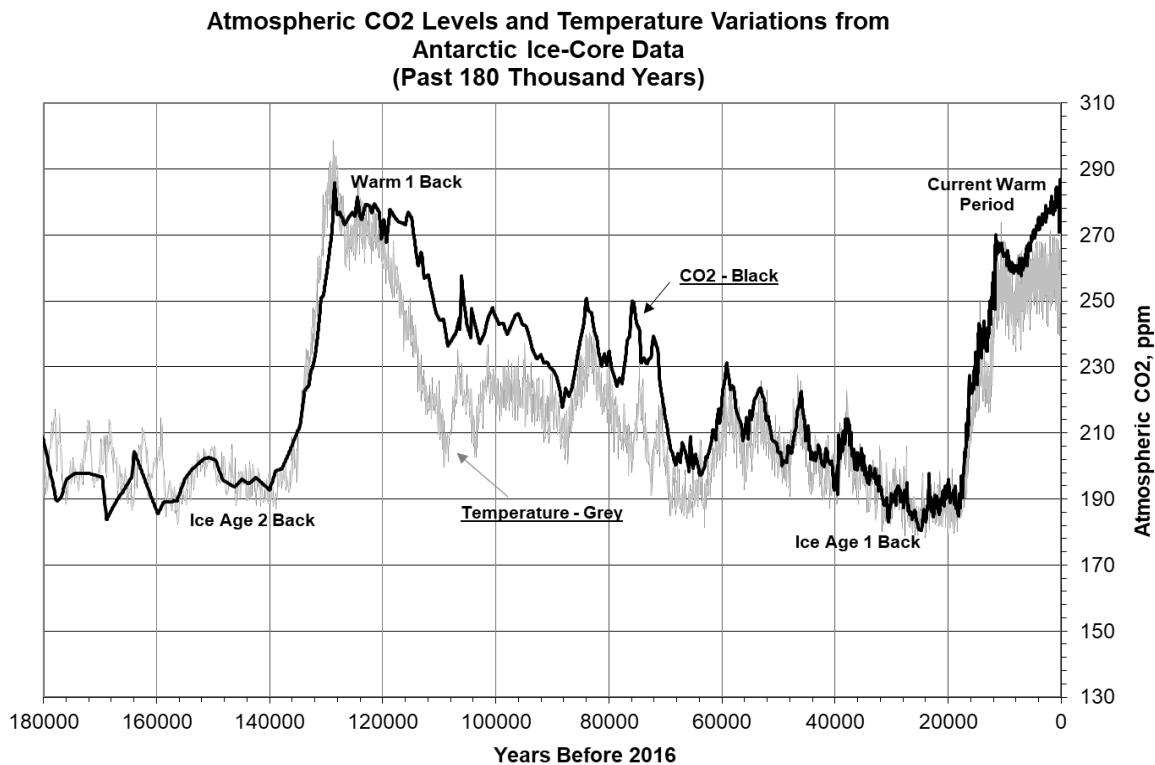


Figure 1.5. This chart depicts atmospheric changes in CO₂ from the ice cores in the Antarctic, the Dome C record, over the past 180 thousand years. The changes in CO₂, shown in black, are overlaid on the natural temperature cycles taken from Figure 1.2 and shown here in grey.

While temperature variations were most extreme at the earth's North and South poles, temperatures at the equator changed little between the climate cycles. This continuity of favorable conditions allowed for the enormous biological diversity found close to the equator, including the evolution of archaic humans and *Homo sapiens* in Africa that occurred over millions of years.

As before noted, temperatures changed slowly in going from a warm interval to an ice age. The changes would be hardly noticeable during one human generation. Our hunter-gatherer predecessors had time to move north or south and to adjust to these gradual changes. Without infrastructure, they and the other living creatures were free to move about to find suitable conditions. As indicated in Figure 1.1, our earlier homo ancestors were already in Asia and Europe 800 thousand years ago and survived the many subsequent climate cycles. We, *Homo sapiens*, were present in Africa, Asia and Europe during the past two ice ages and warm intervals.

Conversely, modern civilization is highly dependent on its infrastructure (cities, roads, industry, agriculture...) that cannot be practically moved in response to rising and falling temperatures and sea levels. The Earth's natural climate cycles do pose a long-term threat to civilization. At some point in the future, people will likely need to undertake the daunting task of engineering the earth's environment to stabilize its climate. (With global warming, that point may be now!)

Current Warm Interval. The current warm interval has persisted for 10 thousand years at relatively stable temperatures, likely varying by less than 1° C above or below the pre-industrial average global temperature of 13.7° C. Previously, stable warm intervals were not the norm. Temperatures were either rising or falling during prior warm conditions as indicated in Figures 1.1 and 1.2. Our current warm interval is unique – it is the only such stable warm interval during the past 800 thousand years. These conditions are fortunate for modern civilization, which relies on a stable environment to sustain infrastructure and population levels.

The duration of the current warm interval is also fortunate. The warm interval two-back in Figure 1.1 lasted only 3 thousand years before dropping back toward ice-age conditions. The warm intervals one and three back had durations comparable to our own, but by the end of 12 thousand years, temperatures were again falling towards ice-age conditions.

The change in CO₂ concentration is another unique feature of the current warm interval. During the past warm and ice-age conditions as depicted in Figures 1.4 and 1.5, CO₂ levels rose and fell along with the rise and fall of temperature. However, over the past 6 thousand years, global temperatures were relatively stable at 13.7° C and yet the level of atmospheric CO₂ rose by 25 ppm as shown by the top graph in Figure 1.6. Could human activity such as land clearing have caused the rising CO₂ levels long before the industrial revolution? We do not know, but something unusual was going on regarding atmospheric CO₂ levels that was not observed in the prior 800 thousand years. This gradual rise in CO₂ may have postponed the next ice age.

Antarctic temperature variations around the pre-industrial global average temperatures are shown in the middle graph in Figure 1.6. Temperatures varied by around 1 dev C above or below the average temperature during the last 6 thousand years. Comparable temperature variations from Greenland ice-core data are depicted by the lower graph in Figure 1.6. Greenland temperatures vary above and below the global average by around 2° C, about double the Antarctic temperature variations due to the stabilizing effect of the vast oceans in the southern hemisphere as opposed to the less stabilizing effect of large land masses in the northern hemisphere.

Greenland temperature variations over the past 6 thousand years, while much less than large variations between ice ages and warm intervals, did have noted effects on civilization. The names and timing of these periods are shown at the bottom of Figure 1.6. During the Roman Warm Period, grapes and olives grew further north in Italy than before. In the Dark Ages Cool Period, fruit did not ripen and the Black Sea and Nile River froze. During the subsequent Medieval Warm Period, grain crops flourished in Europe, alpine tree lines rose, the Vikings colonized Greenland, and wine grapes grew in England. Then temperatures dropped during the Little Ice Age, glaciers advanced, grain crops in Europe failed and famine occurred, Viking colonies in Greenland were abandoned, and warm-weather crops were discontinued in parts of China.

Thus, there are two levels of climate variations at work in nature: the massive climate cycles that occur over thousands of years between ice ages and warm intervals, and the less-extreme and faster-changing climate periods that occur over hundreds of years. Also, climate periods do not appear to involve the feed-back loop that help power the massive climate cycles. Atmospheric CO₂ levels, while increasing slowly over the past 6 thousand years, did not rise and fall with temperature as they did during the prior climate cycles. Together, the climate cycles and climate periods present a complex climate system that is highly unstable and variable (even chaotic).

Atmospheric CO₂ Levels and Temperature Variations from Antarctic Ice-Core Data and Temperature Variations from Greenland Ice-Core Data (Past 10 Thousand Years)

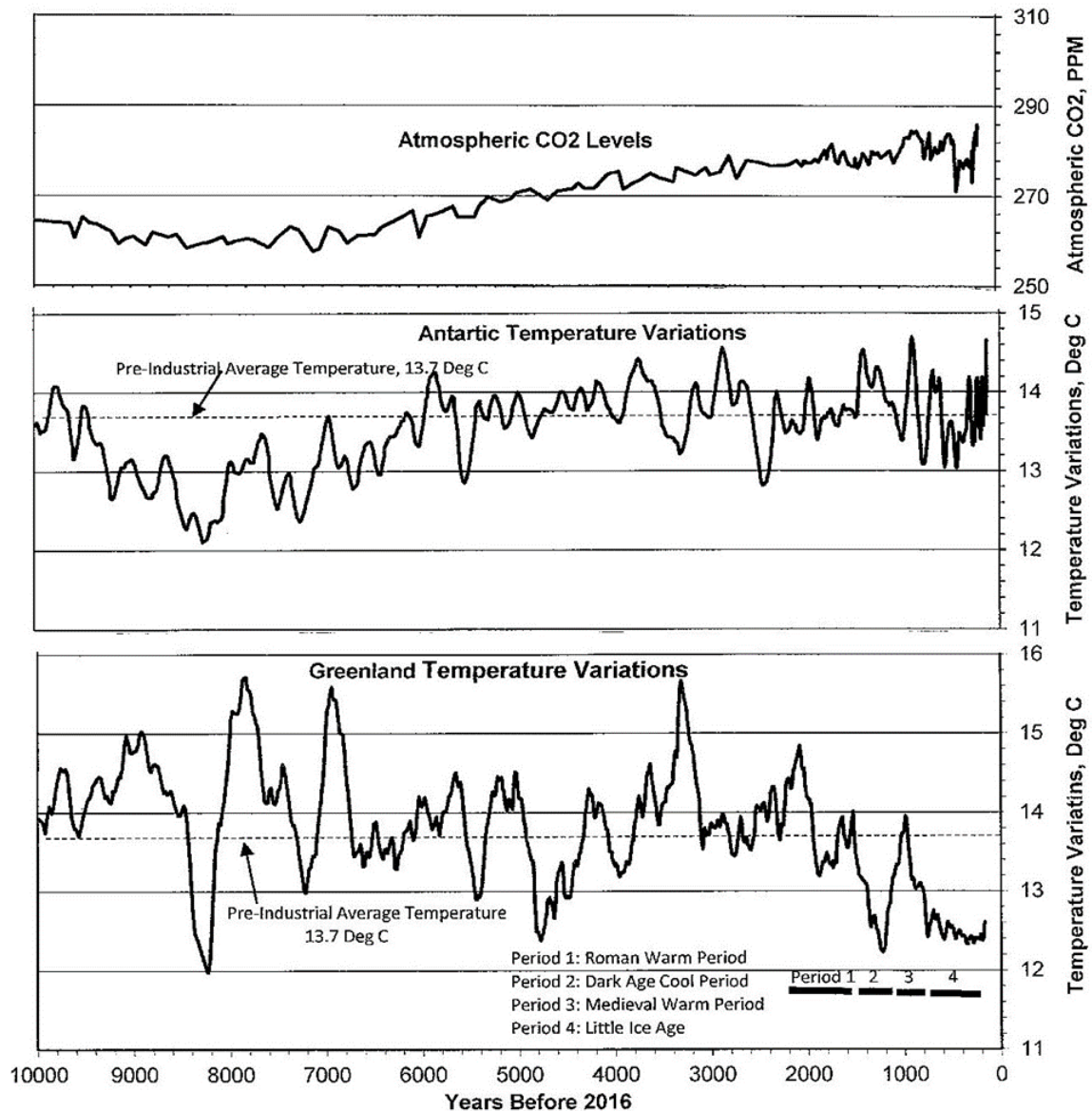


Figure 1.6. This chart depicts atmospheric CO₂ levels in ppm, top line, temperature change data from ice cores in the Antarctic, the Dome C record, middle line and temperature change data from Greenland ice cores over the past 10 thousand years, bottom line. The temperature changes are overlaid on the known pre-industrial average global temperature of 13.7° C and show the years when Antarctic and Greenland (Arctic) temperatures were above or below that temperature.

Summary of Section 1, Earth's Natural Climate Cycles.

- 1. The Earth's climate was very unstable over the past 800 thousand years – the climate repeatedly cycled between warm intervals and ice ages every 100 thousand years.*
- 2. Ice-age conditions were 5.5 times as prevalent as warm conditions over the past 400 thousand years. Thus, our current warm conditions are not really so normal – much colder conditions were the norm.*
- 3. The time scale for climate cycles was very long from a human perspective. It took 6 to 10 thousand years to transition from an ice age to warm conditions, and 9 to 12 thousand years to transition from a warm interval back to an ice age.*
- 4. Ice-core data from Greenland and the Antarctic from the last ice age to the current warm interval show twice the level of temperature rise in Greenland (20° C rise) than in the Antarctic (10° C rise). The stabilizing effect of the vast oceans in the southern hemisphere as opposed to the less stabilizing effect of large land masses in the northern hemisphere may explain this difference.*
- 5. Milankovitch cycles affect the amount and location of the sun's energy striking the earth and are a likely trigger of the Earth's climate cycles. However, they do not explain all observations, and there is still much to learn.*
- 6. Feedback loops on earth amplify the triggering effect of the Milankovitch cycles and cause the major changes in temperatures between warm and cold periods. The feedback loops consist of changing levels of atmospheric greenhouse gases that include water vapor and CO₂, the formation or melting of energy reflecting Arctic ice versus energy absorbing open water, deposits of dust into the oceans and onto Arctic ice sheets, and changes in the oceans' currents.*
- 7. The feedback loops form an enormously complex interrelated system. Our ability to fully identify, understand, quantify, and predict these complex systems is far from complete.*
- 8. At the end of the last ice age, most of Canada and parts of northern US, Europe, Russia and Asia were under ice sheets, while the ocean levels were 100 m (328 ft.) less than today.*
- 9. Ice-age conditions would be devastating for modern civilization with our immobile infrastructure and high population levels. Vast areas of the earth now productively populated would be buried in ice and other areas rendered excessively cold and arid.*
- 10. Conversely, our hunter-gatherer predecessors as well as other creatures had time to move north or south and to adjust to these changes that occurred gradually over thousands of years.*
- 11. Temperatures at the equator changed little between the cycles, allowing for enormous biological diversity close to the equator, including the evolution of Homo sapiens.*
- 12. The current warm interval has persisted for 10 thousand years at stable average temperatures. It is the only such stable warm interval during the past 800 thousand years. These unique conditions are fortunate for civilization, which relies on a stable environment to sustain infrastructure and population levels.*

13. During the prior 800 thousand years, CO₂ levels rose and fell in lock-step with temperature. However, over the past 6 thousand years the level of atmospheric CO₂ continued to rise gradually while temperatures remained stable. The cause of this unique feature is not known, but may relate to human activity such as land clearing.

14. Two levels of climate variations are at work in nature — the massive climate cycles that occur over thousands of years between ice ages and warm intervals, and the less extreme and faster-changing climate periods that occur over hundreds of years.

15. Together, the climate cycles and climate periods present a complex climate system that is highly unstable and variable (even chaotic).

Section 2. The Story of Carbon

Overview. *The story of carbon is essentially the story of life on earth. The earth's earliest environment did not contain any oxygen or carbon dioxide. Then asteroids struck the earth and along with volcanoes released huge amounts of nitrogen and carbon dioxide into the atmosphere. The first life appeared as small organisms that did not require oxygen, since there was still no free oxygen in the atmosphere at this time.*

Bacteria later appeared that were capable, through photosynthesis, of converting atmospheric carbon dioxide (CO₂, a molecule composed of carbon and oxygen) into free oxygen while retaining the carbon in their bodies that settled in the seas and became stored. This release of oxygen and storage of carbon changed the earth's entire atmosphere into one that could support oxygen-breathing organisms that include humans and other animals. Thus, life itself changed the world's initially hostile environment to one supportive of the diverse life forms of today.

One of the challenges in addressing global warming is appreciating the scope of the issue over time frames that are difficult to comprehend. Section 1 addressed climate cycles over the past 800 thousand years. However, the story of carbon covers a much greater time frame. Here, we review the periods, changes, and mass extinctions that occurred over many millions of years in order to understand what has happened on our earth and how fossil fuels formed.

We then consider how oil, coal and natural gas are used, their contribution to world energy needs, the amounts of CO₂ released by burning fossil fuels, and where that CO₂ goes. Today, fossil fuels supply 86% (percent) of the world's energy needs with the remaining 14% split between nuclear, hydroelectric, solar, wind and other renewables. At current use rates, proven reserves for oil and natural gas will last around 50 years while coal will last 114 years. Of the CO₂ released by burning fossil fuels, 56% is retained in the atmosphere and 34% is taken up by the oceans, and the remaining 10% is taken up by the land. Burning fossil fuel appears to be the predominant source of the CO₂ raising atmospheric levels. If all the known fossil fuel reserves were burned, the atmospheric levels of CO₂ would be around 600 ppm, which would far exceed levels over the past 800 thousand years.

The overall purpose of this section is to gain understanding rather than to learn facts, and it should be read in that light. You may also acquire, as we did in preparing the section, a sense of the grandeur of earth and our place in it. Please reread the summary at the end of Section 1 before proceeding.

The Earth's early environment. The *first atmosphere* of the earth – over 10,000 *million* years ago – consisted primarily of hydrogen, water vapor, methane and ammonia. Both oxygen and carbon dioxide were lacking.

The earth's *second atmosphere* formed 3,400 million years ago and was composed mostly of nitrogen, carbon dioxide and water vapor, which were released by volcanoes and huge asteroids that struck the earth. The earth's earliest life forms, ones not requiring the intake of free oxygen (anaerobic organisms), developed in that environment. While the earth was further from the sun then and received 30% less solar heat, the greenhouse effect of high levels of atmospheric CO₂ resulted in a relatively warm earth with liquid, unfrozen water that allowed life to develop.

The earth's *third atmosphere* was formed 2,400 million years ago by cyanobacteria that lived in seas and lakes and still exist today, Figure 2.1. These bacteria released large quantities of oxygen into the atmosphere through photosynthesis (the conversion by living organisms of CO₂ into free oxygen and carbon that was used in the organisms' structure).



Figure 2.1. Cyanobacteria responsible for the buildup of oxygen in the earth's atmosphere. Image from *Wikipedia* archive of Dr. Josef Reischig, Czech Republic.

The increase in free oxygen in the atmosphere allowed for primitive oxygen-breathing life forms to develop, eventually including animals. Oxygen levels in the air increased to over 15% by 570 million years ago and then continued to increase to today's level of 21%. The increase in oxygen supported the rapid development of animals. As oxygen levels rose, carbon dioxide levels fell to below 10% (100 thousand ppm), which was no longer suffocating to animals, and then fell to pre-industrial levels of today (180 to 300 ppm) that have no ill effects on animals. As CO₂ levels fell to today's levels, the earth moved closer to the sun thereby increasing solar heat that maintained a relatively warm earth.

Earth's many periods and fossil fuel formation. The geologic time frames described below were discovered by scientists using isotopic dating to estimate the ages of various rocks from around the world. We begin with the Proterozoic Period.

The Proterozoic Period lasted 1,930 million years (2,500 to 570 million years ago) and witnessed the formation of supercontinents that then fragmented and reformed three times. Mountains arose as the land masses collided. Cyanobacteria and other single-celled organisms became prevalent in the seas, and atmospheric oxygen levels built up for the first time, causing many of the anaerobic bacterial groups to vanish. The first primitive aquatic animals developed by the end of the period, thus completing the carbon cycle of

life where plants use the sun's energy through photosynthesis to convert atmospheric or dissolved CO₂ into free oxygen and carbon used within their structure. Animals eat the plants and combine atmospheric or dissolved oxygen with plant carbon to produce the energy needed to live. In doing so, they release CO₂ into the atmosphere, which is used again by the plants.

The Cambrian Period, lasting 85 million years (570 to 485 million years ago), had atmospheric oxygen levels above 12 % and CO₂ levels around 0.45% (4,500 ppm). Life forms, including animals, rapidly developed in the oceans while the land remained barren and rocky and free of life except for soil microbes. The most dominant animals in the oceans and warm shallow seas were small creatures with exterior skeletons (exoskeletons) similar to shrimp and crabs. Both the plant and animal remains accumulated and provided organic matter that would later form into petroleum. Lower solar radiation from a more distant sun (6% less than today) was countered by high CO₂ levels, resulting in an environment somewhat warmer than today.

During the Ordovician Period that lasted 41 million years (485 to 444 million years ago), invertebrates such as snails, clams, squid and animals with exoskeletons such as shrimp dominated the oceans. Fish, the first true vertebrates, developed and had jaws. These multicellular organisms lived in the sea and reached a new level of complexity that has persisted to the present. Colonization of land was limited to shorelines. Much of the period was very warm, but at its end the climate cooled into an ice age, and the sea level dropped exposing continental shelves and draining vast inland seas. These dramatic changes caused a mass extinction that wiped out 60% of the marine species.

During the Silurian Period, lasting 25 million years (444 to 419 million years ago), jawed and bony fish diversified in the sea, and the first land insects developed while the landscape changed little and remained bare. Relatively stable and warm temperatures were supported by high CO₂ levels of 4,500 ppm. Vascular plants formed that had tissues to carry water and food. The earth's landmasses were combined into one large continent (Pangaea) that covered the equator and much of the southern hemisphere while a large ocean covered much of the northern hemisphere.

The Devonian Period, lasting 60 million years (419 to 359 million years ago) gave rise to forests and other vegetation that covered the continents for the first time, Figure 2.2. Plants developed leaves, roots, seeds and true wood. As this vegetation died and accumulated, it provided the ingredients that later formed into coal. CO₂ levels dropped as forests drew CO₂ out of the atmosphere and stored it in sediment.

Terrestrial insects became well-established, but land herbivores were not yet present. The shifting of continental plates formed the Appalachian Mountains in North America and other mountains in Europe. Sea levels were high with shallow seas and reef formation. The period ended with a major extinction event for reasons unknown.

The Carboniferous Period, lasting 60 million years (359 to 299 million years ago), promoted extensive lowland swamps and forests. The wood fiber and bark of dead trees resisted decay and fossilized into vast quantities of coal. As the carbon was fixed and buried, the atmospheric oxygen levels increased to 35%, the highest ever. The high oxygen level promoted large insects (dragonflies with 75 cm (30 in) wingspans) and amphibians (up to 6 m (20 ft.) long) that dominated the land. Reptiles also developed that were adaptable to dryer climates with their hard-shelled eggs and scales that retained body water. The climate changed from hot and humid to cool and arid conditions late in the period, diminishing the rainforests.



Figure 2.2. The Devonian period started the extensive spread of plants across the lands. Eduard Riou (1838-1900) from *The World Before the Deluge* 1827.

During the Permian Period, lasting 47 million years (299 to 252 million years ago), reptiles, birds, and other animals diversified. Earth was dominated by two continents surrounded by a global ocean. Vast deserts occurred within the continental interiors. The period began with an ice age, and then the climate cycled between warm and cool conditions. With dryer climate conditions, seed ferns and early conifers replaced the lush swamps and vegetation. Large herbivores and carnivores appeared, and small reptiles developed that would later become crocodiles, and the ruling dinosaurs. Early ancestors to warm-blooded animals also developed. The period ended with the most massive extinction event ever recorded: 90-95% of marine species and 70% of land organisms, including many insects, were wiped out. Life on land took 30 million years to recover.

The Triassic Period, lasting 51 million years (252 to 201 million years ago), began in the wake of the prior extinction event. Dinosaurs first appeared at the end of this period, and the first true warm-blooded animals developed. These small animals fed at night on insects. Birds and crocodile-like reptiles dominated as predators. The climate was hot and dry, and no coal deposits formed during the period. The large continent, Pangaea, spanned the equator from pole to pole. The polar regions were moist and temperate with forests that supported vertebrates. The marine fish and reptiles that survived the prior extinction diversified with some growing up to 20 m (65 ft.) long. Another mass extinction occurred at the end of the period that wiped out many large reptiles and amphibians on land and allowed the dinosaurs to dominate the next period. Most marine reptiles died.

During the Jurassic Period, lasting 56 million years (201 to 145 million years ago), dinosaurs ruled the land, and very large flying dinosaurs ruled the skies. Large grazing dinosaurs (up to 30 m (98 ft.) long) and large predatory dinosaurs were common as pictured in Figure 2.3. Mammals developed that gave birth to live young without using shelled eggs. Crocodiles transitioned from land to aquatic life. Fish and marine reptiles dominated the sea. Pangaea, began dividing into two land masses, and the climate shifted from dry to humid resulting in lush rainforests. There was no land or ice over either pole.



Figure 2.3. Various dinosaurs roamed forests of similarly large conifers during the Jurassic period. From *Wikipedia* “Jurassic Period.”

The Cretaceous Period, lasting 79 million years (145 to 66 million years ago), was relatively warm with high sea levels that caused shallow seas to cover parts of the continents. New groups of animals (including birds that were themselves dinosaurs) and flowering plants developed while the dinosaurs, such as the triceratops depicted in Figure 2.4, continued to rule on land.



Figure 2.4. Triceratops, one of the most recognizable genera of the Cretaceous. From *Wikipedia* “Cretaceous Period.”

Bees appeared for the first time as flowering plants flourished. Mammals remained small-sized except birds, which continued to develop into forms similar to those of today. Rays and modern sharks became common in the seas.

Stagnant, deep-sea conditions allowed organic matter to accumulate, which later turned into half of the world’s petroleum reserves in the Gulf of Mexico and the Persian Gulf. The supercontinent of Pangaea completed its breakup into the present-day continents. Great undersea mountain chains formed and raised the sea level. The period ended with a mass extinction of three-quarters of the Earth’s plant and animal species, including the ruling dinosaurs and large marine reptiles. The animals (including birds) that survived fed on insects, larvae, worms and snails, which, in turn, fed on dead plant and animal matter. Crocodiles survived because they could feed on dead organisms. The extinction of the dinosaurs opened the door for the development of animals into today’s forms.

During the Paleogene Period, spanning 43 million years (66 to 23 million years ago), and without the ruling dinosaurs, animals diversified into many species that later developed into what we see today. Many new mammal groups including primates emerged by the end of the period. The first of the huge whales developed in this period, derived from land mammals that gradually acquired swimming adaptations. The climate cooled and became drier, restricting tropical plants to equatorial regions and allowing deciduous plants to become more common. The continents continued to drift towards their current positions as India collided with Asia to form the Himalayas. Africa moved north to meet with Europe and form the Mediterranean. The inland seas retreated from North America, and South America moved closer to North America. Australia separated from Antarctica.

Through the Neogene Period, spanning 20 million years (23 to 2.6 million years ago), animals (including birds) developed into nearly modern forms. North and South America became connected at the Isthmus of Panama. The climate cooled, dried and became seasonal. Ice caps on both poles formed and thickened, and ice ages occurred.

The Quaternary Period, spanning 2.6 million years (2.6 million years ago to the present), is divided into two sub-periods: Pleistocene (2.6 million years ago to 11.7 thousand years ago) and Holocene (11.7 thousand years ago to the present). Cyclic ice ages and warm intervals occurred during the Quaternary Period, which were thought to be driven by the Milankovitch cycles discussed in Section 1. The placement of the continents changed little during this period. The Hudson Bay and Great Lakes were formed by massive glaciers during the ice ages. Archaic forms of humans develop and moved out of Africa. *Homo sapiens* (modern man) later appeared and spread to all continents except Antarctica. At the end of the Pleistocene, many large mammals, included saber-toothed cats, mammoths, and mastodons as well as horses, camels, and cheetahs became extinct in North America, possibly as a result of human predation. Civilization arose during the Holocene sub-period.

Mass extinctions. The causes, mechanisms and effects of mass extinctions are now areas of intense research. Scientists are concerned that some of today's environmental stresses could drive the next mass extinction. Large-scale volcanic activities apparently caused four of the five largest extinctions. Resulting spikes in atmospheric CO₂ levels and associated global warming and ocean acidification are implicated as contributing mechanisms. The impact of asteroids and comets are other possible triggers of mass extinctions. A large asteroid impact accompanied by volcanic activity and the release of sun-blocking aerosols resulted in rapid environmental cooling that wiped out the dinosaurs and large marine reptiles at the end of the Cretaceous Period. We need to know if mass extinctions result from single or multiple environmental stresses to better assess future impacts.

Fossil Fuels. The ingredients of fossil fuels were deposited over vast time frames. The lush forests and vegetation that later formed into coal were present during the Silurian and the Carboniferous periods from 444 to 299 million years ago. The climate then became dryer and produced less vegetation for conversion to coal. Conditions that allowed small marine plants and animals to proliferate and their remains to be deposited in shallow seas and oceans occurred throughout many of the past periods. Their remains would later form into petroleum reserves. Approximately 25% of world petroleum reserves resulted from deposits made from 444 to 252 million years ago. Almost 54% of the world reserves located in the Persian Gulf and the Gulf of Mexico resulted from deposits made 201 to 66 million years ago.

Several things seem evident in considering the earth's past and ongoing changes:

1. The earth has endured repetitive cataclysmic changes in environment, placement of continents, and mass extinctions over times that far exceed modern human experience – the system has grandeur.
2. Carbon taken from the CO₂ in the air and water by bacteria and plants and stored in the ground, some eventually becoming fossil fuels, changed the earth's environment from one initially hostile to animal life to one supportive of animal and human life.
3. As we produce and burn fossil fuels we are in fact *reversing* this natural process of storing carbon that enabled modern life forms to exist. We need to understand and to consider the impacts of our actions on the *grand system* of earth, including the last 800 thousand years of climate cycles, to know what we are about and the consequences thereof.

Formation of oil and natural gas. Oil and natural gas formed from the remains of small aquatic organisms, including phytoplankton (plants such as algae) and zooplankton (small animals), that settled to the sea or lake bottoms in vast quantities millions of years ago. Under stagnant conditions where oxygen was depleted, this debris accumulated rather than decomposed. Over long periods, this organic matter mixed with mud and became buried under heavy layers of sediment. As the sediment became buried deeper, the temperature and pressure increased to where the organic matter was chemically altered, first into a waxy material known as kerogen and then, with more heat, into oil and natural gas. Heat within the earth is supplied primarily by the radioactive decay of uranium and thorium.

For the oil to collect into reservoirs, depicted in Figure 2.5, three rock strata are necessary: 1) a source rock containing plant and animal debris is buried deep enough for subterranean heat to cook it into oil; 2) a porous, permeable reservoir rock for oil to accumulate in, and 3) a cap rock that traps the oil and keeps it from escaping to the surface. Petroleum reserves often consist of three layers: gas, oil and water. Water flow can move oil hundreds of kilometers horizontally before it becomes trapped in an oil field reservoir where it can be recovered by drilling and pumping.

Approximately 60 million years were required for the initial deposits of small marine organisms to become buried under sedimentation and to be converted into fossil fuels. At a depth of 1 km (5/8 of a mile) and 50° C, kerogen forms. Between 2 and 3.8 km below ground and around 100° C, kerogen releases oil – the “oil window.” Between 3.8 and 5 km below ground, liquids become lighter and gradually turn into methane gas through “thermal cracking” – the “gas window.” Below 8 to 10 km there are no hydrocarbons because they are destroyed by the high temperature. If the organic debris is composed mostly of zooplankton (animals), it will produce more oil than gas. If it is composed mainly of plant debris, it will produce mostly gas. Clearly, petroleum is not a renewable energy source since 60 million years are required to bury and convert the deposits into oil and gas.

Natural pressures in oil reserves can often force the oil to the surface for a time until the pressure decreases, and pumping is required. Over time, these “primary” methods become less effective, and a “secondary” production method, such as waterflooding, is used where water is injected into a reservoir to increase pressure and force the oil into the oil well. Primary and secondary production account for 90% of United States

petroleum production. Sometimes “tertiary” recovery is used by injecting steam, carbon dioxide and other gases or chemicals into

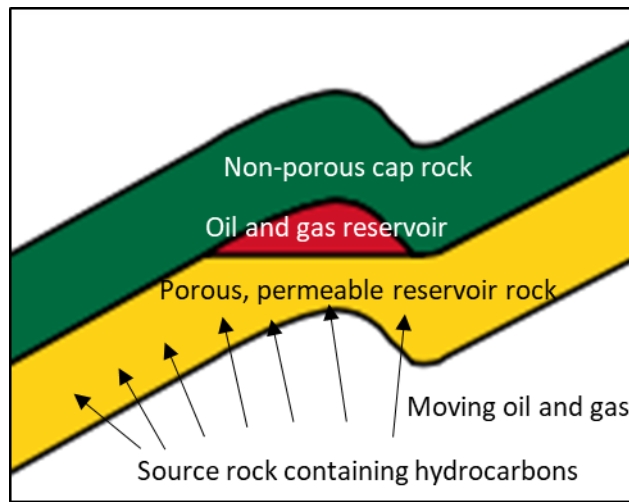


Figure 2.5. Diagram of a hydrocarbon trap. From *Wikipedia* “Crude oil reservoirs.”

the reservoirs to force the oil into the oil well. Still, much of the oil remains in the ground as primary and secondary production recover only 35% of the total oil. Therefore, for every barrel of oil produced, 2 barrels are left in the ground. Scientists are working on new ways, using detergents or small organisms, to help free more of this residual oil. Recovering oil from oil sands and oil shales requires mining the sand or shale and heating it in a vessel or injecting heated liquids into the deposit and then pumping out the oil-saturated liquid – both are costly processes.

Formation of coal. Coal is formed from the remains of trees, ferns and other plants that lived 400 to 300 million years ago as opposed to the small water-based organisms that formed into oil and natural gas. It is formed by pressure and heat in the same way oil and natural gas are formed but at less extreme temperatures and depths within the earth. Coal formed from sea-water swamps often contains large quantities of sulfur that requires treatment to preclude air pollution; whereas coal from fresh-water swamps is often low in sulfur. Coal is found in four grades – from the softest, lowest energy content of lignite to subbituminous to bituminous (soft-coal) to the hardest and highest energy content anthracite. The largest portion of the world’s coal reserves are lignite. There is little anthracite coal to be mined, and most is located in the United States.

Use of fossil fuels. Oil that seeped naturally from the ground was used in small quantities since ancient times. Europeans developed ways to distill petroleum into kerosene and paraffin in the 1850’s. However, it was Edwin Drake’s drilled well, in Titusville Pennsylvania, United States, that touched off the first major oil boom both in drilling and refining. The worldwide demand for kerosene as a fuel for lighting grew quickly. The invention of motor vehicles and the demand for gasoline and diesel fuels for transportation and heating buildings carried the demand to current levels where 90% of worldwide transportation needs are met by oil.

Natural gas was discarded as worthless for many years. Yet, it is very valuable because it burns quickly and cleanly. William A. Hart drilled the first natural gas well in 1821 in New York, United States. During most of the 1800s, natural gas was used primarily as a fuel for city street lamps until electric lamps replaced gas. In 1855, Robert Bunsen invented a burner that mixed air with natural gas to provide heat for cooking and warming buildings. After World War II the United States began building its pipeline network, eventually laying thousands of miles of pipeline in the 1950's and 1960's. Today, natural gas supplies nearly half of all the energy used for home cooking, heating, and appliances. Gas is being used increasingly to generate electricity and in factories as a fuel and as a chemical feed stock. Like oil and coal, it does release CO₂ when burned.

Coal is the most plentiful of the fossil fuels and has the longest and the most varied history. The Romans used it in England during the second and third centuries. However, it was the Industrial Revolution of the 1800's that allowed coal to become a dominant worldwide energy source. In the second half of the 1800s, steamships and steam-powered railroads used coal to fuel their boilers. Coal was first used to generate electricity for homes and factories in the 1880's, and it is now used primarily to generate electricity.

Current consumption, production and reserves of fossil fuels.

Consumption. The world-wide energy consumption for 2015 apportioned between fossil fuels and other sources were as follows (from the UN accredited *World Energy Council, World Energy Resources 2016*):

Oil	33%
Natural gas	24%
Coal	<u>29%</u>
Total fossil fuels	86%

The remaining 14% of energy production, used primarily to generate electricity, was split as follows:

Nuclear	4%
Hydroelectric	7%
Wind, solar and other renewables	<u>3%</u>
Total other fuels	14%

Clearly, civilization today is powered primarily by fossil fuels. If we suddenly stopped producing fossil fuels, most forms of transportation would stop, farm equipment to grow food would stop, oil and gas heating would stop, and the remaining electricity generation would be cut by over one-half and fall far short of current demands. We simply would not have enough energy to support world population levels and modern civilization. While we will not suddenly stop using fossil fuels, we should appreciate our *current* dependence on them. With non-fossil fuels contributing only 14% of total demand today, humanity has much work to do to move away from fossil fuels.

Production and reserves. The worldwide yearly production of fossil fuels for 2015 is as follows (from the *BP Statistical Review of World Energy, June 2016*):

Oil	4.72 billion metric tons (92 million barrels/day)
Natural gas	3,539 billion cubic meters (9,700 million cubic meters/day)
Coal	7.82 billion metric tons (21 million tons/day)

The world's proven reserves of fossil fuels at the end of 2015 were estimated at (from the *BP Statistical Review of World Energy, June 2016*):

Oil	239.4 billion metric tons
Natural gas	186,900 billion cubic meters
Coal	891.5 billion metric tons

If production and reserves of fossil fuels remain the same, then the fuels would be expected to last as follows:

Oil:	51 years (239.4 reserve/4.72 used/year)
Natural gas:	53 years (186,900 reserve/3,539 used/year)
Coal:	114 years (891.5 reserve/7.82 used/year)

In the past, new reserves were discovered that tended to keep pace with increasing usage. For example, in 1985 oil was projected to last 43 years, and it is now projected to last 51 years in spite of all the oil used between 1985 and 2015. Natural gas was projected to last around 50 years in 1985 and is now projected to last 53 years. The projections for coal have dropped from over 220 years in 1995 to around 114 years today. If this trend holds and new reserves continue to be discovered, fossil fuels will last considerably longer than current projections. However, production levels must fall at some time regardless of production efforts, but when this will occur is not known because it depends on both supply and demand.

Relation of atmospheric CO₂ and burning of fossil fuels. The *Global Carbon Budget, 2016* identifies the sources and quantities of carbon dioxide introduced into the atmosphere on a yearly basis. The amount of CO₂ released from fossil fuels was based on the actual amount of fossil fuel used in a given year. In 2015 the amount of CO₂ released by burning fossil fuels was as follows:

<u>Source</u>	<u>Billion Metric Tons CO₂</u>
Oil	12.2
Natural gas	7.0
Coal	<u>15.0</u>
Total	34.2

Another source of CO₂ emission is cement manufacture where limestone is converted in a kiln into lime with the release of CO₂. Land use also releases carbon dioxide based on the balance of deforestation and forestation and on fire emissions. Together cement manufacture and land use released 7.2 billion tons of CO₂ in 2015 (2.4 from cement + 4.8 from land use). Other ongoing natural processes also release CO₂.

While all of the released CO₂ initially goes into the atmosphere, it does not all remain in the atmosphere. The ocean acts as a major sink to take up a large portion of the released CO₂ (based on measurements of CO₂ levels within the waters). The atmosphere does retain a large portion of the released CO₂, which was also measured. The released CO₂ that was not retained in the atmosphere or taken up by the ocean was absorbed up by the land, as there is no other place for it to go. Carbon dioxide is removed from the atmosphere by all plant forms through photosynthesis, which releases oxygen but stores the carbon in plant structures. After the plant dies the carbon is stored in the soil.

The measured uptake of CO₂ by the atmosphere and the oceans for 2015 is shown below:

	Billion Metric Tons CO ₂
Atmospheric growth	23.1
Ocean uptake	<u>11.1</u>
Total	34.2

While in 2015 the uptake of 34.2 billion tons of CO₂ by the atmosphere and the ocean exactly balanced the 34.2 billion tons of CO₂ released by burning fossil fuels, that is not always the case. On average, the CO₂ released by fossil fuels exceeded the atmospheric and ocean uptakes by 2 billion tons per year. This excess quantity of CO₂, as well as that from all other sources, was taken up by the land since there is no other place for it to go. (There is only land, air and water to take up CO₂.)

This material balance indicates that the quantity of CO₂ released by burning fossil fuels is more than enough to account for the measured increases of CO₂ in both the atmosphere and the ocean. If the amount of CO₂ released by fossil fuels was less than the measured CO₂ uptake by the atmosphere and ocean, then other sources of CO₂ would be indicated. Since this is not the case, burning fossil fuels must be the primary source of CO₂, causing the measured increases in atmospheric and ocean CO₂ levels. Scientists also confirm this result by using isotope signatures to identify the CO₂ released by burning fossil fuels.

The trend in total mass of CO₂ released by burning fossil fuels and the total atmospheric uptake between 1960 and 2015 is shown below in Figure 2.6. While both quantities are rising, the lines are curved upwards because the amount of fossil fuels burned each year has increased during this time frame. The measured levels of atmospheric CO₂ of 317 ppm in 1960 and 401 ppm in 2015 indicate a rise of 84 ppm during those years. Over these years, the atmosphere retained approximately 56% of the CO₂ released by fossil fuels, the ocean took up 34%, and the land took up the remaining 10% of the released CO₂. In Section 3, we will consider the *rate* of CO₂ rise.

