the Earth, Save the Economy:

Solving the Climate Crisis Is EASY

John and Mary Ellen Harte

Cool the Earth,
Save the Economy is available ONLY as a free download at:

www.CoolTheEarth.US

Written in plain English by an award-winning scientist who studies environmental problems and his biologist wife, "Cool the Earth, Save the Economy" is an educational resource that covers global warming and its consequences, reviews and assesses the policies and technologies to solve it, and much more.

"*Cool the Earth* breaks wide open the debate on how to solve the climate crisis with a fresh new policy plan that could well save our economy... the book covers all bases: science, technology, economics -- the essential primer for anyone concerned about global warming..."

- Paul Ehrlich, author of "The Population Bomb" and "The Dominant Animal"

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By

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Dedicated to Earth and our descendants

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Preface

Katrina. Droughts across the South. Flooded cities and croplands along the Mississippi. Over a thousand forest fires burning in California. With scenes like this imprinted on our minds, most U.S. citizens are starting to understand that if we don't solve the climate crisis, our economy and well-being will suffer hugely. Our climate and economic problems have a common solution, however, rooted in smart public policy. The United States can lead the world in achieving that solution. And if we act quickly enough, it will be relatively easy. This book outlines that solution, and an innovative policy to implement it.

You are probably thinking: What does "solving the climate crisis" really mean? How can it possibly be "easy" when we are frequently being told that the alternative to the climate crisis is a wrecked economy? And why are we focusing on just the United States when we know that our nation is responsible for "only" about one fourth of the problem? A few words of clarification up front are surely needed.

Defining a Solution

Solving the climate crisis does not mean that the world will not get any warmer; in fact, no matter what we do, some further warming will occur. Solving the climate crisis means reducing emissions of the atmospheric pollutants that cause warming as much as we can, as soon as we can, and as intelligently as we can so that our economy profits rather than plummets. If we do achieve this goal, we will contain the amount of future warming to a level that is not likely to be catastrophic. If we don't, warming will severely jeopardize our well-being, as we explain in the next two chapters.

If the plan described in Chapters 3 through 11 is implemented, the U.S. will be doing its share to achieve the above goal. Our plan, with the acronym EASY (explained by the titles of Chapters 4-7), will do so by reducing our fossil fuel use year after year, so by 2030 our annual emissions of greenhouse gases will be roughly 25% of the amount we emitted in 2007. From the year 2030 onward, we will not need to import any oil from the Middle East, and we will have totally phased out our energy use of coal, the dirtiest of the major fossil fuels in use today. Others, notably Al Gore and some environmental organizations, have insisted that we can be free of coal much earlier, by 2020.[1] As with any social goal, how fast we achieve it will depend on how much we can motivate our society to accelerate the changes needed.

What about Other Greenhouse Gases?

The plan in this book focuses on reducing carbon dioxide emissions, in part because that gas is the dominant contributor to human-caused climate change, but also because the very steps we advocate for reducing carbon dioxide emissions will also result in reductions of other, much more potent but rarer greenhouse gases, methane and nitrous oxide. In particular, fossil fuel use contributes to emissions of these gases, so we derive multiple climate benefits when we reduce fossil fuel consumption. We do not discuss in detail additional methods for reducing methane and nitrous oxide emissions, but simply point out here that practices such as dry-land rice cultivation and reducing beef consumption would reduce methane emissions significantly, and eliminating overuse of nitrogen fertilizers in agriculture would reduce nitrous oxide emissions.

What Do We Mean by "EASY"?

We deliberately use this word as the acronym to describe our blueprint because the technologies are available and the consumer economics are favorable. We also use 'easy' because our plan does not require significant hardship and suffering – we will not need to drink warm beer in cold rooms, or drive slow cars on alternate days. In fact, switching from fossil fuels to alternative energy sources will help us maintain our current lifestyles by eliminating the economic drains of oil wars and future economic catastrophes brought on by the ever-increasing climatic effects of global warming. We can continue to eat the foods we enjoy, have comfortable homes, and explore the world. We will not need to suffer a reduction in disposable income, nor sacrifice freedoms that matter to us. As has happened time and again throughout history, some workers in some industries will be retrained to take on new jobs, but there will be more good jobs available than there are today.

We are sometimes asked, "If EASY is so easy, why hasn't it happened?" In reply, we're both tempted to face each other, smile darkly, and vent in unison, "It's the politics, stupid!" There are many examples of cost-effective policies that would improve the well-being of society, expand opportunities and promote more freedom, but which do not get implemented because of politics. Pertinent examples include shifting subsidies away from the fossil fuel industry and towards renewable energy industries, which would benefit our national security, improve health by eliminating much air pollution, and create more jobs in our economy.

It will not be easy to overcome the political barriers to instituting the incentives that are needed to propel the U.S. down the EASY path. And it will take education and motivation for us to make the personal changes in our lives needed to sustain our quality of life. If the future trajectory of energy policy in the U.S. follows the plan outlined here, the U.S. economy and the technology that propels it will, by 2030, be profoundly different from what they are today. Solving the climate crisis will require huge changes in investment, subsidization, and taxation policies. Life will be different – but better!

Finally, we use the term EASY to indicate that the overall plan relies on technologies that are not only acceptable and available but also affordable, and on economic policies that will leave us all wealthier and healthier. A difficult plan would force huge hardships on the public, and thus it would be difficult to ever see it carried out in a democracy. An EASY plan, in contrast, will be appealing to most people who are informed about it. Our use of the term EASY provides a sharp contrast to a plethora of comments by those who suggest that we can’t stop global warming. These naysayers feel that it is either technologically impossible or too damaging economically to greatly and rapidly reduce our dependence on fossil fuels and thereby prevent catastrophic global warming.

The genesis of the EASY plan was our awareness that many economically attractive options for greatly reducing dependence on fossil fuels are becoming available. Our goal is to demonstrate here that:

- appropriate energy technologies are available,
- the economy will benefit, and
- all that is lacking is the political will to restructure our current system of incentives so as to allow market forces to forge that path to the future.

Why Do We Focus Just on the U.S.?

There are two answers, and both have to do with us, the citizens of the United States: it's because we are selfish … and because we are not selfish. On the one hand, it is in our self interest to invent, and reap the profits from, the new technologies that will shape the next 100 or more years of economic activity around the world. During the past century the oil giants, such as Rockefeller's Standard Oil, didn't achieve their positions of power and wealth by asking other nations to join them and share the risks. And we didn't let the vested interests of makers of horse whips, livery, and carriages cause us to defer to other nations to develop the first major automobile industry. Among the economic giants of the second half of this century will be, as sure as you are reading this sentence, the makers of solar-powered electric generating systems, rechargeable hybrids or all-electric vehicles, and other devices that will pave the EASY path.

If we start first, we will invent first. And, we will end up selling things to those who delay. That's called winning the competition, and it boggles our minds that U.S. auto manufacturers (until recently[2]) and some of today's oil companies don't appear to understand this opportunity. Indeed, the handwriting is already appearing on the wall — Michigan had to close down much of its state government temporarily, because the agreement of its yearly budget faltered over an impasse on its deficit. This deficit, in turn, was created partly from decreasing revenues from the automotive manufacturing industries. These companies have experienced sales slumps, as Americans have chosen more fuel efficient cars made by their foreign rivals.[3] The message is, "Those who do understand the advantage of transitioning to an energy efficient world will bury those who don't."

We also focus on the U.S. because we should selflessly set a good example that will inspire the rest of the world to act. We have the capacity to assume risks and to be leaders in the global community, as we did in World War II and afterwards with the Marshall Plan, and as we have continued to do so, with the communications revolution, for example, and by tackling acid rain, the ozone hole, AIDS, and other global problems. It is our responsibility now as citizens of an endangered planet to use that capacity for the common good. This means all citizens, including executives of oil, coal and automotive companies who have had the good fortune to be entrusted with great power and wealth derived from the people.

Despite this focus on the U.S., the EASY plan is immediately applicable virtually anywhere in the developed world. The European nations, Canada, Japan, Israel, Australia, and New Zealand are as equipped as we are to launch the implementation of EASY, and there is a good chance that they will. The competition will be exciting to watch. But in addition, the more rapidly developing nations such as China, India, South Africa, Argentina, and Brazil are also capable of adopting EASY and becoming the energy giants of the mid 21st century – not consumption giants, but energy efficiency and clean energy production giants. What we present in this book is relevant to all of human society.