What if all proven fossil fuel reserves were burned? The amount of CO₂ released, if all of the proven reserves were burned, can be estimated by taking the CO₂ released in 2015 from oil, natural gas and coal and multiplying by the years of proven reserves for each fuel type:

Source	CO ₂ released 2015		Years of reserves		Total CO ₂ released
Oil	12.2	x	51	=	620
Natural gas	7.0	x	53	=	370
Coal	15.0	x	114	=	<u>1,710</u>
Total CO ₂ released, billion metric tons:					2,700

If 56% of the released CO₂ remained in the atmosphere as stated above, then 1,512 billion metric tons (2,700 BM ton x 0.56) would be retained in the atmosphere. This added quantity of CO₂ would increase the CO₂ concentration in the air by of 194 ppm. Adding this level to the 404 ppm of CO₂ in 2016 would result in almost 600 ppm of CO₂. That level of CO₂ would be double the highest level of CO₂ of 300 ppm during the past 800 thousand years based on ice-core data.

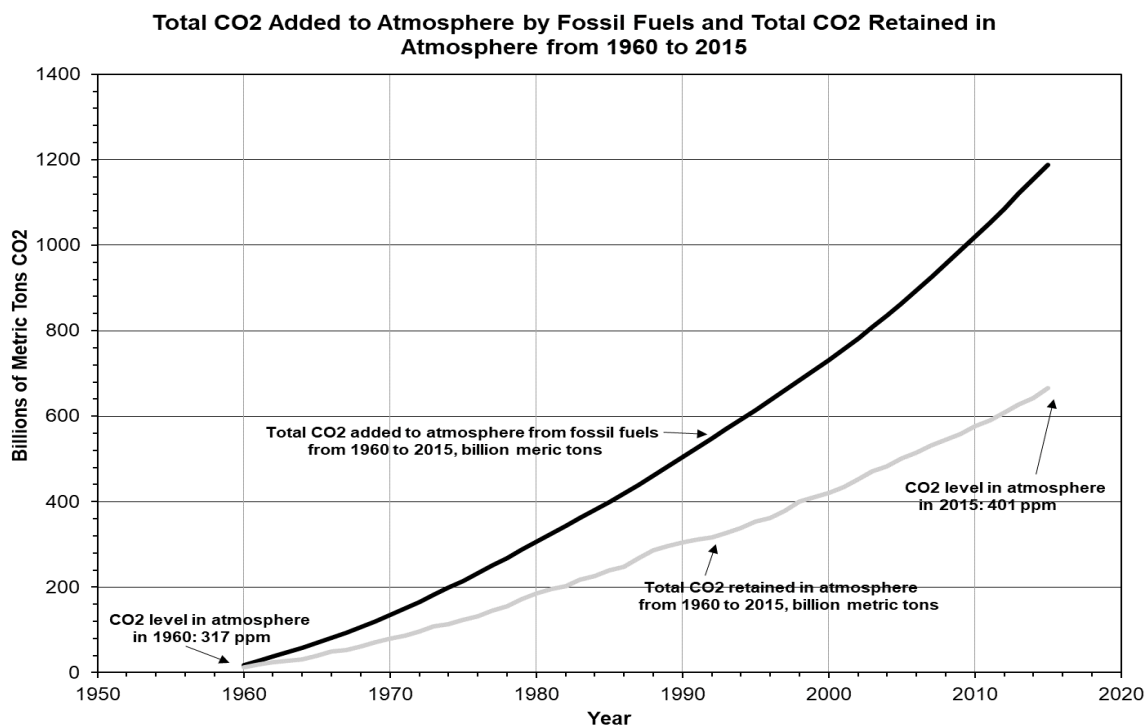


Figure 2.6. Trend in CO₂ added to atmosphere from fossil fuels and amount retained in the atmosphere between 1960 and 2015 in billion metric tons CO₂. From *Global Carbon Budget, 2016*.

<http://www.globalcarbonproject.org/carbonbudget/17/data.htm>

Summary of Section 2, The story of carbon.

1. The earth's atmosphere has changed dramatically three times:

First atmosphere was composed of hydrogen, water vapor, methane and ammonia over 10,000 million years ago.

Second atmosphere consisted of nitrogen, carbon dioxide and water vapor released by volcanos and asteroids around 3,400 million years ago.

Third atmosphere, composed of nitrogen, oxygen, water vapor and lesser amounts of carbon dioxide, formed around 2,400 million years ago and lasted to present.

2. *The earth's third atmosphere was formed by cyanobacteria that lived in seas and lakes. The bacteria released large quantities of oxygen into the atmosphere by converting CO₂ into free oxygen through photosynthesis using the sun's energy. Other water and land plants then developed and did the same thing.*
3. *As the cyanobacteria and other plants used carbon dioxide and released oxygen into the air, they incorporated the carbon into their body structures. Their remains settled and accumulated, thus storing enormous quantities of carbon, some of which later formed into fossil fuels. The storage of carbon was necessary to allow oxygen levels to increase and CO₂ levels to decrease, eventually leading to the environment of today. Without carbon storage, the second atmosphere would have remained – an environment toxic to animals including us.*
4. *As we burn fossil fuels we are in fact reversing the natural process of storing carbon that enabled modern life forms to exist. We should understand the impacts on the earth's systems to know what we are about and the consequences thereof.*
5. *The earth has endured repetitive cataclysmic changes in environment and climate, placement of continents, and mass extinctions at vast time frames far exceeding modern human experience – the system has grandeur.*
6. *Oil and natural gas formed from the remains of small water plants and animals that settled to the bottom of seas and lakes in vast quantities 60 to 400 million years ago. It required about 60 million years for this material to become buried deep enough to allow heat and pressure to chemically change it into oil and natural gas.*
7. *Coal formed from the remains of trees, ferns and other plants that lived 300 to 400 million years ago. This plant matter became buried and subject to heat and pressure in the same way as oil and natural gas were formed but at less extreme conditions and depths.*
8. *Coal is the most plentiful fuel and is used today primarily to generate electricity. Oil is used mainly for transportation and heating and supplies 90% of world transportation needs. Natural gas is a clean fuel used to heat homes and factories, run appliances and generate electricity, and is also used as a chemical feed stock. Each fuel type releases CO₂ when burned.*
9. *Fossil fuels supply 86% of the world's energy needs today while the remaining 14% is split between nuclear 4%, hydroelectric 7%, and wind, solar and other renewables 3%. Civilization today is mainly powered by fossil fuels and depends on that power to exist.*
10. *At today's production rates and proven reserves, oil should last 51 years, natural gas should last 53 years, and coal should last 114 years. However, new reserves will likely continue to be discovered, thereby extending these projections.*
11. *The quantity of CO₂ released by burning fossil fuels was more than enough to account for the measured uptakes by the air and oceans, the two major sinks for CO₂. Other sources of CO₂ would be indicated if fossil fuels released less than the air and ocean uptakes. Since this is not the case, burning fossil fuels must be the primary source of CO₂ increasing the levels of CO₂ in the air and oceans.*
12. *All amounts of CO₂ released that are above the amounts taken up by the air and oceans are taken up by the land since there is no other place for it to go.*

13. If the proven reserves of fossil fuels were all burned, the atmospheric level of CO₂ would increase by 194 ppm over today's level of 404 ppm to around 600 ppm. That level would double the highest CO₂ level of 300 ppm seen during the past 800 thousand years.

Section 3. Global Warming Observations and Problem Definition

Overview. *The earth's natural climate cycles were addressed in Section 1. This section addresses the unnatural climate changes that resulted from the burning of fossil fuels and the associated release of CO₂ into the atmosphere – the only plausible explanation for current global warming. The changes began with the industrial revolution in the 1880's and continue today. Between 1880 and 2016, global average temperatures rose by about 1° C while arctic temperatures rose 3° C. The 3° C rise in arctic temperatures is three times the arctic temperature rises that resulted in the Roman and Medieval warm periods, both of which had major effects on European agriculture.*

The atmospheric level of CO₂ reached 404 ppm in 2016, which exceeds the highest level over the past 800,000 years by over 100 ppm and is at a level not seen for 3 million years when both global temperatures and sea levels were significantly higher than now. Furthermore, CO₂ levels are now rising 157 times faster than during prior climate cycles.

Warming in the arctic is 2.5 times faster than for global average temperatures, causing a rapid decrease in arctic sea ice coverage, melting Greenland glaciers and arctic permafrost, and leading to increased wildfire activity. Sea levels rose 14 cm (5.5 inches) per century after the industrial revolution but are now rising at 34 cm (13 inches) per century. We know that the sea will continue to rise even if we are unsure of when and at what level it will stop. The higher atmospheric levels of CO₂ cause ocean acidification that hinders many marine animals in building their shells.

For certain, global warming is occurring based on direct measurements and observations, potentially displacing millions to billions of people if it continues unabated. We face the risk that the earth's environment is now destabilized, and physical indicators show that it is, even at today's level of atmospheric CO₂. The future extent and pace of global warming is very uncertain because of the complex interactions of the earth's climate system and because of the unnatural rapidity of today's global warming – we simply do not know the outcome. The situation is not hopeless but must be addressed honestly with appropriate action.

These realities present Civilization with the two colossal challenges at the same time: eliminating dependence on fossil fuels while coping with ongoing impacts, and stabilizing the earth's climate. These combined challenges may well be the greatest that Civilization has ever faced and impact each one of us – all 7.6 billion plus future generations. Since civilization today relies on fossil fuels to function, we must continue to burn fossil fuels for some time as alternative energy sources are put in place even though doing so will add further to global warming and ocean rise.

These combined stresses on top of other global stresses such as terrorism and warfare could result in a melt-down of Modern Civilization - a situation too horrible to contemplate with a risk that can't be ignored. We must accept the risk and work to avoid the situation at whatever cost, effort, and change required. Global warming may present Civilization with not only unprecedented challenges, but with unprecedented opportunity to advance technically, economically and socially, and to turn adversity into advantage!

Please reread the summaries at the end of Section 1 and 2 before proceeding.

Rise in surface temperatures since the industrial revolution. Variations in both global and arctic temperatures between years 1880 and 2016 are shown in Figure 3.1. The black line shows global temperature variations, and the grey line shows arctic temperature variations. The lines are jagged because temperature varies from year to year. Longer-term temperature trends are depicted by the solid lines between 1880 to 1960 and between 1960 to 2016.

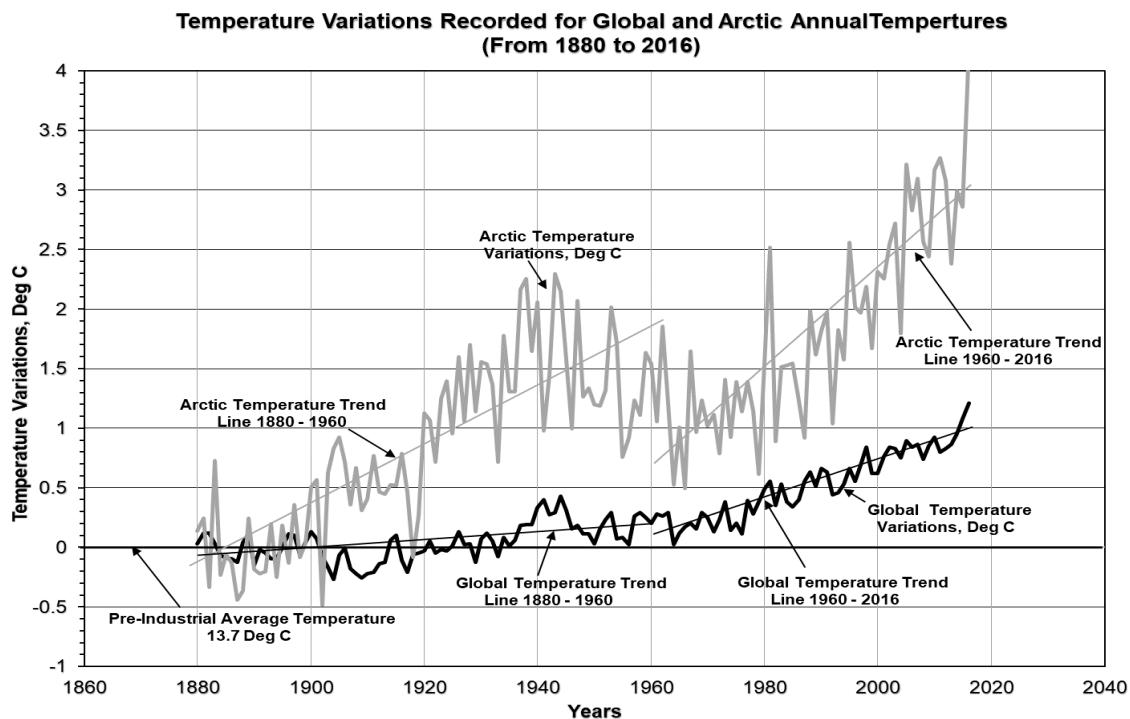


Figure 3.1 Temperature variations recorded for global and arctic annual temperatures from 1880 to 2016. The data were obtained by combining temperature measurements of surface air over land and of surface water around the seas. The trend lines represent linear least-square fits to the data sets. Data is provided by the U.S. National Aeronautics Space Administration (NASA): GISTEMP Team, 2018: *GISS Surface Temperature Analysis (GISTEMP)*. NASA Goddard Institute, <https://data.giss.nasa.gov/gistemp/>.

Overall, global average temperatures have risen by about 1°C between 1880 and 2016, while arctic temperatures have risen by around 3°C during that same period. Since 1960 arctic temperatures rose at an average rate of 4.1°C rise per 100 years, while global temperatures rose at an average rate of 1.6°C rise per 100 yr. Thus, arctic temperatures are now rising 2.5 times faster than global temperatures (4.1°C rise/ 1.6°C rise per 100 years = 2.5).

The trend lines after 1960 slope up more than the trend lines before 1960, which indicate that both global and arctic temperatures are rising at faster rates after 1960 than before 1960. In other words, the rate of global warming accelerated substantially after 1960.

The slight decrease in both global and arctic temperatures between 1940 and 1960 likely resulted from the dramatic increases in all forms of production during this period without pollution control, which, in turn, released large quantities of particles into the air. Atmospheric particles block a portion of the sun's energy and have a cooling affect.

How significant are these temperature increases compared to historical figures? A combined plot of Greenland temperature variations from ice-core data and measured arctic temperature variations are shown in Figure 3.2 over the past 2,000 years.

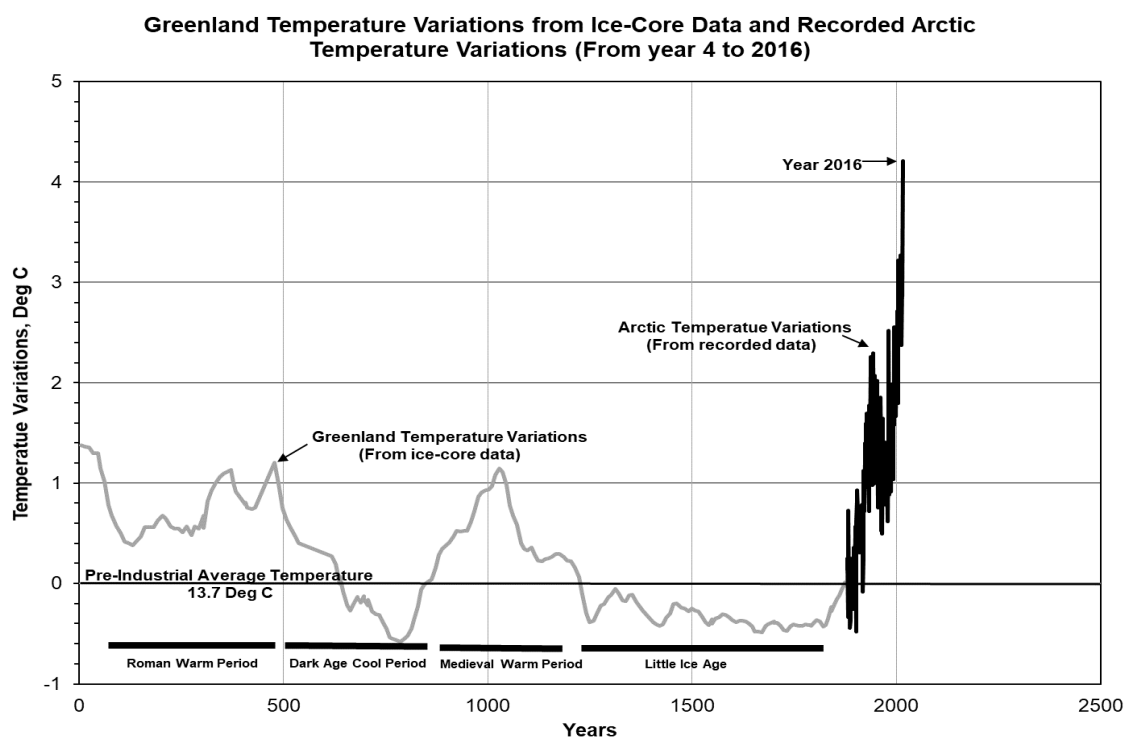


Figure 3.2 Greenland temperature variations from ice-core data and recorded arctic temperature variations from year 4 to 2016. The ice-core data and the measured data were both available between years 1880 and 1900, which allowed the two sets of data to be joined together in the figure. The Greenland data is from the Greenland Ice Sheet Project sponsored by the U.S. National Science Foundation, Office of Polar Programs. The recorded temperature data is provided by the U.S. National Aeronautics Space Administration (NASA): GISTEMP Team, 2018: *GISS Surface Temperature Analysis (GISTEMP)*. NASA Goddard Institute for Space Studies. Dataset accessed 20YY-MM-DD at <https://data.giss.nasa.gov/gistemp/>.

Two trends are noteworthy in Figure 3.2. First, the extent of arctic warming since the year 1,900 is much greater than during the Roman and Medieval warm periods. Both of these periods involved arctic temperature rises of around 1° C and had major effects on European agriculture. Thus, the current 3° C rise in arctic temperatures can be expected to have much more dramatic effects on global agriculture and environment.

Second, arctic temperatures are rising much more rapidly than previously. During the Medieval Warm Period, Greenland temperatures rose at a rate of around 0.7°C per 100 years, whereas the current rate of arctic temperature rise is 6 times faster at around 4.06°C per 100 years. Arctic temperatures are rising 9 times faster than they did from the past ice age to the current warm interval. These rates are unprecedented in the historical records. Together, the extent and rapidity of global warming suggest that the earth's climate system is "shocked."

Rise in atmospheric carbon dioxide (CO_2) levels since industrial revolution. During past ice ages and warm intervals, carbon dioxide (CO_2) levels rose and fell in lock-step with global temperatures. (See Figures 1.4 and 1.5 in Section 1) As temperatures rose, CO_2 that was dissolved in the oceans was released into the atmosphere because the solubility of CO_2 in water decreases as temperature increases. Since CO_2 is a known greenhouse gas, as temperatures rise and CO_2 is released into the atmosphere, it traps more of the sun's energy and raises temperatures further, thereby, constituting a feed-back loop.

The situation is much different now as the earth is in a stable warm interval that has lasted 10,000 years. The current rise in atmospheric CO_2 levels seen in Figure 3.3 is due primarily to the burning of fossil fuels and to a much lesser extent to land clearing and change in surface conditions. Levels of CO_2 from Antarctic

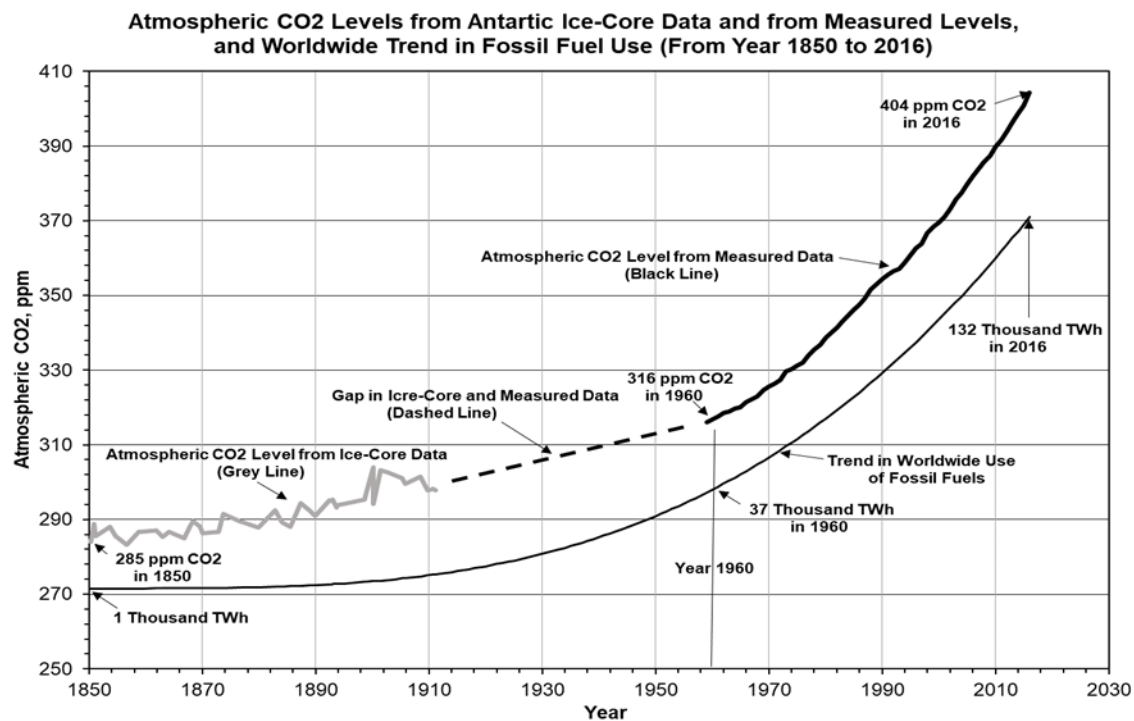


Figure 3.3 Atmospheric levels of CO_2 in parts per million (ppm) as obtained from Antarctic ice-core data (bold grey line) and from direct measurements (Bold black line). Also, the trend in worldwide use of fossil fuels from 1850 to 2016 with values expressed in terawatt-hours (TWh) per year for years 1850, 1960 and 2016. The ice-core CO_2 data is from the Dome C record produced by the European Project for Ice Coring in Antarctica. The measured CO_2 levels were obtained at the Mauna Loa Observatory, Hawaii by the U.S. National Oceanic and Atmospheric Administration (NOAA), Earth System Research Laboratory. The worldwide use of fossil fuels is from Hannah Ritchie and Max Roser (2018) - "Energy Production & Changing Energy Sources". Published online at [OurWorldInData.org](https://ourworldindata.org).

ice core data are depicted in the figure by the bold grey line through 1911 to where the ice core data stopped. The bold black line shows atmospheric CO₂ levels measured since 1959 at the Mauna Loa Observatory, Hawaii. A gap between these two sets of data is shown by the dashed line.

The material balance presented in Section 2 showed that the amount of CO₂ released by burning fossil fuels was very close to the measured uptake of CO₂ by the atmosphere and oceans, thereby indicating that burning fossil fuels is the primary source of CO₂ causing these measured increases. Isotope analysis of CO₂ also confirms this finding. The thin black line in Figure 3.3 shows the trend of worldwide use of fossil fuels. Clearly, as the burning of fossil fuels increased so did the measured levels of atmospheric CO₂ rise. In fact, both rose proportionately between 1850 and 2016, During the 110 years between 1850 and 1960 both rose 27% and during the 56 years from 1960 and 2016 both rose 73%. Therefore, most of the rise in fossil fuel use and atmospheric CO₂ levels occurred after 1960. These proportional rapid increases provide another demonstration that burning fossil fuels is the primary cause of the rapid increase in global and arctic temperatures— no other plausible explanation exists.

The recent rise in atmospheric CO₂ can be compared to historical levels as shown in Figure 3.4. The bold grey line depicts CO₂ levels from Antarctic ice core data, and the bold black line shows levels measured at the

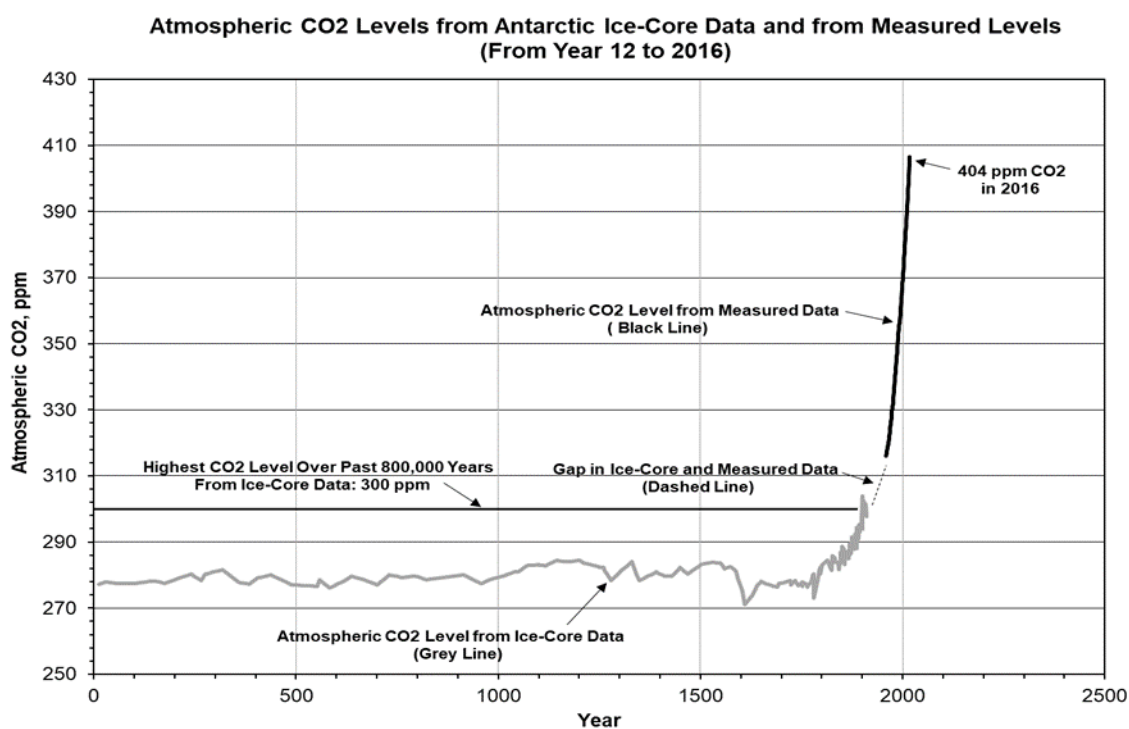


Figure 3.4 Atmospheric levels of CO₂ in parts per million (ppm) as obtained from Antarctic ice-core data (bold grey line) and from direct measurements (Bold black line). The ice-core CO₂ data is from the Dome C record produced by the European Project for Ice Coring in Antarctica. The measured CO₂ levels were obtained at the Mauna Loa Observatory, Hawaii by the U.S. National Oceanic and Atmospheric Administration (NOAA), Earth System Research Laboratory.

Mauna Loa Observatory. The recent rise in CO₂ is much greater than the small natural variations seen between year 1 and 1850. In fact, the 2016 atmospheric level of 404 ppm CO₂ exceeds by over 100 ppm the highest level known to exist over the past 800,000 years. Today's CO₂ level was only reached 3 million years ago when both global temperatures and sea levels were significantly higher than now (*U.S. Fourth National Climate Assessment*, Vol. 1, 2017, p 306. Hereafter "FNCA p ..."). The *U.S. Fourth National Climate Assessment* completed last year provided an extensive analysis of the global warming situation based on the latest observations and emphasized what is known and what is unknown. This Section draws heavily on this very credible assessment.

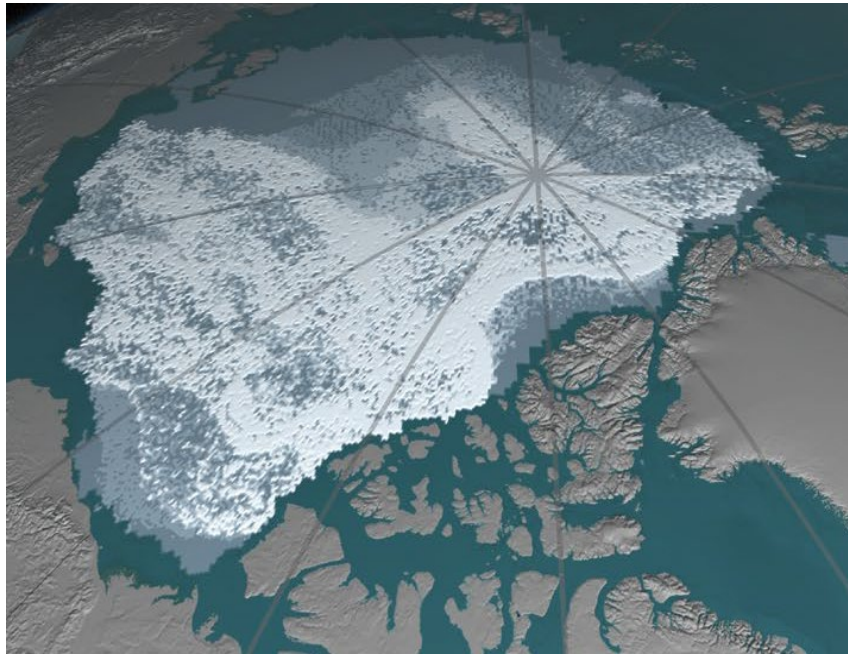
Let's compare the recent CO₂ rise to those that occurred during earth's natural climate cycles. Between 1960 and 2016, a 56-year period, atmospheric levels of CO₂ rose by 88 ppm (404 – 316 ppm from Figure 3.3), which corresponds to a rise of 157 ppm per 100 year. This rise in CO₂ is about the same as occurred during past ice ages and warm intervals when levels rose by 80 to 100 ppm. These natural CO₂ rises were accompanied by Antarctic temperature rises of 10 to 13° C and developed over 6 to 10 thousand years compared to the recent CO₂ rise that took only 56 years. If nature was to repeat itself and Antarctic temperatures do rise proportionally to the CO₂ already released from fossil fuels, then Antarctic temperatures could rise 10 to 13° C above pre-industrial temperatures. Such levels far exceed the 5° C rise of the previous warm interval above pre-industrial temperatures when the entire Greenland Ice Sheet melted, meaning that that the Greenland Ice Sheet may melt at today's CO₂ levels unless interventions not only stop the warming trend, but reverse it.

The current and historical rates of CO₂ rise may also be compared. Over the past 400 thousand years, the historical rate of CO₂ rise between ice ages and warm intervals was 1 ppm per 100 years, whereas the current rate of atmospheric CO₂ rise is 157 ppm per 100 years – 157 times faster. One way to visualize something happening 157 times faster is to think of driving 10 miles per hour versus bolting on a rocket and driving 1,570 miles per hour.

In Section 2, we estimated that if all of the current proven fossil fuel reserves were burned, then the atmospheric concentration of CO₂ would reach around 600 ppm. Carbon dioxide at this level is still be far below the safe US occupational standard of 5,000 ppm. Nevertheless, the US Environmental Protection Agency as well as the indoor air ventilation standard recommend a continuous CO₂ exposure limit of 1,000 ppm or less. Studies (by Satish, Goseph and others) indicate significant negative effects on peoples' cognitive abilities, activity levels, and information usage at this CO₂ level. We should not ignore the possible negative effects on humans if the CO₂ levels continue to rise, particularly inside of buildings. Carbon dioxide levels will continue to rise as long as fossil fuels are burned and could even go above 600 ppm if proven reserves are extended into the future through new discoveries as has repeatedly happened in the past.

Arctic Changes. With arctic temperatures rising 2.5-times faster than the global average temperatures, sea ice on the arctic ocean is disappearing at a dramatic rate as depicted in Figure 3.5, which shows the extent of arctic sea ice in September of 1984 and 2016.

Sea ice decreased by 33% during this 32-year period, and the area of thicker ice 4+ years old decreased by 89% (FNCA, p 306). Loss of the sea ice affects the earth's energy balance. As sea ice melts, much of the sun's energy that was reflected off the ice is now absorbed by the dark open seas and further contributes to global warming – a bad feed-back loop.



1984



2016

Figure 3.5 September sea ice extent and age shown for (a) 1984 and (b) 2016, illustrating significant reductions in sea ice extent and age (thickness). Bar graph in the lower right of each panel illustrates the sea ice area (unit: million km²) covered within each age category (>1 year), and the green bars represent the maximum value for each age range during the record. The year 1984 is representative of September sea ice characteristics during the 1980s. Figures are taken from the *U.S. Fourth National Climate Assessment*, Vol. 1, 2017, p 306. [Tschudi et al. 2016]



1941



2004

[Figure 3.6](#) Two northeast-looking photographs of the Muir Glacier located in southeastern Alaska taken from a Glacier Bay Photo station in (a) 1941 and (b) 2004 by the U.S. Geological Survey. These repeat photographs illustrate that between 1941 and 2004 the Muir Glacier has retreated more than 4 miles to the northwest and out of view. The photographs also illustrate a significant change in the surface type between 1941 and 2004 as bare rock in the foreground has been replaced by dense vegetation. Photos and caption are taken from the *U.S. Fourth National Climate Assessment*, Vol. 1, 2017, p 312.

Not only does arctic sea ice disappear, but arctic glaciers are also shrinking as shown in Figure 3.6 above. Shorter snow cover seasons and higher temperatures increase arctic vulnerability to wildfires, which have recently increased in both arctic forest and tundra (FNCA p 309). Arctic warming is also causing a significant thaw in the permafrost (FNCA p 314).

In addition to the decrease of sea ice on the Arctic Ocean, glacial ice on Antarctica and Greenland are melting at accelerating rates (FNCA p 341). Since this ice is deposited on land above sea level, the melt water flows into the ocean and contributes to sea-level rise. In summary, the rapid loss of arctic sea ice, reductions in arctic glaciers, permafrost melting, and increased wildfire activity are physical responses to the observed rapid warming of the arctic.

Sea Level Rise. Average sea levels rose and fell by around 8 cm (3 inches) during the past 2,000 years prior to the industrial revolution. Sea levels rose about 16 to 21 cm (7 to 8 inches) since 1900, which is greater than any other time in the last 2,000 years (FNCA p 337, 350). Recent tide gauge analyses and satellite data between 1993 and 2015 show an even faster rate of sea level rise of 34 cm (13 inches) per century (FNCA p 339). This rise in sea level is a response to increasing global temperatures (FNCA p 335).

This rise was caused by both the expansion of sea water as it warms, and the increased volume of sea water from ice melting in the Antarctic and Greenland ice sheets and mountain glaciers (FNCA p 335). Since 2005, approximately 1/3 of sea level rise was caused by thermal expansion and 2/3 from ice melting (FNCA p 335).

The extent and frequency of coastal flooding during high-water events such as hurricanes has increased due to sea level rises (FNCA p 347). The number of minor tidal floods has increased 5 to 10-fold since the 1960's (FNCA p 353).

Geological records over the last several million years include times when global average temperatures were comparable to current temperatures, and average sea levels were 6-9 meters (20 to 30 feet) higher than today (FNCA p 337). In light of this historical data, there is no doubt that sea levels will continue to rise although there is uncertainty as to how much and for how long the sea will rise this century (FNCA p 335, 342, 345).

Ocean Acidification. When increased CO₂ levels in the atmosphere are rising, CO₂ is also being absorbed from the air into the world's oceans affecting the sea's carbon chemistry. As the amount of absorbed CO₂ increases, the concentration of carbonic acid increases and is termed ocean acidification (FNCA p 372, 372). Oceans are 30% more acidic now than they were 150 years ago.

This change, in turn, affects calcium carbonate compounds that many marine animals use to build their shells and skeletons (FNCA p 372). As the oceans become more acidic, calcium carbonate compounds dissolve making it impossible for marine animals to build their shells and skeletons. These "corrosive" conditions are now occurring in surface and near-surface waters in the Arctic and northeastern Pacific Oceans (FNCA p 373, 374). Ocean acidification appears to be occurring at the fastest rate in the last 66 million years with potential detrimental impacts to marine ecology (FNCA p 374, 381).

Other Observed Changes. Rising global temperatures are changing weather patterns including:

- a. The tropics have extended northward and southward by about 112 to 322 kilometers (70 to 200 miles) between 1979 and 2009 (FNCA p 173).

b. Within the United States, the frequency of cold waves has decreased, and the frequency of heat waves has increased since the mid-1960s. The number of high temperature records greatly exceed the number of low temperature records over the past 20 years (FNCA p 200).

c. Heavy precipitation events have increased in intensity and frequency in most parts of the United States since 1901 (FNCA p 207).

d. The Atlantic Meridional Overturning Current, part of which is the Gulf Stream, is weakening due to increased temperatures and fresh water from melting arctic glaciers floating on top of denser sea water. Because the Gulf Stream warms parts of Europe, some locales there may temporarily ironically become cooler.

Risk and Potential Surprises. As noted in Section 1, the Earth's climate cycled repeatedly every 100 thousand years between warm intervals and ice ages over the past 800 thousand years – global temperatures were either rising or falling continuously (See Figure 1.1 in Section 1). These dramatic swings in climate can only be explained through the effects of complex feed-back loops that amplify the rise and fall in global temperatures. In addition, as temperatures peaked during the warm intervals or fell to their lowest level during the ice ages, they changed direction quite abruptly, which suggests that unstable conditions built up at the extremes of these cycles. These instabilities, when triggered by solar events and amplified by feed-back loops, apparently drove the earth's climate from one extreme to the other.

In addition to the climate *cycles* between ice ages and warm intervals, less extreme and faster-changing climate *periods* involving hundreds of years occurred during recorded history (See Figure 3.2 in Part I of this Section). Together, the climate cycles and climate periods present a complex climate system, not fully understood, that is highly unstable and variable (even chaotic).

Conversely, the current warm interval has persisted for 10 thousand years. This *relatively* stable warm interval is the only such period in the past 800 thousand years. The causes for this unique warm interval are unknown but may relate to early human activity such as land clearing.

Risk. If a stable condition, in a naturally unstable system, is suddenly shocked, there is always a risk of destabilizing the system. The unprecedented rapid release of CO₂, a known greenhouse gas, from the burning fossil fuels certainly constitutes such a shock – its atmospheric levels are rising at a rate 157 times faster than typical and are now at levels higher than at any time during the past 800 thousand years.

Unfortunately, observed climate changes indicate that the earth's climate is indeed changing rapidly and that the earth's climate cycle is in fact destabilized:

- Current atmospheric CO₂ is at a level not seen for 3 million years and will remain in the atmosphere for thousands of years unless it is purposely removed by humans.

- Arctic temperatures are rising 6 to 9 times faster than at any time during the past 800 thousand years and are continuing to rise at accelerating rates.

- Arctic sea ice coverage is decreasing dramatically; this loss constitutes a bad feed-back-loop since open ocean absorbs much more of the sun's energy than reflecting ice.
- Arctic and Antarctic glaciers are melting at accelerating rates and are contributing to the rise of sea levels.
- Ocean waters are becoming more acidic due to rising levels of atmospheric CO₂ that is absorbed into the seas.
- The tropics are extending northward and southward from the equator towards both poles.

Thus, we need to face the *risk* that earth's climate is now destabilized, even at today's level of atmospheric CO₂.

For certain, global warming is occurring as indicated by direct temperature measurements and physical signs mentioned above. For certain, impacts *could* go from bad, to really bad, to horrific depending on the extent of global warming and sea level rise. Millions to billions of people *could* be displaced from coastal and low-lying areas and from regions rendered too hot for human habitation if global warming continues unabated.

No one knows for sure where the earth's rapidly changing climate will take us – how bad will it get and how quickly? This knowledge gap has two general sources. First, we do not fully understand the earth's enormously complex and interrelated system of feed-back loops nor do we understand the instabilities that apparently result in the abrupt changes from falling to rising temperatures at the end of ice ages, and from rising to falling temperatures at the height of warm intervals. Furthermore, we do not fully understand the mechanism of our highly unusual stable warm interval. These key gaps in understanding cause great uncertainty in our ability to project our climate future – if we do not understand the earth's natural climate changes that previously occurred, how can we foretell future changes?

Potential Surprises. Scientists from around the world are working hard to develop models that can predict future climate conditions. But even using sophisticated tools and models, they too identify potential surprises and devote an entire chapter titled “Potential Surprises: Compound Extremes and Tipping Elements” in the US Fourth National Climate Assessment, Volume 1, 2017. Cited uncertainties include:

- A significant potential for unanticipated surprises with greater risk the faster the earth system is pushed by the continued burning of fossil fuels towards warming (FNCS p 412).
- One or more processes crucial to future warming are not included in today's models, leaving open the possibility of future changes more than model projections (FNCA p 421).
- Self-reinforcing cycles, “tipping elements,” amplified by positive feedbacks, can accelerate and drive the element or the entire system into a radically different state (FNCA p 412, 413, 422). Examples include:

-- The change from an Arctic Ocean covered by ice to one that is ice-free, thereby, leading to increased arctic warming (FNCA p 417).

-- Freshwater entering the ocean from the melting Greenland Ice Sheet, other northern glaciers, and from increased rainfall could slow or shut down Atlantic circulations (FNCA p 418). Projected consequences include increased sea level rise in the US Northeast with cooling temperatures, and reduced ocean uptake of CO₂ causing greater rates of global warming (FNCA p 418). Recently, fresh water is indeed lingering on top of the ocean water and the Atlantic circulation is slowing down.