The Evolving Debate

Two battles have always needed to be won if we are to solve the climate crisis. The first is practically over, and science emerged the victor. It was fought against the naysayers, who for many years denied the scientific facts and basic scientific principles behind global warming. Most scientists, and now much of the American public, understand that global warming is a serious problem. The remaining die-hard naysayers still refuse to accept it despite the mounting avalanche of scientific evidence pointing towards global warming and its harmful consequences.

Why do some still deny the reality? Among the many possible motives, one of the more pervasive is that global warming has been perceived as a costly, overwhelming problem devoid of realistic solutions.[4] And that defines the second battle—overcoming the misinformation that fuels that view. This is a battle that has barely begun, and it is the one we take on in this book. There are many high-profile combatants denying the possibility of a solution. For example, the Newsweek columnist Robert Samuelson recently noted that, “The global-warming debate's great un-mentionable is this: we lack the technology to get from here to there. Just because Governor Arnold Schwarzenegger wants to cut emissions 80 percent below 1990 levels by 2050 doesn't mean it can happen. At best, we might curb emissions growth.”[5] By way of “proving” that it can’t be done, he then goes on to describe a portrayal of the future created by the International Energy Agency that falls far short of the governor’s goal.

If Mr. Samuelson had gone to the engineers and industry leaders actually involved in improving energy efficiency, and in solar and wind energy technology, he would have found that his statement was wrong on both points: we do have the technology, and we can do even better than the governor’s goal. The major stumbling block is lack of political will, and its handmaiden, ignorance. This hampers us from imagining a better future, fueled by the technological innovations that we can create as part of the solution to the climate crisis.

Other common examples of ignorance often appear when the cost of solving the climate crisis is discussed. A prominent Danish statistician and environmental naysayer, Bjørn Lomborg, has argued that there is very little we can do about global warming[6] and that, “The Kyoto Protocol will likely cost at least $150 billion a year and possibly much more.”[7] He then poses a false dichotomy – what shall we do, solve the climate crisis or use the money to benefit the poor of developing nations?

As we shall see, there is much that can be done about global warming, and the sooner we do it, the more profit for all of us. Yes, that's right, profit, not cost. A more accurate way to view the energy transition is as an investment opportunity – invest in a new energy source that solves many current costly problems, and you're likely to make a huge profit from it. Since the poor are likely to suffer the most from global warming, they will benefit hugely from a solution.

Ultimately, the solution will be a net profit for humankind, since it will create more sustainable energy sources that will:

- prevent further economic costs of environmental or health damage created by current energy sources, including the economically catastrophic effects of not addressing global warming; and
- reduce the number of costly wars fought to maintain oil supplies.

Denial of the reality of global warming is also tied to another topic, one more difficult to discuss than energy but of comparable importance: the unsustainable overpopulation of this planet. Given the inherent love human beings have for children, it is natural that some people will not agree that we should be having fewer of them. It is not always appreciated, however, that those who advocate family planning and ultimately reducing the global population also love children. As the economist Herman Daly put it, advocates of family planning want to see as many people as possible on the planet, too – just not all at the same time. By humanely choosing to limit reproduction now, we can best assure that the human enterprise will be sustained for as long as possible. The alternative is the difficult truth that inhumane forces, including hunger, disease and war, will do the job. The term "population control" is understandably and rightfully abhorred by many. If we opt for "population choice" now, we can avoid the inhumane forces mentioned above, which would be truly unwelcome by all.

Finally, there is another reason society has failed to roll up its sleeves and get to work solving the climate crisis – namely, many people are overwhelmed by the huge menu of proposed solutions to the problem, some of which seem rather futuristic and implausible. This was another motivation for our book, which tries to cut through the morass of proposals to identify those which are available, affordable, and acceptable. The result is a relatively simple, straightforward plan that we can implement starting today. But there is a caveat. Think of the plan as a limited-time offer at an incredible bargain price. Because the longer we put off addressing global warming, the faster the price of doing so zooms up – faster than the price of gasoline.

About This Book

The first two chapters of this book explain the process of global warming and its effects on life on Earth. The third chapter presents the EASY plan, which is explained in detail in the subsequent four chapters. Calculations mentioned in these chapters, as well as units of measure used in them, are explained in the appendices at the end of the book. Further chapters discuss the problems associated with other solutions, show how our economy can profit in many ways from the energy source transition, and how we can use economic incentives and the electoral process to prevent catastrophic global warming.

Our book and plan do not attempt to specify the myriad details that will constitute the energy transition that we anticipate will occur over the next several decades. Nobody has the foresight to determine exactly what mix of wind and solar will be deployed where, nor which electricity storage system will prove to be the winner among all the exciting competing technologies today. Nobody can foresee today just how much energy savings will come about from improvements in home appliances, heating and cooling, vehicles, and industry. Nobody knows whether plug-in hybrids, all-electric vehicles, or some other transportation option will win out. Unpredictable market forces and technological innovation spurred on by investment will determine these outcomes, provided, of course, that politics and bureaucracy work to promote them rather than stand in their way.

So, that's what this book is about – defining the problem, providing necessary information, and outlining a relatively straightforward plan for solving the climate crisis.

The footnotes of this book point out a new reality – much of our information now comes from traditionally reputable print sources that have also established themselves on the Internet. Although we often offer in the footnotes sources from the more popular, mainstream media on global warming science, we also follow it up with the original scientific source from which the article was derived, or a summary that contains citations for several original scientific source studies supporting the conclusions. In contrast, warnings and opinions are clearly identified for what they are, and are not necessarily connected specifically to any one scientific report, although they often do derive from many studies. We note the date of retrieval for each Internet address cited, but if a specific webpage has disappeared by the time you try it, you might still be able to access the information by plugging the headline into a good search engine, or digging into the archives of a website.

Beyond this book, there are now excellent online informational and news distribution websites that track daily the outpouring of articles from reputable print and online media around the world on climate change and health:

- Real Climate – www.realclimate.org – is an award-winning website that is probably the single best informational source on climate change, developed by climate scientists to expose the flawed thinking of naysayers. It also links to other excellent websites concerned with explaining global warming and its ramifications.

- World View of Global Warming – www.worldviewofglobalwarming.org – has photographic documentation of the effects of climate change around the globe.
- Climate Crisis Coalition – www.climatecrisiscoalition.org – produces a daily newsfeed, Earth Equity News, focused on climate-related issues.[8]
- Above the Fold – www.EnvironmentalHealthNews.org – is a comprehensive news distribution site covering environmental and health issues.[9]
- Planet Ark – www.planetark.org – is produced by Reuters News Agency and covers world environmental news.[10]

By the time you read this, some of its information will have probably changed or been updated, and new relevant changes will have occurred to the planet and/or our society as a result of further global warming. Indeed, global warming is outpacing the latest Intergovernmental Panel on Climate Change (IPCC) assessment reports, considered the most comprehensive and trusted source of information on global warming, so even the latest reports lack important new developments and are inherently cautious. If you want to stay informed and not have to rely on rumors, the above online sites are excellent sources of information for the public.

Throughout this book we will be emphasizing the urgency with which we must act to address the climate crisis and compare the process to the single-minded dedication of resources and urgency that ultimately helped win World War II. But there are important differences between fighting human wars and “fighting” global warming. Nature is manipulable, but not negotiable. Inexorably, the consequences of our actions proceed, however much we debate or negotiate among ourselves about addressing them. And those consequences, we are now being warned, can occur abruptly and irreversibly…irreversibly. Unlike a war, where one can lose battles but ultimately win, lost opportunities can be irretrievable: from the forests of the Amazon and the diversity of life it supports to the ice sheets and polar bear of the Arctic, these ecosystems, once lost, will be gone forever. And this will make some consequences inevitable.

Thus, global warming is truly bad news that must be confronted with all the urgency, focus, and breadth of resources comparable to what we did to win World War II in five years. The good news is that we have the resources and know-how to solve the climate crisis and the other serious problems connected with our current energy supply system, and we have more than five years to do so. Because we live in a democracy, we also have the means to amend the only thing we lack: the visionary leadership necessary to direct our country in a united, concerted effort to end global warming. We solved the consequences of the last great global problem, the destruction from World War II, with the Marshall Plan. Let’s solve this one with the EASY Plan!

Chapter 1: Truths and Myths about Global Warming

Planet Earth is heating up, and we are responsible. Like bacteria in a petri growth dish, we've been exploding in numbers on a finite piece of rock, as well as developing technology so the "livin' is easy". And we've been burning up the planet to do so, burning oil, coal, natural gas (methane, also a greenhouse gas), and other fuels, and clearing our forests. The carbon dioxide gas (CO_2) produced from all this burning and deforestation, as well as a few other rarer but more climatically potent gases our activities produce, like methane (another carbon compound) and nitrous oxide, have been building up in our atmosphere. These greenhouse gases, of which CO_2 is the main culprit, trap heat that would normally radiate directly into outer space.

A planet's temperature is hugely influenced by the composition of its atmosphere. Earth wears its carbon dioxide like a cloak, and that cloak has thickened about 30% since the start of the Industrial Revolution. At that time, the atmospheric level of CO_2 was about 280 parts per million (ppm).[11] It's now roughly 390 ppm, a level that reflects an all-time high for the past 650,000 years. Adding in the other heat trapping gases raises the effective CO_2 level even further. Worse, the buildup of these greenhouse gases is accelerating rapidly, the rate of buildup having tripled in just the past two decades.[12] So, our planet is getting hotter, enough to trigger major changes in climate that will catastrophically threaten the very quality of our lives if we don't start to do something about it. Now.

How Do We Know That We Are Causing this Climate Change?

This question is often asked by naysayers, who follow up with, “Maybe it's just a natural change in the climate!” We know that WE are changing the climate, because scientists understand the basic physical laws that govern the climate. Models that use this knowledge are used to predict global climate patterns. When fed physical data, these computer models mimic the Earth’s climate under all sorts of scenarios (solar cycles, volcanic activity, human activities, etc.). The scientists then look to see which of the resulting predicted pictures of Earth best match what is actually happening on Earth today. You guessed it, human activities win this competition.

These computer models predict that our activities should create four distinct patterns of warming, and that’s just what we’re seeing today:

- the polar areas are warming more quickly than the middle latitudes;
- winter temperatures are rising faster than summer temperatures;
- night-time temperatures are rising faster than daytime temperatures;
- the lower atmosphere is heating while the upper atmosphere, the stratosphere, is cooling.

The first two patterns are also predicted to occur if a brighter sun is causing global warming. The last two patterns, however, are specific clues telling us that it is the release of heat-trapping gases by humans, not a brighter sun, which is creating global warming.

Myths and Facts about Global Warming

There are many prevailing myths about global warming that have been advanced by naysayers of climate change science. We explain the faulty reasoning behind several of the most well known ones. But if you don't find your favorite myth here, go explore the New Scientist website, or various other websites that debunk the faulty reasoning of the naysayers.[13] You can also, of course, find websites that actually propagate these myths. The methods used by these naysayers are discussed in our section below, "How Global Warming Naysayers Operate".

Popular Myths about Global Warming

* **Satellite data contradict evidence for a warming trend.**
* **Prehistoric climate change was much greater than now, so don't worry.**
* **Variation in sunlight probably explains the recent warming trend.**
* **The warming trend is an artifact of spreading urban heat islands.**
* **The 1940-1970s cooling trend contradicts the global warming concept.**
* **Global warming will make the next ice age milder.**
* **Global warming will be good for agriculture.**
* **Global warming is an unproven theory.**
* **Preventing or slowing global warming will severely impact our economy.**

"Satellite data contradict the evidence for a warming trend." The upper atmosphere — that is, the stratosphere — has indeed cooled over the past several decades, as indicated by satellite data. But this is exactly what global warming science predicts should have happened! It is one of several kinds of evidence that led the recent IPCC to conclude that the signal of greenhouse warming has been detected. Early reports of lower atmosphere cooling were wrong!

Naysayers have been good at pointing out gaps in research. Naysayers pointed to satellite data that appeared to show no atmospheric warming, prompting scientists to re-examine the data. Scientists found that the measuring equipment had not been calibrated correctly. Once corrected, the data showed the Earth's lower atmosphere warming. But not as much as the land surface, naysayers crowed. Exactly what our global warming models had predicted, scientists replied.[14]

"Why worry? Earth has experienced substantial climate change before! We can adapt!"

The claim here is that the Earth has experienced prehistoric climate change far greater than what we anticipate in the next century. So, there is no need to worry, right?

Let's examine this. If nothing is done to reduce carbon dioxide emissions, the warming that we can expect in the next 100 years will be of the same magnitude as the climate changes that occurred over the past million years as our planet's climate swung back and forth between ice ages and the warm inter-glacial periods. Secondly, and of much more relevance, prehistoric climate changes happened much less rapidly. These changes happened over tens of thousands of years, to ecosystems not compromised by human activities, to species capable of adapting at that rate, and to a planet devoid of people that might have been impacted. Most of the ecosystems in which species live today are shrunken and damaged by human exploitation, decreasing the capacity of both ecosystems and individual species to adapt even at normal rates, much less at such a vastly accelerated rate. We can expect lots of species extinctions on top of the many that are happening already. And the billions of people now present on Earth mean that anything that goes wrong is going to impact vast numbers of people, as both Katrina and the 2004 tsunami in southeast Asia[15] demonstrated. Moreover, those events illustrate that society is grossly unprepared to deal with the scale of the human tragedy that global warming will unleash.

A closely related idea is that somehow, through our technological wizardry, we can adapt to global warming. Global warming is a moving target, though, accelerating as time goes on. And we have yet to be able to “adapt” to climatic disasters such as floods and droughts. People die or are injured regularly from such disasters. Homes and livelihoods are destroyed. At best, our adaptation decreases but does not remove these effects, and even this “adaptation” will be rapidly outpaced by the process as greater changes occur faster and faster. Analyses of the overall economic impacts of climate change[16] conclude that economic impacts will affect everyone, place massive strains on our public sector budgets, and damage the essential flow of goods and services to society. No adaptation of ours, for example, will be able to prevent the permanent flooding of much of civilization’s coastal cities, industries, and other infrastructures when sea levels begin to rise rapidly.

Temporary adaptation may provide false hope and could in fact be damaging to the extent that it reduces incentives to alter the energy policies that are the cause of global warming. There are, however, sound reasons for taking certain steps that make sense even if the global warming threat is addressed through improving energy use efficiency and adoption of clean energy sources. For example, restoring coastal wetlands provides benefits by way of storm protection whether or not global warming intensifies and causes future, more powerful, hurricanes. And training more health care workers to deal with infectious diseases makes sense, whether or not global warming intensifies and brings tropical diseases to higher latitudes.

“Variation in sunlight probably explains the recent warming trend.”
Wrong again. Solar variability is not of sufficient strength to either explain or counter the effects of the buildup of greenhouse gases in the atmosphere in recent years. Moreover, if solar variation were the cause, the stratosphere would be warming and night time temperatures would not be rising as fast as the day time temperatures. But, in fact, the stratosphere is cooling and night time temperatures are rising faster than the day time ones, exactly as global warming science predicts.

"The warming trend is an artifact of spreading urban heat islands." While it is true that temperature records taken from within or near big cities can be misleading because of the heat produced by cities, the temperature record that the IPCC uses to show that the planet is warming does not include data from urban-area weather stations.

"The 1940-1970s cooling trend contradicts the global warming theory." Naysayers point out a cooling trend extending roughly from 1940 to the 1970s and argue that this contradicts the global warming concept. During the twentieth century, a slow warming trend that began at the beginning of that century leveled off starting around 1940; this interruption of atmospheric warming is interpreted as a cooling trend by naysayers. Then the temperature began rising again, with the greatest rise showing up in just the past 20 years. Climate models demonstrate that the temporary leveling off was the result of an increase in the amount of particulate pollution in the atmosphere, billowing out from many more and taller stacks of coal-fired plants.

It is no coincidence that it started around World War II, when manufacturing skyrocketed to meet the material demands of warfare. After the war, newly prosperous U.S. citizens craved the new products created from the technical innovations developed during the war. This meant a huge increase in the unregulated burning of coal for electricity production at that time and afterwards, as manufacturing increased to heal economies damaged by the war and to meet the rising consumer demand. These new post-war coal-fired power plants had much taller stacks to loft the particulate pollution away from our breathing space. But this also kept these particles both higher and longer in the atmosphere.