-- Arctic permafrost continues to melt, releasing carbon that can amplify local and global warming (FNCA p 419).

-- Ultimately, melting of the Greenland Ice Sheet would contribute 6 meters (20 feet) rise in ocean levels (FNCA p 419) while melting of the Antarctic Ice Sheets would add another 60 meters (200 feet). (Both ice sheets could melt if temperatures rise in proportion to CO₂ levels as they did in the past, resulting in a total rise in sea levels of 66 meters (220 feet) that would submerge many of the world's coastal cities and flood vast areas of low-lying land such as Florida.)

-- As forests move northward in response to arctic warming, their darker color relative to tundra will amplify regional warming and further accelerate their expansion (FNCA p 20).

In summary, we need to face the risk that earth's climate is now destabilized and accept the great uncertainty regarding the extent, pace and outcome of global warming – we simply do not *know* what is going to happen, but the trends of rising temperatures and ocean levels are certain. Measures we can take can keep the situation from being hopeless, but we all need to acknowledge the risk and take appropriate action now to fill knowledge gaps and deal with it.

Problem Scope and Complexity. The scope and complexity of global warming encompasses two colossal elements:

1. Destabilization of the earth's climate system by burning fossil fuels. Modern Civilization was built during a stable climate interval and today depends on that stability. Even if we stopped burning fossil fuels today, there is real risk (and physical indicators) that the *earth's entire climate system* is now destabilized and moving towards uncertain outcomes. How do we go about *stabilizing* the earth's climate system? The scope and complexity of this challenge is unprecedented.

2. Dependence of Modern Civilization on burning fossil fuels. Modern Civilization uses fossil fuels to power 86% of its systems. The world uses over 90 million barrels of oil per day and 21 million tons of coal *per day*. If we suddenly stopped using fossil fuels, air, ground and sea travel would essentially cease, electricity production would plummet, food production would drop precipitously, and heating/cooling of homes and buildings would greatly diminish, particularly in cities. Essentially all of

the systems that we rely on for convenience and survival would cease. In fact, today civilization is nearly as dependent on fossil fuels to survive as we are on the air we breathe.

We must curtail and eventually eliminate our use of fossil fuels to reduce the release of CO₂. At the practical level, how can we do this? How can we replace the vast and costly infrastructure that depends on fossil fuels – cars, trucks, planes, ships, electricity generators...? And, what other energy sources can replace fossil fuels? Weaning ourselves off of fossil fuels that enabled the building of Modern Civilization and power it today is a second huge problem in scope and complexity that must be addressed now. The more CO₂ that we release into the atmosphere, the more the earth's climate will be destabilized, and the greater will be our difficulties. Therefore, there is great urgency to quickly cut fossil fuel use and CO₂ release.

Some might think that we can work on the problem of reducing fossil fuel use now and worry later about stabilizing the earth's climate system. There is, however, too much risk from the current extent of destabilization of the earth's climate with the amount of CO₂ released to date.

Therefore, we need to address and overcome the two colossal challenges of eliminating dependence on fossil fuels while coping with ongoing impacts, and of stabilizing the earth's climate *at the same time*. These combined challenges are likely the greatest that Civilization has ever faced, impacting *each one of us – all 7.6 billion plus future generations – rich and poor, famous and unknown, powerful and powerless*.

Stakes. Modern Civilization is being buffeted from many directions by global warming:

- The pressing need to shift from the fossil fuels that civilization is dependent on.
- The indications that the earth's climate is destabilized, with the resulting need to begin the daunting task of stabilizing the climate.
- The reality that we must rely on fossil fuels for some time.
- The prospect that the earth will continue warming and changing during this period with unavoidable rise in sea levels, and worldwide changes in living and agricultural conditions.

All of these challenges are interrelated and must be faced simultaneously. Also, they must be dealt with in addition to Moderns Civilization's other challenges that include terrorism, warfare, conflicts, public debt...

Could these combined stresses, if not successfully overcome, cause a melt-down of Modern Civilization? While no one can predict the future, the authors' judgement is "yes", a melt-down is a real possibility, particularly taking a business-as-usual approach.

Such a conclusion must be based on rational judgement while considering the entire situation. The risk of failure does increase dramatically when the actual scope and complexity of a problem are ignored – the unaddressed parts can defeat what is accomplished. Examples of colossal failures when realities are overlooked include the fates for aggressors of World War II and the societies that experimented with communism.

What might a global meltdown involve? At today's population levels with the concentration of people in cities, the complexity and intertwined systems upon which Modern Civilization depends, the result could involve the die-off of vast numbers of people. This situation is too horrible to contemplate, the risk is too real to ignore. The only sane approach is to *accept* the risk and work to avoid the situation at whatever cost, level of effort, and change required.

Looking Ahead. Understanding the global warming problem is itself a difficult challenge. Here, the authors have attempted to present the key pieces of information in an understandable manner so that you can reach your own conclusions. Also, we have tried to consider the entire problem in the broadest sense – to see the “whole elephant.”

What is to be done? The next section presents three broad technical projects to concurrently: 1) eliminate dependence on fossil fuels and cope with unavoidable climate change impacts, 2) stabilize the earth’s climate, and 3) fill key knowledge gaps and seek new energy and stabilization technologies. While these projects will take enormous work and cost, they will undoubtedly yield great benefits in terms of new technologies, new career fields for young people and future generations, and expanded economic opportunities.

However, with today’s extravagant waste of human potential through conflict, war, poverty... we may simply not have the capacity to deal with the many aspects of the global warming problem *simultaneously*. Therefore, the authors foresee yet another dimension to global warming that should not be ignored - how to tap the full human potential *successfully* to deal with the challenge. To do so may require new and better approaches.

In this light, global warming may present mankind with not only unprecedented challenges, but with unprecedented opportunities to advance technically, economically and socially, driven by necessity. We must (and we can) turn adversity to advantage!

The next section, Taking Action, addresses technical aspects of global warming, and the last section suggests adaptations to tap the full human potential to advance civilization.

Summary of Section 3, Global Warming Observations and Problem Definition.

- 1. From 1880 to 2016, global average temperatures rose by about 1°C while arctic temperatures rose 3°C with the rate of rise accelerating substantially after 1960. Arctic temperatures now rise 2.5 times faster than global temperatures.*
- 2. The 3°C rise in arctic temperatures is three-times greater than the 1°C rise that resulted in the Roman and Medieval warm periods, both of which had major effects on European agriculture. Thus, the current temperature rise will have even greater effects.*
- 3. Global warming, is due primarily to the build-up of CO₂ in the atmosphere, a known greenhouse gas, which, in turn, results primarily from the unprecedented and rapid burning of fossil fuels – there is no other plausible explanation.*
- 4. As the arctic warms 2.5 times faster than the global average temperatures, observed changes there include a decrease in arctic sea ice coverage by 33% in the past 32 years, the melting of Greenland and Antarctic glaciers at accelerating rates, the melting of arctic permafrost, and increased wildfire activity.*
- 5. The atmospheric level of CO₂ reached 404 ppm in 2016 and far exceeds the highest level over the past 800,000 years by over 100 ppm. This level has not occurred since 3 million years ago when both global temperatures and sea levels were significantly higher than now. Levels of CO₂ are now rising 157 times faster than during prior natural climate cycles and constitute a “shock” to the earth’s climate system.*

6. *Changing weather patterns that are consistent with rising temperatures include the northward and southward extension of the tropics by 112 to 322 kilometers (70 to 200 miles), the decrease in frequency of US cold waves and the increase in frequency of heat waves, and an increase in intensity and frequency of heavy precipitation events in most of the US. Also, the Gulf Stream is weakening due to increased temperatures and melt water from glaciers.*
7. *Sea levels rose 14 cm (5.5 inches) per century between the industrial revolution and year 2,000. The rise has now accelerated to 34 cm (13 inches) per century, with 1/3 of the rise caused by thermal expansion and 2/3 from ice melting. The seas will continue to rise during this century unless the warming trend is stopped and reversed.*
8. *The extent of coastal flooding during high-water events such as hurricanes has increased as seas continue to rise.*
9. *At higher atmospheric levels, CO₂ is being absorbed from the air into the world's oceans and causing ocean acidification, which in turn hinders many marine animals in building their shells and skeletons. Ocean waters are 30% more acidic now than 150 years ago, and acidification is occurring at the fastest rate in the last 66 million years.*
10. *We all face the risk that the earth's environment is now destabilized, even at today's level of atmospheric CO₂.*
11. *For certain, global warming is occurring based on direct temperature measurements and observations, only the extent and pace remain uncertain with impacts ranging from bad, to really bad, to horrific, potentially displacing millions to billions of people if global warming continues unabated.*
12. *These realities present two colossal challenges: a. eliminating dependence on fossil fuels to reduce additional global warming while coping with ongoing impacts, and b. stabilizing the earth's climate to control the destabilization that has already occurred.*
13. *Since civilization today relies on fossil fuels to function, we must continue to burn fossil fuels for some time as alternate energy sources are put in place, but there is urgency in cutting fossil fuel use immediately to minimize future global warming and ocean rise. We also need to contemplate how to reverse effects already in place or occurring in the near future.*
14. *The combined stresses of continued climate change, reducing dependence on fossil fuels, and stabilizing the earth's climate on top of other global stresses such as terrorism and warfare could result in a melt-down of Modern Civilization - a risk too real to ignore. We must acknowledge the risk and work to avoid the situation at whatever cost, effort, and change required.*
15. *The situation is not hopeless. Addressing global warming truthfully and with appropriate action will yield new technologies, new career fields for young people and future generations, and expanded economic benefits. It will require tapping the full human potential - now extravagantly wasted through conflict, war, poverty... - thereby presenting Modern Civilization with unprecedented opportunities and necessity to for social advancement. We must (and can) turn adversity to advantage!*

Section 4. Taking Action

Overview. *Section 4 presents specific projects and actions that help solve the global warming problem. The United Nations' Paris Agreement is a major step in international cooperation to reduce greenhouse gas release, the underlying cause of global warming. The Agreement went into effect in November 2016 and was accepted by all nations a year later. Subsequently, the US gave notice to withdraw from the Agreement effective in 2020. The agreement contains two specific goals:*

- *Hold global temperature rises to below 2°C and try to keep them below 1.5°C.*
- *Rapidly reduce greenhouse gas emissions in order to balance human release & removal by 2100.*

Progress toward Agreement goals includes supplying 19% of world energy needs with renewables. However, studies show that national reduction pledges will not keep global temperature rise below 2° C, indicating a need for increased pledges to reduce CO₂, the primary greenhouse gas.

With the Paris Agreement as a starting point, three technical challenges remain:

- *First. Halt the release in atmospheric CO₂ resulting from burning fossil fuels while adapting to unavoidable global warming impacts.*
- *Second. Stabilize the earth's climate system, now changing in uncertain, detrimental ways that will likely bring about more instability.*
- *Third. Fill key knowledge gaps about the workings of the earth's climate system and discover then develop advanced energy and stabilization technologies.*

These challenges are complex, broad, system problems often called “wicked problems” with technical, economic and political components mixed together. Fortunately, “wicked-problem approaches” are available to solve such problems, and they form the basis of three proposed projects to address the three global warming challenges.

These “people's projects” must be performed by engineers, scientists, economists and other multidisciplinary people from around the world who choose to work together through the Internet to develop practical, affordable and socially/politically acceptable solutions to global warming. This strategy is driven by necessity since global warming is a worldwide problem requiring global

problem-solving efforts. Only the Internet provides the low-cost, rapid transfer of data, ideas, and results needed to link together thousands of people.

The three projects focus on technical challenges but will accomplish even more by bringing fragmented national efforts together globally and mobilizing the world's scientists, engineers, economists and others to find practical solutions that are supported by the people and leaders of the world. The projects also provide opportunities to learn and to help solve a problem that threatens Modern Civilization. Since global warming affects all, everyone has a role in successfully implementing solutions and in overcoming social/political barriers to success. Doing so will provide technical advancements, open new career fields for young people and future generations, and expand economic and social opportunities. This unprecedented opportunity stands before us – let us work together and overcome global warming!

Please reread the summaries at the end of Section 1, 2 and 3 before proceeding.

Paris Agreement. One-hundred and ninety-six state parties negotiated the Paris Agreement under the United Nations Framework Convention on Climate Change. The Agreement reached final form in December 2015 with two specific goals:

1. “Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change;” (Article 2, paragraph 1. (a))
2. “In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, recognizing that peaking will take longer for developing country Parties, and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty.” (Article 4, paragraph 1)

In other words, keep global temperature rises to below 2°C and try to keep them below 1.5°C by balancing greenhouse gas release and removal by 2100. The second goal will likewise halt the ongoing release of atmospheric greenhouse gas (CO₂) resulting from burning fossil fuels. The Agreement does not specify how this goal is to be achieved or which energy sources should be emphasized.

Other key provisions are:

- “Each Party shall prepare...nationally determined contributions that it intends to achieve.” (Article 4, paragraph 2), and “...shall communicate a nationally determined contribution every five years...” (Article 4, paragraph 9)
- “Parties hereby establish the global goal on...reducing vulnerability to climate change...” (Article 7 paragraph 1)

- “Developed country Parties shall provide financial resources to assist developing country Parties with respect to both mitigation and adaptation...” (Article 9, paragraph 1)
- “The Conference of the Parties ...shall periodically take stock of the implementation of this Agreement to assess the collective progress...(referred to as the “global stocktake”)” [and] ”...shall undertake its first global stocktake in 2023 and every five years thereafter...” (Article 14, paragraph 1, 2)

The Paris Agreement went into effect on November 4, 2016. Nicaragua and Syria, the last two countries to accept the Agreement, formally signed it in October and November of 2017. With all nations participating, the Agreement clearly represented a major step in international cooperation to control climate change.

Subsequently on August 4, 2017, the US Administration of President Trump delivered official notice to the United Nations that the U.S. intends to withdraw from the Paris Agreement as soon as it can legally do so on November 4, 2019 with the earliest effective withdrawal occurring in November 2020. This action leaves the US as the only country not participating in the Agreement. The US has already shifted away from the Agreement by emphasizing increased coal and petroleum productions. As the world’s second largest CO₂ emitter after China, US withdrawal significantly detracts from international cooperation on climate change. Nevertheless, many US states, cities and businesses are acting on their own to fulfill the Paris Agreement.

A study in *Nature*, June 30, 2016 (www.nature.com/articles/nature18307), concluded that current pledges by all countries are insufficient to keep global temperature rise well below 2° C, while the United Nations Environment Program agency predicts that temperatures will rise by 3° C – far above the Paris Agreement goal (www.theguardian.com/environment/2016/nov/03/). Therefore, nations need to substantially enhance their reduction pledges to achieve the target of keeping global warming well below 2° C. Unfortunately, a study published in *Nature*, August 1, 2017, found that every major industrialized nation is failing to meet its current pledges under the Paris Agreement (www.nature.com/news/prove-paris-was-more-than-paper-promises-1.22378). In 2018, the United Nations Intergovernmental Panel on Climate Change identified further urgency to keep global warming below 1.5° C (IPCC SR 1.5, 10.06.180), while the United Nations Climate Institute called for rolling back global temperatures to no more than 0.5° C above preindustrial levels (global temperatures are already 1° C above). A more recent study in *Nature Climate Change*, (April 2019, Vol 9, 290-294 www.nature.com/naatureclimatechange) concluded that “Even under optimistic assumptions about the climate sensitivity, pathways to a tolerable climate/economic future are rapidly narrowing” implying the need for urgent action to cut fossil fuel use over the next one to two decades.

In summary, the Paris Agreement is a starting point of international cooperation to reduce greenhouse gas release and to limit global warming. However, it and actions by participating nations will not solve the global warming problem without additional steps even though they are moving in the right direction and should be encouraged. Indeed, the Paris Agreement calls on nations to do more than their pledges and to expand their pledges in the near future in order to avert the very serious consequences of global warming.

Current greenhouse gases reductions. The Paris Agreement specifies reductions in “greenhouse gas” emissions resulting from human activity. Greenhouse gases include CO₂, methane, nitrous oxide and chlorofluorocarbons. Among these, CO₂ is by far the greatest contributor to global warming. Since 1990, CO₂ accounts for 86% of the increase in greenhouse gas effects on global warming and currently contributes over

2/3 of the warming by greenhouse gases (<https://www.esrl.noaa.gov/gmd/aggi/aggi.html>). As a result, the remainder of this report focuses on CO₂ reductions although reductions in the other greenhouse gases will help limit global warming.

Renewable energy that does not increase atmospheric CO₂ levels supplied 19% of the world's energy needs in 2016, apportioned as follows: synthetic fuels, ethanol and biodiesel (9%), heat from biomass, geothermal and solar (4%), hydroelectricity (4%), and electricity from wind, solar, geothermal and biomass (2%). More than half of all new electricity capacity installed in 2015 was renewable. The following countries among others fulfill most of their electricity needs with renewable energy: Canada (65%), Denmark (69%), New Zealand (81%), Norway (98%), Iceland (100%) and Ethiopia (100%) (Wikipedia, REN21's 2016 report and US Energy Information Admin.,

(https://en.wikipedia.org/wiki/List_of_countries_by_electricity_production_from_renewable_sources).

Nuclear power supplied 11% of world electricity needs in 2016 and releases no CO₂. The six largest nuclear power producers are United States, France, China, Russia, South Korea and Canada. From 1970 through 2006, worldwide nuclear power generation increased, then plateaued, and then dropped slightly. It increased slightly over the past four years but is still 8% below its peak in 2006 (World Nuclear Association www.world-nuclear.org/...library/).

Progress can also be judged by looking at total CO₂ emissions from burning fossil fuels and from producing cement. Between 2000 and 2015 US CO₂ emissions fell by 12% while European Union emissions fell by 18%. These reductions were, however, more than offset by the rapid increases in China's CO₂ emissions that went up by 58% and by India's increase of 92% (www.carbonbrief.org/what-global-co2-emissions-2016-mean-climate-change).

Worldwide, the amount of CO₂ released between 2000 to 2010 increased each year by over 3%, primarily due to growth by China and India. Since 2010, the amount of increase slowed and held nearly steady in 2014, 2015 and 2016, then rose again in 2017 to historic highs as global energy demand increased due to strong economic growth. The main reason for the plateauing of CO₂ emissions per year was China's switch from burning coal to burning oil and natural gas for power generation. Since China is the world's largest CO₂ emitter, changes in its energy policy have global consequences (www.carbonbrief.org/what-global-co2-emissions-2016-mean-climate-change).

As nations continue to burn fossil fuels and to emit CO₂, particularly at current record levels, CO₂ continues to build up in the atmosphere. Direct measurement of CO₂ levels in the atmosphere verify this fact. Since 2000 to the present, atmospheric CO₂ levels rose at an average of 2% per year with a slight increase to 2.1% per year since 2010 (NOAA Earth Research Laboratory, www.esrl.noaa.gov/gmd/ccgg/trends/gr.html).

Carbon dioxide levels will continue increasing unless and until releases and uptakes are brought into balance. Achieving this goal will not reduce atmospheric CO₂ levels, leaving the earth's climate system at risk and already destabilized even at current CO₂ levels. Nevertheless, plateauing CO₂ released per year is a major first step in reaching Paris Agreement goals.

Global Warming Challenges. With the Paris Agreement in place the following three challenges remain.

First challenge: Halt the continued release of atmospheric CO₂ resulting from burning fossil fuels while adapting to unavoidable future impacts of global warming. A worldwide practical plan to overcome these issues does

not exist. Since global warming is a worldwide problem involving all nations, the plan must be developed and implemented on a coordinated global basis. To be “practical,” the worldwide plan must a. be technically feasible and effective using proven technology, b. be economically feasible to all nations and regions, c. be politically implementable and supported by the vast majority of *the people*. The plan should not be a collection of goals, targets and options but rather a plan of specific actions implemented over defined time periods. In light of the rapidity, extent and expected impacts of unavoidable global warming, the plan should address halting the continuing release of atmospheric CO₂ from fossil fuels starting immediately and accomplishing this goal by or before year 2100 as stated in the Paris Agreement, and also by years 2075 and 2050 and even sooner as contingency measures. The plan must also include assessment of global warming impacts such as rising sea levels and increased storm intensities, and identify practical approaches to adapt to these changes. These challenges involve engineering, economics and science and will be addressed primarily by engineers, economists and scientists, and other multidisciplinary people.

Second challenge: Stabilize the earth’s climate system, now likely already destabilized and changing in uncertain, detrimental ways. To face this challenge, practical measures must be developed, tested and implemented to halt then reverse global warming. Since the climate system encompasses the whole earth, the measures must be planned, developed and implemented globally. To be “practical” the measures must again be a. technically feasible and effective relying on proven technology, b. economically feasible to all nations and regions, c. politically implementable and supported by the vast majority of *the people*. Measures to stabilize the earth’s climate system by years 2100, 2075 and 2050 should be evaluated to provide timing options for minimizing climate change impacts. Achieving this goal requires a thorough understanding of the earth’s energy and carbon balances and natural cycles in order to accurately evaluate and compare stabilization options. These challenges involve engineering and science and will be addressed primarily by engineers, and scientists along with economists and other multidisciplinary people.

Third challenge: Fill identified knowledge gaps about the workings of the earth’s climate system in order to accurately evaluate and compare stabilization and fossil fuel reduction options. A second element of this challenge requires assessing and prioritizing ongoing research and development (R&D) plus additional creative ideas on new energy technologies that tap new energy sources or existing sources at greater efficiencies. These breakthroughs are needed to reduce the risk that we may not be able to reduce fossil fuel use while stabilizing the earth’s climate system, and maintaining Modern Civilization with today’s energy technology. This effort will proceed in parallel the urgent efforts to reduce fossil fuel use and to cut atmospheric CO₂ release using available technology. A third component of this challenge is investigating, analyzing and demonstrating new technologies to stabilize the earth’s climate system. This challenge involves engineering and science, and will be implemented primarily by engineers and scientists with economists and other multidisciplinary people.

Overcoming the three challenges requires that science and engineering work together. Differences between science and engineering are explained below so readers may better understand why this is so.

Science is defined as systematized knowledge derived from observation, study, experimentation and hypotheses to determine the nature or principles of things. Scientists usually specialize in one of the natural sciences such as biology, chemistry, or physics. Since knowledge is open ended, so too is science since one discovery usually

leads to new questions. Scientists emphasize discovery, investigating the unknown. As new knowledge is acquired, scientists try to use the results to generate hypotheses and theories to interpret and explain their results. Scientists publish their results through a “peer review” process to help assure that results are valid. As future data and discoveries occur, past theories are often modified based on the new information. Thus, theories represent the best thinking at the time based on available information, but they are subject to change. This “scientific method” works very well as witnessed by the ever-increasing array of new and useful discoveries.

A relevant example of science is collecting and analyzing ice core samples from Antarctica and Greenland. In the pursuit of knowledge scientists camped out on glaciers under harsh conditions for a number of years to gather ice core samples, then meticulously analyzed each sample and presented the results. The plot of temperature variations over the past 800 thousand years presented in Figure 1.1 in Section 1 is based on 7,570 individual samples. Without this data the world would be largely ignorant of the earth’s natural climate cycles and greatly handicapped in dealing with global warming. In keeping with the role of science, scientists will play a key role on the third challenge in order to fill knowledge gaps and to discover new energy and stabilization technologies.

Engineering involves putting scientific knowledge to practical use. Engineers usually specialize in a branch of engineering such as mechanical, electrical, or chemical engineering. Unlike scientists that seek new knowledge and discoveries, engineers focus on achieving specific objectives within stated time periods using *available* knowledge and technologies – “a problem-solving approach.”

For example, engineers design and oversee the building of bridges and oil refineries on agreed upon schedules. Because the bridge must not fall down or the refinery blow up, engineers rely on proven science, engineering practices and technologies. They often add safety factors by over designing components to reduce the risk of unforeseen failures. For example, if a bridge must carry 1,000 tons, engineers may design the bridge to carry 1,100 tons or more. Engineers balance reliability, costs, schedules and other factors. As a result, engineers do not strive for perfection; they strive for practical results that are *good enough* to do the job.

Since the first two challenges focus on meeting specific goals with available technology, they should be conducted primarily by engineers. Also, both of these challenges involve integrating information and processes on a global basis. Engineers are skilled in working with complex systems and integrating many components into a working whole.

Science and engineering do overlap. When scientists make a discovery having broad benefit, engineers then develop that discovery for commercial and public use. Very often scientists hand off laboratory scale results to engineers who then test and refine the discovery at a pilot scale before commercialization. For this reason, engineers will need to assist the scientists when they discover the basis for new energy technologies under the third challenge. Conversely, scientists will need to assist the engineers working on the first two challenges when they identify key knowledge or technology gaps vital to the success of otherwise workable results.

In summary, scientists and engineers employ very different thought processes. Scientists pursue an open-ended quest for new knowledge and discoveries. Engineers take a problem-solving approach to obtain an agreed upon goal within a specified time using proven technology. Without scientists, technological advancement would not occur, and without engineers, new discoveries would not reach practical application.

Solving the global warming problem. Global warming presents the earth's people with a *problem* – likely the greatest that mankind ever faced and one that threatens the future of Modern Civilization. Because global warming is a problem, it must be addressed using a problem-solving approach involving broad based, intense effort (hard work!) directed at solving the problem. The remainder of this report focuses on solving the global warming problem.

As mentioned previously, the global warming problem encompasses both halting the release of atmospheric CO₂ while simultaneously stabilizing the earth's climate system and coping with climate change impacts. This type of complex, broad scoped, interrelated *systems* problem is called a “wicked problem.” Wicked problems are so complex that they cannot be solved by a pre-planned series of steps. Such problems usually have technical, economic and political components snarled together like a “Gordian knot.”

Fortunately, “wicked-problem approaches” are available to solve wicked problems including the global warming problem. The wicked-problem approach used here is simple and has demonstrated success in solving both highly complex technical problems with scientists and engineers as well community problems with citizen teams. The approach adapts standard engineering project management and team leadership techniques to solving wicked problems.

The wicked-problem approach involves breaking a complex problem into many components, then establishing multidisciplinary teams to work on each component simultaneously. As the teams identify options to solve each problem component, they evaluate each option on technical feasibility and effectiveness, cost and benefits, and social/political acceptability.

Teams independently develop solutions for their problem elements and periodically share and integrate results. Sharing of results brings new knowledge and ideas to each team as work progresses and integration assembles team solutions into an overall solution of the wicked problem. This *iterative* (repetitive) process continues until a satisfactory, integrated solution is achieved.

The wicked problem approach strives for solutions that are practical – technically feasible and effective in addressing the problem, economically supportable, and socially/politically implementable. The solution is not practical if anyone of these criteria is not met. Negative aspects of a solution, such as environmental degradation, must also be identified and evaluated along with positive aspects. Therefore, a practical solution represents a balancing or compromise of these criteria. It may not be the ideal solution, rather it is the best practical solution to solve the problem. A *good enough* solution is all that is needed.

As the effort proceeds, everyone is learning more about the problem and how best to solve it. They learn from investigating the elements they are working on and by sharing and integrating results between the teams. Learning is not only necessary to gather factual information; it also catalyzes creative thinking. The wicked-problem approach does not *solve* the problem. People solve the problem with the approach providing a flexible structure to focus people in a working environment of truth, compromise, and goodwill. The overall goal of the approach is to tap the *full human potential* to solve wicked problems. It works because that potential is already in us – we just need to use it!

The People's Projects. Three separate projects utilizing a wicked-problem approach are needed to address the three global warming challenges discussed previously:

- 1) People's Project to Halt the release of CO₂ & Adapt to Climate Change
- 2) People's Project to Stabilize the Earth's Climate System
- 3) People's Project on Climate Science, Energy & Stabilization Technology

Project 1 goals: Identify and evaluate national, regional, and worldwide options to halt the release of atmospheric CO₂ resulting from burning fossil fuels, and to adapt to unavoidable climate change. The resulting integrated strategies must be technically feasible, economically affordable and socially/politically implementable, and supported by *the people*. Support and promote international cooperation to implement nationally, regionally, and worldwide the resulting best practical approaches to halt further rise in atmospheric CO₂ levels and to adapt to unavoidable climate change. The recent book *Drawdown* identifies and compares 80 technologies and ways to deal with global warming, providing an excellent starting point for Project 1 (www.drawdown.org). The project will also establish a platform to facilitate communications and data sharing among worldwide participants in the three projects.

Project 2 goals: Identify and evaluate options to stabilize the earth's climate system, halt/reverse global warming and avoid future climate swings, and then coordinate the options into an integrated system. The system must be tested to prove its effectiveness prior to implementation. As with Project 1, the resulting integrated strategy must be technically feasible, economically affordable and socially/politically implementable, and supported by *the people*. Support and promote international cooperation to test and implement the best integrated strategy to halt/reverse global warming.

Project 3 goals: Evaluate current climate models and identify, prioritize and fill key knowledge and data gaps in order to more fully understand the earth's climate system and to allow for improved future projections. With better understanding of the earth's climate system, improve climate models and engineering energy and CO₂ mass balances, and make sound projections and evaluations of actions to halt/reverse global warming. The project will assemble an international global-warming data base platform to supply the three projects with accurate, current data and to share project results. The project will identify, evaluate and prioritize a. advanced energy technologies currently in R&D and additional new approaches that tap new sources of energy as well as existing sources with greater efficiency, and b. advanced technologies to stabilize the earth's climate. Advanced technologies can help fulfill future energy needs as fossil fuel use is curtailed and can stabilize the earth's climate system. Support and promote international cooperation to test and implement the best integrated approaches to halt/reverse global warming.

The three projects must be carried out simultaneously because they are interrelated and each is necessary at this time to successfully address global warming. They are "people's projects" since they must be performed on behalf of the people of the world and by the world's people.

Several points must be emphasized. The three projects are in addition to, not in place of ongoing efforts to cut fossil fuel use and CO₂ release, and to develop and field other energy sources. These ongoing efforts are vitally needed and must be continued and accelerated. A main thrust of the projects is to mobilize the world's engineers, economists and others to work together on all aspects of global warming to develop practical international solutions. The foundation of the projects will be the vast knowledge base that already exists, most of which was obtained by scientists. Engineers will use this information in their problem-solving efforts. Projects 1 and 2 must be accomplished as quickly as possible, not exceeding 1 to 2 years. The resulting practical, integrated global strategy can then be used to fine-tune ongoing work and to implement additional required efforts to deal successfully with global warming. The Project 3 assessment work must likewise be completed quickly, 1 to 2 years, to have a reliable strategy to guide ongoing and future R&D efforts on energy

and stabilization technologies so that they support the global strategy. The R&D efforts, as well as implementing the solutions to global warming will take longer.

Project participants. To be successful, scientists, engineers, economists, and other multidisciplinary people from around the world must choose to work together on the three projects, which likely will involve thousands of people. Integration must be conducted through the Internet to link everyone's efforts and to achieve global solutions. Some type of home base platform will be needed to facilitate the exchange of information. Open source software development platforms have successfully supported online collaborations among thousands of software developers, and their experience may be helpful here. While many participants will work only part-time on the projects, others already employed in studying global warming may choose to link with these global efforts. Project participants will include people from university departments, industrial organizations, government and non-profit organizations willing to commit time and resources. Retirees and essentially anyone with the desire and applicable skills can participate.

Motivation is key to success. If people want to do something, they usually find a way to do it, particularly if they feel a sense of urgency. If enough people are motivated to act, and given the enormous human potential of the people, success is likely. The overriding motivator is the fact that global warming poses a serious threat to Modern Civilization, which is likely the most wicked problem ever faced. No person or even a group of people can solve this problem alone. Global warming is a worldwide problem with actions in one region affecting other regions. The world's peoples must *choose* to work and cooperate together in order to be successful. Governments, government organizations, corporations, and universities have their own priorities and cannot be *made* to work on global warming. Political priorities can change quickly as seen recently in the United States. In short, we the people of earth have burned fossil fuels resulting in global warming, and only we the people of earth can solve the problem.

There are a number of very positive motivators. Global warming solutions will require decades if not centuries of effort. New career fields will develop that benefit young people and future generations. By working on the three projects, people in universities and their departments will learn first-hand what is involved and how best to structure their curricula and research to meet evolving needs. People in businesses and corporations that participate can be the first to see business opportunities, and participants in government organizations will be able to keep abreast of the latest developments while contributing to global solutions, gaining international respect, and breaking down barriers.

At the individual level, working on global warming provides the opportunity to learn and to work on a truly important problem that threatens Modern Civilization. People do take pleasure in their work and do like to contribute. Participating also allows people from around the world to meet each other and to link together for the betterment of all.

Since no central funding source exists, the projects must be funded using distributed funding. That is, the individuals that choose to work on the projects must obtain their own funding sources, which may not be too difficult. Many government agencies already fund work on global warming. University professors have flexibility in selecting research and development (R&D) topics. Businesses and corporations may grant employees a portion of their time to work on the projects, thereby, keeping abreast of new developments and contributing to the common good. Retirees may devote time to the projects without additional funding. The old adage "Where there is a will there is a way." applies here.

The Internet is vital to project success. Only the Internet provides the low-cost and rapid transfer of information, ideas, results and discussion needed for these broad and complex projects. While people enjoy meeting face-to-face, the costs and time would be prohibitive on a worldwide basis. Some participants may be able to meet on their own initiative, but the communication backbone of the projects must be the Internet. In this way, the many separate efforts from around the world can be knit together, allowing for rapid progress and holistic solutions.

None of this will happen overnight. Global warming solutions will require prolonged effort. New career fields, new energy sources, new products and new ways of doing things will develop over time and help everyone. As the three projects progress, more and more people can become involved allowing the efforts to snowball. Governments will then, hopefully, legislate regulations that will benefit their citizens by implementing project solutions and preserve an environment that supports life as we know it

For those interested in participating on one of the three People's Projects, at the end of this section the three projects are described in greater detail along with ways project participants could work together on the projects. All readers are encouraged to scan the information to better understand what is involved.

Expectations. The three projects just described aim at meeting the project goals described previously. This desired outcome can be obtained by executing the three projects simultaneously to capitalize on their synergy, and by using a wicked-problem approach that can accomplish even more than the project goals. These complementary expectations are described below.

The Paris Agreement is an important global milestone to reduce greenhouse gas release, but it is being largely pursued by countries working independently. Since the climate system is one interrelated system spanning the entire earth, practical solutions must be global, integrated solutions. These three projects are specifically designed to accomplish just that - bring people together from around the world to collectively develop integrated, practical global strategies, thereby, maximizing the success of everyone working on global warming.

The three projects are not roadmaps to solve the global warming problem. Wicked problems, including global warming, are too complex and interrelated to solve through a series of pre-planned steps. The three projects will bring together a critical mass of minds (thousands), focus them on the global warming problem, and accomplish tasks *useful* to solving the problem. With this progress and with deeper understanding, creativity and new insights, the people will guide the effort, integrate results, and solve the global warming problem. By developing an overarching reliable "game plan" to overcome global warming, ongoing efforts can be combined with additional needed approaches to successfully overcome global warming. The stakes are too high (survival of Modern Civilization), and the risks are too great to assume that actions and plans of today are *sufficient* to meet the global warming challenge. The three projects will greatly help to reduce that risk.

The global warming problem is inherently a problem of fact – nature's physical reality. Nature does not care about political ideology and elections or corporate profits. Dealing with the physical reality of global warming requires fact-based problem solving rather than opinion-based problem solving. The wicked-problem approach used here is a structured, proven, fact-based approach that fits the global warming problem hand-in-glove. It is specifically designed to tap our full human potential to solve wicked problems by divide the problem into doable work units so progress can be made, and continuously integrating results throughout

the process. People work together and think as hard as possible in an atmosphere of truth, compromise and goodwill.

To date, scientists have shouldered most of the burden in dealing with global warming. They gather physical data on the earth's climate system and on climate change, develop climate models, and make predictions of future climate change. Engineers design and build windmills, solar arrays and other forms of energy systems as well as improve motor efficiencies, thereby contributing to global warming solutions. However, the world's engineers are needed to address global warming in its broadest sense because engineers are problem solvers, and global warming is a massive “wicked” problem. To this end, the three projects will mobilize and focus engineers, economists, scientists and many other multidisciplinary people on key issues of global warming. These same people can then play key rolls in implementing the global warming solutions developed by the three projects.

Recommendations from the three projects must be believed and accepted by *the people* of the world and their political leaders and governments in order to be implemented. Reaching effective, practical solutions should help. Having a critical mass of talent from around the world develop *their* strategy, one without self-serving interests and political agendas, should also help. Participants can then inform others of the solutions and actions needed. By focusing on facts and avoiding political influence, the three projects will not compete with political leaders for political power. Rather, the resulting practical solutions can inform (indeed support!) the world's political leaders and governments. Together, these factors offer the best opportunity to reach a global consensus and then to implement solutions to global warming.

As mentioned in Section 3, while global warming poses unprecedented challenges, it also provides unprecedented opportunity. Problem facilitators, engineers, scientists, economists and others who choose to lead project teams and sub-teams on each of the three projects, will work hard. However, gaining leadership skills and experience to solve the wicked problem of global warming is a lifetime opportunity – with these skills, what problem couldn't a person tackle? Working on the projects is also a unique opportunity to address a problem threatening Modern Civilization and to establish a precedence of people from around the world working together through the Internet to solve extremely complex problems.

In summary, the three projects offer a way to successfully deal with global warming. Self-interest and interest in the future of Modern Civilization demand that we take action now. No central body exists with the authority, resources or capability to direct worldwide action on global warming. In addition, global warming affects everyone on earth – no one is exempt! Everyone needs to play a role not only in supporting and implementing global-warming solutions, but in overcoming social and political barriers that may undermine success. Overcoming these barriers can yield additional opportunity to advance as suggested in Section 5, the final section of this report. *It is up to us, we the people of earth. Let us work together and beat the global-warming problem!!*

Summary of Section 4, Taking Action.

1. The United Nations Paris Agreement, a major step in international cooperation to reduce greenhouse gas release, contains two specific goals: Keep global temperature rise to below 2°C but try to keep it below 1.5°C and balance greenhouse gas release and removal by 2100. The second goal will likewise halt the release of CO₂ into the atmospheric that results from burning fossil fuels.

2. The Agreement was accepted by all nations of the world in November 2016. Subsequently, the US gave notice of its intention to withdraw effective November 2020.

3. Recent studies indicate further needs to keep global temperature rise below 1.5°C while current greenhouse gas reduction pledges will not even keep global temperature rise below 2°C , indicating a need for increased national reduction pledges and action and much faster action to cut fossil fuel use and the release in atmospheric CO_2 .

4. Progress under the Paris Agreement to reduce CO_2 , the dominant greenhouse gas resulting from burning fossil fuels includes:

- Half of new electricity capacity and 19% of world energy production uses renewables.
- A number of countries fulfill most of their electricity needs with renewable energy.
- Nuclear energy supplies 11% of world electricity with no CO_2 release.
- Worldwide, the amount of CO_2 released each year peaked in 2014, but atmospheric concentrations of CO_2 keep rising 2% per year due to continued CO_2 releases.

5. With the Paris Agreement in place, three global warming technical challenges remain:

First. Halt the ongoing release of atmospheric CO_2 resulting from burning fossil fuels while adapting to unavoidable global warming impacts.

Second. Stabilize the earth's climate system, which is likely already destabilized and changing in detrimental ways.

Third. Fill identified knowledge gaps about the workings of the earth's climate system and discover new energy technologies that tap new energy sources or existing sources with greater efficiencies, and find new technologies to stabilize the earth's climate system.

6. The three challenges involve complex, broad, interrelated system problems usually called "wicked problems" with technical, economic and political components snarled together like a "Gordian knot."

7. Fortunately, "wicked-problem approaches" are available to solve such problems and form the basis of three projects that address the three global warming challenges:

Project 1. People's Project to Halt Release Atmospheric CO_2 & Adapt to Climate Change

Project 2. People's Project to Stabilize the Earth's Climate System

Project 3. People's Project on Climate Science, Energy & Stabilization Technology

8. To succeed, these "people's projects" must be performed by scientists, engineers, economists and other multidisciplinary people from around the world who choose to work together through the Internet to develop practical, economically feasible and socially/politically acceptable solutions. Project participants can then play key roles in implementing the solutions.

9. *This strategy is driven by necessity:*

- *Global warming is a worldwide problem so solutions must be developed globally.*
- *Only the Internet provides the needed low-cost, rapid transfer of data, ideas & results.*
- *No central body exists with the authority, resources or capability to direct worldwide action on global warming – solutions must come from the people who choose to work on global warming motivated by opportunity, self-interest and concern for the future of Modern Civilization.*

10. *The three projects aim to solve technical goals, but will accomplish even more:*

- *Bring fragmented national efforts together to maximize overall success.*
- *Apply a wicked-problem approach to focus a critical mass of minds (thousands) on the global warming problem enabling the people to solve the global warming problem.*
- *Mobilize the world's engineers, economists, scientists and others to expand the ongoing work of scientists on global warming.*
- *Develop effective, practical solutions by people from around the world, which can lead to global consensus for action among people, political leaders and governments.*
- *Provide lifetime opportunities to learn problem-solving skills and to help in solving an unprecedented problem threatening Modern Civilization.*

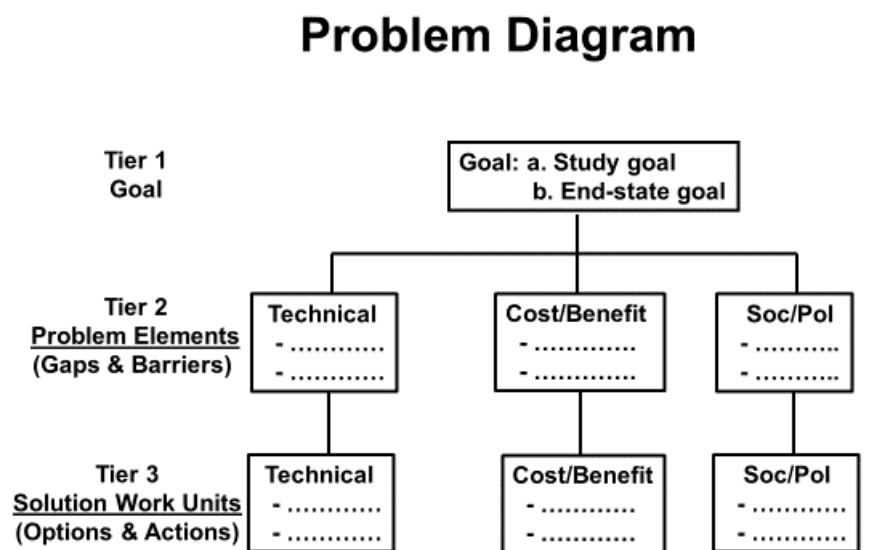
11. *The three projects need to be completed quickly in 1 to 2 years so that the results are available to guide ongoing and future efforts to overcome global warming. These projects are in addition to, not in place of current efforts to cut fossil fuel use and CO₂ release. These on-going efforts need to be continued and accelerated to avoid even more serious future impacts.*

12. *Global warming affects all – no one is exempt! Everyone has a role in implementing the solutions and in overcoming social/political barriers to success. Doing so will provide technical advancements, open new career fields for young people and future generations, and expand economic and social opportunities. This unprecedented opportunity stands before us – let us work together and succeed!!*

Applying the Wicked-Problem Approach to the Problem of Global Warming.

This information is intended primarily for people who may want to work on the three projects, although everyone is invited to review it in order to gain a better understanding of what is involved.

Problem Diagrams. The first step in the wicked-problem approach is developing a problem diagram used to orient and focus the problem solvers. The overall effort is referred to as a “project” that is given a title and executed by “project participants” working together in “project teams.” A problem diagram, comprised of three tiers, is shown schematically in Figure 4.1.



Slide 3

Figure 4.1. Problem diagram used in wicked-problem approach and comprised of three indicated tiers.

The Tier 1 goals are divided into two types of goals. The project goal defines what the project teams plan to accomplish. The end-state goal states the expected overall benefits that can result from achieving the project goal. The Tier 2 problem elements list the known questions and barriers that need to be overcome in order to accomplish the project goal. These are subdivided into technical, cost/benefit, and social/political problem elements. Technical problem elements include all the technical, physical and knowledge gap impediments and questions. The cost/benefit elements are the economic questions and barriers associated with different solution options. The social/political elements are social and political questions and barriers associated with different solution options.

The Tier 3 solution work units list the options and actions to address each of the problem elements and are similarly divided into technical, cost/benefit, and social/political solution work units. Solution work units comprise a statement of work for the project teams. They must be both executable and provide results that

taken together accomplish the project goal. The problem elements and solution work units are selected to minimize overlap in order to avoid confusion. For simplicity, each solution work unit corresponds to a single problem element.

Ideally, project participants develop the problem diagram. Since teams have yet to be assembled, problem diagrams presented here are initial drafts. Teams update the diagrams as efforts proceed and new questions, barriers, solution work units and options not originally identified surface. In this way the problem diagrams provide a living picture of the efforts and reflect the best current thinking.

The following three draft problem diagrams correspond to the three global warming challenges and the associated projects previously discussed.

Project 1, Problem Diagram (Draft)

People's Project to Halt Ongoing Release of CO₂ & Adapt to Climate Change

Tier 1. Goals

Project Goal: Identify and evaluate national, regional, and worldwide options to halt the release of atmospheric CO₂ resulting from burning fossil fuels, and to adapt to unavoidable climate change. Develop integrated strategies that are technically feasible and effective, economically supportable and political implementable and supported by *the people*. Support and promote international cooperation to implement the best strategies.

End-State Goal: Best practical approaches to halt the release of atmospheric CO₂ resulting from burning fossil fuels and to adapt to unavoidable climate change nationally, regionally, and worldwide are in place and moving forward successfully.

Note: The release of other greenhouse gases should also be reduced, but since CO₂ release from burning fossil fuels is the most serious contributor to global warming, it is the main focus of this project.

Tier 2. Problem Elements (Questions and Barriers)

Technical Problem Elements

Standardization.

(1) Standard parameters need to be selected for use in this project so that results can be accurately compared and integrated.

Halt the ongoing release atmospheric CO₂ from burning fossil fuels.

(1) What are the current national, regional, worldwide energy consumptions by type of energy and associated releases of CO₂ from each energy type?

(2) What are the available, proven approaches to fill energy needs nationally, regionally, worldwide that do not produce greenhouse gases?

- (3) What are the available, proven approaches to fill energy needs nationally, regionally, worldwide that produce, capture, and sequester greenhouse gases without any atmospheric release?
- (4) What are the available, proven approaches to increase energy efficiencies?
- (5) What are available, proven approaches to conserve energy resources nationally, regionally, worldwide that would otherwise contribute to greenhouse release?
- (6) What are the current national, regional, worldwide plans to implement these approaches, and what are the projected national, regional, worldwide energy requirements by energy type and by year 2050, 2075, and 2100?
- (7) Based on these plans, what will be the total annual release of CO₂ nationally, regionally, worldwide by the year 2050, 2075, and 2100, and what will the atmospheric greenhouse gas levels be by those years? Will the Paris Agreement goal of balancing greenhouse gas emissions and uptake (i.e. halt rise of atmospheric CO₂) be met by 2100?
- (8) What are options using available, proven approaches to reach no net release of greenhouse gas by 2050, 2075 and 2100 if not met with current plans?
- (9) What are key technical barriers to achieving no net release of greenhouse gas by 2050, 2075 and 2100?
- (10) What are the anticipated population growths nationally, regionally, worldwide and to what extent would voluntarily reduce population growth decrease energy requirements, the release of greenhouse gas and help to adapt to the unavoidable impacts of climate change?
- (11) What technologies are currently in development that can assist in reducing greenhouse gas emissions and what are their development risks, likely availabilities, implementation costs, limitations and benefits? What further reductions in greenhouse gas emissions would occur if these developments are deployed at achievable levels?
- (12) What are the feasibilities, effectiveness and negative impacts of the options considered?

Adapting to unavoidable climate change.

- (1) From what areas and how many people nationally, regionally, worldwide will be forced to evacuate due to expected levels of ocean rise by 2050, 2075 and 2100?
- (2) From what areas and how many people nationally, regionally, worldwide will be forced to evacuate due to expected rises in temperatures by 2050, 2075 and 2100?
- (3) From what areas and how many people nationally, regionally, worldwide will be otherwise severely impacted by anticipated climate changes via rainfall, storms, temperatures by 2050, 2075 and 2100?
- (4) What are practical options to cope with and mitigate these impacts?
- (5) What are the feasibilities, effectiveness and negative impacts of the options considered?

Cost/Benefit Problem Elements

- (1) How can the cost analyses be determined on a consistent basis nationally, regionally, worldwide?
- (2) What are the annual costs and total costs to implement current national plans to reduce CO₂ release by 2050, 2075 and 2100? What are the annual costs and total costs to implement options nationally, regionally, worldwide to halt the rise of atmospheric CO₂ by 2050, 2075 and 2100?
- (3) What are the annual and total costs to implement practical options nationally, regionally, worldwide to cope with and mitigate unavoidable climate change by 2050, 2075 and 2100?
- (4) What are the annual and total costs nationally, regionally, worldwide to halt the rise of atmospheric CO₂, and to cope with and mitigate unavoidable climate change by 2050, 2075 and 2100?

- (5) How can these costs be paid for nationally, regionally, worldwide, and what is the affordability of paying for these costs nationally, regionally, worldwide?
- (6) What are the cost impacts of advanced technologies identified in Project 3 to reduce CO₂ if they are implemented?
- (7) What are the results of a cost/benefit analysis of the options considered?

Social/Political Problem Elements

- (1) What are the social/political barriers to implement current plans and identified options to halt the rise of atmospheric CO₂ by 2050, 2075 and 2100?
- (2) What are the social/political barriers to implement practical options to adapt to unavoidable climate change by 2050, 2075 and 2100?
- (3) How can these barriers be overcome nationally, regionally and globally to successfully halt the rise of atmospheric CO₂, and to adapt to unavoidable climate change by 2050, 2075 and 2100?
- (4) What is the social/political acceptability of each option to halt the rise of atmospheric CO₂ and to adapt to unavoidable climate change?

Integration & Implementation Elements

- (1) What would be an integrated global strategy that balances technical feasibility and effectiveness, cost and social/political factors to halt the rise of atmospheric CO₂, and adapt to climate change by years 2050, 2075 and 2100?
- (2) How can that strategy be successfully implemented?
- (3) How can project participants support and promote international cooperation to implement the best strategies?

Tier 3. Solution Work Units (Options & Action)

Technical Work Units

Standardization.

- (1) Select parameters for consistent use in this project to include a base year, the different regions of the earth to be addressed, and standardized units of measurement for mass, energy, greenhouse gas concentration, temperature, and for other parameters used within this project.

Halt the ongoing release of atmospheric CO₂ from burning fossil fuels.

- (1) Identify the current national, regional, worldwide energy consumption by type of energy and associated release of CO₂ from each energy type.
- (2) Identify the available, proven approaches to fill energy needs nationally, regionally, worldwide that do not produce greenhouse gases. Analyze each approach for net energy yield per year using standardized energy units and considering energy required to install, maintain and fuel each approach.
- (3) Identify the available, proven approaches to fill energy needs nationally, regionally, worldwide that produce, capture, and sequester greenhouse gases without any atmospheric release. Analyze each approach

for net energy yield per year using standardized energy units and considering energy required to install, maintain and fuel each approach.

- (4) Identify the available, proven approaches to increase energy efficiencies. Analyze each approach for energy savings per year using standardized energy units.
- (5) Identify the available, proven approaches to conserve energy resources nationally, regionally, worldwide that would otherwise contribute to greenhouse release. Analyze each approach for net energy saving per year using standardized energy units and considering energy required to install, maintain and fuel each approach.
- (6) Determine the current national, regional, worldwide plans to implement these approaches and project what the national, regional, worldwide energy requirements will be by energy type and by year 2050, 2075, and 2100.
- (7) Based on these plans, determine what the total annual release of CO₂ nationally, regionally, worldwide will be by the year 2050, 2075, and 2100 and what the atmospheric greenhouse gas levels will be by those years. Determine if the Paris Agreement goal of no net release of greenhouse gas will be met by 2100 or when it will be met.
- (8) Develop options with available, proven approaches to reach no net release of greenhouse gas by 2050, 2075 and 2100 if not met with current plans.
- (9) Identify key technical barriers to achieving no net release of greenhouse gas by 2050, 2075 and 2100.
- (10) Identify the anticipated population growths nationally, regionally, worldwide and determine to what extent voluntarily reduced population growth would decrease energy requirements, the release of CO₂, and help to adapt to the unavoidable impacts of climate change?
- (11) Identify technologies currently in development that can assist in reducing greenhouse gas emissions and assess their development risk, likely availability, implementation costs, limitations and benefits. Project the further reductions in greenhouse gas emissions if these developments are deployed at achievable levels.
- (12) Estimate the feasibilities, effectiveness and negative impacts of the options considered?

Adapting to unavoidable climate change.

- (1) Project from what areas and how many people nationally, regionally, worldwide will be forced to evacuate due to expected levels of ocean rise by 2050, 2075 and 2100.
- (2) Project from what areas and how many people nationally, regionally, worldwide will be forced to evacuate due to expected rises in temperatures by 2050, 2075 and 2100.
- (3) Project from what areas and how many people nationally, regionally, worldwide will be otherwise severely impacted by anticipated climate change via rainfall, storms, temperatures by 2050, 2075 and 2100.
- (4) Develop practical options to cope with and mitigate these impacts.
- (5) Estimate the feasibilities, effectiveness and negative impacts of the options considered?

Cost/Benefit Solution Work Units

- (1) Determine how the cost analyses can be determined on a consistent basis nationally, regionally, worldwide.
- (2) Estimate the annual costs and total costs to implement current national plans to reduce CO₂ release by 2050, 2075 and 2100. Estimate the annual costs and total costs to implement options nationally, regionally, worldwide to halt the rise of atmospheric CO₂ by 2050, 2075 and 2100.
- (3) Estimate the annual and total costs to implement practical options to cope with and mitigate the unavoidable climate change nationally, regionally, worldwide by 2050, 2075 and 2100.

- (4) Estimate the annual and total costs nationally, regionally, worldwide to halt the rise of atmospheric CO₂, and to cope with unavoidable climate change by 2050, 2075 and 2100.
- (5) Identify how these costs can be paid for nationally, regionally, worldwide, and determine the affordability of paying these costs nationally, regionally, worldwide.
- (6) Estimate the cost impacts of advanced technologies identified in Project 3 to reduce CO₂ when implemented.
- (7) Prepare a cost/benefit analysis of the options considered and of the resulting integrated approaches.

Social/Political Solution Work Units

- (1) Identify the social/political barriers to implement current plans and identified options to halt the rise of atmospheric CO₂ by 2050, 2075 and 2100.
- (2) Identify the social/political barriers to implement practical options to adapt to unavoidable climate change by 2050, 2075 and 2100.
- (3) Determine how these barriers can be overcome nationally, regionally and globally to successfully halt the rise of atmospheric CO₂, and to adapt to unavoidable climate change by 2050, 2075 and 2100.
- (4) Estimate the social/political acceptability of each option to halt the rise of atmospheric CO₂ and to adapt to unavoidable climate change.

Integration & Implementation Work Units

- (1) Develop an integrated global strategy that balances technical feasibility and effectiveness, cost and social/political factors to halt the rise of atmospheric CO₂, and to adapt to climate change by years 2050, 2075 and 2100.
- (2) Determine how that strategy can be successfully implemented.
- (3) Support and promote international cooperation to implement the best strategies.

Project 2, Problem Diagram (Draft)

People's Project to Stabilize the Earth's Climate System

Tier 1. Goals

Project Goal: Identify and evaluate options to stabilize the earth's climate system that halts/reverses global warming and avoids future climate swings. Coordinate the options into an integrated system that is technically feasible and effective, economically supportable and political implementable and supported by *the people*. Support and promote international cooperation to test and implement the best integrated system.

End-State Goal: A best practical approach to stabilize the earth's climate system that halts/reverses global warming and avoids future climate swings is in place and functioning successfully.

Tier 2. Problem Elements (Questions and Barriers)

Technical Problem Elements

Standardization.

(1) Standard parameters need to be selected for use in this project so that results can be accurately compared and integrated.

Earth-based stabilization systems.

(1) What earth-based approaches could alter the amount of solar radiation heating the earth's surface?

(2) What are practical approaches for removing CO₂ from the atmosphere?

(3) These approaches need to be evaluated and compared on a consistent basis including evaluation of negative impacts.

Space-based stabilization systems.

(1) What space-based approaches could alter the amount of solar radiation heating the earth's surface?

(2) These approaches need to be evaluated and compared on a consistent basis including evaluation of negative impacts.

Cost/Benefit Problem Elements

(1) How can the cost analyses be determined on a consistent basis nationally, regionally, worldwide and consistent with the standardized approach used in Problem 1?

(2) What are the cost estimates for each earth-based and space-based stabilization system including remaining R&D, testing and demonstration, capital and deployment, and yearly operation, and maintenance costs?

(3) What is the affordability of paying for these costs nationally, regionally, worldwide, and how can these costs be paid nationally, regionally, worldwide?

(4) What are the results of a cost/benefit analysis of the options considered?

Social/Political Problem Elements

(1) What are the social/political barriers to implement the earth and space-based stabilization systems?

(2) How can these barriers be overcome nationally, regionally and globally to successfully implement the systems?

(3) What is the social/political acceptability of each earth and space-based system?

Integration & Implementation Elements

(1) What would be an integrated global strategy that balances technical feasibility and effectiveness, cost and social/political factors to halt/reverse global warming and to avoid future climate swings by years 2050, 2075 and 2100?

(2) How can the strategy be successfully implemented?

(3) How can project participants support and promote international cooperation to test and implement the best integrated system?

Tier 3. Solution Work Units (Options & Action)

Technical Solution Work Units

Standardization.

- (1) Use standard parameters selected for Project 1 and select additional parameters for consistent use in this project.

Earth-based stabilization systems.

- (1) Identify earth-based approaches to alter the amount of solar radiation heating the earth's surface. (Examples: remove CO₂ from atmosphere, increase cloud cover)
- (2) Identify approaches for removing CO₂ from the atmosphere to achieve pre-industrial levels.
- (3) Evaluate each approach on
 - Technical feasibility, state of development, and time frame when available for national, regional, global application,
 - Regional applicability and limitations on the extent that it could be applied,
 - Effectiveness in stopping/reversing global warming and avoiding future climate swings when applied at different levels,
 - Environmental impacts and risks at national, regional, global levels if applied up to practical limitations.
 - Remaining R&D and testing needed to complete development for national, regional and global application.

Space-based stabilization systems.

- (1) Identify space-based approaches to alter the amount of solar radiation heating the earth's surface. (Example: deflect sun energy with solar shield)
- (2) Evaluate each approach on
 - Technical feasibility, state of development, and time frame when available for global application,
 - R&D and testing needed to complete development for global application,
 - Limitations on the scale that it could be applied,
 - Effectiveness in stopping/reversing global warming and avoiding future climate swings when applied at different scales,
 - Environmental impacts and risks at national, regional, global levels if applied up to the practical limitations on scale.

Cost/Benefit Solution Work Units

- (1) Determine how the cost analyses can be determined on a consistent basis nationally, regionally, worldwide and consistent with the standardized approach used in Problem 1.
- (2) Develop cost estimates for each earth-based and space-based stabilization system that include remaining R&D, testing and demonstration, capital and deployment, and yearly operation, and maintenance costs.
- (3) Assess the affordability of paying for these costs nationally, regionally, worldwide and develop a strategy to pay for these costs nationally, regionally, worldwide.

- (4) Prepare a cost/benefit analysis of the options considered and of the resulting integrated approaches.

Social/Political Solution Work Units

- (1) Identify the social/political barriers to implement the earth and space-based stabilization systems.
- (2) Determine how these barriers can be overcome nationally, regionally and globally to successfully implement the systems.
- (3) Evaluate each earth and space-based system for its social/political acceptability.

Integration & Implementation Work Units

- (1) Develop an integrated global strategy that balances technical feasibility and effectiveness, cost and social/political factors to halt/reverse global warming and to avoid future climate swings by years 2050, 2075 and 2100.
- (2) Determine how the strategy can be successfully implemented.
- (3) Support and promote international cooperation to test and implement the best integrated strategy.

Project 3, Problem Diagram (Draft)

People's Project on Climate Science, Energy & Stabilization Technology

Tier 1. Goals

Project Goal: Identify, prioritize and fill knowledge/data gaps to more fully understand, describe and model the earth's dynamic climate system including natural climate cycles and human impacts, and to make sound future projections. Develop earth energy and CO₂ mass balances to support engineering analysis of technical options in the three projects. Establish an international global warming data base to support the three projects. Identify, evaluate and prioritize advanced energy technologies currently in R&D and additional creative approaches that tap new sources or existing sources with greater efficiency, and advanced technologies to stabilize the earth's climate system. Support and promote international cooperation to develop, test and implement the best approaches.

End-State Goal: An understanding, description and model of the earth's climate system and energy and CO₂ balances enables sound future projections and evaluation of actions identified in the three projects including new energy and stabilization technologies. An international global warming data base is established and supporting the three projects and follow-on implementation work. Advanced technologies are identified, demonstrated and implemented that can fulfill future energy needs as fossil fuel use is fully curtailed and that can stabilize the earth's climate system.

Tier 2. Problem Elements (Questions and Barriers)

Technical Problem Elements

Standardization

(1) Standard parameters need to be selected for use in this project so that results can be accurately compared and integrated.

International global warming data base

- (1) What are the data needs of the teams working on the three projects?
- (2) What are the best sources for this data?
- (3) How can the data be assembled and made available through an Internet portal to support the teams working on the three projects?
- (4) How can the data base be maintained and updated?

Key data gaps

- (1) What are knowledge/data gaps that when filled will enable a fuller understanding of the earth's dynamic climate system including its natural climate cycles and human impacts?
- (2) How can these knowledge/data gaps be filled?
- (3) What are the results upon filling these knowledge/data gaps?

Climate system model

- (1) Accurate climate models of the earth's climate system are needed in order to make sound climate projections.
- (2) Engineering time varying global energy and carbon balances based are needed to assess the ability of earth-based and space-based systems to halt/reverse global warming and to support engineering analysis of options from Projects 1 and 2..
- (3) Accurate projections of temperature rise and sea level increases are needed as a function of annual release of CO₂ as projected in Project 1 and with application of various stabilization systems identified in Project 2.

Advanced energy and stabilization technology

- (1) What are advanced energy technologies currently in R&D and other creative approaches that can fulfill future energy needs as fossil fuel use is drastically reduced?
- (2) What are advanced technologies that could help to stabilize the earth's climate system?
- (3) For each option, what is the technical feasibility, effectiveness, state of development, time frame when available for global application, and environmental impacts and risks?
- (4) For each option what are the negative impacts?

Cost/Benefit Problem Elements

- (1) What are the projected costs to perform R&D and the testing needed to prove the technologies at laboratory scale?
- (2) What are the projected costs to develop and implement the technologies?

(3) What are the results of a cost/benefit analysis of the options considered?

Social/Political Problem Elements

- (1) What are the potential social/political barriers to implementing each of the new technologies?
- (2) How might these barriers be overcome nationally, regionally and globally to successfully implement the technologies?

Integration & Implementation Work Units

- (1) What would be integrated global strategies for new and advanced energy and stabilization approaches?
- (2) How could the strategies can be successfully implemented.
- (3) How can participants support and promote international cooperation to test and implement the best integrated approaches?

Tier 3. Solution Work Units (Options & Action)

Technical Solution Work Units

Standardization

- (1) Use standard parameters selected for Project 1, and select additional parameters for consistent use in this project.

International global warming data base

- (1) Identify the global warming and climate system reference data needs of the teams working on the three projects.
- (2) Determine the best sources for this data.
- (3) Assemble the global warming and climate system data into an Internet platform providing reference data base for use by everyone working on the three projects, and also for sharing project results and reports.
- (4) Maintain and update the data base as new or better data becomes available.

Key data gaps

- (1) Identify knowledge/data gaps that when filled will enable a fuller understanding of the earth's dynamic climate system including its natural climate cycles and human impacts. Examples include:
 - What causes temperatures to suddenly start rising at the end of the long ice ages?
 - Why do the temperatures often peak during a warm interval and begin falling back towards an ice age?
 - What drives the temperatures to rise and then fall over long periods in going from an ice age to a warm interval and then back to an ice age?
 - Why did the temperatures rise and then stabilize during the current warm interval?
 - What is the actual role and mechanism of the Milankovitch cycles in the earth's natural climate cycles?
- (2) Prioritize and determine how can these knowledge/data gaps be filled and then support filling these knowledge/data gaps.

Climate system Models

- (1) Develop a clear description of the earth's dynamic climate based on factual data and observations that describes the mechanism of earth's natural climate cycles and human impacts.
- (2) Evaluate current climate system models and identify areas where they may be improved with additional data and understanding. Continue to improve the models in order to make accurate climate projections.
- (3) Develop engineering time varying global energy and carbon balances based on direct observations and proven principles for use in assessing the ability of earth-based and space-based systems to halt/reverse global warming and to evaluate other options identified in the three projects. Determine to what extent the energy and carbon balances follow the earth's natural climate cycles.
- (4) Determine how the climate system models and the engineering energy and carbon balances can best work together to make accurate assessments and future projections of temperature rises and sea level increases as a function of atmospheric CO₂ levels as projected in Project 1 and with application of stabilization systems identified in Project 2.
- (3) Reliably project temperature rises and sea level increases as a function of annual release of CO₂ as projected in Project 1 and with the application of various stabilization systems identified in Project 2.

Advanced energy and stabilization technology

- (1) Identify and evaluate advanced energy technologies currently in R&D as well as other creative approaches that tap new sources or existing sources with greater efficiency to fulfill future energy needs as fossil fuel use is drastically reduced. Examples include:
 - Cascade systems where one energy source unlocks a much larger energy source.
 - Nano and atomic level processes for nuclear fusion, nuclear fission and for energy processes that directly produce electricity or hydrogen without employing heating/cooling cycles.
- (2) Identify and evaluate advanced earth-based and space-based technologies that could help to stabilize the earth's climate system. Examples include:
 - Earth-based removal of CO₂ from atmosphere
 - Space-based dynamic particle arrays.
- (3) Evaluate each technology on:
 - Technical feasibility, effectiveness, state of development, and time frame when available for global application,
 - R&D and testing needed to prove technology at laboratory scale and steps to develop for global application.
 - Environmental impacts and risks at national, regional, global levels if technology is broadly applied.
- (4) Prioritize the energy and stabilization technologies to help focus ongoing and future R&D and provide support to these developments.

Cost/Benefit Solution Work Units

- (1) Estimate the projected costs to perform R&D and testing needed to prove the advanced technologies at laboratory scale.
- (2) Project the costs to develop the advanced technologies for global application.
- (3) Prepare a cost/benefit analysis of the options considered and of the resulting integrated approaches.

Social/Political Solution Work Units

- (1) Identify potential social/political barriers to implementing each of the advanced technologies.
- (2) Suggest how these barriers might be overcome nationally, regionally and globally to successfully implement the technologies.

Integration & Implementation Work Units

- (1) Develop integrated global strategies that balances technical feasibility and effectiveness, cost and social/political factors for new and advanced energy and stabilization approaches.
- (2) Determine how the strategies can be successfully tested and implemented.
- (3) Support and promote international cooperation to test and implement the best integrated approaches.

Project execution. In the wicked-problem approach, separate teams must be established to address each solution work unit shown in the problem diagrams. The teams will all work concurrently and share their results periodically, usually once a month or once every other month. Project facilitators are needed to organize and to facilitate the team's work and to interface with other supporting teams. Notional examples of how project participants could be organized are shown below for each of the three projects.

Project 1. Since Project 1 will develop an integrated world-wide strategy to halt the rise of atmospheric CO₂ and adapt to unavoidable climate change, a *project core team* is needed to facilitate and integrate a global strategy across the five world regions (continents). Likewise, a *regional core team* is needed for each region to facilitate and integrate results across the countries of that region. A country core team is needed for each country to facilitate and integrate results within that country.

A notional example of how project participants could be organized for Project 1 is shown in Figure 4.2.

The *Project 1 Core Team* is shown in the middle box at the top of the figure. This team with its standardization and integration teams would pull together the results from all the regional teams into global solutions to halt the rise of atmospheric CO₂ and to adapt to climate change. The Project Standardization Team establishes reporting formats and units of measurements for use by all teams and sub-teams in order to facilitate communications between teams. It also establishes a platform for communications and data sharing among the three projects, teams and participants. The Project Integration Team evaluates solution options on technical feasibility and effectiveness, cost/benefit, and social/political factors, including any negative impacts, in order to identify the best practical global solution to meet project goals. The integration team also prepares and distributes monthly reports to share progress among all teams and projects.

The *Region A Core Team* is shown in the bold box immediately below the Project Core Team. Each of the world's regions would likewise have a Region Core Team connected to the Project Core Team. A Region Integration Team is needed for each region and performs the same functions for the region as the Project Integration Team does for the world.

The *Country A Core Team* is shown in the bold box below the Region A Core team. Each country within the region would likewise have a Country Core Team. Each Country Core Team would have an Integration Team, a Cost/Benefit Team, and a Social/Political Team associated with it. The Integration Teams would perform the same functions as previously described. The Cost/Benefit and the Social/Political Teams would evaluate the technical options on cost/benefits and social/political aspects, respectively. Negative impacts of the technical options are also considered in the evaluations.

Notional Team Organization, Project 1
People's Project to Balance CO₂ Release/Uptake & Adapt to Climate Change

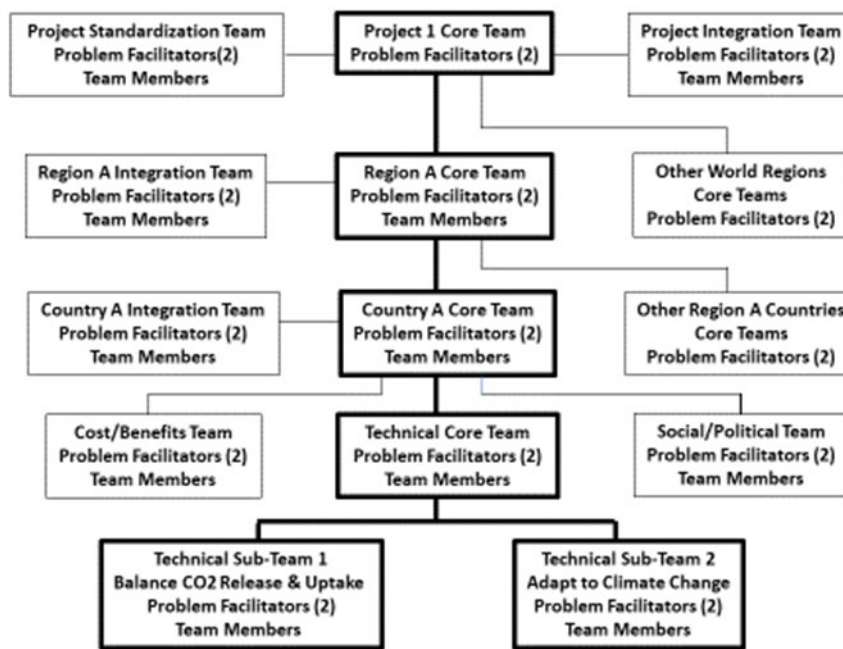


Figure 4.2. Project 1 organization schematic. Facilitators and team participants will include engineers, scientists, economists and other multidisciplinary people.

A *Technical Core Team*, shown in bold under the Country A Core Team, would establish other technical teams for each solution work unit and assures that each technical approach is consistently evaluated for technical feasibility and effectiveness to enable accurate comparisons. *Technical Sub-Teams*, shown at the bottom of the figure, would address the different technical work units and approaches to balance CO₂ release and uptake, and to adapt to climate change.

Together, the country's Technical Core and Sub-Teams have the central task of identifying and evaluating practical ways to meet Project 1 goals. The other teams organize efforts, integrate results, and conduct cost/benefit and social/political evaluations. In this way the world's 195 countries can each participate in the project, and develop and share their strategies with the others in order to arrive at a global consensus to halt the release of CO₂ and cope with global warming impacts.

While these team organization charts may look like a typical top-down management structure, this is not the case. The separate teams correspond to the solution work units, and each has full responsibility to perform that work unit. The project and regional core teams integrate and summarize the periodic results across the other teams and provide that information back to all the team and sub-team members. In other words, the core teams are working to fulfill a needed function and to facilitate rather than direct.

Project 2. A notional team organization for Project 2 is shown in figure 4.3. Two lead problem facilitators with their team members comprise the *Project Core Team* shown in bold. The cost and social/political elements teams, and the standardization and integration teams have the same functions as explained for Project 1. The Technical Core Team shown in bold under the Project Core Team establishes other technical teams and assures that each technical approach is consistently evaluated for technical feasibility and effectiveness to enable accurate comparisons. The two Technical Teams, shown in bold below the Technical Core Team, determine what technologies and what approaches can best meet the project goals. Because of the variety of technical options that must be considered, the Technical Teams may establish Technical Sub-Teams as shown at the bottom of Figure 4.3.

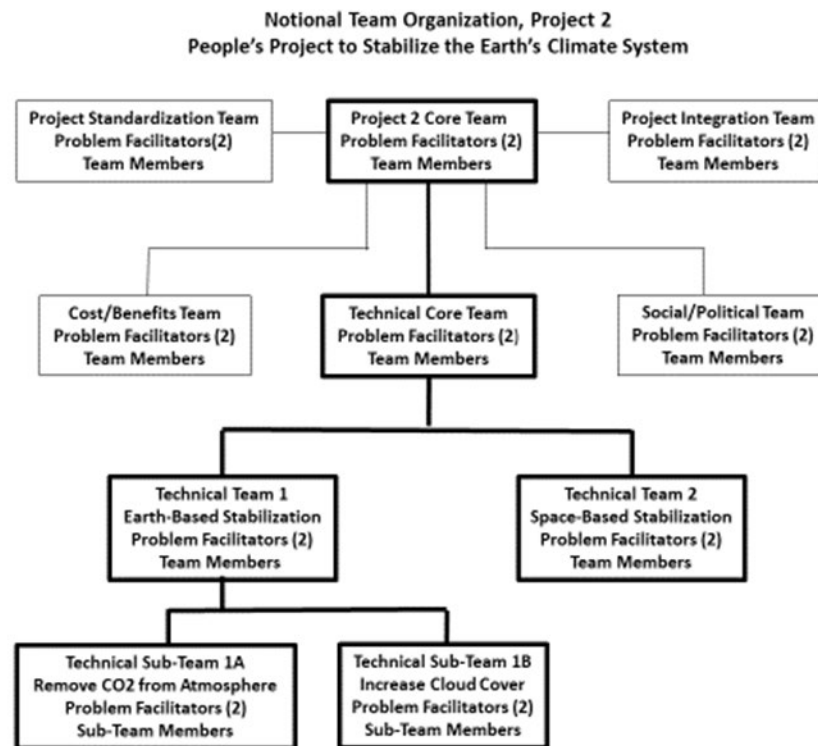


Figure 4.3. Project 2 organization schematic. Facilitators and team participants will include engineers, scientists and other multidisciplinary people.

Project 3. A notional team organization for Project 3 is shown in Figure 4.4. Two lead problem facilitators with their team members comprise the *Project Core Team* shown in bold. The standardization, integration, cost/benefit and social/political teams have the same functions as explained for Project 1. The *Technical Core Team* shown in bold under the Project Core Team establishes other technical teams and assures that each new energy and stabilization technology is consistently evaluated for technical feasibility and effectiveness to enable accurate comparisons. The three Technical Elements Teams, shown in bold below the Technical Elements Core Team, identify and fill data gaps, establish a data base for the three projects, identify and evaluate new energy and stabilization technologies, and develop and run the climate system model and energy and mass

balances. Because of the variety of tasks and technical options that must be considered, the Technical Teams may establish Technical Sub-Teams as shown at the bottom of Figure 4.3. Results from Project 3 will be shared with Projects 1 and 2 for integration into overall systems to halt the rise of atmospheric CO₂, cope with climate change impacts, and stabilize the earth's climate system.

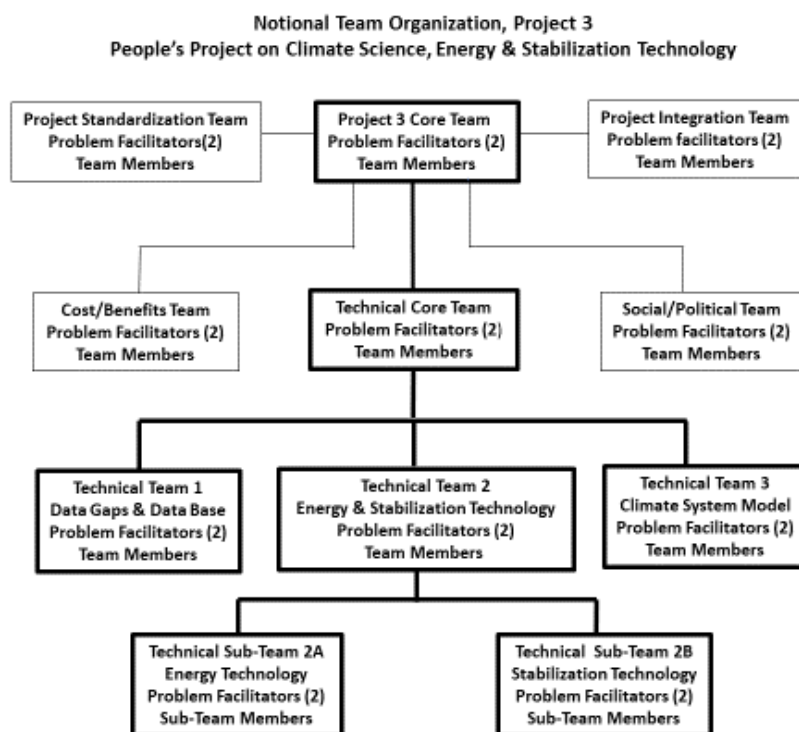


Figure 4.4. Project 3 organization schematic. Facilitators and team participants will include scientists, engineers and other multidisciplinary people.

Problem Facilitators and Team Participants. Based on experience, two problem facilitators are needed for each team and sub-team under each project. One facilitator focuses on project execution and the other focuses on communication and support to team participants. Problem facilitators also recruit participants for their team and recruit problem facilitators for the teams or sub-teams connected to their team in the organization schematics. They assist in planning and coordinating the efforts and serve as leaders and focal points on each team and sub-team. They insure open lines of communication between teams and sub-teams, answer questions, and address issues as they arise. They also serve as points of contact for outside inquiries.

The facilitators assemble and distribute monthly progress reports for their team or sub-team and maintain rosters of team and sub-team participants. They assemble the final report for their solution work units based on input from team participants. The project core and integration teams assemble the team reports into a final project report. While all participants work together without bosses, facilitators do have the opportunity to

provide leadership. With a thorough understanding of the wicked-problem approach, they can effectively lead and support team participants.

Team participants from around the world do the bulk of the project work and ideally include a mix of ages, genders, knowledge and skills. Participants must be self-motivated, and willing to work as equals on the basis of truth, compromise and goodwill. Each participant shares a responsibility for overall project success and a commitment to see the project through. Good ideas can come from any team participant at any time and are often key to overall success. Therefore, all team participants must be sensitive to good ideas so they are not lost.

In addition to sharing progress reports, participants on one team can serve as observers on another team in order to gain additional learning experience and new insights, and to encourage creativity – a process termed “interweaving.” Observers answer questions about their own team and serve as a conduit of information between teams.

Problem facilitators, in particular, will enjoy more confidence and find it easier to perform their roles if they have a thorough understanding of the wicked-problem approach. Section 4 provides an overview of the approach but not a sufficient working knowledge. To fill this gap, a six-part, self-taught training program on the wicked-problem approach is included in Appendix A of this report. Problem facilitators are very much encouraged to complete this course before assembling their teams and beginning work. Of course, all project participants can benefit from the training in order to gain a better appreciation of their role.

Part II. Adaptations for Advancement and Survival

Introduction and Overview. Part I of the Peoples Assessment of Global Warming focused on understanding the physical features of global warming and suggested three People's Projects to help solve the technical aspects of the global warming problem – a problem unique in its immense scope and complexity, and one that threatens the future wellbeing of Modern Civilization. With this unprecedented challenge also comes unprecedented opportunity. The People's Projects will undoubtedly lead to new discoveries, new career paths and better ways of doing things.

Part II, Adaptations for Advancement and Survival, focuses on broader needs and even greater opportunities. Global warming is intertwined with other world problems, which pose social/political barriers to overcoming global warming successfully. Examples include terrorism, international warfare and confrontation, national debt, and others. Global warming, itself a very wicked problem, in combination with other social/political problems pose an even more wicked problem, *a line-in-the-sand*, that threatens the survival of Modern Civilization and *unprecedented opportunity to advance civilization driven by necessity*.

The authors analyze the combined challenge of global warming and detracting social/political issues and consider the human potential to deal with this combined challenge. Finally, the authors propose three “Adaptations” for overcoming the social/political issues and achieving overall success in dealing with global warming. As you may imagine, the combined challenge is very complex and offers no clear path. So, various *apparent* aspects of the problem were investigated as pieces of a puzzle, which were then sifted and sorted and fit together into an integrated picture.

The final outcome is a vision of Advanced Civilization where each person has the opportunity to reach his or her full potential. This vision results from the critical need for all people on earth to work together at their full potential to successfully overcome global warming. All social/political change must, of course, make sense intellectually. Equally important, changes must be compatible with human nature, including the human spirit because social changes – not in keeping with human nature – fail, as with communism. The important but uncertain spiritual component of human nature is considered in End Notes to Part II.

Appendix A then presents a self-taught training course on the wicked-problem approach for those choosing to work on the three People's Projects in Part I as well as for those wanting to address the social/political problems identified in Part II of this report.