Why did the warming resume? This occurred because the atmospheric lifetime of particulates is much shorter than that of the atmospheric greenhouse gases we emit. Thus, the greenhouse gas (GHG) buildup eventually overwhelmed the particulate pollution effect. But this process was accelerated by pollution laws. These laws were enacted by the U. S. and other countries to reduce atmospheric soot and other particulate levels a few decades after the war, due to concern over the harmful effects of pollutants from coal burning. So, the warming trend started up again — just as climate models predicted.

Although climate models have shown that the level of particulate pollution existing from 1940 to the1970s kept Earth cooler at the middle latitudes, this didn't help the polar latitudes, where that same particulate pollution probably caused an overall warming.

"Global warming will make the next ice age milder." This extreme view holds that we should welcome global warming because it will "warm" the next ice age. This is definitely stretching to find the "silver lining" of this "cloud." The confusion here is over time scale. Yes, the world will be plunged into a new ice age in the future. No, it will not happen during the next several hundred years, and possibly not even in the next few thousand years. When it does happen, it will happen slowly. So, trying to predict whether global warming will moderate the next ice age is not only impossible but irrelevant. It doesn't help us get through the next few centuries. And one can only imagine our future, shivering, ice age descendants cursing us for leaving them no fossil fuels to create a global warming "greenhouse" effect when one is really needed.

"Global warming will be good for agriculture." In the "every cloud has a silver lining" club, some people also argue that global warming will be good for agriculture because carbon dioxide will promote greater crop yields. Carbon dioxide, along with water, sunlight, and a variety of nutrients, is an ingredient of photosynthesis. However, rather than carbon dioxide, it is nitrogen, phosphorus, and water that usually limit plant growth. Scientists have shown the increased carbon dioxide effect is slight and will be greatly overwhelmed by the negative effects of less soil moisture brought on by greater heat, and erratic precipitation patterns (read droughts and floods).[17] Indeed, we will likely be facing famine from crop failures due to climate change.[18]

"Global warming is just an unproven theory." Where to begin on this one! First of all, science does not EVER prove its theories to be correct. The quantum theory, atomic theory, the theory of evolution, and the theory of relativity can never be proven. At best, scientists can disprove a theory by finding facts that contradict it, and that is what scientists spend considerable time trying to do. So far, no facts contradict global warming science. Climatologists see no reason to discard its basic scientific premises and conclusions. Moreover, no alternative explanations of past trends that are consistent with all available data have even been proposed. Finally, the phrase "just a theory" demonstrates a misunderstanding of science in general, and global warming science in particular. In science, successful theories such as the quantum theory are what science strives to attain. Although in popular parlance the term "theory" may be taken to mean wooly-headed, in science it is anything but. So the term "just" is not warranted. In addition, global warming science is not, in and of itself, a scientific theory. Rather, it is built up from several scientific theories, including thermodynamics, fluid dynamics, and electrodynamics. Statements such as the above, or a comparable one with "Evolution" substituted for "Global Warming" beautifully display the ignorance of the naysayer.

Finally, here is the biggest myth of all. The debunking of this myth is what this book is all about:

"Preventing or slowing further warming will severely impact the American economy." Read on to understand just how big a myth this is. We particularly draw your attention to Chapters 3, 4, 7, and 10.

How Global Warming Naysayers Operate

Even when a vast majority of scientists present evidence showing that we are causing global warming, there will always be a small, extremist residue of skeptical scientists and their promoters. Many of them, in turn, are often financed by fossil fuel industries that want people to keep buying their fuels. These extreme naysayers often have several other things in common. They do not engage directly in scientific research about global warming — it's much easier to wave hands from an armchair. They are often bent on consciously distorting information, "cherry picking" evidence to bolster their view, posturing arrogantly, and deriding rather than debating. Their "sources" are often books or websites with inaccurate or misinformation that they, themselves, have written. They are often funded by organizations or people interested in maintaining a comfortable state of denial. Their logic (or lack thereof) darts around like rabbits in a meadow — as soon as you knock down their first illogical argument, rather than acknowledge their error, they dart to another, equally flawed, argument. After doing this a few more times, they dart back, unfazed, to their original arguments, or run away. They then continue to promote their illogical arguments to others, attempting to convert the more gullible, less-informed populace.

How Science Operates

In contrast, the sources for the scientific information presented in this book are based on research papers published in peer-reviewed journals or assembled by respected scientists in the fields of climate change. We have, if anything, erred on the side of caution regarding recent studies because experience has taught us that science is a work in progress, particularly in the arena of environmental impacts. Thus, the anticipated impacts of global warming that we describe here represent only what we take to be the most robust of the many predictions that have been published. The IPCC is a source for much of the scientific findings. It represents the consensus of thousands of scientists from all over the planet. If you want more detailed explanations, check out their publications listed in the footnotes sprinkled throughout this book. We have tried to be conservative in the findings we present, since even peer-reviewed findings are sometimes upended by further emerging data.

Does Global Warming Cause Unusual Events?

When huge wildfires occur, such as the Los Angeles and San Diego area fires in the autumn of 2007, or a devastating hurricane occurs, such as Katrina, we are frequently asked by the media, “Was this event caused by global warming?” The scientifically accurate response to such a question requires a two-part answer.

First, the word “cause” is ambiguous. Thus, a child playing with matches might ignite (cause) a fire, but a long period of drought might cause what the child started to become a wildfire. Hurricanes typically form in the Atlantic Ocean in late summer, but unusually warm sea surface temperatures that were caused in part by global warming may enhance the intensity of storms. So, the responsible answer to the question of causation is, “We can’t say whether global warming caused the fire/hurricane to occur, but it very likely increased the severity of the fire/hurricane, making it that much more destructive and dangerous.”

Secondly, it's important for the media to focus on the larger, more important picture, which is the shape of things to come — a portrayal of the likely pattern of future events, rather than a dissection of the various causes of past events. Thus the scientifically responsible reply is: “No matter what caused this recent event, it is a preview of the type of storm (or fire) that we will likely experience more often in the future because of global warming.”

An Emergency

The UN Secretary General has declared global warming an emergency,[19] many scientists think that immediate action is required,[20] and the G8 leaders of the world (representing countries that comprise about 65% of the global economy) agree it is an urgent problem.[21] Despite all the evidence about global warming, however, our government is not addressing the issue urgently. So, why should we?

Chapter 2: Why We Must Act NOW

Okay, the planet's heating up. Why the rush to stop it? Let's first look at the consequences of not taking action to prevent further global warming.[22] Here's an overall picture of the main effects, in order of scientific consensus and certainty, just to get started.

The Consequences of Unchecked Global Warming

Levels of Certainty about the Consequences of Global Warming

*There **is near unanimity among active climate change scientists** and a high level of confidence in the predictions involving:*

- a greater intensity, frequency and duration of harmful summer heat waves;
- melting glaciers and sea ice, loss of alpine and arctic habitat – loss of polar bears and walruses, for example;
- a sea level rise of at least half a meter by 2100 and the resulting loss of some island nations;
- reduced snow pack and resulting loss of water for crops, cities and ecosystems;
- coral reefs will continue to die off.

*Scientists **agree on the underlying science and facts**, but work is needed to sharpen predictions on the following:*

- increased intensity and frequency of erratic weather, including droughts;
- reduced crop yields because of extreme events and persistent droughts;
- increased threat of major wildfires;
- ocean acidification.

*Scientists **agree that the following problems are real, important, and serious**, even if data gaps and some basic science have to be resolved:*

- increasing intensity of hurricanes;
- major spread of infectious diseases, both tropical and subtropical, to the mid latitudes, such as the United States;
- a sea level rise of up to 40 feet because of Greenland and Antarctic ice melting, resulting in catastrophic damage to huge numbers of people and much coastal infrastructure;
- a great extinction episode as big as the one that wiped out dinosaurs with an attendant loss of ecosystem services.