Global warming puzzle. Pieces of the global warming puzzle are presented in this subsection. Each piece covers a vast amount of knowledge, often documented in many books. As a result, what is presented here can only summarize what is known in order to keep the presentations short and understandable.

The puzzle pieces below are not in any particular order since the various aspects of wicked problems are intertwined and mixed together. For this reason, assembling the pieces into a cohesive picture is delayed until after the pieces are presented. However, the reader is encouraged to consider how the pieces may fit together while reading about each puzzle piece.

Puzzle Piece 1. Hunter-gatherer societies. The encroachment of civilization on hunter-gatherer societies, as happened across the United States, usually destroyed their way of life and often their persons. Nevertheless, a few hunter-gatherer societies, with great determination, managed to survive into modern times. Anthropologists lived with these groups to see how they lived and what might be learned from them. Richard Lee (*The dobe Ju/'bonasi*) and Frank Marlow (*The Hunter-Gatherers of Tanzania, Hazda*) recently studied two hunter-gatherer societies in Africa, including the Hazda pictured below in Figure 5.1.

They found that the two groups each had similar social adaptations allowing them to *survive together* through mutual support and dependence:

- Accept individual autonomy & equality.
- Rely on extensive food sharing in camp.
- Exchange gifts for friendship.
- Exercise modesty regarding hunting success.
- Avoid domination & "big men" in spite of natural tendencies to do so.
- Rely primarily on discourse to regulate social behavior.
- Have spiritual and religious beliefs.
- Utilize fire, cooking, bows & poisoned arrows, spears, snares.
- Employ medical practices & medicinal plants.

The reported characteristics of the two societies included:

- Everyone participates in joint decisions
- Maintain equality among all, including men and women.
- Lifestyle "...is to a great extent peaceful, healthy & fulfilling."
- Population densities remain low.

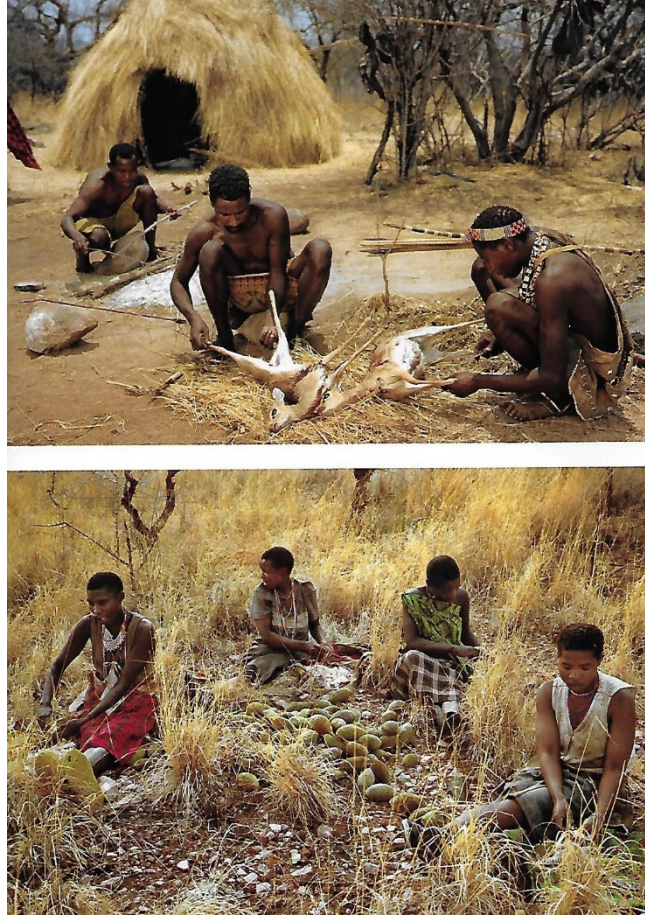


Figure 5.1. Hazda hunters (top) and gatherers (bottom), photo by Martin Schoeller, *National Geographic*, “The Hadza”, December 2009, p 103.

Still, these hunter-gatherers did not have an easy life. They often endured broken bones, wounds and illness, and braved a childhood mortality rate close to 50%. They felt anger, jealousy, greed, and envy just like us. However, their social norm kept these feelings in check. One thing that the Ju/'hoansi did to encourage a successful hunter to act modestly was to “insult the meat.” Food sharing was key to survival in their intimately social and mutually dependent groups. Sharing failed when arguments occurred and could only be restored by mending fences and getting along. If a fight did occur, antagonists were quickly separated and often went to another camp to resolve their feelings.

Naturally, social practices among the world’s hunter-gatherer societies varied greatly. However, individual equality, food sharing, and discourse to regulate social behavior were common core adaptations for *surviving together*. For example, Lewis and Clark reported on meeting the Shoshones in Western United States in 1805: “Each individual is his own sovereign master, and acts from the dictates of his own mind; the authority of the Chief being nothing more than mere admonition supported by the influence which the propriety of his own exemplary conduct may have acquired him in the minds of the individuals who compose the band.” (*The Lewis and Clark Journals, An American Epic of Discovery*, Edited by Gary E. Moulton, University of Nebraska Press,

Lincoln and London, 2003). Community Elders often played a key role in mentoring and sharing ancient knowledge and wisdom.

Orienting daily on nature, hunter-gatherers relied primarily on truth-based rather than on power-based decision making and leadership in spite of natural human tendencies to seek power and to dominate others. These practices infer that hunter-gatherers exercised:

- 1) *Personal self-control* to abide by these social practices, and
- 2) *Personal responsibility* to maintain and pass them on to the next generation.

In short, the hunter-gatherers demonstrated the human potential to consciously avoid power-based processes and to rely on equality and truth-based decision making and leadership in order to survive and thrive together.

Puzzle piece 2. Theory of truth, an inconvenient reality. Deep within the Qur'an, the Prophet Muhammad posed a general *theory of truth* in the form of a question:

“So what is there after discarding the truth but error?”

(*The Quran*, Arabic text with a new [English] translation by Muhammad Zafrulla Khan, Olive Branch Press, NY, NY 1997, Part 11, Chapter 10, 32-34, p 195)

This theory from 1,400 years ago may be the most important one every recorded during the course of civilization. The theory can be explained further. If we *discard truth* (the reality of a situation), we will probably operate on a false premise (an untruth) and thereby incur a cost associated with being wrong. As an example, suppose you are driving down a highway, and the road actually curves to the left. If you are daydreaming or distracted, you may continue to drive straight under the false premise that the road continues straight. Your likely outcome is an accident, possibly resulting in a damaged car and personal injury. In this example you discard truth, act under a false premise, and incur the cost of being wrong. Whether you knowingly or unknowingly discard the truth does not matter—the outcome will be the same. The truth that the road curved will prevail over the untruth that the road continues straight.

In general, an untruth does not even exist, and therefore, it cannot triumph over the realities of an issue. Although we sometimes do the “right thing for the wrong reason,” it is good luck rather than the wrong reason that prevails, which is not a sound basis for making important decisions. We may generalize the above example into a theory of truth:

If we discard or do not seek truth, we likely operate on false premises and incur a cost for being wrong.

The theory's proof, or more accurately its relevance, must lie in the reader's judgment. Most people have a deep respect for truth and practice it in their lives and careers. It is certainly within the human potential to operate on truth-based processes as demonstrated by advances in science, engineering, art and many other areas. It is also within the human potential to rely on power-based approaches to obtain political power, fame

and fortune. In either case, the theory of truth predicts that those who discard truth can expect to pay a cost for acting on a false premise and being wrong.

Puzzle Piece 3. Taking action on climate change. As discussed in Section 4, the United Nations Paris Agreement establishes international cooperation aimed at keeping global temperature rise to below 1.5 to 2°C and balancing greenhouse gas release and removal by 2100. To meet these goals, three international projects are proposed:

Project 1. People’s Project to Halt Ongoing Release of CO₂ & Adapt to Climate Change.

Project 2. People’s Project to Stabilize the Earth’s Climate System.

Project 3. People’s Project on Climate Science, Energy & Stabilization Technology.

These three challenges involve complex, interrelated system problems often called “wicked problems” with a snarled mix of technical, economic and political components. Fortunately, “wicked-problem approaches” are available to address such problems and form the basis of three projects. To succeed, scientists, engineers, economists and other multidisciplinary people from around the world must choose to work together through the Internet to develop effective, practical, affordable and socially/politically acceptable solutions. While focusing on technical goals, the three projects will also bring fragmented national efforts together, focus a critical mass of minds (thousands) on global warming, mobilize the world’s engineers, economists and others to expand the work of scientists, help develop a global consensus for action, and provide opportunities to learn problem-solving skills and help to solve a problem threatening Modern Civilization.

Puzzle Piece 4. Full human potential. Below is a notional equation that depicts the “full human potential” of everyone on earth at any given time. It is the sum-total of the full individual human potential where each person has the opportunity to develop and exercise their full potential. It represents an ideal state – the very best that the world’s people can do.

$$\text{Full human potential} = (\text{natural force multiplier}) * \sum_1^{7.5B} \text{Full individual human potential}$$

The summation symbol $\sum$ is a shorthand way to represent the sum of each person’s individual human potential from person 1 to person 7.5 billion, the world’s population. Written out, this summation = full human potential of person 1 + full human potential of person 2 + ... full human potential of person 7.5 billion – a very long equation.

This summation is multiplied (*) by a “natural force multiplier.” When people cooperate and think together in a natural, unconstrained way to accomplish a goal or to solve a problem, they can accomplish much more than they could by working separately. The old saying that “Two minds are 3 times as good as one” is often true. The great human accomplishments from building skyscrapers to sending people into space resulted from people’s superb ability to work together. To gain this natural benefit, people must be able to work together in a “natural” way without hostility or other stresses that drive them apart. The actual size of the natural force multiplier is not known, but it is probably at least 3 and may be considerably more.

Unfortunately, a number of social/political issues not only detract from successfully dealing with global warming, but they also reduce the “available human potential” that could otherwise be used to overcome both global warming and the issues themselves as indicated below:

Terrorism and mass shootings instill fear and uncertainty that reduce the natural force multiplier, and reduce available human potential by killing and injuring people and by using human resources to respond and repair damage.

Warfare and international confrontation undermine cooperation, thereby, subtracting from the natural force multiplier. Warfare saps human potential by killing and wounding people and by using vast human resources to prepare, fight & repair.

Nuclear weapons raise international risk and uncertainty thus subtracting from the natural force multiplier and divert human potential from other needed tasks to preparing, maintaining and monitoring for attack.

Concentration of wealth results in a relatively few people having many more resources than they need while depriving other people of the means and opportunity needed to realize their full human potential, thus subtracting from individual human potential that would otherwise be available.

National debt not only burdens future generations, but leaves open the question of where will the money come from to mobilize the human potential needed to deal with global warming? If further expansion of national debt risks financial instability and if money cannot be secured from other sources, then the overall effect of national debt is to limit the available human potential needed to deal successfully with global warming.

Population growth in itself creates more individual human potential. However, it adds further stress and potential conflicts in responding to unavoidable climate change, thereby, subtracting from the natural force multiplier. It also places further demands on energy and other resources, thereby, diverting human potential away from overcoming global warming. Under current conditions, population growth will likely reduce rather than increase available human potential.

Political and social environment. With today’s political systems that focus on power, party and ideology, much of the human potential outside of the political systems that could help develop honest, workable solutions to pressing problems is not utilized, thereby, subtracting from *effective* use of available human potential. Today’s social environment of ever-increasing change with little regard for consequences can lead to difficulties such as global warming, requiring expenditure of human potential to fixing situations that might have been avoided. The net result is a waste of human potential that subtracts from the whole.

Of course, there are many social trends that have very positive effects on the availability of individual human potential, such as improved education, health care, communications, housing, food and living conditions and poverty reductions. In the above equations, these factors are the baseline environment, while the above social/political issues detract from the otherwise available human potential. The initial equation is now rewritten to include the detracting factors.

Available human potential = (natural force multiplier – terrorism & mass shootings fear – warfare & confrontation – nuclear risk – population growth stress)

$$\begin{aligned}
 & \text{7.5B} \\
 & * \sum_1^{\text{full individual human potential}} - (\text{terrorism \& warfare} \\
 & \quad \text{casualties}) - (\text{individual human potential spent on terrorism} \\
 & \quad \text{response \& repair; warfare preparations, fighting \& repair; nuclear} \\
 & \quad \text{preparations, maintenance \& monitoring}) - (\text{individual human} \\
 & \quad \text{potential diminished by concentration of wealth; national debt;} \\
 & \quad \text{population growth; political focus on power, party \& ideology;} \\
 & \quad \text{social focus on change without regard for consequences})
 \end{aligned}$$

What does this equation tell us? First, the natural force multiplier that occurs when people are free and unconstrained to cooperate is reduced by the stress and uncertainty associated with the indicated issues. Second, the full individual human potential available when each person can develop and exercise their full potential is greatly reduced by these issues. Therefore, the available human potential in the above equation is considerably less than the full human potential of the first equation. That we do as well as we do in spite of these detracting influences is testimony to the enormous size of the global human potential, and to people's determination to use their potential.

Nevertheless, global warming presents an unprecedented challenge in itself at the same time that these many detracting issues can undermine coping efforts. Is the available human potential, depicted in the above equation, enough to successfully deal with global warming, given the number of difficult, detracting issues? No one knows. Certainly, there is a risk that the answer is "no." Given that global warming stakes include the survival of Modern Civilization, action to increase the available human potential seems warranted.

The above equation raises a companion question. What could humans accomplish without the burden of the detracting issues? Certainly, that condition would put humanity in the best position possible to successfully overcome global warming since the full human potential is all that we have. Achieving that condition could also lead to social advancement benefiting everyone.

Puzzle piece 5. A surprising discovery. A "wicked-problem approach" was introduced in Section 4 to address three global warming challenges. As mentioned, the approach is based on standard engineering project management and team leadership techniques that are adapted to solving wicked problems with technical, economic and social/political factors mixed together. People on problem-solving teams break such problems into many components and then divide into sub-teams to work on each component simultaneously. They integrate results as work proceeds into wholistic solutions to the wicked problems. Learning is a key ingredient of the approach.

US Army engineers first discovered the approach in the 1990s while developing verification measures for the Chemical Weapons Convention. They then used it a second time to determine how cities could best respond to biological terrorist attacks, thus demonstrating the effectiveness of the approach and its general applicability to technical problems.

In addition to the approach's practical success, the engineers were struck by the enormous human potential to solve complex problems. Could the approach be used to solve social/political problems using part-time participants? To answer this question, one of the authors proposed to local town officials, Selectmen, in the rural village of Penobscot, Maine, United States (population 1,200), testing the wicked-problem approach on town issues using citizen volunteers.

The Selectmen supported the proposal stating "We would welcome help in honestly and thoroughly analyzing town issues in order to make better decisions. We do not have the time to do this work given our day-to-day demands." Thus, began the "Penobscot Initiative." After recruiting local participants through town meetings, newspaper announcements, flyers and door-to-door canvassing, the "People's Forum of Penobscot" came into being in the fall of 2015. Participants were trained on the wicked-problem approach and began work on two issues: designing a town Webpage and assessing waste-disposal options.

Forum participants thoroughly investigated the two issues and documented their results. The findings and suggestions were accepted by the Selectmen and enabled the town to make an informed decision on selecting a waste-disposal option and to establish an official Webpage. At the end of year, participants gave the following feedback:

- Felt gratification from learning, working and serving together.
- Appreciated practicing problem solving & leadership.
- Liked exercising their minds & having a voice in local decisions.

All but one participant chose to participate for another year. Since then, the Forum analyzed the complex issue of Penobscot school sustainment despite low enrollment and then helped to implement the study's recommendations. It also initiated work on gaining high-speed Internet in the town and on updating the town's Comprehensive Plan.

The Penobscot Initiative demonstrated that people have the potential and the will to materially assist in solving social/political issues using a structured, proven and fact-based problem-solving approach rather than an unstructured, ad hoc, and opinion-based approach. They successfully maintained a working environment of truth, compromise and goodwill.

"Problem facilitators" who led the problem-solving teams needed to be well versed in the wicked-problem approach. The facilitator training program included in Appendix A is aimed at filling this need. The same training is applicable for addressing technical issues, including the three People's Projects proposed in Section 4, as well as social/political issues as demonstrated in the Penobscot Initiative. In fact, the approach is applicable to all types of complex problems.

In demonstrating their *human potential and willingness* to solve wicked problems using this approach, people revealed perhaps our greatest and most underutilized natural resource.

Puzzle piece 6. Rise of civilization. A few examples will illustrate how civilizations have contributed to rapid technological advancement and to the power of societies. The massive stone wall of Jericho, constructed 10,000 years ago in the Middle East, indicates a permanent settlement comprised of 2 to 3 thousand people and represents the first steps toward civilization along with evidence of very early agriculture. The size of the wall and its surrounding ditch cut into solid bedrock implies social organization, division of labor and classes.

Ancient Egypt comprised the next great milestone in civilization, forming 5,000 years ago and lasting 3,000 years. Concentrated along the Nile River in North Africa, Egypt exploited the predictable flooding and controlled irrigation of the fertile river valley, which provided surplus crops and allowed for denser populations, and social/cultural development. Under the control of a pharaoh, a bureaucracy of elite scribes, religious leaders, and administrators ensured the cooperation and unity of the Egyptian people.

Egyptian advancements included a writing system, construction of monumental pyramids (Figure 5.2), temples and obelisks, trade with surrounding regions, and a military to assert Egyptian dominance. The many achievements of the ancient Egyptians include: quarrying, surveying, systems of mathematics, medicine, irrigation, planked boats, new agriculture techniques, glass technology, new forms of literature, art and architecture. The Egyptians formalized spiritual beliefs into religion and incorporated it as an element of the rulers' power structure – Pharaohs ruled as gods.



Figure 5.2. The Great Pyramid of Giza, build 4,500 years ago, is the largest of the Egyptian pyramids and the last remaining ancient wonder of the world. SCULPLES/ISTOCKPHOTO

The Roman Empire formed 2,000 years ago and lasted in various forms for 1,400 years. At its height it controlled over 70 million people, representing 21% of the world's population. Because of its longevity and extent, the empire had lasting influence throughout Europe on language, culture, religion, inventions, architecture, philosophy, laws and forms of government. The empire expanded by controlling territories through military warfare. After dividing into two parts, the Western Roman Empire ruled by Rome fell to Germanic migrations and invasions late in the 4th century AD and the Eastern Roman Empire centered in Constantinople collapsed in the middle of the 14th century AD through Islamic warfare. An example of Roman engineering skill is shown in Figure 5.3.

The main political elements of the Roman empire included the central government, the military, and the provincial governments. The Roman emperor held ultimate authority in policy and decision-making including control of the hierarchy of Roman society, central religious authority, and the rights to declare war, ratify treaties and negotiate with foreign leaders.



Figure 5.3. An example of Roman engineering skill, an ancient Roman aqueduct in South France build 2,000 years ago and functional for 900 years until maintenance was abandoned, but still standing.

https://en.wikipedia.org/wiki/Pont_du_Gard#/media/File:Pont_du_Gard_BLS.jpg

These early civilizations had a number of similar characteristics:

- Supreme leaders (pharaohs, emperors).
- Institutionalized political power in combination with religion.
- Military conquest & expansion.
- Creation & accumulation of wealth.
- Population growth and centers of population.
- Stratification of society.
- Individual specialization.
- Expansion of science, engineering, art, religion, warfare technology.

Political power was concentrated in the hands of supreme leaders supported by subordinates (nobility), military, and state religion – the fundamental foundations for the empires. The supreme leaders sometimes inherited their position, but just as often fought for the positions using all available means.

The concept for democracies came from the ancient Greek city-states of Athens and Sparta where the citizens elected leaders and cast votes on decisions in assemblies. The early Roman Republic that came before the Roman Empire also followed democratic principles, but limited participation to the wealthy and noble families.

Modern Democracies came into being with the establishment of the United States and then spread to other countries around the world through both peaceful political movements and violent revolutions. Today, there are many types of democracies including full presidential republics as in the United States, Central and South America, parliamentary constitutional monarchies in the British Commonwealth, Semi-presidential republics like Russia as well as other variations. There are still some absolute monarchies such as in Saudi Arabia and one-party states such as in China and North Korea.

Important characteristics of today's democracies include legal equality, political freedom and rule of law. Other rights include elected leaders, checks and balances, constitutional rights, and separation of state and religion. These rights have contributed greatly to the advancement of Modern Civilization by empowering and freeing the human potential of average people. The amazing advancement of democracies around the world testify to the enormity of the human potential. Even in countries centrally directed like China, the inclusion of economic freedoms has sparked vast improvements in living conditions and personal wealth.

In practice, political power is sought by individuals and political parties using all legal means to influence election outcomes with a focus on power, party and ideology. Political processes are highly competitive and aimed at winning elections and implementing party ideology. Once people are in political office, their natural career desires can come into play, tempting them to use the authority of their office to sustain their position through reelection or to enhance their power through gaining higher office. This power feedback loop can include personal fame and wealth, both of which can be derived from and converted into political power. The framers of the United States Constitution assumed that the self-interest of people in political office would tend to influence political decisions, and purposely included checks-and-balances to control domination by the few.

Nevertheless, if enough individuals and their political parties are driven by a desire to acquire, maintain, and enhance their political power, then the entire political system is dominated by *power-based politics*. In this environment, truth and compromise can become casualties whenever either is in the way of political objectives. Creating "truth" and concealing reality can be more expedient than the laborious task of seeking truth and compromise. Such seems to be the case with essentially all governments in the world, both democratic and authoritarian. In essence, power-based politics is the underlying foundation of government authority today just as it has been since the first civilization some 5,000 years ago. That is not to say that today's governments are "bad." Modern Civilization has accomplished too much and raised the living standards of too many people to suggest any blanket criticism. The challenge here is not to criticize but to identify current reality and look for improvements.

Puzzle piece 7. Closest living relatives – chimpanzees. Primates originated around 60 million years ago and diversified into the great apes (chimpanzees, orangutans, and gorilla and bonobo) and into human ancestors 23 million years ago. Chimpanzees are our closest living relative with human and chimpanzee DNA differing by only a little over 1%. Jane Goodall (*Through a Window*, 1990) and Frans DeWall (*Our Inner Ape*, 2005) devoted much of their lives to studying the social behavior of chimpanzees both in the wilds of Africa and in captivity. Louis Leakey, a renowned paleoanthropologist, encouraged Dr. Jane Goodall to observe apes in their natural habitats to see what insights they might yield about early humans. She greets a very young chimpanzee in Figure 5.4.

Both Goodall and DeWall found that chimpanzees:

- Have similar emotions to humans: pleasure, joy, sorrow, anger.
- Are highly social and hunt, gather and share food.
- Give consolation to others, and recognize their own reflection.



Figure 5.4. Jane Goodall studying chimpanzees in Tanzania, Africa. Photograph by Hugo van Lawick for *National Geographic*. <https://www.sciencefriday.com/segments/jane-goodall-and-her-life-in-the-field/>

Their key social instincts include:

- a. Male obsession to be alpha male.
 - Employ charging displays, props, and fight if necessary.
 - Young males practice their routines before taking on other males.
 - Form coalitions with other males for support.
 - Exercise great courage and persistence.
 - Jealously guard power.
- b. Male domination of females.
 - Young males dominate *each* female as a first step to becoming alpha male.
 - Male domination continues in adulthood.
- c. Male defense of their group's territory.
 - Males patrol boundaries and repel intruders.
 - Males may expand territory and sometimes exterminate neighbors (war).

Dr. Goodall observed young males practicing their charging displays in private until they felt ready to confront other males. The displays were meant to impress and frighten other males into accepting their dominance without having to actually fight. One young male incorporated empty tin cans taken from anthropologist's camp into his charging display. He would hit and kick them ahead as he ran towards his rivals and succeeded in intimidating all of them, eventually becoming alpha male. Another younger male started to imitate this behavior until the anthropologists took the cans out of circulation.

These observations demonstrate how chimpanzees employ learned and creative behaviors that resemble key human behaviors, namely humanity's quest for domination and political power, a tendency of males to dominate females, and a we-versus-them attitude sometimes leading to violent conflicts.

While it cannot be proven, it seems unlikely that chimpanzees learned this behavior from humans and just as unlikely that humans learned it from chimpanzees. More plausibly, these common tendencies came from the prior ape species from which humans and chimpanzees developed. Certainly, the human potential includes these ape-like tendencies: lust for power, male domination of females and we-versus-them attitudes. In short, there is a lot of ape within each and every one of us!

Puzzle Piece 8. The story of carbon. As mentioned in Section 2, the earth's atmosphere, similar to today's, was formed 2,400 million years ago by aquatic cyanobacteria that released large quantities of oxygen into the atmosphere by converting CO₂ into free oxygen through photosynthesis using the sun's energy. Other water and land plants then developed and did the same thing. As the cyanobacteria and plants used carbon dioxide and released oxygen into the air, they incorporated the carbon into their body structures that then settled and accumulated in enormous quantities with some later formed into fossil fuels. The storage of carbon was necessary to allow oxygen levels to increase and CO₂ levels to decrease, eventually leading to the environment of today. Without carbon storage, the earth's atmosphere would have remained toxic to animals including humans.

Oil and natural gas formed 60 to 400 million years ago as the remains of small water plants and animals settled to the bottom of seas and lakes then became buried deep enough to allow the earth's heat and pressure to change them into petroleum. Coal formed from the remains of trees, ferns and other plants that lived 300 to 400 million years ago and were then buried and subjected to heat and pressure similar to fossil fuels, but at less extreme conditions and depths.

Coal is the most plentiful fuel and is used primarily to generate electricity. Oil is used mainly for transportation and heating and supplies 90% of world transportation needs. Natural gas is a relatively clean fuel used to heat homes and factories, run appliances and generate electricity, and is also used as a chemical feed stock. Fossil fuels supply 86% of the world's energy needs today while the remaining 14% is split between nuclear, hydroelectric, wind, solar and other renewables. Civilization today is mainly powered by fossil fuels and depends on that power to exist.

Puzzle piece 9. Other detracting issues. Unfortunately, global warming is not a problem isolated from other world issues. The following world issues will likely detract from successfully dealing with global warming:

Warfare and international confrontation. Ongoing armed conflicts involved some 57 nations, almost 30% of the world's 195 countries, in 2017, and resulted in 145,000 violent deaths. Worldwide military spending totaled 1.7 trillion in 2017, holding nearly steady since 2010, and representing 6% of all central government spending. The United States spends more on its military than the next seven largest-spending countries combined. Sanctions against individual countries are another form of international confrontation. Forty-five nations had sanctions levied against them in 2017, which is nearly 1/4 of the world's nations. Twenty-nine nations, 15% of all countries, are currently under United States' sanctions. International warfare and confrontation not only divert vast resources and personnel that might otherwise be applied to global warming, but the resulting wide-

spread hostility can undermine the international cooperation and understanding needed to cope effectively with global warming.

Terrorism and mass shootings. Some 340 mass shootings occurred in the United States during 2017. During this same year, there were 8,500 terrorist attacks worldwide resulting in 18,700 fatalities and 19,400 injuries. These numbers are small compared to a current world population of 7.7 billion: one person out of 200 thousand was killed or injured by terrorists in 2017. However, the psychological impact of mass shootings and terrorism affects many more people, instilling fear and uncertainty and diverting attention and resources from other needed efforts, including global warming, that require worldwide attention and cooperation.

Threat of nuclear war. Eight nations have declared nuclear weapons including China, France, India, North Korea, Pakistan, Russia, United Kingdom, and United States. Israel is thought to have nuclear weapons but neither admits or denies possession. The United States and Russia own the majority of the world's 14,500 nuclear weapons. South Africa is the only nation that possessed nuclear weapons and then dismantled their program. Several other nations are suspected of seeking nuclear weapons. The threat of nuclear war appears to have three components:

1. A nuclear war could be initiated by accident or by an irrational decision.
2. A nuclear weapon could fall into the hands of a terrorist group and be used.
3. An imminent, severe threat to a possessing nation could result in a nuclear strike.

The simple fact that nuclear weapons exist raises the risk and uncertainty that they may be used with devastating results. (It is generally agreed that a global nuclear war would destroy Modern Civilization.) Thus, nuclear weapons pose one more stumbling block to the international cooperation needed to overcome global warming.

Concentration of wealth. Some 70% of the world's adults, having wealth under \$10,000, hold only 3% of total global wealth while 9% of the world's wealthiest adults having wealth over \$100,000 hold 86% of total global wealth. The top 1% of the world's richest people own half of the world's total wealth. Over 70% of the world's millionaires live in Europe and North America, while most of the others live in Japan, China and Korea. While the United States has more wealth than any other country and the most super-rich, its middle-income adults have less than half of the wealth share of middle-income classes in most other developed countries. Wealth disparity in the United States has continued to increase since the last recession starting in 2007. The impacts of global warming will fall as heavily on the 70% of the world's people holding only 3% of global wealth as it will on the 9% holding 86% of global wealth. Addressing climate change will require an expenditure of money, which must come mainly from the wealthy since the lower 70% has so little money to spare. Yet, it is the wealthy that hold most political and corporate power. Will they be willing to expend their wealth for the common good in coping with climate change?

National debt. National debt worldwide totaled \$63 trillion in 2016 and continues to rise by around 5% per year. This level of debt apportions to \$8,400 for each person on earth. By way of comparison, the United States' national debt totaled \$20 trillion in 2016, equaling 32% of the total world national debt, while the

United States comprises only 4.4% of world population. United States national debt continues to rise about 4.3% per year, which equates to \$61,700 per inhabitant. Many countries are running national debts as a normal course of business. There is general concern that too much debt is not healthy for national or global economies. These levels of national debt leave open the question of where the money will come from to respond to the formidable and costly impacts from unavoidable global warming as well as to curb the use of fossil fuels and to stabilize the earth's climate system.

Population growth. The current world population is 7.6 billion people and is increasing by 800 million people every 10 years. The rate of increase has slowed somewhat from 1.8% per year in 1980 to 1.1% per year in 2017. At least two impacts on dealing with global warming are anticipated: 1. More people mean greater demand for energy resources – will there be enough available energy to go around as fossil fuel use is cut? and 2. More people will be affected by the unavoidable impacts of global warming including possible displacements; thereby, adding to their difficulties to cope with climate changes.

Political and social environment. As mentioned before, global warming is a problem of fact. We the people of earth have destabilized the earth's climate system by burning fossil fuels. The situation can only be dealt with through on-the-ground action since nature does not respond to words. This action must be global in scope to be successful and result from informed, honest problem solving. Today's political systems tend to focus on power, party and ideology, often leaving truth as an option of last resort. For example, disinformation campaigns regarding global warming are apparent. How to successfully overcome the problem of global warming through today's political systems is an open question.

This list of other detracting issues is not included to be discouraging. Rather, because these issues could potentially defeat otherwise successful efforts to deal with global warming, they must be considered. They are a part of today's *human* environment. Global warming impacts may indeed be accentuating international confrontation, national debt and focus on power, party and ideology, thereby creating a positive feedback loop magnifying these issues. The news and social media focus on conflicts, disasters and the sensational rather than on important issues of fact such as global warming may also accentuate this feedback loop.

Puzzle Piece 10. Earth's natural climate cycles. As indicated in Section 1, the Earth's climate cycled repeatedly over the past 800 thousand years, varying between warm intervals and ice ages every 100 thousand years. Ice age conditions would be devastating for modern civilization with its immobile infrastructure and high population levels. In addition, less extreme and faster-changing climate periods occurred over hundreds of years. Feedback loops, such as changing levels of atmospheric greenhouse gases and the advance and retreat of energy-reflecting ice, amplified the earth's climate cycles while other unknown factors caused the less extreme climate periods. Feedback loops, climate cycles, and periods form an enormously complex interrelated climate system that scientists do not fully understand. What is known is that earth's climate system is highly unstable and variable (even chaotic).

The current warm interval lasting 10 thousand years is unique during the past 800 thousand years. This period of quite stable average temperatures was accompanied by a slow rise in atmospheric CO₂ levels that may have resulted from human activity such as land clearing. These unique conditions are fortunate for civilization, which relies on a stable environment to sustain infrastructure and population levels.

Puzzle Piece 11. Global warming observations and problem definition. As discussed in Section 3, by burning fossil fuels and releasing carbon as CO₂ into the atmosphere, we are in fact reversing the natural process of storing carbon that enabled modern life forms to exist. The rise in average global temperatures since the start of the industrial revolution in 1880 corresponds to the rise in atmospheric CO₂, a known greenhouse gas. This rise in CO₂ levels, in turn, results primarily from the burning of fossil fuels – there is no other plausible explanation.

From 1880 to 2016, global average temperatures rose by about 1°C while arctic temperatures rose 3°C with the greatest rise occurring after 1960. Observed physical changes include a decrease in arctic sea ice coverage, the melting of Greenland and Antarctic glaciers and arctic permafrost, increased wildfire activity, rises in sea levels, ocean acidification and changing weather patterns with more severe weather events.

All people face the risk that the earth's environment is now destabilized, even at today's level of atmospheric CO₂. Global warming is certain to continue with only the extent and pace remaining uncertain due to knowledge gaps of the earth's complex climate system. Impacts could range from bad, to really bad, to horrific depending on the extend of global warming, potentially displacing millions to billions of people if global warming continues unabated.

These realities present three colossal challenges: a. eliminating dependence on fossil fuels to reduce additional global warming, and coping with the unavoidable impacts of global warming already underway and continuing; b. stabilizing the earth's climate system to halt and reverse the temperature rise that has already occurred; and c. filling knowledge gaps about the earth's climate system and developing new energy and stabilization technologies. These combined challenges, which must be overcome simultaneously, pose the greatest threat that civilization has ever faced, impacting each person (all 7.6 billion) plus future generations.

Puzzle piece 12. Human development. Primates first appeared 60 million years ago. Then 23 million years ago the group of primates containing human ancestors and apes began to diversify. Around six million years ago *Ardipithecus* appeared with human characteristics distinct from apes that included reduced canine teeth and lack of knuckle-walking. Proceeding from then, Figure 5.5 depicts the development of humans over the past six million years to the present where each horizontal line represents one million years and each tick-mark covers 100 thousand years. Fossil remains found in various parts of the world, particularly Africa where humans first developed, supply the physical evidence for this human development. Modern DNA analysis also confirms the close relationship of humans to the great apes, particularly chimpanzees, our closest living relative.

Several insights result from considering this depiction of human development.

1. Human development in nature spanned a vast time frame of many millions of years while *Homo sapiens* (modern humans) developed only in the past 200 to 300 thousand years and then displaced all other Hominid forms including the Neanderthals.
2. During this vast time span and up to the last 10 thousand years, humans and our ancestors lived in nature as hunter-gatherers.
3. The past 10 thousand years of civilization is a very short time period in terms of human biological development.

That is not to say that human development has stopped. DNA research indicates that Tibetans, Andeans and Ethiopians adapted to living at high altitudes over the past 12,000 years, and Australian Aboriginals adapted to desert climate over the past 8,000 years. Still, there is no evidence that such physical adaptations, including racial appearances, have changed the basic social and intellectual nature of humans. That said, biologically we are all hunter gatherers and should have the same human potential as our hunter-gatherer ancestors.

Human Development – Fossil Record

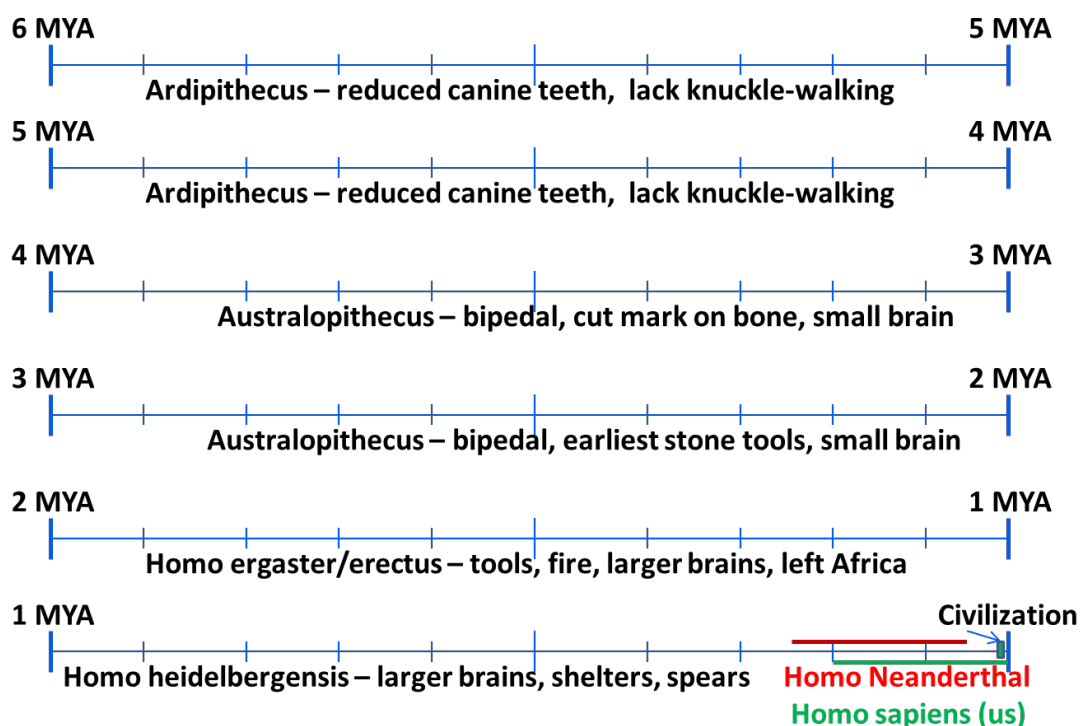
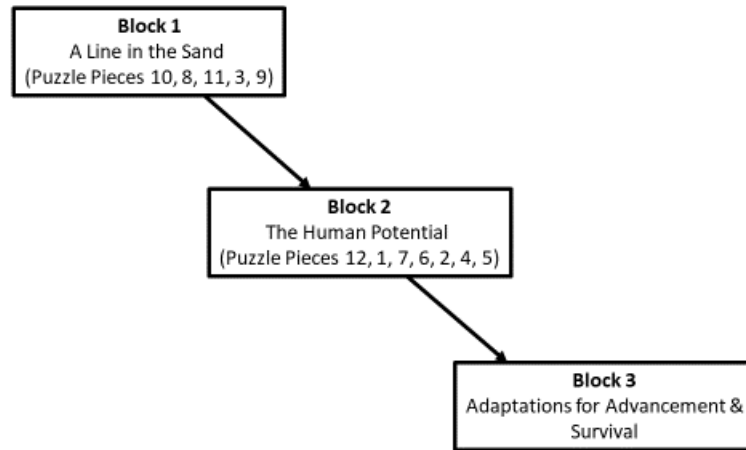


Figure 5.5. Depiction of human development over the past 6 million years up to the present. Source: *Masters of the Planet*, Ian Tattersall, 2012

The listing of puzzle pieces ends here. The challenge now is to assemble the pieces.

Assembling the puzzle pieces. It is not easy to gain an integrated picture of global warming and its impacts on Modern Civilization because of the situation's immense scope and many interrelated components. Grouping the puzzle pieces into three blocks may help to form a clearer picture, Figure 5.6, where block 1 contains the puzzle pieces relating to global warming, block 2 contains those associated with the human potential to deal with global warming, and block 3 includes adaptations for advancement and survival needed to deal successfully with global warming.

BLOCK FLOW DIAGRAM



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Figure 5.6. Block flow diagram where block 1 contains puzzle pieces associated with global warming, block 2 contains those pieces dealing with the human potential to deal with global warming, and block 3 includes adaptations for advancement and survival needed to deal successfully with global warming.

Block 1. A Line in the Sand. (combining puzzle pieces 10, 8, 11, 3, and 9)

Puzzle Piece 10 – Earth’s natural climate cycles tell us that the Earth’s climate system is naturally unstable and would devastate Modern Civilization if it were not for the good fortune of today’s unique 10-thousand-year long warm interval.

Puzzle Piece 8 – The story of carbon informs us that the storing of carbon and the release of oxygen by bacteria and plants started million years ago and resulted in fossil fuels and an oxygen-rich atmosphere that supported animals including humans. Modern Civilization now depends on burning fossil fuels to survive, but doing so reverses the natural process that allowed animals (us) to exist.

Puzzle Piece 11 – Global warming observations and problem definition explain how our release of CO₂ by burning fossil fuels is raising global temperatures and destabilizing the earth’s climate system leading to global impacts ranging from bad to horrific, potentially displacing millions of people from sea-level rise and climate change. Result: we are faced with three colossal challenges to overcome simultaneously:

1. Eliminate dependence on fossil fuels while coping with unavoidable global-warming impacts.
2. Stabilizing the earth’s climate system to halt and reverse global warming.
3. Filling key knowledge gaps and developing new energy and stabilization technologies.

Puzzle Piece 3 – Taking action on climate change proposes international projects to meet these challenges:

Project 1. People's Project to Halt Ongoing Release of CO₂ & Adapt to Climate Change.

Project 2. People's Project to Stabilize the Earth's Climate System.

Project 3. People's Project on Climate Science, Energy & Stabilization Technology.

Engineers, scientists, economists and others from around the world must choose to work together through the Internet to execute these projects to develop practical, affordable and socially/politically acceptable solutions.

Puzzle Piece 9 – Other detracting issues include warfare and confrontation, terrorism and mass shootings, threat of nuclear war, concentration of wealth, national debt, population growth and political/social environment. The People's Projects can proceed immediately, but each detracting issue reduces available resources and hinders international cooperation needed to implement the solutions and to actually overcome global warming.

Block 1 – A line in the Sand. Thus, we face the prospects of simultaneously coping with unavoidable global warming impacts, eliminating dependence on fossil fuels, stabilizing the earth's now destabilized climate system in combination with other detracting issues that impede international cooperation, divert needed resources and reduce political will to successfully address global warming. The result is an unprecedented "line-in-the-sand" drawn by nature that threatens the wellbeing and probably the survival of Modern Civilization. Doing what came natural brought Modern Civilization to this line – more of the same will not work.

There is no rational choice than to acknowledge this situation and to successfully cross this line at whatever cost, effort, and change required. Since the full human potential of all people is the best that we can do, tapping this potential to work together globally offers the best chance for success. In this way, global warming may not only present unprecedented challenges, but also unprecedented opportunity driven by necessity to advance – to turn adversity to advantage!

Block 2. The Human Potential. (combining puzzle pieces 12, 1, 7, 6, 2, 4, and 5)

Puzzle Piece 12 – Human development. Humans lived and perfected in nature as hunter-gatherers over millions of years until civilization, over just the last 10 thousand years, changed that lifestyle, implying that humans today are biologically hunter-gatherers and have the same human potential as our hunter-gatherer ancestors.

Puzzle piece 1 – Hunter-gatherer societies that survived into modern times developed common core adaptations for surviving together: individual equality, food sharing, discourse, and spiritual beliefs to regulate social behavior while consciously controlling their natural tendencies to seek power and to dominate others. They had to exercise the personal self-control to abide by these social norms, and the personal responsibility to maintain and pass them on. Being biologically hunter-gatherers, people today must have these same abilities.

Puzzle piece 7 – Closest living relatives – chimpanzees – often employ behaviors common with humans: alpha-male quest to dominate and gain political power, male domination of females, and we-versus-them attitude often leading to conflict and violence. There is a lot of ape within each one of us.

Surprisingly, hunter-gatherers, living in mutually dependent groups, controlled their ape-like behaviors through their social norms, thereby giving testimony to the enormity of the human potential. How did hunter-gatherers do it?

They likely used their unique *human intellect* to analyze behavior and identify superior approaches. However, modern experience shows that human intellect cannot alone control the ape within us – most people do not favor war, yet we still have wars. Hunter-gatherers must have used their *human spirit*, that which quests for truth, freedom, equality, and spiritual beliefs, *in combination* with intellect to control their natural ape-like behavior.

The human spirit is often ignored in a work of this type because it is too vague. However, social change does not work if it is incompatible with human nature, including the human spirit, as shown with the communist experiment. Acknowledging its uncertainty, the authors address spiritual items and related concepts as optional reading in Endnotes to Part II.

Puzzle piece 6 – Rise of civilization resulted from concentrating political power into centralized governments controlled by powerful leaders, which created *power-based politics* where rulers and their assistants focused on power, party and ideology to maintain and enhance their power. Power, fame and wealth became highly sought throughout civilized societies as interchangeable commodities, while most people focused on work and survival, and supported the powerful few. Thus, we *essentially re-empowered the ape within us* that hunter-gatherers worked hard to control.

While democracies enhanced the rights of individuals, further freeing the human potential, power-based politics remained essentially the same, but played under tighter rules. In this environment, truth and compromise are often casualties whenever either is in the way of political objectives.

Puzzle piece 2 – Theory of truth, an inconvenient reality was first stated by the Prophet Muhammad some 1,400 years ago and can be restated as: If we discard or do not seek truth, we likely operate on false premises and incur a cost from being wrong. When truth is discarded through power-based politics, the cost of being wrong usually falls on society. The unavoidable costs of discarding or not seeking truth is an *Achilles heel* of Modern Civilization – a fatal flaw in the face of global warming.

Puzzle piece 4 – Full human potential is the sum of the human potential of each person on earth multiplied by a force multiplier gained when people can cooperate and think together. The available human potential is much less because of the seven detracting issues previously listed. Overcoming the detracting issues will not only remove their threat to society, but will increase the available human potential to overcome global warming – a double advantage giving the best prospects for future advancement and survival.

Puzzle piece 5 – A surprising discovery occurred in the 1990's, a “wicked-problem approach,” that enabled teams of people to solve highly complex technical problems as well as complex community issues while working in an atmosphere of truth, compromise and good will. The discovery and subsequent testing of the approach

applied the enormous human potential to solve such complex problems – likely the greatest and most underutilized natural resource available to humanity.

Block 2 – The Human Potential. We find that humans developed over millions of years as hunter-gatherers and are biologically still hunter-gatherers with the same human potential. Chimpanzees, our closest living relatives, demonstrate social norms of alpha-male domination and conflict that are common with humans. Since hunter-gatherers were able to control these ape-like behaviors, presumably using their human intellect and spirit, so could we. A key reason for doing so is to avoid discarding truth through power-based politics and incurring the enormous costs of being wrong, as exemplified by the seven detracting issues facing the world today in addition to global warming. The discovery of an approach to solve complex wicked problems offers a possible alternative to power-based politics where *the people* provide problem-solving support to government officials allowing truth, compromise and goodwill to underly all political decisions, thereby avoiding the loss from discarding truth. Dealing simultaneously with the challenges of global warming and the detracting issues will likely require tapping the *full human potential*.

Block 3. Adaptations for advancement and survival. The following three adaptations seek to free-up the full human potential in order to deal successfully with global warming and the seven detracting issues. Together, the adaptations can empower the human intellect and human spirit to re-control the ape within us leading to bountiful social advancement from Modern Civilization to “Advanced Civilization.”

Adaptation 1 – Transition to truth-based politics. This adaptation requires transitioning from power-based politics where power, party and ideology dominate to truth-based politics where, *with the problem-solving support of the people*, truth, compromise and goodwill underlie all political decisions.

Rational. This adaptation will accomplish two complementary goals: 1) to overcome power-based politics’ unavoidable flaw of discarding truth, thereby making decisions on false premise, and incurring the costs of being wrong, and 2) to tap into the enormous human potential of the people to solve complex problems using fact-based approaches.

Benefits. The first benefit is to avoid the huge cost of discarding truth and making unwise political decisions on false premise. These costs, be they needless wars, conflicts or wasted resources, are generally born by *the people* and subtract from the people’s full human potential. A second benefit is to make wiser, more informed political decisions by tapping the enormous, and largely ignored, people’s ability to develop truthful, effective solutions to complex social/political problems.

Injecting “truth” into the political process will, in turn and over time, help to change from today’s political environment that focuses on power, party and ideology to one relying on truth, compromise and goodwill. Given that global warming is a problem *of fact* that threatens the future wellbeing and survival of Modern Civilization, it can only be overcome on the basis of fact and truth. Conversely, the seven detracting issues largely resulted from power-based politics and cannot be solved by more of the same. The truth-based, problem-solving support of the people is required.

How to achieve? Today's politicians and political systems should not be blamed because grasping power is often a successful tactic whether or not it leads to efficiency or social advancement. Power-based politics has been the norm over the past 7,000 years, it has worked, and is deeply ingrained as a social norm. It would be fruitless to pass a law that requires "politicians to be strictly truthful." There is no other source of truth other than *the people*. Only *the people*, who's social norm is predominately truthful and honest, can change the political system in this way from the bottom-up.

The very modest Penobscot Initiative where people formed a People's Forum and used fact-based problem solving (the wicked-problem approach) to address local social/political issues demonstrated a feasible approach. The initiative came from the people. They demonstrated not only their ability to successfully investigate social issues, but also the will and enthusiasm to do so. Further, since the results were based on honest effort without political agenda, local elected officials welcomed the help and used the results in making their decisions. Even dictators would likely appreciate such help from their people, which focuses on solving common problems, not on starting revolutions and overthrowing leaders or governments.

What is needed is for people in every community, city, state, and nation around the world to form their own people's forums to develop and offer to government authorities, effective solutions to social/political issues. As people gain experience and confidence in using fact-based problem solving, some will likely enter political positions and bring with them the problem-solving skills, knowledge and confidence to rely on the people's assistance. In this way, truth-based politics can become a *social norm* among the people and government officials through supporting rather than confronting action.

Adaptation 2 – Strive for a world without enemies. To live in a world without enemies requires changing from confrontation/power based international relations to relations based on truth, compromise (mutual benefit) and goodwill. This change requires accepting a reality – we must get along; no other practical option exists.

Rational. The costs of war in terms of its preparations and conduct, people killed and wounded, physical destruction of assets, displacement of people, and psychological impacts and suffering far outweigh the benefits. For example, the cost to the United States of its recent Iraq and Afghanistan wars was approximately \$6 trillion, or \$20,000 per United States citizen. What is the net gain? The outcomes from all types of international confrontations be they sanctions, embargoes, covert aggression, or terrorism also produce no clear gain. Conversely, all forms of confrontations detract from international cooperation. With current international confrontations, the added stress from the unavoidable effects of global warming could expand international conflicts and defeat international efforts to cope successfully with global warming. Also, all types of hostilities and warfare subtract from the otherwise available human potential of people working together. Thus, a change in approach is needed.

Benefits. The overriding benefit of striving for a world without enemies is to avoid the net loss associated with all types of international confrontation and to gain the benefits of win-win relations with other nations and the international cooperation needed on urgent matters including global warming.

How to achieve? Basing all foreign policy on truth, compromise and goodwill would create an atmosphere for success. Then, working with enemies and adversaries to find compromise, win-win solutions, accepting that

we must get along, would move in the right direction. Furthermore, the problem-solving support of the peoples from involved countries should be used to help in developing practical, win-win solutions.

While these approaches make logical sense, are entirely doable, and would yield great benefits, the bias with power-based politics was and is towards international confrontation. Political leaders covet their power to wage war and dominate – it is part of the ape within us. Conversely, by transitioning to truth-based politics, this approach will make sense and could be implemented. There is every likelihood of success if people from hostile nations work together to find beneficial ways to get along. In general, most people do not want war and hostility.

Another important aspect of this adaptation is that everyone can apply the same principles in their own lives by basing interpersonal relations on truth, compromise and goodwill. In this way, each person can work with their enemies or adversaries to find win-win compromises. People, of course, do this all the time, but by making it a social norm, the approach can influence international relations as well.

Adaptation 3 – Embrace a whole-earth perspective. Embracing a whole-earth perspective requires accepting reality: the whole earth is our home and all humanity are one family. We have no other home and the earth is one integrated system that cannot be divided into separate parts by artificial division into nations and states. Other than physical race differences that developed in response to environmental conditions, we are all *Homo sapiens*, one family, with individual person-to-person variations.

Rational. The main purposes of this adaptation are to 1) support a change from a power-based, we-versus-them, confrontational perspective to a truth-based perspective of equality and cooperation as required by the first two adaptations and 2) engender a personal sense of responsibility for the welfare of the *entire* earth, which is our *only* home.

Benefits. This adaptation is needed to help in achieving adaptations 1 and 2. The sense of oneness between all peoples and with the whole earth will create a needed social norm of equality and responsibility. It will help break down the barriers to people from around the world working together for mutual benefit.

How to achieve? One way to make a whole-earth perspective a social norm is to include it in the education of children and young adults. The perspective could be supported with global projects and through the world's religions. An example project might be a whole-earth trail system allowing people to walk around the earth with nothing more official than a passport and be among friends the whole way. Creative people will think of many ways to reinforce this perspective.

Combined Benefits - 3 Adaptations + 3 People's Projects. The three Adaptations together will likely impact each of the seven detracting issues:

Terrorism and mass shootings - instilling fear, diverting attention & resources. Involving all people in truth-based political decisions will provide an effective and non-violent way for all people to be heard, thereby, reducing incentives for violent demonstrations (Adaptation 1) while actively seeking a world without enemies will lower hostility and confrontation, also reducing the motivation for terrorism (Adaptation 2). Creating a social norm of individual equality and value, again, will diminish motivation for terrorism (Adaptation 3).

Warfare and confrontation - using vast resources and hindering international cooperation. Reducing and resolving international conflict on the basis of truth, compromise and goodwill will reduce the need for vast military expenditure and avoid warfare's destruction while enabling international cooperation to flourish on a win-win basis (Adaptations 2 & 3). Truth-based politics will support rational political decisions with input from the people who are generally against warfare (Adaptation 1).

Threat of nuclear war – raising fear and impeding international cooperation. The need for nuclear weapons should diminish as warfare and confrontation diminish (Adaptations 2 & 3). Truth-based politics with input from the people will likely recognize that mutually assured destruction is not a rational solution and that over time, nuclear weapons can be eliminated (Adaptation 1).

Concentration of wealth – will the 9% of the people with 86% of world dollars assist with global warming? Truth-based politics with people's input may avoid political decisions that now favor the further concentration of wealth (Adaptation 1). As a whole-earth perspective becomes a social norm, people may voluntarily control their lust for power, fame and fortune in favor of fair wealth distributions, and paying to overcome global warming (Adaptation 3).

National debt – where will dollars to cope with global warming come from? Truth-based politics with input from the people who understand the problems of going into debt will help curb unnecessary political spending, while making political decisions based on truth rather than on power, party and ideology will avoid wasting tax money on non-productive enterprises (Adaptation 1). Reducing the need for vast expenditures and the destructive consequences of warfare will also reduce the need for increased national debt (Adaptation 2).

Population growth – increasing energy demands and numbers of people impacted/displaced. Voluntary population control can become feasible as a sense of worldwide responsibility and belonging becomes a social norm, and people understand the actual needs and benefits of getting along and controlling population (Adaptations 2 and 3).

Political and social environment – confrontation based on power, party and ideology. Truth-based politics aims at achieving a political/social environment of truth, compromise and goodwill, while avoiding today's confrontational environment focused on power, party and ideology (Adaptation 1). Reductions in international warfare and confrontations, and a perspective of whole-earth togetherness and responsibility will reduce tensions within government and support more informed and superior political decisions (Adaptations 2 & 3).

You may note that the three Adaptations are not only compatible, but mutually supporting. Together, and over time, they can reduce and eventually overcome the seven detracting issues. This type of solution, called an “evaporating cloud solution,” changes the underlying cause and foundation of complex problems, allowing them to diminish and disappear over time. They are “simple solutions” to extremely complex problems that cannot otherwise be solved under current conditions.

The three People's Projects to halt the ongoing rise of CO₂ and to adapt to climate change, stabilize the earth's climate system, and develop climate, energy and stabilization technology require scientists, engineers, economists and other multi-disciplined people from around the world to work together on practical, affordable solutions. In doing so, people will demonstrate the largely untapped human potential to overcome

highly-complex problems using a wicked-problem approach. With confidence gained from these demonstrations, people will feel more assured to work together using the same approach to address political/social problems through Adaptation 1. At the same time, the three Adaptations will foster the international cooperation and consensus needed to overcome global warming. In addition, the three projects will yield new career paths and economic opportunities that will support global feelings of oneness and wellness.

Thus, the three People's Projects and three Adaptations offer an integrated, mutually supporting way to overcome global warming and the seven detracting issues.

Feasibility. To succeed, the three suggested People's Projects and the three Adaptations must first be feasible from several perspectives:

Human potential. Do we the people have the ability and the human potential to accomplish the three People's Projects and three Adaptations? As indicated before, the ability of people to work together to solve complex problems consisting of a mix of technical, economic and social/political factors ("wicked problems") using a wicked-problem approach was demonstrated.

Therefore, accomplishing the three People's Projects is certainly feasible and within the human potential. Performing these projects using the Internet with people from around the world who choose to work together on the projects is timely, but not totally new. Open source software development platforms such as GitHub have successfully supported online collaborations among thousands of software developers. Their experience may be helpful here. Most scientists, engineers, economists and other specialists *do* have some level of available time that will enable them to work part-time on the Peoples Projects. Some participants may find funding sources that allow them to spend more or full-time on the projects. Thousands of willing people from around the world working together should provide enough brain-power to accomplish these three projects. Therefore, executing the three People's Projects seems feasible and within the human potential.

The Penobscot Initiative successfully demonstrated that community volunteers can work together using a wicked-problem approach to analyze and solve town issues and that town officials and citizens can use and accept the results. In essence, the initiative demonstrated truth-based politics at a limited scale. If the concept could work in a small rural community in Maine, United States, there is no reason why it could not work in other communities. Equally important, the work showed that people enjoyed working together in an atmosphere of truth, compromise and goodwill and came back willingly to work on additional town issues. Therefore, transitioning to truth-based politics (Adaptation 1) is certainly within the human potential and feasible.

The authors believe that success in transitioning to truth-based politics is required to enable Adaptations 2 and 3. Striving for a world without enemies and embracing a whole-earth perspective can best flourish when truth, compromise and goodwill underly political decisions. That said, there is no reason why governments could not focus their foreign policy on getting along and achieving win-win relations now (Adaptation 2). Equally, there is no reason why individuals cannot apply these same approaches to resolve personal conflicts. People can also adopt and creatively encourage a whole-earth perspective now (Adaption 3). The perspective is consistent with physical reality. In summary, all three Adaptations plus the three People's Projects are within the human potential and feasible. As these efforts proceed, smart creative people will find new ways to achieve the desired results.

Human nature. The three People's Projects intended to deal with global warming as well as the three Adaptations are based on facts and rational analysis and, therefore, should make sense from a human intellect standpoint. However, the important judge is you the reader – do the three People's Projects and three Adaptations make sense to you?

Compatibility of the three People's Projects and three Adaptations with the human spirit requires subjective judgement. Actual experience shows that people are comfortable, indeed enjoy, working together using the wicked-problem approach to solve both complex technical problems and social/political issues. Working in a supportive atmosphere grounded in truth, compromise and goodwill appears compatible with the human spirit and likely contributes to problem-solving success. People's spiritual drive for honesty, freedom and equality should be nourished by the three Adaptations and People's Projects. Again, the important judge is the reader – would you like to live in a world with truth-based politics, without enemies, and embracing a whole-earth perspective?

Political realities. The three People's Projects require people from around the world to work together on global warming using the Internet. Political impediments to this cooperation should not exist in democracies, but some autocratic countries limit the access of their people to the Internet. In such countries, leaders will have to decide whether or not to allow their people to cooperate on the three People's Projects. They may do so because of the pressing challenges of global warming.

Transitioning from power-based to truth-based politics (Adaptation 1) might seem a direct challenge to today's political leaders. To avoid political confrontations, the authors suggest that people establish People's Forums in support of their political leaders, not in opposition to established authorities. To this end, they should offer to 1) work on issues identified by the political leaders, 2) use a wicked-problem approach to focus efforts on fact-based rather than opinion-based problem solving, and 3) present the results from their efforts as advisory only. In other words, conduct the forum work in a non-political, non-confrontational manner. In this way, most political leaders will likely welcome the people's help. Then over time, as people gain knowledge of local issues and success in solving them, some will enter political positions, and over time, truth-based politics will become the norm because it works better!

Adaptations 2 and 3 could be adopted at the personal level as a critical first step and later become the norm in government operations as truth-based politics is accepted.

Cost. By depending on people to use their discretionary time (or find available resources) to accomplish the three People's Projects, the cost in terms of dollars would be minimal. Human effort is the real cost. By dividing the work up among many people, the burden on each person should not be too great. Conversely, the cost to implement the results of the three People's Projects and to actually overcome global warming will likely be great. The People's Projects will provide a sound technical, engineering and economic basis for committing the necessary money and effort. They will also generate a world-wide consensus on how best to proceed. The world will be forced to cope with global warming and pay whatever price is required. If we pay a steep price on options that fail, civilization will be imperiled. The People's Projects aim to assure that the world invests in options that work – options that open new work opportunities and provide positive returns on investment, thereby benefiting all people.

The People's Forums needed to achieve truth-based politics (Adaptation 1) can operate effectively by involving no more than 10% of a community's residents who would each work on one project per year requiring about 40 hours of effort per participant. Such levels of effort were found acceptable in the Penobscot Initiative and enabled the Forum to work on several issues at the same time.

Risk. There is essentially no risk in the three People's Projects since they will not require additional government spending and they will result in honest, practical results to deal with global warming. Technical risks will be identified and actions to reduce risk can then be implemented. In fact, the three projects are designed to reduce overall risk by confronting global warming in an honest, organized, international manner. Implementing the resulting solutions will require great effort and investment. However, doing so will open new career paths for young people and economic opportunities that greatly benefit current society and future generations.

The risks in implementing the three Adaptations are likewise very low. They focus on tapping the full human potential to confront problems facing world society through voluntary citizen effort. These inherently bottoms-up initiatives require neither government spending nor do they threaten today's governments or government officials.

Human will. If the three People's Projects and three Adaptations are within the human potential, are compatible with human intellect and human spirit, avoid political impediments, and are affordable in dollars and human effort, what more is needed? The human will to undertake the work and to control the ape within us is what is needed. The three Adaptations could have been implemented at any time throughout civilization's 7,000-year history, but were not. Why? First, civilization resulted from ingrained human instincts and abilities, and natural circumstances. And second, it developed in its own natural way, and it worked.

What has changed is the need to change. Global warming along with other complex detracting issues seem to demand social/political change – change for survival. The collective will of the world's people must rise to the occasion as there is no other option.

A final vision. Today, a great portion of available human potential that could be used to solve society's complex problems is not being fully utilized, and another great portion of human potential is being wasted by many detracting issues. To live in a world where each person has the opportunity to reach his or her full potential would be a world worthy of being called "*Advanced Civilization*." In Advanced Civilization, the full human potential would be available for useful application. There is no limit to what people could accomplish working together on the basis of truth, compromise and goodwill.

This incredible opportunity to change the course of civilization stands before us today, achievable through practical effort and driven by the necessities of global warming. What is needed is the will of people to change direction – backed up by self-discipline and responsibility to assist and maintain that change. (That is, empower our human intellect and human spirit to control the ape in each one of us.) In this way and over time the three Adaptations can form a new social norm throughout the world as depicted in Figure 5.8.

Advancement & Survival

Transition from Modern to Advanced Civilization

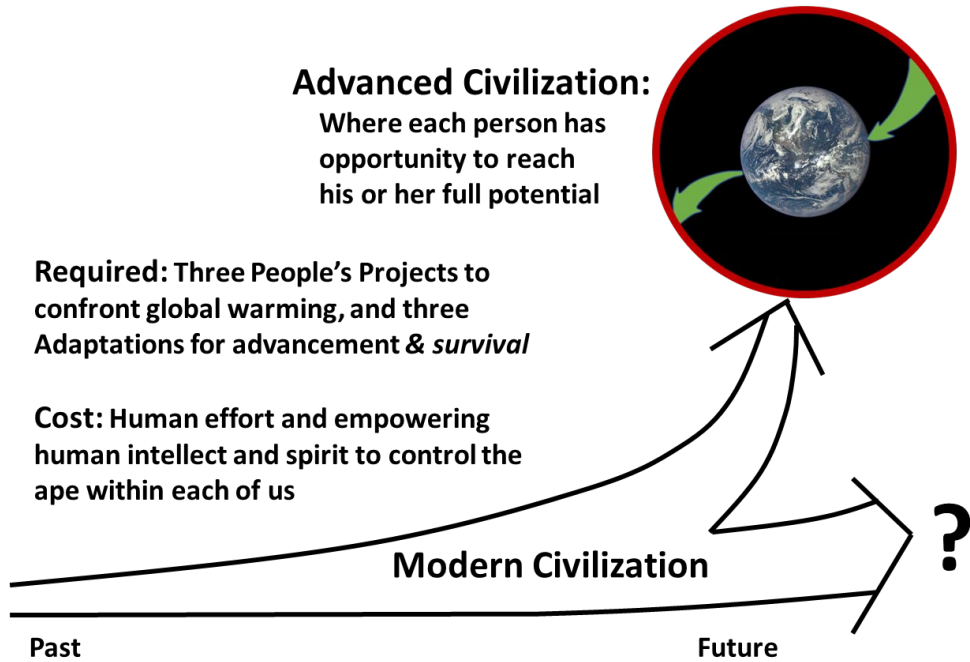


Figure 5.8. A vision for transitioning from Modern Civilization to Advanced Civilization where each person has opportunity to reach their full potential.

Endnotes to Part II

These optional endnotes consider the uncertain spiritual component of human nature. As mentioned before, social adaptations that run counter to human nature, including the human spirit, cannot succeed, particularly for *bottom-up* change that can only come from the people of the world. The authors hope that these notes will complement Part II and spark additional ideas.

1. Avoid a melt-down of Modern Civilization at all costs. One of the authors had a dream about the destruction of civilization during the height of the Soviet-US cold war. “I awoke in the night from blinding flashes of light coming through our bedroom windows. I *knew* that the flashes were from nuclear bombs falling on Washington, the US capital. I aroused my wife, and we went into the cellar and crouched along a wall facing Washington for protection. I had no sense of personal fear. But then I thought of the ongoing total destruction of our capital with its innocent people. I imagined how our nuclear bombs were falling on Moscow and its innocent people. At this point, a feeling of crushing *despair* descended on my shoulders – the failure of civilization. This overwhelming feeling penetrated my mind and spirit. I awoke, almost in shock and still feeling the same crushing despair. After a few moments, I noticed that there were no flashes of light, I was still in bed, and my wife was sleeping soundly. Oh! It was a dream. The despair slowly left me. I was very thankful and resaid my prayers!”

We include this dream because it may provide a sense of the psychological impact of a melt-down of civilization that, over and above the physical destruction, could be paralyzing. No, a melt-down of civilization is simply not an option and must be avoided no matter the cost or effort, including social change as suggested by the three Adaptations.

2. Compatibility of truth-based politics and human nature. Truth is the underlying foundation of truth-based politics as well as the other two Adaptations. Truthfulness is the norm of most people; they cherish truth and base their lives on it. Great prophets and thinkers extolled truth and wisdom:

King Solomon: “...*better to be poor than a liar.*” (3,000 yr. ago) (*Holy Bible, New International Version*, Copyright 1973, 1978, 1984 International Bible Society. Used by permission of Zondervan Bible Publishers, Proverbs 19.22)

Bhagavad Gita: “*As a fire is obscured by smoke, as a mirror is covered by dust, as a fetus is wrapped in its membrane, so wisdom is obscured by desire.*” (2,200 yr. ago) (*Bhagavad Gita*, a new translation by Stephen Mitchell, Three Rivers Press, New York, 2000, Chapter 3, 3.38)

Jesus of Nazareth: “...*the truth will set you free.*” (2,000 yr. ago) (*Holy Bible, New International Version*, Copyright 1973, 1978, 1984 International Bible Society. Used by permission of Zondervan Bible Publishers, John 8.3.1)

Prophet Muhammad: as quoted before, “*So what is there after discarding the truth but error?*” (1,400 yr. ago) (*The Quran*, Arabic text with a new translation by Muhammad Zafrulla Khan, Olive Branch Press, NY, 1997, Part 11, Chapter 10, 32-34, p 195)

Abraham Lincoln: “*Reason—cold, calculating, unimpassioned reason—must furnish all the materials for our future support and defense...*” (175 yr. ago) (Lincoln, Abraham, Lyceum Address, January 27, 1838, from *The Life and Writings of Abraham Lincoln*, ed. Philip Van Doren Stern, Random House, NY, 1999, p 24)

Gandhi: “If untruth does not so much as exist, its victory is out of the question. And truth being that which is can never be destroyed.” (80 yr. ago) (Gandhi, M. K., *Satyagraha in South Africa*, Navajivan Publishing House Ahmedabad, 1928, p 260)

Gandhi: “...the very insistence on truth has taught me to appreciate the beauty of compromise.” (60 yr. ago) (Gandhi, M. K., *Gandhi's Autobiography, The Story of My Experiments With Truth*, Public Affairs Press, Washington, D.C., 1948, p 184)

Gandhi: “But truth is as hard as adamant and tender as a blossom.” (60 yr. ago) (Ibid. page 184)

Therefore, truth and truthfulness, often lacking in power-based politics, are compatible with human nature based on the insights of the prophets and other great thinkers. Truth-based politics is not an idealistic dream, but rather a reflection of how most people live their lives.

3. Religion, a unifying force. Religion often divides rather than unites people. This endnote offers several ideas to help transition religion into a unifying force. Both God and religion far predate the religions of today. Beliefs in gods and spirits were common among almost all the hunter-gatherer societies that survived into modern times, implying that spiritual beliefs and religion were a component of human nature into the distant past. Accepting this reality, there is no factual basis for setting one religion above another and having religious conflicts. Religious conflicts, rather than reflecting God's will, likely arise from the human desire to dominate others and exercise we-versus-them attitudes (the ape within us).

A unifying perspective for believers may be:

The truths (physical realities) of nature = The truths of God (who created and stands over nature, including us).

For non-believers: The truths of nature = The truths of nature (which simply are)

Since the truths of nature are universal for all religions, religion should and can be a unifying force throughout the world, as long as all faiths accept the truths (realities) of nature in their doctrine. Also, since the truths of nature are the same for believers and non-believers, there should be no religious basis for conflicts between them either.

Acknowledging observable events that religious people of all faiths attribute to God might also help unify religions.

“Miracles,” those unexpected, low probability, timely events that render great help to individuals and to peoples are observable facts of nature. Believers acknowledge God as the source of miracles whereas non-believers consider them random events of nature. Here, only the attribution differs between believers and non-believers, but the facts stay the same.

The old saying “When God shuts a door, God will open a window” reflect believers' faith that if a person strives and persists to do what is right and good, then God will remove barriers and provide support. That

people strive and persist to do what is right and good and that they overcome many barriers to be successful are also observable facts of nature. Believers acknowledge God's helping hand while non-believers credit random events and increased chances from repetitive attempts. Again, the facts remain the same, only the explanation differs between believers and non-believers.

These observable events and faith that they come from God are universal among all religions, and should have a unifying effect. Likewise, there should be no conflict between believers and non-believers since only the explanation differs based on one's personal faith.

The authors know of no religion that does not promote truth, compromise, and goodwill as required by the three Adaptations. For example, the central premises of the four gospels in the Holy Bible are:

- 1) Seek truth,
- 2) Come to serve rather than to be served, and
- 3) Have love and faith in God, self and neighbor.

Seeking truth underlies the three Adaptations. Coming to serve is an attitude that is demonstrated through a willingness to compromise. People that *demand* to be served resist compromise and prefer to dominate and have their way. Having love and faith in God, self and neighbor are personal feelings, which are demonstrated by dealing with everyone on the basis of goodwill. There is no question that the major religions of the world and the three Adaptations share the same values of truth, compromise and goodwill.

A beautiful prophesy of Jesus of Nazareth states: "Blessed are the meek, for they will inherit the earth" (*Holy Bible, New International Version*, Copyright 1973, 1978, 1984 International Bible Society. Used by permission of Zondervan Bible Publishers, Mark 5-3-11). This prediction can be read as a passive statement of what will come to pass. Perhaps the intent was more active – "...they will inherit the earth." Transitioning to truth-based politics would be an active step in fulfilling this prophesy that can yield great benefit.

It is imperative that religion be a unifying force throughout the world in order to deal successfully with global warming. Active support of the three Adaptations and the three People's Projects by religious bodies would move religion in that direction and greatly help to overcome global warming and improve social conditions.

4. Motivation for working on People's Projects and the three Adaptations. King Solomon, in his quest to find the meaning of life, conducted perhaps the first experiment to test what is most important in life. He documented his results in "Ecclesiastes," the *Holy Bible*, and arrived at a short list of what is most valuable:

- 1) "A man can do nothing better than to eat and drink and find satisfaction in his work." (2-24)
- 2) "Enjoy life with your wife, whom you love..." (9-9)
- 3) "Moreover, when God gives any man wealth and possessions, and enables him to enjoy them, to accept his lot and be happy in his work – this is a gift of God." (5-19)

Reference: (*Holy Bible, New International Version*, Copyright 1973, 1978, 1984 International Bible Society. Used by permission of Zondervan Bible Publishers, Ecclesiastes section as indicated)

King Solomon gave greatest emphasis to *finding satisfaction in your work* and repeated it no less than five times in “Ecclesiastes.” In the same way, gaining personal satisfaction by working on the People’s Projects and contributing to truth-based politics is a key motivator.

Another aspect of motivation is the fear of attempting something new. Joining people’s forums to analyze social/political issues as well as choosing to work on the three People’s Projects is new. People may feel uncertainty; it is always easier to sit back and let others take on new challenges. The *Bhagavad Gita*, a holy book of Hindu, gives excellent advice for approaching tasks that are right and good, but that raise feelings of uncertainties:

*“Without concern for results, perform the necessary action;
surrendering all attachments, accomplish life’s highest good.”*

(*Bhagavad Gita*, a new translation by Stephen Mitchell, Three Rivers Press, New York, 2000, Chapter 3, 3.19)

5. Gaining understanding from history. If everyone better *understood* where we came from, where we are, and who we are, people might better appreciate the need and opportunity to move from Modern Civilization to Advanced Civilization. History education in elementary and high-school could provide this understanding if organized to emphasize *understanding* along with factual knowledge. History teachers are best qualified to develop such a program. The following ideas are shared only to initiate consideration.

History during the first 6 grades in elementary school could focus each year on one society beginning with the hunter-gatherer, and then Egyptian, Roman, Medieval, Colonial and modern societies. The purpose of the instruction would be to impart an understanding of how average people as well as the rulers actually lived in those times. Students might use skits and planned exercises to roll-play daily life in each society.

History from grades 7 through 12 could focus on a different aspect of society each year and follow the progression of that aspect from earliest society to today. Aspects of society could include: 1) agriculture, animal husbandry and diet, 2) medicine and life expectancy, 3) art and religion, 4) science and engineering, 5) industry and standards of living, and 6) government. Focusing on one aspect of history over time can impart an understanding of the continuity and flow of history over time. The history courses could be augmented with a high-school biology course that traced the development of humans from earliest times to the present based on fossil records, artifacts, and modern DNA analysis, including human’s close relationship to chimpanzees both genetically and behaviorally.

This approach should enable students to see how each aspect of society progressed over time to gain an overall understanding of where we came from, where we are, and who we are.

6. Learning from hunter-gatherers. As mentioned before, humans and their ancestors were all hunter-gatherers for millions of years before the very recent advent of civilization. Hunter-gatherers survived and thrived during that long period and peopled the earth. They must have done something right. What can we learn from the remaining hunter-gatherer societies?

With the advent and spread of civilization, existing hunter-gatherer societies were largely destroyed by disease, destruction and displacement – they were simply in the way or a commodity to be exploited rather than fellow humans worthy of understanding. Ms. Sarah Winnemucca Hopkins, a young Piute hunter-gatherer in Nevada, United States, gave witness when the first white people came into her people’s country:

“They came like a lion, yes, like a roaring lion, and have continued so ever since, and I have never forgotten their first coming.” (Hopkins, Sarah Winnemucca, *Life Among the Piutes*, (1883), Ed. By Mrs. Horace Mann, Arcadia Press 2017).

Today, small remnants of hunter-gatherer societies live in generally remote and inhospitable areas such as the Hazda and Ju/'honasi in Africa. Fortunately, anthropologists have stayed with hunter-gatherer societies to record how they live and have provided valuable insights. Nevertheless, there is much more to learn – people and societies are very complex. Just how do hunter-gatherers control their natural (ape) tendencies to seek power and to dominate others? How do they exercise the *personal self-control* to abide by their social practices, and the *personal responsibility* to maintain and pass them on to the next generation? How do they educate their children to survive a rigorous lifestyle in a hostile environment and yet be respectful and kind?

Given the need to transition from power-based to truth-based politics and to get along throughout the world, we need to learn these things now. All of the remaining hunter-gatherer societies are under pressure from civilization to change - time is running short. Descendants from past hunter-gatherer societies are, likewise, under pressures to fully adapt to Modern Civilization and to forget about their past. Given these circumstances, the authors offer the following three suggestions:

- 1) Strengthen protection of today's hunter-gatherer societies throughout the world to enable them to continue their traditional ways of life.
- 2) Support Hunter-Gatherer Graduate Schools and Programs on each continent to allow hunter-gatherers and their descendants to study and document their traditional ways of life and to gain a true understanding of how they functioned. Hunter-gatherers and their descendants are best qualified to establish and run these graduate schools and programs.
- 3) Associated with these graduate schools and programs, enable small self-sufficient groups of hunter-gatherers and their descendants to live in their traditional way, as a cultural preservation and appreciation, and as a living laboratory. Suitable lands would need to be provided for this purpose.

In this way, hunter-gatherer cultures could be preserved and acknowledged for the benefit of all people.

7. Controlling the ape within us. When we allow our natural lust for power, fame and fortune to dominate over our desire for truth, compromise and goodwill, we are allowing the ape within us to take control. Contending with these opposing forces is a struggle that each person faces. Fortunately, most people win the struggle in favor of truth, compromise and goodwill. One way to strengthen dedication to these related values is through education, which is now occurring in many countries.

As an example, the U.S. Department of Education developed a program of “Positive Behavioral Interventions & Supports” (PBIS) aimed at improving social, emotional and academic outcomes for all students. The Penobscot Community School implemented PBIS six years ago in pre-kindergarten through 8th grade. The program seeks to instill four values:

Be respectful	Be safe
Be responsible	Be kind

The teachers repeatedly instruct and give examples of the four values, and provide verbal recognition during weekly school assemblies to students for their acts that demonstrate the values. Teachers write the student names and acts on slips of paper and link these together to form a chain called “links of pride.” By stressing the four values consistently through the nine grades, students gain a common understanding of the values and use a common language. Both the teachers and the principal state that the program has improved the overall atmosphere at the school, resulting in better and more friendly behavior and improved learning. In essence, the program establishes a social norm within the school that is supported and reinforced by the students themselves.

Through such education, by implementing the three Adaptations, and by recognizing the survival need to control the ape within us, people can make truth, compromise and goodwill a social norm throughout the world, including governments. This optimism is based on two facts: 1). Most people do control the ape within themselves and favor truth, compromise and goodwill, and 2) Hunter-gatherers were able to control the ape within themselves to allow their small social groups to survive. The only difference is scale. Since global warming can only be successfully addressed through world-wide cooperation, the social group now encompasses all of the people of earth. Let’s do it!

8. Advanced Civilization – hope for tomorrow. The same author that dreamed of nuclear war had a dream years later of great joy: “I entered a round hut in the land of Tolstoy’s *Cossacks*. There was a young female *gorilla* sitting on the large stove smiling at me with flashing dark eyes. The mother gorilla, who spoke English, welcomed me with a smile, and we talked. I felt a sense of joy in being embraced by the unquestioning, welcoming presence of these animals. Then the husband entered. He was immense. He smiled and motioned for me to sit down in his home. The wife explained that he did not speak English. I asked her what his name was. She said “Alumba.” I said “Alumba” with the syllables run together. She said “No, Alumba” with the middle symbol drawn out and emphasized. I said “Oh Alumba.” She said “No, Alumba” with the middle syllable drawn out and the last syllable said explosively. I said “Oh Alumba.” She said “Yes.” I then awoke filled in mind and spirit with an intense feeling of joy from the friendly, welcoming presence of these fellow creatures.”

The feeling from this dream was the extreme opposite of that from the prior dream of nuclear warfare. We include it because people might experience such a feeling in a world without enemies, where truth, compromise and goodwill underly political decisions and where people embrace a whole-earth perspective. If so, the rewards of creating such an Advanced Civilization would be beyond imagination.

More factual hope for tomorrow comes from the action and leadership of many individuals from around the world who do amazing good. *The Christian Science Monitor* reports on such unsung heroes in their “People Making a Difference” section (<https://www.csmonitor.com/Specials/Difference-Maker>) excerpted below:

Marisol Lizelle Salvador found meaning in her life in helping kids by creating a foundation that supports an orphanage in the Philippines.

Dominic Deng Diing, a refugee in the U.S who escaped violence in the Sudan, raises funds to educate 3,000 children back in South Sudan.

Tinha Carvalho, a successful gym owner in Rio de Janeiro, teaches martial arts to entice kids to stay in school.

James Ansara, a U.S. millionaire contractor, is building a hospital in Haiti contributing personal funds, construction leadership, and his hands-on work.

Jane Golden heads the Mural Arts Program in Philadelphia, U.S. where volunteers paint over graffiti while celebrating their history and culture.

Don Ritchie lives in a clifftop house in Sydney, Australia and found himself stopping suicides by inviting potential jumpers inside for a cup of tea.

Liu Pifeng, a law firm founder, works to defend the rights of China's poorest migrant workers while trying to fix China's faulty legal system.

Babar Ali, a teenager in West Bengal, India, started a free school in his parents' backyard for his village's poorest children.

Leslie Clark, an artist in California, U.S., creates 'fixed points' along nomads' routes in Niger to provide health care and education.

Marcia Merrick in Kansas City, U.S. packs 400 lunches each day along with a note of encouragement and then delivers them to the city's homeless.

And, the list goes on and on... continuously...