Heat waves. Perhaps the most obvious effect of global warming is the prolonged and more intense heat waves occurring throughout the world. In the U.S. alone, heat is now the main cause of weather related deaths; it has been estimated that between 1999 and 2003 alone, more than 3,400 people have died because of the more intense heat waves being experienced in the U.S.[23] This number is projected to increase as the planet heats further. Cities in the southern tier of the U.S., such as Phoenix, are suffering under summer time peak temperatures of up to 115° F. Climate models project that in the future many more U.S. cities, including those along the east eoast, will experience similar temperatures, and that southern-tier cities will experience even more intense, longer lasting, and more frequent heat waves.

During the intense summer heat waves of 2005, more than 20,000 Europeans died from heat related causes. By August 2007, more Europeans, especially Greeks, were dying from wildfires caused by yet another very hot summer. The old, the sick, and the very young are most vulnerable to fatal heat strokes. And as the planet heats further, it will only get worse.

Melting ice and rising sea levels. Heating is causing our planet to develop bipolar disorder: it's melting ice – lots of it, at both poles. Although much of the ice of Antarctica remains stable or is possibly increasing slightly, a large portion of it, the western Antarctic ice shelf, is melting significantly. Should the shelf disappear under a scenario of increased global warming, this could contribute to further Antarctic melting. (See the Positive Feedbacks section below.) Today, ice melt is most rapid in the northern polar regions (and from mountain glaciers as well), and it is occurring at much faster rates than were previously predicted.[24] How hot is it getting in the polar regions? In the summer of 2007, scientists at a field station in the Canadian high Arctic watched in amazement as the thermometer tipped 72° F, about 59° F above the average.[25]

The resulting melt water is starting to cause sea levels to rise. And sea levels are predicted to rise high enough to flood much of our immovable buildings, factories and homes along our coasts, possibly before the end of this century. The IPCC predicts at least a half meter rise by 2100. Much of this rise is due to thermal expansion of seawater, because water expands slightly in volume when heated. Although slight, this expansion amounts to a significant rise in sea level when the volume of water is large, as in the oceans.

Recent research suggests that melt rates are higher than previously anticipated. Current projections include the possibility that as much as a 40-foot rise in sea level could occur over the coming centuries with the melting of the Greenland and West Antarctic ice sheets, and increases by as much as six feet are now considered possible by the end of this century.[26] But even if only the low-end estimates of rising sea levels occur, considerable damage will be inflicted.

For Florida alone, for example, one study predicts that with only a half-meter rise in sea level by 2100, rising sea levels will cost Florida $345 billion a year in lost economic activity by 2100, inundating vast acreage of land, thousands of hotels, two nuclear plants and three prisons.[27] Considering that 53% of the U.S. population is concentrated along the coastal fringe,[28] there will probably be damage elsewhere along the coast as well.

Rising sea levels will also cause salt water intrusion into important underground water sources, the coastal aquifers, rendering drinking water supplies too briny for human consumption. Most glaciers, such as those in the Himalayas, also act as giant reservoirs, naturally storing and releasing water in the spring when needed for crops; once these glaciers are gone, growing enough food for Asia and South America, for example, is going to be much more difficult.

Melting ice and the expansion of warming seawater are already causing a discernible rise in sea level. Some argue that sea levels have been rising for centuries with no harmful effects. That’s true — sea levels have been very slowly rising over the centuries as glaciers slowly melted from the end of the last ice age. But global warming is drastically speeding up that effect, and what we are now facing is a much higher rate of sea level rise due to a much faster rate of glacial meltdown.

If you’re living on low coastal land or a Pacific island right now, you are worried, as well you should be. Pacific islands are already experiencing erosion of land through rising storm surges. For those on relatively low, flat islands their homeland is drowning. New Zealand has already appointed a minister to look into planning for the environmental refugee problems predicted to result there from people fleeing the rising sea levels that will submerge other, smaller Pacific islands. In the Arctic, the disappearance of buffering coastal ice has led to storm surges that are now shrinking coastlines, a nightmare for some coastal inhabitants. In Bangladesh, island people are finding it increasingly difficult to live on islands as sea levels and storm surges rise – this is troublesome because much of the rest of the population is concentrated on low-lying coastal land.

As the seas rise further, we can expect storm surges that will inundate our coastal cities and subsequent permanent flooding that will destroy them. In Europe, Venice is already beginning to feel the effects of higher water levels: the open square of one of its cultural jewels, St. Marks Cathedral, is now more often flooded than dry. As the waters rise, people will be faced with desperate choices: can they afford to move their cultural sites to higher grounds, or must they watch as the rising waters destroy them?

Besides depriving polar bears and walruses of habitat, melting Arctic sea ice also represents a melting ecosystem. Beneath existing ice, a rich community of tiny worms, shrimp, algae, and other life forms create the basis of a food chain that significantly contributes to Arctic marine systems. When the Arctic ice disappears, the impacts on the sea life will be huge, and like any other food chain, will extend right up to its top: fish, seals, whales, and bears.

It is difficult, though, for some people to see the connection between melting polar ice caps and our lives here in the U.S. — why be concerned? But climatologists will tell you that in a very real way, the climate at the poles acts as a climate generator for the rest of Earth, since the great masses of cold air and water generated there help drive the main air and water circulation systems of our planet. The Antarctic ice cap alone is estimated to hold 70% of the world's fresh water.[29] If the polar generators undergo significant changes, expect big changes in climate elsewhere on Earth.

Declining snowpack and dwindling glaciers. Higher global temperatures result in more rain and less snowfall, as well as decreasing glaciers in mountain ranges. Rain instantly runs off, while alpine snowpack and glaciers act as natural time-release mechanisms of water to the ecosystems below them. If there is no glacier left or little to no snowpack present in the mountains, the plants and animals, including people, living below them will suffer drought when the decreased runoff runs out during the warmer, crop-growing seasons following winter.

The worldwide melting of the planet's glaciers is one of the most dramatic illustrations of global warming. Thousands dot the polar and high alpine regions of the planet, of which a subset are monitored by the World Glacier Monitoring Service.[30] Thirty monitored glaciers spread out over six continents — the Americas, Europe, Asia, Africa and Antarctica — are melting about six times faster than they were in the 1980s, just a few decades ago.

The effects on people globally are similar. In the Andes, melting glaciers, predicted to disappear by 2050, represent a dwindling source of water for the dependent people living below them. In the Alps, melting glaciers, decreasing snowpack, and shorter winters have cut into the winter tourism industry of Switzerland.[31] This also results in earlier, decreased seasonal runoff, the subsequent lack of which threatens farming later in the season with drought. The melting Mingyong Glacier on the Tibetan plateau threatens the nearby tourist economy built around the glacier. The villagers there note that they are now harvesting two crops per year instead of one, but the crops are ravaged by pests they have never seen before.[32] Additionally, melting Himalayan glaciers threaten local settlements with flooding.[33]

In the forested eastern Rockies, ski resorts are similarly threatened by shorter, warmer winters. But scientists there observed an interesting effect created by the decreasing snowpack: the resulting cooler winter soils, no longer insulated by snow, emitted less carbon dioxide. This seemingly good effect was far outweighed later in the season, however, by the drought stress to the trees from the resulting drier soils, which substantially decreased the trees' ability to grow and absorb carbon dioxide, resulting in a net addition of carbon dioxide to the atmosphere.[34]

Coral reefs are dying. Higher oceanic temperatures are starting to cause coral reefs, an important source of food fish, to die off. It’s literally getting too hot for the corals to survive, the heat bleaching the stressed corals as they evict the colored symbiotic algae that they normally harbor and that are necessary to their survival. Living within a few degrees of their upper thermal limits, corals are highly susceptible to slight, sustained increases in oceanic temperatures. Abnormally high, sustained oceanic surface temperatures in 1998 caused a rare, widespread global bleaching of vast areas of coral reefs, seriously damaging 16% of the planet's reefs.[35] Such bleaching events are predicted to become more common under continued global warming, which has been identified as the major emerging threat to coral reefs within the past decade. By 2005, 20% of the world's reefs had died from a combination of human pressures and coral bleaching induced by the hot surface water temperatures caused by global warming. Another 50% of the reefs are in danger of doing so from human pressures such as pollution and over-fishing, and of that 50%, half are in imminent danger.[36] These, then, are compromised ecosystems, facing a major emerging threat.