It does not take too much imagination to envision a world where such self-motivated, natural leaders are encouraged to enter truth-based politics, to seek a world without enemies and to support a whole-earth perspective. Once we turn the corner and head towards Advanced Civilization, we will not want to look back, only ahead with hope.

In truth there is hope!!

Appendix A. Self-Taught Training on the Wicked-Problem Approach

Introduction. Wicked problems have a mix of technical, economic and social/political factors mixed together – the most difficult problems. Global warming is likely the hardest wicked problem ever faced, but many social/political problems are also wicked problems. This course aims to provide those of you who will lead teams of problem solvers with the basics needed to be successful. The wicked-problem approach taught here has proven its merit with an array of wicked problem involving people having very diverse backgrounds. While the approach does not make solving wicked problems easy, it does make it possible.

The course is designed for people with experience in project management and team leadership and for those who do not. It is applicable to very large complex problems including global warming as well as much smaller social/political issues in local communities. The approach can be scaled to the size of any wicked problem by varying the numbers of people and teams that participate.

Standard project management and team leadership form the basis of this approach. However, they are modified in important ways to solve wicked problems. The wicked-problem approach is a disciplined approach. With discipline, all types of people can successfully solve wicked problems – an amazing accomplishment and one applicable in many career fields.

The course is comprised of six sessions. Most of the time required for the course is devoted to discussions among the students. Discussions are necessary to allow you to understand and to internalize the wicked-problem approach. In other words, you need to make the approach your approach through your personal commitment and self-discipline to fully participate in the course and later, to use it to solve wicked problems. Each session and student assignments will require two to three hours of your time.

There are also other wicked problem approaches that were developed for different purposes. The *Lean Six Sigma* approach focuses on defining and achieving an organization's strategic objectives. The *Route or Event Mapping* approach aims to reach executable actions by stakeholders in order to reach future visions. Descriptions of these different approaches as well as the one taught here can be viewed on the Stable Climate Group's Webpage under "Strategy." <http://www.stableclimate.org/home/>

The PowerPoint slides us in this training program can also be downloaded from that site.

Listing of Sessions

Session 1.	Pages A3-A21	Slides 1-19
Session 2.	Pages A22-A46	Slides 20-43
Session 3.	Pages A47-A58	Slides 44-55
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Session 1

Session 1

Wicked-Problem Approach

Facilitator Training

Dick Hutchinson

Welcome

Slide 1

Slide 1. I'm Dick Hutchinson. Let me welcome you to this self-taught training course on the “Wicked-Problem Approach” for solving wicked problems.

Student & Instructor Introductions

Self-Training

- Advantages**
- How to proceed**

Slide 2

Slide 2. Let's start by introducing yourselves.

My formal training is in chemical engineering. Most of my career was spent with the US Army working as a civilian in chemical and biological-defense R&D at Aberdeen Proving Ground in Maryland. While there, colleagues and I stumbled onto the wicked-problem approach (WPA) that is being taught here.

Let's begin by considering self-training.

Although I would like to be with you to help present the course, there are advantages to self-teaching:

The instructor is not there talking, so that gives you, the students, more time to talk and to think.

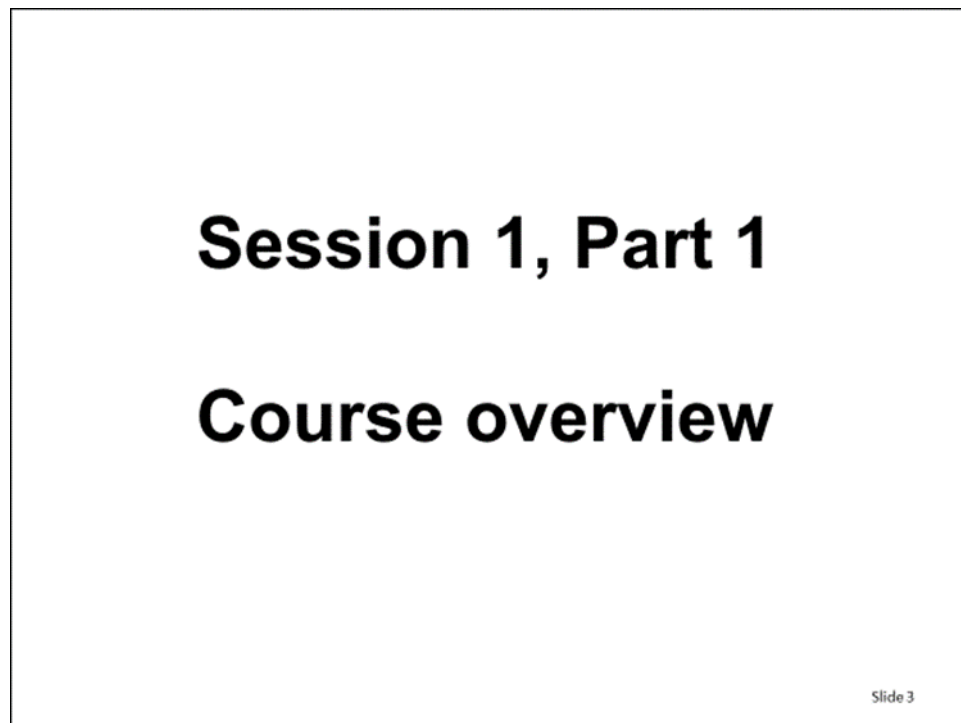
Learning to use the WPA to facilitate (lead) teams of people not only requires learning the steps, but also internalizing the approach and combining it with your own ways of doing things so that it becomes your WPA with which you are comfortable. Self-training gives you more time to achieve this end.

So, here is how best to apply self-teaching in this course.

This training requires brainstorming among students. Two students meeting and working together is a minimum. Having more students together is better.

I suggest that as you go through a session that you have the slides up on a computer or projector. Then, for each slide have a student read my comments for that slide, and discuss the slide among yourselves. Do you understand and agree with my comments? Could you do what I suggest or accept these points? Your answers may not always be “Yes.”

In any event, do not become bogged down. Keep going to the next slide because this course is iterative and reinforces as it goes. Your learning and internalizing will grow as you progress.



Slide 3. We begin with an overview of the course.

Wicked-Problem Approach (WPA)

“Wicked Problem:”

- **Mix: technical, economic & political**
- **Ill-defined, “too hard to do”**
- **Most political & global issues**

Background (discovered, not invented)

- **Treaty verification, biological terrorism**
- **Document approach**
- **Like Senge’s “Learning Organizations”**
- **Tested approach in different settings**

Key Observation: Enormous human potential

Slide 4

Slide 4. We use the term “wicked problem.” So, what is it? It is most difficult type of problem that we face with a mix of technical, economic and social/political elements snarled together in a gordian knot. This type of problem is usually ill-defined where one problem element is a symptom of other problem elements. Most social/political and global issues are wicked problems, either “solved” by default or simply left as too hard to do. National debt is a good example of such a wicked problem.

The WPA was discovered by a group of engineers at Aberdeen Proving Ground trying to develop an integrated, practical approach to verifying the Chemical Weapons Convention, which was then still being negotiated in Geneva. The Convention was complex and called for on-site inspection of a host of activities associated with chemical weapons and their use. The project management approach used here worked well and produced results impacting both the provisions of the Convention and subsequent inspection procedures. As we planned for our next assigned problem: how cities could respond to biological weapons terrorism, we were *surprised* to see that the approach used on the Chemical Weapons Convention could be used here – thus the WPA.

While documenting the approach, reviewers advised us to look at Dr. Senge’s book on “Learning Organizations.” It reports on what factors contributed to the success of some of the best US corporations. Senge and his group of corporate executives identified the factors and environment needed for corporate excellence. We found these same factors are required to solve wicked problems. We later tested the approach

on social/political issues, first at a local Senior College and then in the small community of Penobscot, Maine. The key observation from all of this work is the enormous and largely underutilized *human potential* to solve complex, wicked problems.

Problem-Solving *Environment*

- **Participants – volunteers, equals, no bosses**
- **Provide a service**
- **Encourage leadership**
- **Let truth, compromise & goodwill prevail**

Slide 5

Slide 5. The problem-solving environment is key to the success of the WPA. Often, participants in the problem-solving effort have different backgrounds and choose to donate their time to the effort. All must be treated as equals without imposing, ordering bosses. Participants need to view the effort as a service to the greater good – of their organization, their community, their world. While bossing people will not solve wicked problems, leadership must be encouraged in all participants. You, the future “problem facilitators” will be the key leaders of the problem-solving efforts.

Truth, compromise and goodwill are the bedrock of the needed environment. Wicked problems can only be solved using facts – truth-based approaches. If opinions, prejudices, and self-serving objectives are mixed into the effort, then results will be based on a false premise and will likely fail, or there will be no results, just debates.

These elements of the environment were found to enable people to work together effectively, to be self-motivated, to think hard, and to do their best. The goal is to tap the full human potential.

Essence of Approach

Apply skills in:

- **Project management**
 - **Going from point A to point B**
 - **Follow a disciplined plan**
- **Team Leadership**
 - **Focus, motivate, support**
 - **Encourage creativity**

in unique way to wicked problems

Tap full human-potential

Slide 6

Slide 6. In working on the wicked problems previously mentioned, we naturally applied our normal project management and team leadership skills, but in a unique way for wicked problems. This training includes some of the necessary basics of project management and team leadership for those wishing to lead problem-solving efforts, but without prior experience in those skills.

Benefits

- **Overall:**
 - **Superior solutions - thorough, unbiased analysis**
 - **Informed participants**
- **Participants' feedback:**
 - **Gratification of learning, working, serving together**
 - **Practice problem solving & leadership**
 - **Exercise mind & have a voice**

Slide 7

Slide 7. Observed benefits from using the WPA include superior, unbiased solutions based on facts that are then accepted and acted on by higher authorities. Equally important, volunteers liked working in groups using the WPA to solve important issues, and they volunteered to work on additional issues. People liked to learn new things and to use their minds; to work together in an honest open environment; to solve important problems; and to have a voice in both technical and social/political issues.

Course Outline

	<u>Slide</u>
Session 1. Overview & “wicked problems”	1-19
Session 2. WPA & human potential	20-43
Session 3. Project management & planning	44-55
Session 4. Leadership & problem-solving team	56-72
Session 5. Problem-solving	73-87
Session 6. Wrap up	88-101

Slide 8

Slide 8. We covered the course introduction and overview, so now we will cover the course outline.

In Session 2 we will go through the steps of the WPA and then work on problem diagrams that define the study goals, the problem itself, and steps to attack the problem.

Session 3 will focus on project management and planning the problem-solving effort.

Team leadership will be addressed in Session 4.

Session 5 focuses on how to conduct the problem-solving effort.

The last Section 6 will allow you to present and consider your plan to apply the WPA to your example problem.

Student Take-a Way:

- **Ability & confidence to use WPA**
 - **To address technical and social/political issues**
 - **In & outside your career field**

- **Actually lead & focus volunteer teams using the WPA**

Slide 9

Slide 9. What do we hope to accomplish by the end of this course?

We want you to have the ability and the confidence to apply the WPA to the most difficult technical and social/political issues both in and outside of your career field.

Then, we hope that you to actually lead volunteer teams to solve wicked problems using this approach. Certainly, your confidence and ability will grow with practice, and you will naturally adapt the WPA to your personal style while keeping the fundamentals intact.

Student Involvement *Necessary*

**Learning WPA is a wicked problem
(We use an iterative approach)**

Slide 10

Slide 10. Student involvement in the course is very necessary. Learning the presented material is not enough. Understanding the approach and seeing how you can apply it is required. Remember, our end goal is for you to actually take on and solve wicked problems with teams of volunteers.

For all of these reasons, learning and applying the WPA is itself a wicked problem. The situation would be hopeless if the enormous human potential to solve such problems did not already exist. That potential is largely hidden and usually overlooked. Your ultimate goal is to tap into that potential.

Let us take a stretch break and then turn to Part 2 of this session.

Session 1, Part 2

Understanding Wicked Problems

Slide 11

Slide 11. In this part we need to gain an understanding of wicked problems and how they differ from more usual (non-wicked) problems.

Non-Wicked Problems:

- **Solve with series of steps**
- **Can define problem**

Slide 12

Slide 12. What about non-wicked problems – normal problems that people solve every day.

Such problems are usually solved by a series of steps that are learned and applied routinely. Some steps can be solved in parallel, but all can be pre-planned with confidence that the steps will solve the problem – like baking a cake or building a house.

They are defined problems. We can specify the starting point (A), end point (B) and the steps to go from A to B. Circumstances do influence point A, point B and the needed steps, but the variations are usually within standard practice.

As an example. You take your car in for service. It is not running normally and you do not know why. The mechanic usually starts by checking basic systems such as oil level, etc.; then the problem symptoms; then the possible (known) causes; and finally identifies the problem, fixes it and checks that the symptoms have gone away. Such an approach usually works for routine problems. If the problem continues despite repeated attempts and fixes, then we have a wicked problem, and a big bill!

Brainstorm Examples of Non-Wicked Problems

Identify:

- **Starting point and end point**
- **Steps required**
- **Problem elements**
- **Problem boundaries**
- **Interactions between elements**

Slide 13

Slide 13. Go ahead and brainstorm, and discuss examples of non-wicked (routine) problems. Think of the types of problems you handle routinely.

Then, for each one, identify starting and end points and the steps required. What are the problem components and boundaries of the problem?

Do the problem components interact in known ways, or is there uncertainty regarding interactions?

Wicked Problems:

- **Mix of technical, economic & political problem elements**
- **Ill-defined**
- **Non-linear (parts going in all directions)**
- **Interactions between elements**
- **“Systems problems”**

Slide 14

Slide 14. Wicked problems usually have a mix of technical, economic and social/political elements mixed together in uncertain ways.

They are usually ill-defined. One problem element sometimes being the symptom of another impacting problem.

They are non-linear in that a series of steps to solve the problem cannot be planned with any confidence.

Problem elements often have uncertain or unknown interactions.

Engineers often refer to such problems as “system problems” where one problem element interacts with others. Solving such problems requires understanding the entire system and its inner-workings, then making the necessary adjustments to have the entire system function as desired.

The term “wicked problem” was first defined in 1973 by design theorists Horst Rittel and Melvin Webber to draw attention to the complexities and challenges of addressing planning and social policy problems. Stony Brook University has a website listed below that is devoted to wicked problems and lists 10 characteristics of as described by Rittel and Webber. Please review the short writeup at this site.

<https://www.stonybrook.edu/commcms/wicked-problem/about/What-is-a-wicked-problem>

Brainstorm Examples of Wicked Problems

Identify:

- **Starting point and end point**
- **Steps required**
- **Problem elements**
- **Problem boundaries**
- **Interactions between elements**

Slide 15

Slide 15. Go ahead and brainstorm examples of wicked problems. The detracting issues discussed in Part II of the report are some examples of wicked problems. Think of the wicked problems that you have encountered.

Then, for each one, identify starting and end points and steps required. What are the problem components and boundaries of the problem?

Do the problem components interact in known ways, or is there uncertainty regarding interactions?

Brainstorm in your own words:

What makes non-wicked problem so?

What makes wicked-problems so?

Slide 16

Slide 16. Go ahead and brainstorm in your own words what makes non-wicked problems so and what makes wicked problems so?

Brainstorm Differences

Non-wicked versus wicked problems?

Slide 17

Slide 17. What are the key differences between non-wicked and wicked problems? Brainstorm the differences until you feel comfortable with the differences and can tell the two types apart.

Note: It is hard to have a clear understanding of a wicked problem since one of the characteristics of a wicked problem is that it is ill-defined – it cannot be understood, at least not at the outset. Thus, you can decide if a problem is a wicked one or not based on how well you can see through the problem, its internal interaction of components, and its links to other problems that it could impact.

Thus, identifying a problem as wicked or non-wicked is based on your judgement. The best way to sort out the difference is to try to define the starting and end points and the steps required to solve the problem. Also, think through the elements and boundaries of the problem and interactions. If you, and particularly you as a group, cannot define these aspects of the problem, it is likely a wicked-problem. If you can lay out a roadmap to solve the problem with confidence, then it is probably a non-wicked problem.

Fortunately, nothing is lost by applying the WPA to a non-wicked problem. You will simply lay out the steps to solve the problem and then work toward a solution. However, if you try to solve a wicked problem in the manner of a non-wicked problem, you will likely fail. Herein lies the need and purpose of the WPA.

Questions, discussion?

Student Assignments

- 1. Read reference article**
- 2. Review slides – gain understanding**
- 3. Answer review questions**

Plan your next session: date, time, place

Slide 18

Slide 18. That ends our first session. Please try to resolve any questions that you have among yourselves. Much of what we covered here will be reinforced in later sessions.

Here are your assignments to complete prior to session 2.

Please read the review article that covers the discovery of our WPA. Read it to gain insight into what was done and how the WPA resulted from the work.

Review article: Hutchinson, Richard W., Stephen L. English and Mohamed A. Mughal, “A General Problem-Solving Approach for Wicked Problems: Theory and Application to Chemical Weapons Verification and Biological Terrorism,” *Group Decision and Negotiation*, Kluwer Academic Publishers, Netherlands, 2002, Issue 4, July Nol 11, p 257-279.

Note: We will try to make this available to you as a PDF file on the following website:

<http://www.stableclimate.org/home/>

Please review the Session 1 training material to gain further understanding.

Finally, please answer the review questions that follow. We will go over them at the beginning of Session 2.

Review Questions, Session 1

1. What are the three key values of the WPA?

2. What are the benefits of using the WPA?

3. What are your goals in taking the course?

4. Main differences between wicked – non-wicked problems?

Slide 19

Slide 19. Here are the review questions from Session 1. Please complete them before you meet for Session 2.

Session 2

Session 2

Wicked-Problem Approach

Facilitator Training

WPA & Human Potential

Welcome

Slide 20

Slide 20. Welcome back to Session 2 of facilitator training for solving wicked problems.

Discuss answers to questions
Any comments on WPA article?

Slide 21

Slide 21. Let's start by discussing among yourselves your answers to the review questions from Session 1.

Here is what I came up with for the answers.

Question 1. The three key values of the WPA are truth, compromise and goodwill. Why?

Truth and facts must be the basis for any problem-solving effort that aims to reach valid, unbiased solutions to complex problems. In addition, if the problem-solving environment turns to opinion-based arguments, those uncomfortable with such arguing will turn off and drop out, and the effort will fail.

Given the nature of wicked problems with technical, economic and social/political aspects, any practical solution must somehow balance these factors. For example, an ideal technical solution that is economically not affordable is not a practical solution.

Goodwill among your problem-solving team is necessary to have an open exchange of ideas by all participants. It turns out, based on actual experience, that good ideas can come from any participant at any time. An atmosphere that intimidates participation will cut off people's good ideas along with their active participation and motivation.

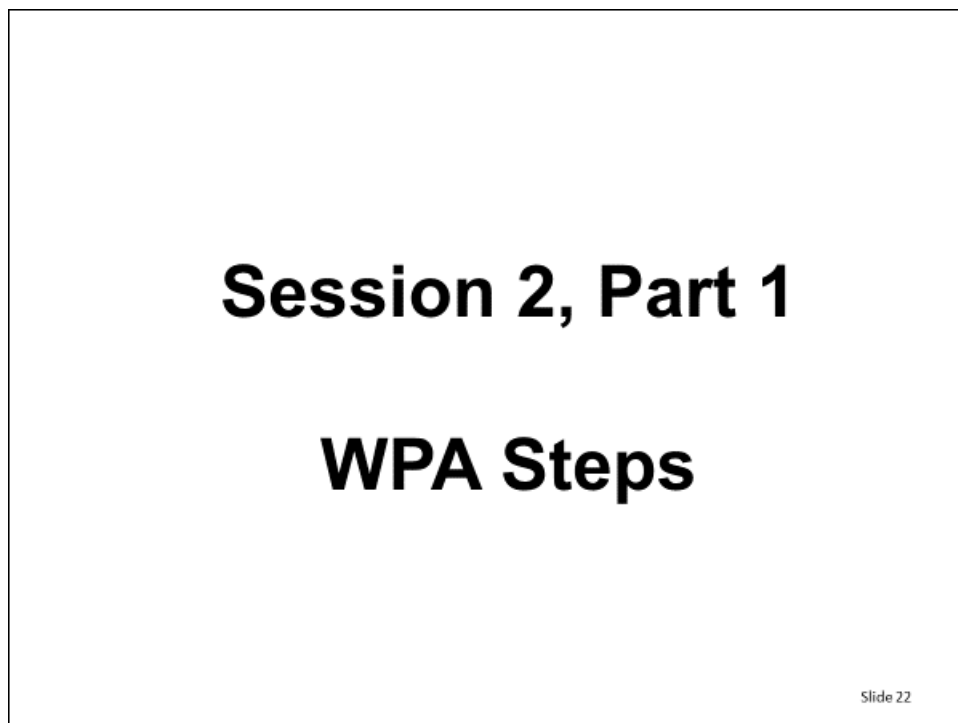
These key values are not suggested as moralistic ideals, but rather as practical necessities in solving wicked problems.

Question 2. The main benefit in using the WPA is to actually find effective, practical solutions to wicked problems – the most complex types of problems. Wicked problems cannot be solved using normal step-by-step approaches that are routinely effective for non-wicked problems.

Question 3. Hopefully, your goal in taking the training is to actually lead teams of volunteers to solve wicked problems.

Question 4. The main difference between wicked and non-wicked problems is uncertainty and complexity. Wicked problems often have a mix of many elements that interact in uncertain ways. A sequence of steps to solve a wicked problem cannot be laid out with confidence – there is simply no roadmap.

Please discuss the WPA article that you read and share your comments.



Slide 22. Now we will review the steps that we have found useful in analyzing and solving wicked problems.

Step 1. Identify Problem Facilitators & Problem-Solving Team

- **Problem Facilitators (2)**
 - **Plan and coordinate effort**
 - **Arrange meetings, site visits, guests**
 - **Recruit team participants**
 - **Organize interim & final reports**
- **Team participants (includes facilitators)**
 - **Mix of ages, genders, knowledge, skills**
 - **Unbiased on issue**
 - **Work as equals**
 - **Need self control & commitment**

Slide 23

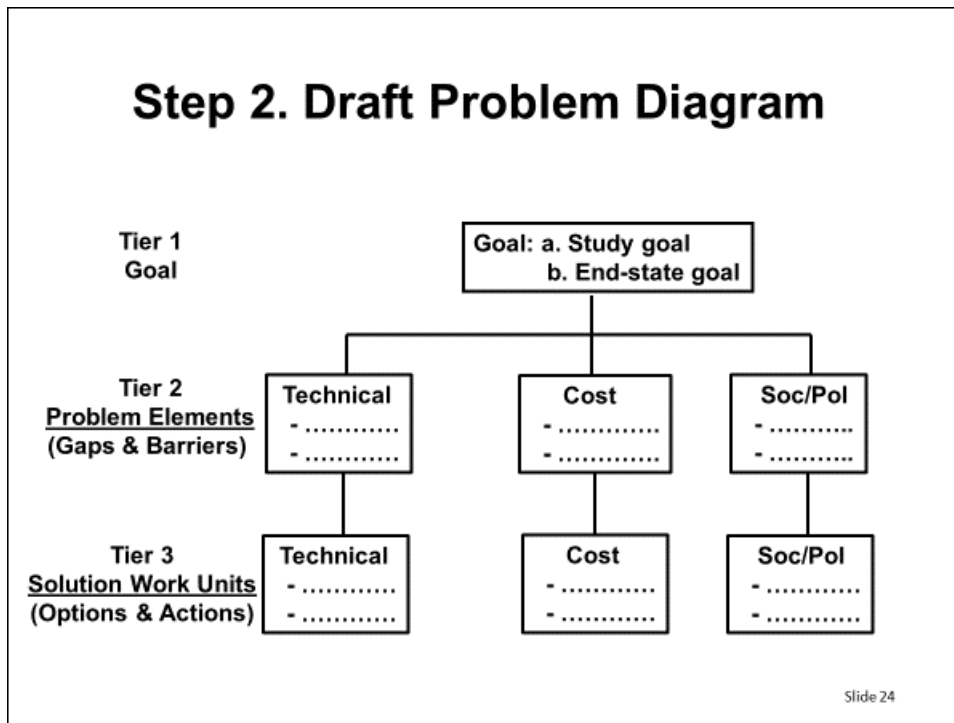
Slide 23. This course is geared to train “problem facilitators.” What do they do? They lead the problem-solving effort by planning and coordinating the work. They arrange meetings (physical or Internet based), site visits and guests. They recruit team members and organize interim and final reports.

We call them “problem facilitators” to emphasize that they lead by planning ahead, by recruiting the team, etc. They lead by facilitating the effort rather than by directing the effort. The responsibility to solve the wicked problem rests with the team participants, including the facilitators; all working together as equals.

To the extent possible, team participants should have a broad mix of ages, genders, knowledge and skills. They should be unbiased on the issues and willing to work as equals. They need to exercise the self-control to honor the WPA values and the commitment to see the effort through to completion.

We refer to team participants rather than team members because the team is not a club that people join. People are team participants while they work together on the problem.

Step 2. Draft Problem Diagram



Slide 24. The next step is to draft a “problem diagram.” Here is a schematic of a problem diagram. The Tier 1 states the overall study (project) goal: What is the desired outcome from the problem-solving effort? In other words, what does the problem-solving team wish to accomplish. The end-state goal states the desired outcome, given that the study goal is accomplished. Accomplishing the study goal is the responsibility of the problem-solving team; whereas, the end-state goal involves actions by others outside of the team, often of higher authority.

For example, a study goal could be to find practical solutions to problem X, while an end-state goal could be to implement the solution to actually resolve problem X.

The elements of the problem are listed in Tier 2. These elements are divided into technical elements: what are the physical gaps, barriers and questions that need to be assessed/answered to understand/ solve the problem?

The Tier 2 cost elements list cost questions that need to be assessed and determined. The Tier 2 social/political elements list the questions and assessments required to understand the political aspects of the problem.

The Tier 3 solution work units state what actions and options that the team will take to address each of the problem elements.

Developing a problem diagram is a way to break a wicked-problem into pieces (elements).

Step 2. Draft Problem Diagram

- **Who drafts? Entire team brainstorms
Problem facilitators document**
- **Obtain town officials input & go-ahead
if effort is in support of a community**
- **Update as effort proceeds (keep on track)**

Slide 25

Slide 25. Who drafts the problem diagram? Ideally the entire team will brainstorm and draft the diagram. Alternately, the problem facilitators draft the diagram and then the entire team goes over it, making changes and additions to reach an initial problem diagram that they all agree on.

If the problem-solving effort is being done in support of a community at the request of town officials, the draft diagram should be reviewed by town officials to obtain their input and go-ahead before initiating the problem-solving work.

A key aspect of the problem diagram is that it is a living document that needs to be updated as the effort proceeds. Keeping the diagram current as new findings and knowledge are obtained helps to keep the entire effort on track.

We mentioned before that wicked-problems cannot be solved by a series of pre-identified steps. So, the solution work units, rather than being a series of steps, are a listing of tasks that are thought to be important in solving the wicked problem. These are included to address questions and relevant gaps in knowledge identified in the problem elements.

Step 3. Plan Problem-Solving Effort

- **Identify events (investigations, workshops...)**
- **Develop event and overall schedule**
- **Identify sub-teams – divide problem**
- **Include learning in each event
(learning atmosphere – inform, motivate,
catalyze creativity)**

Slide 26

Slide 26. To plan the problem-solving effort, identify the events that will pace the effort. Here we use “events” in a broad way. Events can be the individual investigations and tasks taken from the problem diagram. It can include meetings, workshops, site-visits, and experiments. Essentially, events are any pacing work units of the problem-solving effort that can be scheduled.

Then, develop schedules for when the events will occur. Together, the schedule of individual events will provide an overall schedule for the problem-solving effort.

The problem diagram divides the problem into elements to be accomplished – the solution work units. Identify teams, sub-teams, sub-sub-teams as necessary to work on the problem elements simultaneously.

Step 4. Conduct Problem-Solving Effort

- **Set up & initiate events**
- **As the events proceed:**
 - **Gather information**
 - **Identify & evaluate options**
 - **Integrate results**
 - **Update problem diagram & plans**
 - **Prepare minutes or summary reports**
- **Be sensitive to good ideas**
- **Stick to schedule! (In spite of confusion)**

Slide 27

Slide 27. To conduct the problem-solving effort, set up and initiate the events. That is, establish the problem-solving facilitators, teams and sub-teams, divide the solution work units and sub-units among the teams and sub-teams, and begin.

As the work proceeds, document the information and facts obtained, and evaluate the chosen solution options.

Results from the teams and sub-teams need to be integrated periodically as the work proceeds. If progress reports are prepared monthly or bimonthly, then these should be integrated and documented in a monthly/bimonthly integrated update. Since work on all the solution elements occurs simultaneously, the continuous integration of the separate results is key to the success of the wicked-problem approach. Thus, preparing minutes of meetings and summary reports is required for success. The summary reports should be distributed back to all the participants. This feedback of information allows everyone to be updated and provides learning to all participants.

Plans and the problem diagram should be updated monthly/bimonthly as the effort proceeds. These updates along with the monthly/bimonthly updates of results and integrated findings make the WPA an iterative process, which is necessary to solve wicked problems that never offer a clear sequential path.

Experience in using the WPA has shown that good ideas – sometimes critically important ideas – can occur at any time from any participant. So, all participants, and particularly the problem facilitators, must be sensitive to good ideas at all times.

Working on all the solution elements simultaneously rather than on a planned series of steps injects an element of chaos and confusion into the problem-solving effort. The best way to deal with this confusion is not to stop, but to keep going and stick to the schedule. The human mind has an amazing ability to sift, sort, and integrate over time but not immediately. By keeping going, this ability is given a chance to operate and the fog will clear.

Step 5. Prepare Final Report & Present

- **Include**
 - **Goals & description of effort**
 - **Options considered & evaluated**
 - **Results & recommendations**
 - **List of team members & acknowledgements**
- **Peer review**
- **Present to Town or other officials for input**
- **Finalize and distribute**

Slide 28

Slide 28. As the wicked problem is “solved” – a compromise of technical, economic, and social/political factors – the teams and sub-teams will need to document their final results and recommendations into a final report.

At a minimum, this report should include the goals and description of the effort. It should present the options considered and the evaluation results along with final recommendations. All team and sub-team members should be listed.

The draft report should be peer reviewed by others not associated with the effort and then presented to the town and its officials or to other relevant officials, as appropriate, to obtain their input. Approval of the final report by officials is not required because the objective of the WPA is a fact-based, independent problem solution free of political and corporate influence. That said, the social/political elements included in the problem are there to objectively evaluate social/political factors with the goal of reaching a practical solution that is technically feasible and effective, economically supportable, and socially/politically implementable. The final report should then be published, distributed, and presented as appropriate.

Step 6. Follow-up as requested by town & other officials

Examples:

- **Presentations**
- **Pilot test results**
- **Implement recommendations**

Slide 29

Slide 29. Solving a problem using the WPA results in a group of participants that have a depth and breadth of knowledge about the problem and a unified view on the solution. This educated and focused group is now a valuable resource in its own right. These people are often called upon for follow up work.

For example:

Participants are sometimes asked to present their results to a local community to vote on, or to government officials deciding policy questions.

To reduce risk, some recommendations may need to be pilot tested before implementation.

Participants are sometimes asked to help to implement their recommendation.

Overview of WPA

- **Bring people together & focus**
- **Iterative, open, flexible**
- **Structured, proven, fact-based**
not
Unstructured, ad hoc, opinion-based
- **Tap full human potential – think hard!**

Slide 30

Slide 30. Quick review. The WPA:

1. Brings people (volunteers) together and focuses them on a wicked problem.
2. It is iterative, open and flexible to new ideas, new facts, and new participants as the effort proceeds.
3. It is a structured, proven, fact-based approach (it is disciplined!),
rather than
an unstructured, ad hoc, opinion-based approach (too often the default).
4. Its overall goal is to tap the full human potential to solve wicked problems.

Break Time!

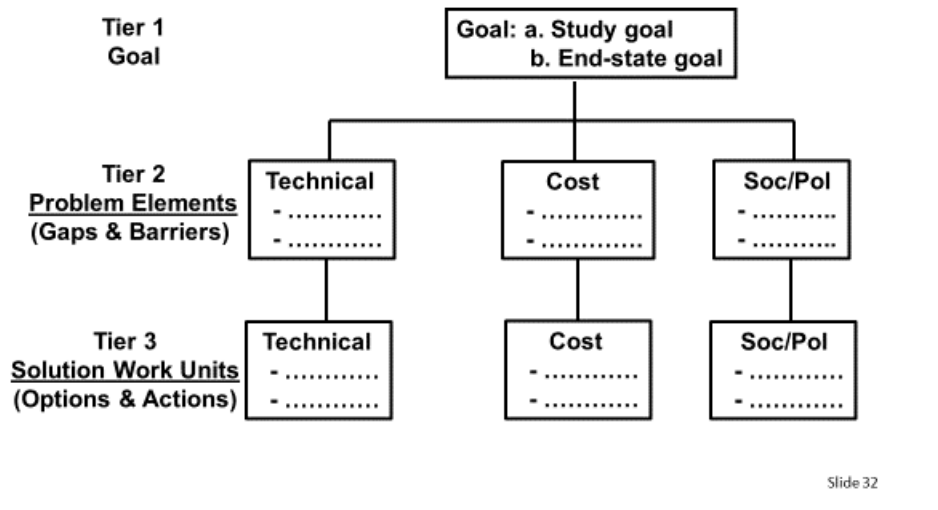
Session 2, Part 2

Problem Diagram

Slide 31

Slide 31. We now come back to focus more on the problem diagram since it provides the starting point for solving a wicked problem.

Step 2. Draft Problem Diagram



Slide 32. Here again is our schematic of a problem diagram. Please look at it again and discuss any questions that you may have.

Purpose of Problem Diagram

- **Define problem (Tier 1)**
 - **Study goal: What team will accomplish**
 - **End-state goal: Overall purpose**
- **Identify study needs – knowledge gaps, barriers... (Tier 2)**
- **Identify options & team actions to fill needs (Tier 3)**

Slide 33

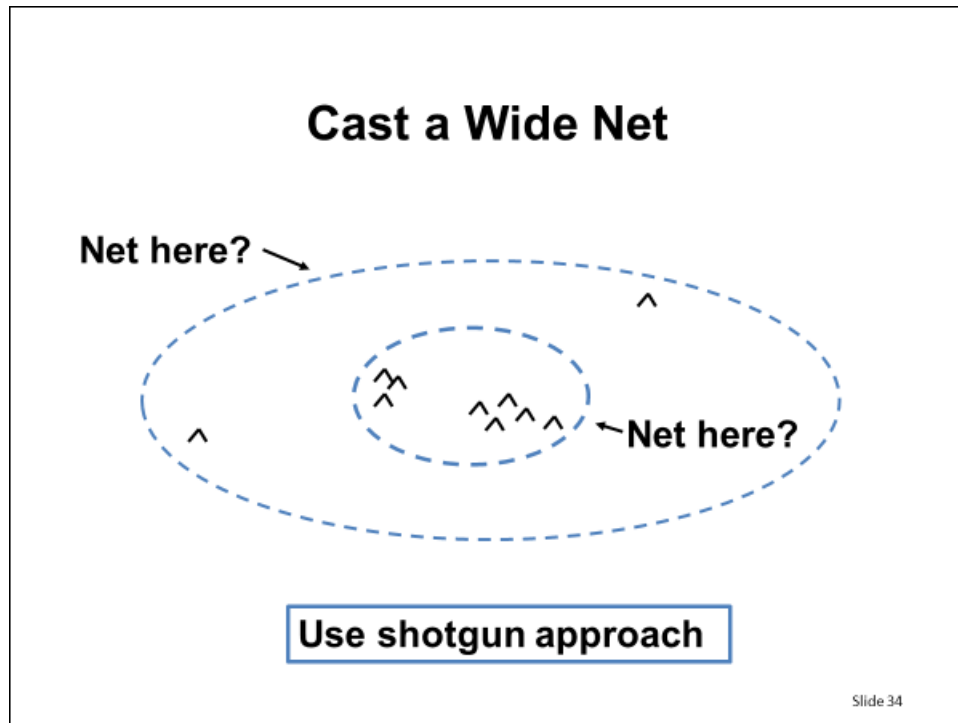
Slide 33. Does having a Tier 1 study goal of what the team will accomplish versus an end-state goal of the overall purpose or outcome make sense?

Any questions about the Tier 2 problem elements that include questions, knowledge gaps, barriers that need to be overcome?

Also, we divide these into technical, economic and social/political elements. Technical refers to all the physical and technical questions of the problem. Everything other than economic and social/political elements is a technical element.

The Tier 3 solution work units include all the options and actions that the team and sub-teams will consider and the work they will perform.

You will be working on a solution work unit shortly, and you may have more questions then.



Slide 34. There is a subtle aspect of the problem diagram that we have implied that must be clear to you.

It is this: Since there is no clear series of steps that we can lay out to solve a wicked problem, we brainstorm the problem elements and solution work units that we think are needed to solve the problem, and then we work on these simultaneously. (They are our best educated guesses.)

We do not know that these are the only or needed work units, and we do not understand how they actually interact.

To use an analogy, if we were trying to net a school of fish and we see a few rising here and there and a higher number in the middle, how would we cast our net? Since we do not really know where the center of the school actually is, wouldn't we try to cast wide to encompass all of the rising fish?

We try to do that in developing the problem diagram. We would not want to include elements that we feel have no relevance since the amount of work to address the issue increases with the number of elements. However, we do want to include all the elements that we feel may well have relevance. If we leave an important element out, we will likely discover it later in the effort, but rework may be required. The compromise is to include as many elements as makes sense. This is essentially a shotgun approach; the best we can do. Makes sense/questions?

Brainstorm Problem Diagram

Use Example Wicked Problem from Session 1

Remember:

- **Non-wicked problem – solve in steps**
- **Wicked problem – cast net wide**

Slide 35

Slide 35. Now we are getting into the heart of the course – student exercises.

Together, we want to now brainstorm a problem diagram. Pick one of the wicked problems that you came up with in Session 1.

Remember: wicked problems, cast a wide net; non-wicked problems, develop solutions in identified steps.

Go ahead and together brainstorm a problem diagram for the example problem.

Now Divide into Facilitator Pairs

**Choose another example problem
that you came up with in Session 1**

**Your student assignment will be for
you and your partner to brainstorm
a problem diagram for your example**

Slide 36

Slide 36. Before leaving today's session, would you please divide into pairs of facilitators. Together in pairs you will be role-playing facilitators. You can have a group of three facilitators if the pairs do not evenly work out. It is important that you have at least one facilitator partner.

Session 2, Part 3

Rationale - Why are we here?

Slide 37

Slide 37. The WPA has a number of layers. There are the steps that we reviewed. There is the understanding of these steps and what is really necessary – the self-discipline part of the WPA. Then, there is an even more basic question of rationale, and why are we doing this.

Let me share some thoughts on the latter. You can think about it later.

Truth-Based Problem Solving

What do we mean?

- **Rely on facts, discourse, rational analysis**
- **Integrate information & evaluate options**
- **Bottom up, not top down**
- **Open to full human potential**

Slide 38

Slide 38. What we are trying to accomplish in an overall sense is truth-based problem solving. It is also fact-based, but “truth” is a more general term that includes using facts in an honest way. We all know of how “the facts” can be presented in a self-serving way to confuse an issue.

With truth-based problem solving we rely on facts, discourse and rational analyses. This is the best we can do.

We integrate the results and information and evaluate options against fixed criteria.

This approach is inherently bottoms-up rather than a top-down directed approach.

In this way, the door is open for people to apply their full human potential to solve the problem. (Motivated to think as hard as possible!)

As Opposed to: *Power-Based* Problem Solving

What do we mean?

- **Directed from above (power structure)**
- **Power, party, profits, ideology dominate**
- **Truth often discarded or not sought**
- **Human potential not fully utilized**

The standard political process

Slide 39

Slide 39. With power-based problem solving:

Answers and or doctrine are directed from above through the power structure

Power, party, profits, ideology dominate

Truth is often discarded or not sought

The human problem-solving potential of those not in power structure is often bypassed

Is this a standard political and corporate process?

Theory of Truth

- **Theory: If discard or not seek truth, operate on false premises & incur cost of error***
- **People bear cost: casualties, national debt (Vietnam & Iraq Wars)**
- **Problem: Power-based problem solving often discards or does not seek truth**

*** Original statement: "So what is there after discarding the truth but error?"
(Prophet Muhammad, *Quran*)**

Slide 40

Slide 40. Unfortunately, when we discard or do not seek truth as in power-based problem solving, there is a cost to bear: We operate on false premises and incur a cost for the error.

Theory of truth as first stated in the *Quran*: "So what is there after discarding the truth but error?"

Do you think this theory is correct?

Why We are Here

Apply truth-based problem solving to wicked problems

- Obtain unbiased, practical solutions**
- Apply full *human potential* (all we have)**

**Why bother? ...for us, our collective wellbeing,
(We are all “a part of the main!”)**

Slide 41

Slide 41. So, why are we here?