Increasing intensity and frequency of erratic weather, including droughts. More generally, we're starting to see more erratic patterns of rainfall and weather – think heat waves, droughts, floods, hurricanes, and tornadoes – not good for people, or for growing the food to sustain them. Australia, for example, is experiencing droughts that now threaten its agriculture and spur wildfires. The droughts and wildfires have woken Australians up to the threat of global warming.[37] China is losing a million acres of agricultural land a year to desertification because of drought, possibly due to global warming, further exacerbating a cycle of droughts and floods, according to China's water resources minister.[38] The U.S. has experienced severe drought in the southeast, as well as record breaking wildfires in the west. California experienced the worst wildfires in recorded history in 2007, causing a half million people to at least temporarily evacuate, and the loss of over a thousand homes and businesses. Besides lost crops, droughts affect other important sectors such as transportation of goods.[39] In the summer of 2007, Europe experienced a heady mix of droughts with wildfires and floods from storms; weather patterns broke records in countries across Europe. Later that year, Mexico had 80% of an entire state flooded.[40] The U.S. northwest and northeast regions are experiencing a surge of more intense storms.[41] Why is this mix of droughts and storms happening?

Uncertainties abound in predicting local and regional climate changes, but here is a rough explanation of the mechanics. Think about heating a pot of water. As you supply heat to the bottom of the pot and create a larger and larger temperature difference from bottom to top, the heated water rises faster and faster, forcing the cooler liquid down faster. Now, remember that one of the heating patterns that Earth is experiencing is vertical — the lower atmosphere is heating more than upper atmosphere. This is creating a larger vertical temperature difference, causing hotter air to rise faster. The faster uplift of larger masses of hotter air creates larger, more intense storms and later forces faster downdrafts of the same air, wrung dry from those storms. Intense storms can cause floods; however, the fast downdrafts create high-pressure zones that repel moist, lower-pressure masses of air — that is, the sources of rain. Thus, this change in the vertical heating gradient is creating both wetter and drier periods of weather than previously. Droughts and floods? As one North Carolina native wryly put it on National Public Radio, while he'd certainly like some precipitation to break the drought, he doesn't want it in the form of flooding from a tropical storm or hurricane.

Besides creating new and erratic weather patterns, this larger vertical heat gradient in the atmosphere is also driving a disturbing climate change being tracked by our satellites: since 1979, the areas of tropical climate have pushed poleward in each direction by roughly 70 miles. Our jet streams, vast rivers of air that push global weather ever eastward and mark the edges of our tropical regions, have also moved poleward. Since the zones just outside the tropics are dry and contain the world's great deserts, this indicates a historic shift of the global dry zones poleward. Areas that form a northern, land-rich global band just outside the tropics are drying particularly fast. These areas include the Mediterranean, Turkey, northern China, Florida, and the Gulf Coast in the U.S. Not only is this process believed to be exacerbating the droughts in these areas, but this may also mark a relatively permanent

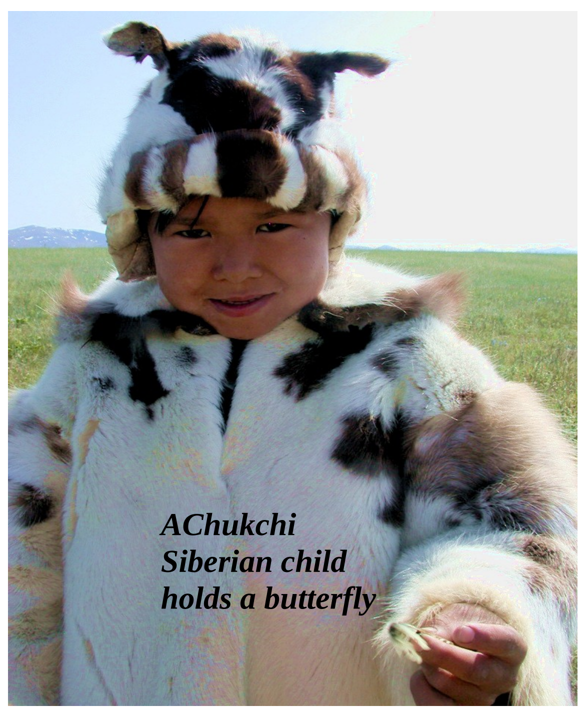
Under global warming, we can expect more erratic weather threatening our …

forests and wildflowers…

Amazonian biodiversity….

polar bears...

and our children.



AChukchi Siberian child holds a butterfly

change in climate in those areas.[42] If this process continues, the devastating specter of deserts could spread to many more heavily populated areas in the U.S. beyond the deserts already present in the southwest.

In the southern hemisphere, Australia is already in the grip of a drought of unprecedented intensity and duration, and one of its most senior climatologists is beginning to believe the change is indeed permanent.[43] Not surprisingly, Australians have suddenly become a lot more concerned about global warming[44] and have elected a new leader who has made the climate crisis a top priority of his administration.[45]

Reduced crop yields from extreme weather and droughts. Droughts over farmland inevitably result in lower crop yields, as farmers in Australia, China, and the state of Georgia are being reminded. Storms and floods also destroy crops. In addition, crops growing under increased levels of carbon dioxide absorb more of it, often at the expense of other nutrients, resulting in lower protein levels, and thus less nutrition, in the harvested food.[46] This has ramifications for both the people and animals that are fed from these crops. Furthermore, examination of fossil leaves from a comparable global warming event 56 million years ago indicates a significant increase in the amount of plants being eaten during that period.[47] Whether this was because insects had to eat more of what might have been less nutritious foliage to survive, or because warming increased insect reproduction, the comparison is ominous: it suggests that there will be an increase in future insect damage on our crops as a result of global warming.

There are almost 40 countries already experiencing critical food shortages.[48] Global grain reserves are declining as the United Nation's Food and Agriculture Organization's food price index, which tracks the overall global price of food, simultaneously increased more than 40% in 2007.[49] Experts claim global warming is partly responsible, creating reduced crop yields and spurring a rise in food prices as more profitable biofuel crops displace food crops. What are some of the results? While food shortages have incited food riots in many countries and food rationing in others, the United Nations has reached the limit of its resources and now admits that it will have to ration food aid to the increasing numbers of hungry people in the world.[50] Recent analyses indicate that global warming will affect agriculture in the lower latitudes the most,[51] precisely where most of the poor live today, with projected agricultural declines of as much as 40% for India, 30% for Africa, and 20% for Latin America.[52] The Fourth Assessment Report of the IPCC predicts worse for Africa — a halving of production by 2020.[53] This can only exacerbate the gap between the global rich and poor. And it will get worse as global warming continues and crop competition for biofuel production increases.[54]

Increased threats of wildfires. Warmer temperatures and the reduced snowpack, as well as the earlier seasonal snowmelt now being experienced in our forested mountains as a result of global warming, produce much longer fire seasons — by at least one estimate, the fire season in some areas has increased by over two months in just the past 15 years.[55] This, combined with the buildup of dry fuel in forests from the conscious prevention of forest fires by the U.S. Forest Service over the past century, has resulted in many more and far larger fires, called megafires, burning over 16 million acres in 2006 and 2007 alone, according to one CBS news report.[56] Often, these fires are so intense that they literally burn the organic soil that would normally survive and fuel the subsequent reforestation, leading experts to fear that many of the burned forests will not recover for centuries or more. Dr. Thomas Swetnam, one of the world's leading fire ecologists, estimates that the U.S. stands to lose about 50% of its current western forests by 2100 or sooner, given the current trends in wildfire size, intensity, and frequency.[57] Furthermore, because forest fires create CO_2 as they burn trees, the size of these fires can cause a forest to go from an overall carbon reservoir to a carbon emitter, as in the case of the subarctic boreal forests.[58] Remember also that drought-stricken areas are more susceptible to wildfires, as Greece found out in 2007.

In the future, the wildfire situation may well be worse. Global warming models project that in many regions wet years will be wetter and dry years will be drier, resulting in a double whammy when it comes to wildfire. During very wet years, a tremendous amount of plant growth occurs. In a subsequent drought year, when plants wither, the accumulated biomass becomes additional fuel for wildfire.

Ocean acidification. In addition to climate warming causing coral bleaching, there is a second threat to coral reefs. Increasing atmospheric CO_2 levels cause the oceans to absorb more CO_2. Because CO_2 acts like a weak acid in seawater, the increase of CO_2 in our oceans is causing them to acidify slightly. And it's been shown that even slight acidification makes it more difficult for animals, like the already slow-growing coral, to grow. Both the projected global atmospheric increase of 3.5° F by 2100 and the resulting slight acidification are predicted to decrease coral diversity and make carbonate corals increasingly rare. This will lead to the physical breakdown of our reefs, which are built on the massive skeletons, both living and dead, of carbonate corals.[59] It may even become acid enough to prevent the growth of seashells, many species of plankton, shrimp, crabs, and other calcium-shelled marine creatures.[60]

Increasing intensity of hurricanes. Higher oceanic surface temperatures may not be bad only for corals. Greater scientific understanding is needed of the factors that result in extremely intense hurricanes,[61] but there is evidence that a rise in ocean surface temperatures strengthens hurricanes.[62] It is difficult to discern any distinct trend in the frequency and intensity of hurricanes globally, partly due to a lack of long term records. Long term records for the North Atlantic show that there has been a dramatic increase in the intensity of hurricanes since 1995, which in turn correlates with a rise in oceanic surface temperatures there.[63] The 2007 Intergovernmental Panel on Climate Change Fourth Assessment Report predicts more intense tropical storms in the future in association with warmer oceanic surface waters.[64] New Orleans is just the first casualty, destroyed by flooding caused partly by the type of intense hurricanes scientists have predicted to occur because of global warming. Stronger hurricanes, in turn, not only damage homes but forested areas, which then release more CO_2 to the atmosphere.[65] Experts are also predicting an increase in the number of storms in general.[66]

Nowhere are the consequences of this message being heard more strongly than in the insurance business.[67] Lloyd’s of London, for example, notes that climate change is the top issue confronting their industry. In the wake of Katrina, Allstate is decreasing the number of Floridians it will insure for hurricane losses. Allianz, the largest European insurer, expects losses due to extreme weather events to increase by an average of 37% annually over the next decade. Mindy Lubber, president of CERES, a coalition of investors that holds collectively more than $4 trillion in assets notes, "Climate is one of the most underestimated risks out there…The subprime (mortgage lending) problem really overall is a situation where everyone underestimated the risk of what might happen." This is causing banks to start considering climate change when making financial and investment decisions.[68]

Spread of infectious disease. The geographic areas in which specific infectious diseases occur are partly constrained by climate. The pathogens that cause the disease and the insects or other “vectors” that carry the pathogen from one victim to another often require certain climatic conditions; thus, those diseases are confined to regions with those conditions. For example, many tropical and subtropical diseases are confined to areas without winter frost. As the frost line moves poleward under global warming, tropical and subtropical diseases may spread to regions that currently have temperate climates. One serious African disease, chikungunya, has already shown up, unexpectedly, in central Italy,[69] while the British government is warning its national health service to expect outbreaks of malaria there by 2013 because of global warming.[70] Closer to home, cases of the tropical mosquito-borne disease dengue fever have started popping up in Texas, spurring worried senior health officials to call for urgent study. They warn that this could be the start of the disease's spread to other parts of the U.S.[71]

Massive sea level rise. Glaciers and polar ice hold an incredible amount of water. If either the western Antarctic ice shelf or the Greenland ice sheet melted completely, for example, a 20-foot rise in sea level would occur, doing incalculable damage to life on Earth, including human society. A decade ago, this seemed highly unlikely, and it certainly was not expected to occur within the next 100 years. But now we know that if the threat of global warming is not dealt with rapidly, it could occur within our children's lifetimes. The new assessment stems from the unexpectedly high rate of deterioration of the summertime Greenland ice sheet.[72] Arctic Ocean ice is also melting faster than we predicted a decade ago. But, like an ice cube melting in a drink, the melting of that floating ice will not raise sea level.

Global warming exacerbates the extinction crisis. Human pressures generated by our exploding population are already threatening many species, and global warming will add significantly to the threat. The World Conservation Union (IUCN), a global partnership of many governments, organizations, and scientists, has analyzed vast amount of data and estimates that 40% — that's right, close to half — of the world's species are threatened.[73] Estimating the threat to biodiversity is a relatively new field of study, however, so even this is only a rough estimate.[74] Efforts to improve the accuracy of projected extinctions are underway by many researchers.

How bad is the threat? Let's look at birds, for example. Birds all over the world are declining,[75] including penguins.[76] In the U.S., the Audubon Society has documented dramatic declines in many species of common birds due to pollution and to loss of habitat, such as wetlands to development.[77] In China, the decline has been so great that simply sighting wild birds is becoming a rare event. This is especially evident in Chinese cities, where the only birds you are likely to see are those kept as pets in cages or for sale at outdoor markets. In Europe, a nearly 50% decline in birds over the past 20 years can be traced to loss of habitat to agriculture, reports the Hungarian Ornithological and Nature Conservation Society.[78] BirdLife International notes that more than 20% of all bird species are threatened or near threatened — that's 2,005 out of a total of 9,800 species in trouble.[79]

Loss of our natural habitats, particularly our global rainforests, means that their inhabitants — plants, insects and other animals — are also disappearing. Many scientists have concluded that we are already undergoing a mass extinction on this planet of both animals and plants through massive disruption and destruction of ecosystems as we co-opt the land for our own use.[80] Just as stressed ecosystems are more susceptible to damage from global warming, threatened species are more susceptible to extinction under global warming.

In addition to all the species we have threatened with or sent into oblivion from damaging their ecosystems, we have depleted the stocks of many food species, such as fish. So, now small remaining fish stocks are in greater danger of extinction from further disruptions due to the climate crisis. Erosion of valuable biodiversity is becoming widespread even in our global agricultural sector, where the rise of megafarms that concentrate solely on planting a few special strains has pushed many other strains that may be of future value to the edge of existence.[81] As more plants species become threatened, so do our sources of new medicines, which could provoke a global healthcare crisis, some warn.[82]

A recent study that examined the fossil record showed that historically, when temperatures rise on Earth, so do extinction rates. It also shows that we are a century or less away from reaching temperature levels that in the past have been associated with mass extinctions.[83] Indeed, there is already some evidence that climate change from the climate crisis has contributed or led to the extinction of numerous animals and plants.[84]

Why might global warming cause even more massive waves of extinction? Consider a mountain and its butterflies.[85] As temperatures rise at all altitudes, those species of butterflies that need lower temperatures are being forced ever higher up the mountain, where their codependent species (food sources, prey or predators, sheltering plants) may not follow as quickly, or at all. The reasons for not following might be physical: the seeds of codependent plants can't spread that quickly, or the soil up the mountain won't sustain them. Or if the codependent species to the butterfly is a predator such as a bird, the codependent species necessary to <u>that</u> bird might not exist further up the mountain. So, the butterflies might find themselves forced up the mountain and into the thin air of extinction. A similar situation exists for species trying to migrate poleward towards cooler climes. In both cases, lacy delicate webs of life are stretched and then shredded as some parts must move and others cannot. Now imagine that happening to different ecosystems all over the planet. And if ecosystems are webs of life and extinctions are breaks in those webs – how many breaks can a web sustain before the web ceases to function? Another dangerous unknown.

Another way that global warming can cause extinctions is through temperature changes that allow opportunistic species to invade new ecosystems, extinguishing native species that have evolved in their absence. A good example exists in the marine habitats. Scientists warn that the unique bottom fauna of the deep Antarctic, full of interesting creatures that have evolved in the absence of predatory crabs and sharks, will be at risk of extinction as the waters warm enough to allow these predators to penetrate this ecosystem, isolated by cold up until now.[86] In the Arctic, we, the authors, listened to Siberian Chukchi natives in the summer of 2007 describe with wonder something they had never seen before: a shark that had washed up on their shores.

A timeline of the snowballing effects of global climate change in combination with the damage we have already created to ecosystems has been compiled, utilizing the predictions of various reputable studies.[87] It pretty much summarizes all that we have discussed above and the picture it paints is grim. Grim as it is, however, it probably underestimates the effects, given that many of our predictions have already been shown to underestimate the effects of climate change. We are leaving an impoverished legacy for our children and their unborn children.