We want to apply truth-based problem solving to wicked problems to:

Obtain unbiased, practical solutions

Apply full human potential, which is the best that we have

The collective wellbeing of all affects each one of us – we are all “a part of the main” (from “For Whom the Bells Toll” poem)

Questions, discussion?

Student Assignments

- 1. Each pair meet and brainstorm problem diagram for your example problem**
- 2. Review slides – gain understanding**
- 3. Answer review questions**

Plan your next session: date, time, place

Slide 42

Slide 42. If you have any questions, please discuss them and try to resolve them among yourselves.

Here is work for you to do prior to the next session.

1. Each pair meet and brainstorm a problem diagram for a wicked problem that you identified in the first session.
2. Review the slides and narrative to gain understanding of the WPA.
3. Each pair meet prior to the next session, and review your problem diagram to be sure it reflects your best thinking and encompasses all of the likely problem elements.
4. Answer the Session 2 review questions listed below prior to the next session.

Review Questions, Session 2

1. How would you describe the WPA?

2. What are the six steps in the WPA? (Use short descriptors.)

3. What is the consequence of discarding truth?

4. What are the three tiers of a problem diagram?

5. Why cast a wide net in addressing wicked problems?

Session 3

Session 3

Wicked-Problem Approach

Facilitator Training

Project Management & Planning

Welcome

Slide 44

Slide 44. Welcome to Session 3 of facilitator training for solving wicked problems. In this session we will address project management and planning.

Discuss answers to questions

**Share and discuss problem diagram
from each facilitator pair**

Slide 45

Slide 45. Answers to questions from last session.

1. There are a number of aspects of the WPA so you may all describe it differently. I might call it a structured, proven, fact-based approach for solving wicked problems.
2. The six steps of the WPA are:
 - 1) Identify problem facilitators and team participants.
 - 2) Draft problem diagram
 - 3) Plan the problem-solving effort
 - 4) Conduct the problem-solving effort
 - 5) Prepare final report
 - 6) Follow up as requested
3. When you discard truth, you likely make decisions based on false premises and arrive at invalid solutions. You incur a cost from implementing invalid solutions.
4. Tier 1 contains the study goal and end-state goal; Tier 2 lists the problem elements; and Tier 3 lists the solution work units.

5. Since the problem elements of a wicked problem cannot be known with certainty at the outset of the problem-solving effort, we try to include all of the elements in the problem diagram that we feel may be a part of the problem, thereby casting a wide net so as not to overlook an important element of the problem.

If you have two or more problem-facilitator pairs in the session, please exchange the problem diagrams that you developed since the last session and discuss them.

Session 3, Part 1.

**Project Management
Basics**

Slide 46

Slide 46. In Part 1 of Session 3, we will look at the basics of project management and how they can be adapted to solving wicked problems.

Project Management Approach

- **Go from point A to point B**
- **Focus on defined end point (study goal)**
- **Divide work into units (work simultaneously)**
- **Perform each work unit in series of steps**
- **Evaluate and integrate work unit results**

Slide 47

Slide 47. The most fundamental aspect of a project management (problem-solving) approach is to go from point A to point B. In this case, we define point A as the problem and solution work units in our problem diagram. Point B is the study goal we seek to fulfill.

The effort focuses on that defined end point B, and other factors that are deemed irrelevant to reaching that end point are ignored.

We divide the work into units (solution work units/sub-units) and work on all the work units simultaneously.

Work on each work unit should, and usually can be worked on with a series of defined steps.

Results on all the work units are summarized periodically (ex. monthly/bimonthly), and then evaluated and integrated across the work units to see how the results fit together.

The ongoing process of work, evaluation, and integration is repeated throughout the problem-solving effort until the best practical solution(s) is identified.

This iterative tactic is key to the success of the WPA. It is how we deal with the uncertainty of wicked problems. The result is a repeated sifting-sorting-integrating of results from the work units until a best practical solution evolves.

Project Management Tools

- **Gather and analyze information/data**
 - **Site visits**
 - **Field exercises**
 - **Expert presentations**
 - **Anything as required**
- **Evaluate & compare options**
 - **Technical (feasibility & effectiveness)**
 - **Cost (investment and yearly costs)**
 - **Social/Political (acceptability)**

Slide 48

Slide 48. Overall, the project management tasks are to gather and analyze information and data. The tools to do this are many and for wicked problems include anything that is needed. Listed on the slide are several ways to gather information and data such as:

Site visits to see a problem first-hand

Field exercises to try out possible solutions or to observe aspects of the problem

Expert presentations to bring in knowledge from outside the problem-solving group

Another key tool is to evaluate and compare the identified options. Each option needs to be evaluated for its technical feasibility and for its effectiveness in helping to solve the wicked problem. The costs of the options, both the initial investment costs and the ongoing yearly costs need to be estimated and compared between the options. Thirdly, the social/political acceptability of each option needs to be identified and compared. Best practical solutions must be a balance of these three criteria. For example, a solution that is feasible, low cost and socially/politically acceptable, but which does little to solve the problem is not a practical solution.

Why Necessary?

- **Without end point, effort wanders**
- **Without structure, confusion increases**
- **Without parallel work units, effort drags**
- **With structure, work known & doable**
- **With end point, effort focused**
- **With steady progress, people motivated**

Slide 49

Slide 49. Why do we use this basic project management approach?

If we do not have an end point the entire effort will wander and likely never reach a practical solution.

Without some level of structure through the problem diagram, by defining of work units, and through periodic reporting, evaluating and integration of results, the entire effort will become confused and bog down.

Work on all of the work units is performed in parallel (simultaneously) to allow progress to proceed at a reasonable rate and to allow the iterative aspect of the WPA to function. Otherwise, the effort would drag and confusion would increase.

Conversely, with the WPA structure the separate work units can be accomplished and steady progress can be made. Making steady progress is a key motivator of people. When forward progress stops, people lose interest, and the problem-solving potential of the team dissipates.

What's Novel in WPA?

- **Standard project management except:**
 - **Accomplish all work units in parallel**
 - **Periodically evaluate & integrate results**
 - **Iterate (repeat) process until solution found**
 - **Periodically update problem diagram**
- **Rely on learning + rational analysis + creativity + integration to solve problem (Not on a series of known steps)**

Sometimes described as “controlled chaos”

Slide 50

Slide 50. While the WPA is based on standard project management approaches, it has the following unique aspects:

All of the work units are accomplished in parallel rather than sequentially

Throughout the effort, results on all work units are periodically evaluated and integrated.

These steps are repeated over and over until a best practical solution is identified.

The entire process is flexible. The problem diagram and plans are updated as the work proceeds and new insights and results occur.

Now, the scary part. Rather than relying on a known series of steps, and applying known and proven methods (as in standard engineering project management), we are relying on people's learning, rational analysis, and *creativity* along with integration and iteration to solve the problem.

We know of no other way to solve wicked problems that have never been solved before and that offer no roadmap.

Some people that used this WPA described it as “controlled chaos.” Admittedly, there is some truth to that observation.

Session 3, Part 2

Plan Problem-Solving Effort

Slide 51

Slide 51. Let us now turn to your student assignment: to plan your problem-solving effort using the problem diagram that you developed since the last session.

Plan Problem-Solving Effort

For each solution work unit in your problem diagram:

- Identify how you will accomplish that work unit – the steps you will take**
- What options will you consider**
- Plan events (workshops, site visits...)**
- Develop work units and overall schedule**
- Include learning in each work unit**

Slide 52

Slide 52. To plan your problem-solving effort, look at each solution work unit in your problem diagram.

For each work unit, identify how you will accomplish that work unit. What steps you will need to take. Just to clarify, while wicked problems cannot be solved with a pre-determined series of steps, the individual work units should be solved by a series of planned steps. If the work unit is too complex to plan a series of steps, then break it into sub-work units that can each be accomplished by a series of steps. Then, integrate the results from the sub-work units for the entire work unit.

Identify for each work unit what options you plan to investigate and evaluate and the steps needed to investigate each option.

As a part of planning to accomplish each work unit, identify the types of events (expert presentations, field tests, analyses...etc.) that are needed.

Then, develop a schedule to accomplish each work unit and associated events, and compile these into an overall schedule for the problem-solving effort.

Give consideration of how learning will be included in each work unit. Learning catalyzes creativity and is an important part of the WPA.

Brainstorm Evaluation Criteria

Describe how to rank options (ex. high, medium, low) for the 3 evaluation criteria:

- **Technical feasibility and effectiveness**
- **Cost, investment and recurring costs**
- **Social/political acceptability**
- **Plan to use the same 3 criteria and ranking for each option**
- **Think backwards: Will each work unit provide information needed for evaluation?**

Slide 53

Slide 53. Each option resulting from the problem-solving effort will need to be evaluated for its:

1. Technical feasibility and effectiveness in solving the problem
2. Cost including both investment and recurring costs
3. Social/political acceptability

To rank and compare each option against these criteria, you need to define high, medium and low scores for each of the 3 evaluation criteria.

Note: It is often best to use the cost estimates for each option directly to rank the options from the highest to the lowest costs rather than set dollar bars for high, medium and low scores.

With your criteria thus defined, review each work unit to see if it will provide the information needed to allow for the evaluation. If not, then adjust the work unit so that it will provide the needed information.

Questions, discussion?

Student Assignments

- 1. Each pair plan effort for your problem**
- 2. Review slides – gain understanding**
- 3. Answer review questions**

Plan your next session: date, time, place

Slide 54

Slide 54. If you have any questions, please discuss them and try to resolve them among yourselves.

We end the session here, but each pair can stay and work on their student assignment, which is to plan out your problem-solving effort according to the slides just presented and your problem diagram.

Prior to your next session, please review the slides to increase your understanding and answer the review questions.

Go ahead and plan when you will meet for your next session.

Review Questions, Session 3

1. What are three key aspects of project management?

2. What are three key tools of project management?

3. What are the three evaluation criteria for each option?

4. What are three key reasons for using project management?

5. What is novel in using project management on wicked problems?

Slide 55

Session 4

Session 4

Wicked-Problem Approach

Facilitator Training

Leadership &
Problem-Solving Team

Welcome

Slide 56

Slide 56. Welcome to Session 3 of facilitator training for solving wicked problems.

Discuss answers to questions

**Share and discuss program plan
from each facilitator pair**

Slide 57

Slide 57.

Answers to questions from last session.

1. Three key aspects of project management include:

Go from point A (problem diagram) to point B (study goal)

Divide work into executable work units

Periodically update progress, evaluate and integrate results

2. Project management tools include anything required to do the job such as expert presentations, site visits, experiments...

3. Three evaluation criteria to evaluate different solution options:

Technical feasibility and effectiveness in solving problem

Costs including initial investment and yearly costs

Social/political acceptability

4. Key reasons to use project management approach include:

Focus effort on end point

Work on structured work units that are known and doable

Achieve steady progress to keep people motivated

5. Novel aspects of project management for wicked problems:

Do all work units in parallel since no known sequence of steps exists

Evaluate and integrate results periodically as effort progresses

Iterate process until a best practical solution is achieved

Would you now please share and discuss the project plans that you developed since the last session.

Session 4, Part 1

Team Leadership Basics

Slide 58

Slide 58. We will begin by looking at team leadership basics and consider how it is applied to solving wicked problems.

“Leadership” Sometimes Described:

“like herding cats”

Can be Mind-Numbingly Complex

Practical Approach: Deal with Basics

Slide 59

Slide 59. Leading a group of people, particularly volunteers, is a little like herding cats. The natural tendency is to go in all directions and ignore the facilitators.

To objectively figure out how to lead people can often be mind-numbing, perhaps even impossible.

The best way is to stick to basic approaches grounded in truth, compromise and goodwill, and depend on the people to do their thing without excessive guidance and oversight.

Purpose of Team Leadership

- **Focus** people on issue & effort
- **Motivate** people to think/work hard
- **Enable** people to contribute

Slide 60

Slide 60. Overall, team leadership seeks to:

Focus people on the issue and the problem-solving effort

Motivate people to think and work as hard as possible on the problem

Enable (help) people to contribute

Team Leadership Basics

1. Use WPA purposefully

- **Problem diagram to understand & focus**
- **Form sub-teams to divide work & foster individual participation**
- **Include learning to inform & motivate**
- **Use unbiased participants, avoid politics**

Slide 61

Slide 61. The WPA is designed to assist team leadership by:

Having a problem diagram so that all team participants can understand the problem. The solution work units help to focus people on the effort.

Dividing into sub-teams and sub-sub teams corresponding to the work units allows for more individual participation. If three people work together on a problem, then each person normally communicates more with the others than when 10 people work together. In other words, smaller groups foster more individual participation and individual contribution.

Learning in all problem-solving activities is needed to acquire the necessary information, but learning also motivates and encourages *creativity*. Learning also comes by periodically sharing the results from all sub-teams as the effort progresses.

To the extent possible, it is best to have unbiased participants on the problem-solving teams to avoid political or self-serving influences. All of us have some biases, but we can consciously control our biases knowing that we are working together to reach honest, unbiased solutions to a pressing problem.

People that have vested interests in the solution to the problem should not be a participant on the problem-solving team. The effort must be independent of outside control or influence to result in honest, unbiased

solutions. However, stakeholders who do have a vested interest in the outcome should not be ignored. Rather, they should be queried for their opinions and suggestions as the problem-solving progresses. The participant teams can then use this input to evaluate social/political realities. Stakeholders may include political authorities, corporate executives, the public and others. In this way the evaluation of social/political factors can be tied to the real world rather than speculation.

Team Leadership Basics

2. Support team along the way

- **Encourage rather than direct to have self-motivated volunteers**
- **Insure sense of progress by working on doable work units**
- **Build confidence – recognize creativity, progress, contributions, challenges**
- **Focus on facts & truth, avoid politics**

Slide 62

Slide 62. Team leadership involves more of a supporting than a directing role.

It is better to encourage people than to direct them in order to have self-motivated volunteers.

Insuring a sense of progress by working on doable work units is key to keeping people motivated.

The confidence of team participants can be increased by recognizing creativity, progress, and contributions/challenges overcome. Confidence leads to self-motivation.

An honest problem-solving effort must focus on facts and truth to achieve valid results. Most people function using truth and facts, and most people are intimidated and turned off by political, self-serving arguments and atmosphere. Therefore, team leaders need to continuously emphasize truth and facts over opinions and strive to keep an open atmosphere based on truth, compromise and goodwill.

Team Leadership Basics

3. Ongoing Communications

Face-to-face in meetings, events

By phone calls

By e-mail



“Problem facilitators” *must* communicate

Slide 63

Slide 63. Communication is fundamental to all problem-solving efforts. Face-to-face meetings and dialogue allow for the most effective exchanges. However, getting people together in one place physically takes time and money. E-mail followed by phone calls are other approaches that are less effective, but much easier and more convenient.

No matter what forms of communication are used, it is critically important that “problem facilitators” communicate frequently. We put problem facilitators in quotations to indicate that it is a term that we use for the leaders of teams and sub-teams.

Team Leadership Basics

4. Problem facilitators versus problem solvers

- **Sometimes easier to do yourself**
- **If effort is not facilitated, team suffers**
- **Compromise: Facilitate team first, fill in gaps second**

Slide 64

Slide 64. One thing that a problem facilitator will face is when to jump in to help on solving the problem rather than facilitating the effort. There are situations when it is easier and quicker to do something yourself. However, if that detracts from your ability to lead and facilitate the team, then the entire team suffers along with the work. A compromise may be to do your facilitation job first, and then help the effort to the extent that you can.

Team Leadership Basics

5. Dealing with workload

- **Need two facilitators/team**
 - Back up, if one is away
 - Share work
 - 2 minds = 3x1 mind
- **Helpful: one focuses on *project management* & other on *team leadership***
- **May need problem-facilitator team**

Slide 65

Slide 65. The workload of problem facilitators is considerable and continuous.

Experience has shown that two problem facilitators are needed for each problem-solving team. Two facilitators may also be required for each sub-team and sub-sub team depending on the size of sub-team and scope of effort. Certainly, any sub-team of 5 or more people would benefit from having two problem facilitators. Facilitators will have more time to work on problem-solving if the sub-team is small.

The reason for having two facilitators on each team is so there is a backup if one is away. It also allows for a sharing of work and doing a better job since two minds are about three times as good as one mind.

Facilitators may want to divide their workload with one focusing on project management tasks and the other focusing on team leadership. In this way, both aspects are addressed continuously and one or the other does not become ignored. Also, some people are more comfortable with one rather than the other.

The two problem facilitators may need the support of a team of people to accomplish all of the work necessary to support very large problem-solving efforts like global warming.

Session 4, Part 2

Problem-Solving Team

Slide 66

Slide 66. Let's turn our attention now to the problem-solving team and sub-teams.

Types and Numbers of People

Base on problem diagram work units:

- **Team participants (includes facilitators)**
 - **Mix of ages, genders, knowledge, skills**
 - **Unbiased on issue**
 - **Work as equals**
 - **Need self control & commitment**
- **Numbers of people: minimum two/sub-team**

Slide 67

Slide 67. The types and numbers of people on the teams and sub-teams is based on the solution work units in the problem diagram.

Each team should have a mix of ages, genders, knowledge and skills to assure that the efforts have broad input and to reduce the likelihood that an important factor is overlooked.

As mentioned before, team participants should be unbiased or at least able to control their biases to arrive at honest, truthful results.

All participants will need to work as equals, including the problem facilitators who mainly assist rather than direct.

The WPA is a disciplined approach that requires participants to exercise the self-control to do the work thoroughly and accurately without cutting corners and to have the commitment to see the effort through to completion.

No sub-team should have less than two participants and generally, should have three or more.

Student Exercise:

Brainstorm Problem-Solving Team and Sub-teams

Use example problem diagram and plan:

- Types of people**
- Numbers of people for each team & sub-team**

Slide 68

Slide 68. You are now ready for another student exercise: to brainstorm your problem-solving team.

Based on your problem diagram (the solution work units) along with your plans from the last session plan, go ahead and brainstorm for each team and sub-team: the types and numbers of people needed for each team and sub-team.

As with all the student exercises, please record your results so you can review them at the beginning of the next exercise.

Brainstorm how you will:

- **Focus participants on issue & effort**
- **Motivate participants to think/work hard**
- **Enable participants to contribute**

Slide 69

Slide 69. Now you may go ahead and brainstorm how you will go about focusing the participants on the effort and issue; how you will motivate the participants and enable each to contribute.

Summary

- 1. Use WPA structure, learning environment, and basics to Focus, Motivate & Enable**
- 2. Everyone has a personal style (art)**
- 3. Underlying principle: Maintain problem-solving environment of truth, compromise and good will**

Slide 70

Slide 70. Summary. We use the WPA to provide: a structure for the effort, a learning environment, and the basics of team leadership. Why? To focus, motivate and enable the participants.

As in all forms of leadership, everyone has a personal style, which is really an art. The basics presented here are to help all facilitators be successful in their role as they apply their own personal style.

If there is one underlying principle and requirement of the WPA, it is to maintain a problem-solving environment of truth, compromise and good will.

Questions, discussion?

Student Assignments

- 1. Each pair develop team & sub-team composition and plan how to focus, motivate & enable participants**
- 2. Review slides – gain understanding**
- 3. Answer review questions**

Plan your next session: date, time, place

Slide 71

Slide 71. Please discuss among yourselves any questions that you have.

Prior to the next session, please complete your planned team and sub-team composition (types and numbers of participants) and how you would go about focusing, motivating and enabling the team and sub-team participants.

Review the slides from this session to further your understanding and answer the review questions.

Review Questions, Session 4

1. What are the key objectives of team leadership?

2. What is built into the WPA to achieve these objectives?

3. How can facilitators support the team?

4. What are three key tools used in team leadership?

5. How would you deal with the workload of being a facilitator?

Slide 72

Session 5

Session 5

Wicked-Problem Approach

Facilitator Training

Problem-Solving

Welcome

Slide 73

Slide 73. Welcome to Session 5 of facilitator training for solving wicked problems. This session will focus on problem-solving.

Discuss answers to questions

**Exchange & discuss team composition
plan and your plan to focus, motivate
and enable team participants**

Slide 74

Slide 74.

Please discuss your answers to the questions from last session. Instructor answers are below.

1. The key objectives of team leadership are to focus, motivate and enable the participants.

2. The WPA supports these objectives in the following ways:

The problem diagram helps to focus the participants on the end objective and the work units.

The work is divided into work units that are doable and allow for a sense of progress, and the participants are divided into smaller sub-teams, which allows for more individual participation.

Learning is included throughout the problem-solving effort through the need to gather information (facts) to perform the work units and by sharing information and progress between all team members as work progresses.

3. Problem facilitators support the team and sub-team by:

- Encouraging rather than directing

- Insuring a sense of progress by having doable work units

- Building confidence through recognition of individual contributions

- Encouraging participants to celebrate successes

4. Facilitator's workload, which is ongoing, can best be dealt with by:

Having two facilitators for all teams and sub-teams

Having a facilitator team supporting the two facilitators for very large projects

Facilitators giving first priority to their supportive work and only help with problem solving if they have the time to do so

You should now share and discuss your team composition plans and your plans to focus, motivate and enable the team participants that you completed at or since the last session.

Session 5, Part 1

Problem-Solving Effort

Slide 75

Slide 75. In Part 1 of this session we will look at the problem-solving effort.

Basic Problem-Solving Activities

As work progresses:

- **Gather information**
- **Identify & evaluate options**
- **Prepare minutes of meetings & periodically summarize progress**
- **Integrate sub-team results**
- **Update problem diagram & plans**
- **Be sensitive to good ideas**
- **Stick to schedule! (In spite of confusion)**

Slide 76

Slide 76. Gathering information through literature and web searches, from expert consultations, from site visits, experiments, etc. is a continuous task throughout the effort.

Identifying, investigating and evaluating different solution options against the three criteria is also ongoing.

The sub-teams need to periodically summarize progress and to integrate results. These then need to be integrated across the sub-teams to see progress in solving the entire problem. The integrated results and updates are then shared with all the team and sub-team participants. The periodic updates may be monthly or bi-monthly (every other month)

The problem diagram should be updated periodically as options and work units are added or discontinued so that it reflects the current picture of the entire effort.

Throughout the effort, all facilitators and participants need to be sensitive to good ideas so they do not fall through the cracks.

Because of the complexity of wicked problems, and the need to work on all the work units in parallel, there will likely be times of confusion. Experience has shown that the best way to deal with confusion is to keep

going – stick to your plans and schedule. Given some time, people have an amazing ability to integrate results and see through complexity. In other words, keep going, and the fog will clear!

Between Events & Periodic Updates

- **Accomplish agreed-to tasks
(individuals & sub-teams)**
- **Series of events & periodic updates provide
an iterative approach**
- **Allow time for people to integrate
information & results**

Slide 77

Slide 77. Between events and periodic updates, work should progress and individuals and sub-teams should accomplish their agreed-to tasks.

This series of events and periodic updates provides an iterative problem-solving approach.

The time between the events and updates allows time for people to integrate information and results, which adds to their understanding and creativity.

Brainstorm Problem-Solving Effort for Your Example Problems

- **Actions at each event & between updates?**
- **Integration of information & results**
- **Evaluation of options – apply criteria**
- **Project Management?**
- **Team leadership?**

Slide 78

Slide 78. Each facilitator pair should now brainstorm their problem-solving effort for their example problem. Use your problem diagram, project management and team-leadership plans as a starting point.

Decide what tasks your team and sub-teams need to accomplish at or between scheduled events and periodic updates.

Plan how and where among the team and sub-team you will evaluate options against the three criteria.

Plan how to periodically integrate and update sub-team results and to then share the updates with all participants.

Look over your project management and team leadership plans to see if they need any revision.

Session 5, Part 2

Problem-Solving Specifics

Slide 79

Slide 79. We will now consider some of the specifics of problem-solving that are needed to solve wicked problems.

Technical Feasibility & Effectiveness Evaluation

- **Technical feasibility:**
 - **Is some physical device or action possible?**
 - **Commercially available device or routine actions generally feasible**
 - **Items in R&D and non-routine actions require expert evaluation**
- **Effectiveness:**
 - **Estimate extent device or action solves problem**

Slide 80

Slide 80. Technical feasibility addresses the question: Is the device or action possible?

Devices that are commercially available and actions that are routine are generally feasible. If these are being used in a new and novel way, then expert evaluation is needed.

Conversely, items that are in research and development (R&D) or non-routine actions will require evaluation by experts such as engineers with the needed knowledge. The needed experts can ideally be included in the team and sub-teams or their assistance acquired from outside.

The technical feasibility of different options is usually ranked as high, medium or low.

Effectiveness addresses the question: To what extent does the device or action solve the problem? In highly complex problems such as stabilizing the earth's environment, detailed technical analysis by technical experts will be required. With most options, the team and sub-team can evaluate effectiveness on a relative basis between options.

The effectiveness of different options is usually ranked as high, medium or low.

Cost Evaluation

- **Need costs for valid comparison of options (not exact “to-build” cost estimates)**
 - **Estimate investment costs (building cost...)**
 - **Estimate yearly costs (operations, maintenance)**
 - **Divide investment costs/useful life* = \$/yr.**
 - **Sum yearly + investment costs/yr. = total \$/yr.**
- * Estimate useful life based on available information and participant knowledge**

Slide 81

Slide 81. Costs for the different solution options need to be evaluated with enough accuracy to allow for a valid comparison of options. The costs do not need to be exact (such as quoted costs to build or supply items, although these are fine if available).

All investment costs (such as the building or purchase cost) associated with an option and the yearly recurring costs need to be estimated.

Divide the investment cost by the number of useful years that the investment will last. Then add the investment/year to the other yearly costs to obtain the total average yearly cost for the option. The estimated useful life of an investment should be based on available information and participant or other expert knowledge.

These total average yearly costs can then be used to compare the different options. The ranking of options will reflect their relative costs from lowest (most desirable) to highest (least desirable).

While each option will usually have a cost, they may also yield a cost advantage by creating new jobs and by avoiding the need for other existing and more costly operations. A cost-benefit analysis is needed to evaluate these factors. If such analysis is important to solving a particular wicked problem, then people skilled in such analyses need to be included or available to the teams and sub-teams.

Social/Political Evaluation

- **Social/Political evaluation – can device or action be practically implemented?**
- **May be based on citizen surveys or interviews with political & corporate leaders**
- **Evaluation and ranking of options done by team and sub-teams**

Slide 82

Slide 82. The social/political evaluation answers the question: Can the device or action be implemented given the social and political realities?

Information on social/political acceptability of different options can be obtained through citizen surveys and interviews with political and corporate leaders.

The team and sub-teams can then evaluate the information and rank the options as high, medium or low within social/political acceptability.

Types of Solutions

- **Simple, practical solutions**
 - **Technically feasible & effective**
 - **Cost affordable**
 - **Socially/politically acceptable**
- **Adequate OK (ultimate or ideal not required)**
- **“Evaporating cloud” – change system to make problem go away**

Slide 83

Slide 83. What type of solution are we looking for from the WPA?

Overall, the solution needs to be technically feasible and effective in solving the problem. It needs to be cost affordable, and it needs to be socially/politically acceptable so that it can be implemented. Generally, these three factors must be balanced in selecting a best-practical solution to the problem.

The best practical solution may not be the ultimate or ideal solution because such solutions for a wicked problem may not exist or ever be identified.

An adequate best-practical solution is OK!

Another type of solution for wicked problem is called an “evaporating cloud” solution. Such solutions change the underlying system that caused in the wicked problem so that, over time, the problem goes away. Such solutions may not exist or be possible for a given wicked problem, but the possibility of such solutions should not be overlooked.

Confusing Periods – Expected!

- Keep going with planned events
(project management)**
- Rely on learning and iterative approach
(WPA structure)**
- Keep “pulling on the oars”
(team leadership)**

In time, the fog will clear

Slide 84

Slide 84. I know that we have considered confusing periods before; because they can threaten an otherwise successful effort; and because the problem facilitators will be the point people to deal with such periods, let us go over them one last time.

When confusion occurs, the best things to do are:

- 1) Keep going with the planned events and work units by sticking to on project management plans.
- 2) Rely on the learning and the iterative approach built into the WPA.
- 3) Use team leadership to encourage all the participants to “keep pulling on their oars.”

In this way, the confusion will subside and the fog will clear!

Questions, discussion?

Student Assignments

- 1. Prepare summary presentations**
- 2. Review slides – gain understanding**
- 3. Answer review questions**

Plan your next and last session: date, time, place

Slide 85

Slide 85. Please discuss any questions among yourselves.

For the next and last session, would each facilitator pair please prepare a summary presentation that includes the items listed on the next slide.

Please review the slides from Session 5 to gain further understanding.

Please answer the review questions from this session.

Before you leave, go ahead and schedule your last session.

Summary Presentation By Each Student Pair

Include:

- Problem diagram**
- Planned events and schedule**
- Sub-teams and their work units**
- Options to be evaluated**
- Evaluation criteria**
- Expected accomplishments over time**

Bring hard copies to share with others

Slide 86

Slide 86. You should assemble everything together that you have done on your selected wicked problem and give a short presentation at the next session. Please have hard copies to share with the other students.

The items to include in your presentation are listed on the slide.

Review Questions, Session 5

1. What are five problem-solving steps?

2. What should be done between events or periodic updates?

3. What are the components of a cost analysis?

4. What types of solutions are needed for wicked problems?

5. How would you deal with confusing periods?

Slide 87

Session 6

Session 6

Wicked-Problem Approach

Facilitator Training

Wrap Up

Welcome Back!

Slide 88

Slide 88. Welcome back! We have arrived at our last session to wrap things up.

Discuss answers to questions

Slide 89

Slide 89. Let's go over the review questions from Session 5. Please discuss your answers among yourselves. My answers are below.

1. Five problem-solving activities include:

Gather information

Identify and evaluate options to solve the problem (or parts of the problem)

Integrate results within each sub-team and then integrate results across the sub-teams for the entire problem

Periodically summarize progress for each sub-team and for entire effort

Be sensitive to good ideas – can come from anyone at any time

2. Between meetings, events and periodic updates

Participants should do the agreed tasks

Allow time for people's minds to integrate information and results

3. The components of a cost analysis are:

Initial investment cost plus investment cost divided by years of useful life to arrive at investment cost per year

Yearly recurring costs for operation and maintenance

The total yearly costs are the sum of the yearly recurring costs + the investment cost per year

These costs can be used to compare the costs between options

A cost-benefit analysis developed by experts can also be included

4. Wicked problems require solutions that are:

Simple and practical; such solutions must be technically feasible and effective in solving the problem

They must be cost affordable

They must be socially/politically acceptable to be implemented

These best-practical solutions are arrived at by balancing the above three factors

“Evaporating cloud” solutions are sometimes found that change the underlying structure to make the problem go away

5. Confusing periods are an unavoidable aspect of solving wicked problems. They can best be dealt with by:

Sticking to the schedule and keep going

Relying on learning and the iterative aspects of the WPA

Encouraging all participants to keep going

Having confidence that over time the fog will clear

Session 6, Part 1

Final Report & Follow-Up

Slide 90

Slide 90. We would like to continue by looking at the final report and follow-up actions after the problem-solving effort is completed.

Report Outline

- **Cover**
 - **Title of study**
 - **Name of problem-solving team**
 - **Date**
 - **Names of team participants if not too many**
- **Executive Summary**

Slide 91

Slide 91. The report cover should include:

Title of the study

The name and logo of the problem-solving team if available

Date of the final report or the draft report

Names of team participants, if there aren't too many for the cover. If so, a note on the cover should refer the reader to the listing of participants in the front of the report

The report should begin with an executive summary.

The report front information includes publication and availability information, acknowledgements, table of contents, and listing of team participants unless the list is too long and is included later.

Report Outline (continued)

- **Body**
 - **Goals and a description of the problem**
 - **Summary of Study activities – meetings, sites visited, information obtained...**
 - **Description of options & summary of information obtained**
 - **Evaluation of options**
 - **Concluding analysis & recommendations**
- **Appendix**
 - **Problem diagram (final version)**
 - **Useful records of meetings, visits, data...**

Slide 92

Slide 92. The body of the report should include:

The study and end-state goals and a description of the problem.

A summary of problem-solving activities that describes how the study was conducted.

A listing of solution options that were considered and evaluated and a description of each option along with a summary of the information obtained for each option. Information supporting the evaluation of each option should be included.

The evaluation of each option along with the supporting information and rationale for each evaluation.

The concluding analysis compares all the options against the same three criteria. Study recommendations are presented and explained based on the results of the option evaluations. Recommendations for follow-up actions are made. These often include suggestions of how to implement the study recommendations.

The appendix should include the final problem diagram and other useful records of meetings, visits, data, etc.

You may download an example report prepared by a citizen team in Penobscot, Maine US that addressed the issue of local school sustainment. Please go to the Stable Climate Group Website: <http://www.stableclimate.org/home/> for the document.

Final Report Bottom Line

- **Need professional, “technical” report**
(“technical” = fact-based, unbiased, rational)
- **Must be credible & understandable**

Slide 93

Slide 93. Bottom line: the report needs to be a professional, technical report. By technical, we mean that it is fact based, unbiased and presents rational analysis and results.

It must also be understandable and credible to have an impact.

Report Use & Distribution

- **Coordinate**
 - **Peer review by participants and others**
 - **Review by study requestor, if any**
- **Distribute – e-mail, hard copy, webpage, commercial publisher or self-publish**
- **Present – town meetings, interested citizens, special interest groups, political officials...**

Slide 94

Slide 94. Before the report is released, it should be peer reviewed by all the participants and others to obtain feedback and suggestions from different perspectives. If the study was requested by a town or other officials, then those officials should also review and comment on the report before release.

Reports can be distributed in many ways such as a PDF file posted on a Webpage, e-mail and hard copies. The report may also be commercially published or self-published.

The report may be presented at town meetings and to interested citizens, special interest groups, political officials, and others as appropriate.

Follow-Up Actions

Examples:

- **Participants may assist in implementing study recommendations as requested by officials with the authority and means to put them into effect**
- **Participants may help to test results (ex. pilot tests)**

Slide 95

Slide 95. Team participants may offer or be asked to assist in implementing the study recommendations. The participants are a very valuable resource because of their intimate understanding of the problem and the actions needed to solve the problem.

Generally, implementation actions must be requested by officials with the authority and the means to do so.

Pilot testing of study recommendation may be warranted in some cases to reduce risk. Participants may offer or be asked to assist with such testing.

Session 6, Part 2

Student Presentations

Slide 96

Slide 96. At this time, each facilitator pair should share and present their plans to apply the WPA to their selected wicked problem.

Well done!

Session 6, Part 3

Stepping Back & Closing

Slide 97

Slide 97. Let's step back and consider a few closing points.

What Are We Really About?

“Truth-based problem solving”

Based on: truth, compromise & goodwill

Slide 98

Slide 98. What are we really about with the WPA?

We are trying to accomplish truth-based problem solving rather than opinion-based problem solving.

The underlying tenants of the approach are truth (using facts in an honest way), compromise (balancing options to find best practical solutions), and goodwill (most people will and can only apply their full potential in that environment)

Challenges for Facilitators

- **Wicked problems:**
 - Tangled mess of factors (Gordian knot)
 - No beginning or end
 - Hard to solve, takes work
- Use ad hoc group assembled for first time to solve most difficult types of problems
- WPA does not make solving wicked problems easy – it makes it possible

Slide 99

Slide 99. Using the WPA to solve wicked problems poses several challenges to the facilitators:

We know that wicked problems are a tangled mess of factors (like a Gordian knot)

They have no identified beginning or end

They are the hardest types of problems to solve, and it takes unavoidable work

The WPA does not make solving such problems easy, but it does make it possible

Wicked Problem Approach

- **WPA relies on *human potential* to solve problem**
- **Tapping that potential is goal of facilitators**
- **Requires self-discipline and commitment**

Solving wicked problems a great challenge & opportunity – if mastered, what can't you do?!!

Slide 100

Slide 100. The WPA relies entirely on the human potential to solve wicked problems.

Facilitators have the challenge of tapping that potential.

To do so requires self-discipline and constant oversight, avoiding cutting corners, and commitment to see the task through – it is not an easy job, but a rewarding self-fulfilling job.

Solving wicked problems is a great challenge and likewise a great opportunity:

If you can master solving wicked problems using ad hoc teams of volunteers –

What can't you do?!!

Note: In my referenced article on an approach for solving wicked problems, the related work of Peter Senge in learning organizations was reviewed. He describes how many of the same aspects of the WPA can be used in a corporate setting to achieve corporate excellence. I would encourage you to read his book to gain additional insights. Reference: Senge, Petr M., *The Fifth Discipline, The Art & Practice of The Leaning Organization*, Doubleday Currency, New York, NY, 1990.

Thank you!!

Please complete course evaluation

Need your feedback and suggestions

Graduation!!

Congratulations!!!

Slide 101

Slide 101. Thank you so much for taking this course. I surely hope that it will assist you on facilitating teams to solve wicked problems. There are a lot of them around, and they seem to multiply faster that we have been able to solve them.

Would you please complete the course evaluation by answering the following questions, and e-mail them to me at: dickhutch67@gmail.com

Do you feel ready to facilitate a problem-solving team?

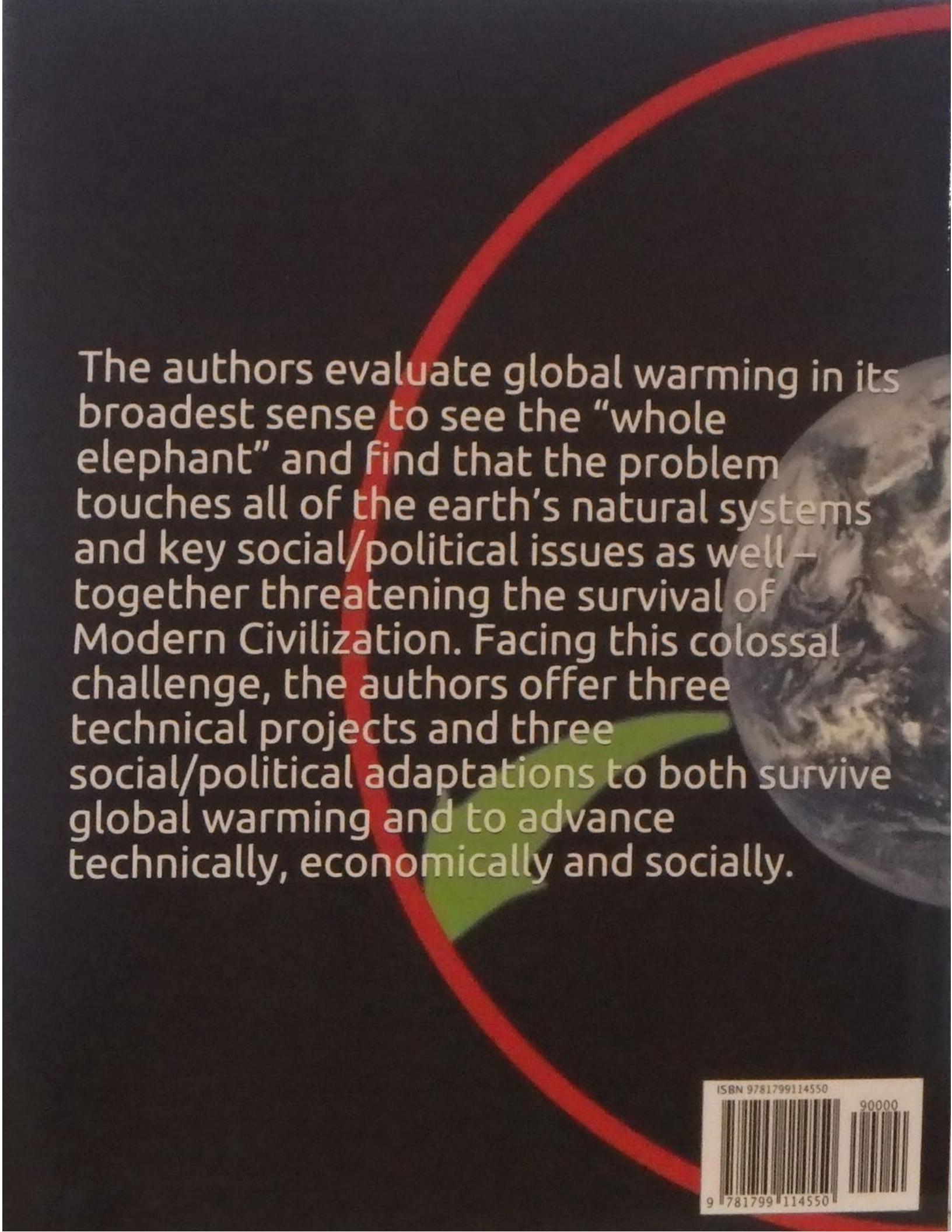
Was the course material understandable?

What are your suggestions to improve the course?

I really appreciate your feedback – thanks!

You have graduated!!

My Hearty Congratulations for completing the course, and I wish you well in solving wicked problems!!!



The authors evaluate global warming in its broadest sense to see the “whole elephant” and find that the problem touches all of the earth’s natural systems and key social/political issues as well – together threatening the survival of Modern Civilization. Facing this colossal challenge, the authors offer three technical projects and three social/political adaptations to both survive global warming and to advance technically, economically and socially.

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