More Reasons for Concern about Global Warming

Social effects of global warming. Global warming may already be creating tragic social effects. Both UN Secretary General Ban Ki-moon and British Home Secretary John Reid agree that the Darfur conflict originated as a climatic crisis: a lengthening drought in that area has ethnic groups competing for dwindling land and water resources, which has turned into war. Ban Ki-moon believes that this is due at least in part to climate change. Mr. Reid observed that this crisis should be viewed as a warning sign.[88] If it is, then the warning is that hunger, droughts, environmental damage, and land loss from rising sea levels or desertification will damage human societies around the globe, through resource wars, diseases, and starvation.[89] Based on IPCC findings, there are now strategic studies that predict massive flows of environmental refugees fueling political instabilities and threatening billions of people, countries competing for resources, and developed nations trying to stave off the influx of poor people fleeing the worst environmental damage within the next century.[90] Indeed, history has already shown that climate changes lead to famine and war.[91]

Positive feedback effects exacerbate global warming. As if all of these physical and social effects weren't bad enough, the global heating itself is causing our planet to respond in a way that accelerates further heating, in a phenomenon known as positive feedback. Some feedbacks are already incorporated into the global climate models upon which IPCC based its projections. One of these is triggered by the melting of ice. To understand this, pretend you're in an airplane looking down on a big expanse of ice, nice and white, in contrast to the darker ocean surrounding it. White ice reflects light, while the darker surrounding seawater absorbs it more, transforming the light into heat energy. Melt the ice, and you've simply added more heat-absorbing area to the Earth's surface, accelerating the absorption of heat — precisely the thing you want to stop.

But feedbacks can also be triggered by ecosystem responses to climate change. For example, just as melting ice changes lighter areas into darker, more heat-absorbing ones, the heating of the arctic can be accelerated as warmer temperatures allow the spread of darker, boreal forests into the lighter, arctic tundra.[92] We showed another example of this ecosystem biofeedback mechanism at work earlier in the chapter with forest fires turning forests from carbon reservoirs to carbon emitters, thereby increasing the amount of carbon dioxide in the atmosphere. What other feedback mechanisms might be lurking on our planet?

One clue lies in a tantalizing piece of ancient history. A famous ice sample, the Vostok Ice Core, is a long column that scientists extracted from Antarctica. This core represents nearly a million years of Earth's atmospheric and temperature history. By observing traces of a rare form of oxygen and sampling tiny trapped gas bubbles, scientists were able to reconstruct the temperature and GHG levels during that time period. The record indicates that atmospheric temperature and greenhouse gases, such as carbon dioxide (CO_2) and methane, vary in lockstep – when temperatures decrease in glacial times, CO_2 and methane levels also decrease; when temperatures increase between glacial times, the levels of these greenhouse gases also increase**.** This indicates that some sort of feedback has occurred historically between CO_2 levels and temperature.

To understand what has been happening over the past million years, we first have to separate the forces at work. One set of forces influences the timing of glacial and interglacial periods — the pacemaker of climate change. Another set causes the temperature changes to be as large as they actually are — as much as 15° F or 20° F between glacial and interglacial periods. The pacemaker of the glacial-interglacial cycles consists of several cycles that vary the amount and seasonal distribution of sunlight reaching Earth. These cycles, in turn, are driven by small cyclic variations in three planetary movements. One is the shape of Earth's orbit around the Sun. The second and third movements involve the direction of the axis around which the Earth spins. Seen from afar, let's say the North Star, the tip of Earth's axis describes a circle as it wobbles, much like a spinning top. Thirdly, the angle at which the spin axis is tilted away from pointing directly toward the North Star varies cyclically.

But while the resulting overall variability in solar input explains the <u>timing</u> of warming and cooling episodes over the past million years, these shifts in solar input are known to be much too small to explain the <u>size</u> of the warming and cooling during these cycles. The key to the size of the fluctuations in global temperature is that lockstep behavior noted above from the Vostok Core. So, when the planet warms a little because of a slight increase in sunlight, the atmospheric levels of the greenhouse gases CO_2 and methane rise, causing more warming. Thus, there is a positive feedback in Earth's climate system: a small initial warming (brought about by a change in solar input) causes CO_2 and methane levels to rise, which in turn causes more warming, and therefore additional release of CO_2 and methane into the atmosphere. A reversal occurs when a slight decrease in sunlight occurs, cooling the planet a little.

This raises yet another question: why does warming the planet trigger an increase in the amount of CO_2 and methane in the atmosphere? The mechanisms that cause this feedback response are not fully understood. However, we can identify both oceanic and terrestrial processes that could plausibly bring it about. When seawater is heated it cannot hold as much bicarbonate (dissolved carbon dioxide), so some of the huge quantity of carbon stored in the sea is released to the atmosphere as carbon dioxide.

When terrestrial ecosystems are heated they, too, are likely to release carbon dioxide to the atmosphere. Why?

- Forests are more prone to burning in a hotter climate.
- Organic carbon in soils, which contain 3-5 times more carbon than the atmosphere, might decompose faster in a hotter world.
- Photosynthesis (which removes carbon dioxide from the air) is likely to be inhibited in a hotter, drier climate.
- Methane stored frozen in the deep ocean, as gas below subsea permafrost, or created in warming bogs and tundra soils could plausibly be released to the atmosphere in large quantities when the climate warms.

Let's go into some of these factors a bit more, and note some additional ones. Supporting studies have not been done yet for forests, but studies in alpine meadows have shown that just a slight rise in temperature can cause a floral shift that reduces soil carbon, increasing the net flow of this carbon dioxide into the atmosphere.[93] Another positive feedback from forests has already been observed, however. Examining data over the past 20 years for northern forests, scientists have noted a lengthening of the warming into autumn and spring. They note that the effects on how plants give off (during respiration) or take in (during photosynthesis) carbon dioxide are quite different in the two seasons. During the autumn, the plants give off more carbon dioxide than they take in, because growth is slowing at the end of the growing season. During the spring, plants take in more carbon dioxide (new growth) than they give off. Currently, scientists are observing that the autumn effect is outpacing the spring effect, causing an overall weakening of the ability of forests to absorb carbon dioxide. Thus, global warming is causing these forests to absorb less carbon dioxide annually, which in turn leads to a higher buildup of carbon dioxide in the atmosphere from fossil fuel burning.[94]

What about the permafrost in the Arctic? As the organically rich permafrost melts, a waterlogged underground environment is created where there is little oxygen. Anaerobic microbes (those that do not need oxygen) start breaking down the organic matter; some of which, like mammoth dung, has been frozen for eons. A byproduct of this process is methane, a much more potent global warming gas than carbon dioxide, which is released into the atmosphere.[95]

Even the oceans have the potential for positive feedback. As seawater warms, it expels carbon dioxide to the atmosphere. Because the ocean today stores nearly 50 times as much carbon dioxide as is in the atmosphere, the potential exists for huge releases of carbon dioxide from warming oceans.

Indeed, this may at least partially explain the Vostok feedback described above.

Of great and recent concern, however, is the methane trapped beneath the cap of permafrost on the Siberian continental shelf under the Arctic Ocean. Sea bottoms are the ultimate resting place for uncounted numbers of marine animal corpses. There, special microbes have been breaking down the corpses anaerobically through the eons, once again creating methane, which forms an ice-like crystalline solid called methane hydrate. Each crystal usually contains one methane molecule encased in a cage of water molecules. These crystals can form solid frozen surface layers several hundred feet thick, and often have gaseous methane deposits beneath them as well.[96]

If warming waters above circulate down and start melting the permafrost lid, the hydrates could also melt and result in a massive release of methane into the atmosphere, greatly accelerating global warming. Indeed, there is evidence that massive deep-sea releases of methane influenced climate change during the last ice age,[97] and recent real-life examples of another greenhouse gas being explosively released from underwater bottoms exist. In 1986, for example, carbon dioxide, trapped at the bottom of Nyos Lake in Cameroon, Africa, exploded to the surface. The resulting rush of carbon dioxide suffocated close to two thousand people, as well as farm animals before dissipating to breathable, low levels.[98] And no, no one knows how much heat is needed to spring the current submarine methane trap – or has it already been sprung?

Various expeditions since the 1990s have been measuring atmospheric concentrations of methane above the Siberian undersea methane deposits.[99] Around 2003, scientists began noticing areas exhibiting elevated methane levels as much as 100 times that of surrounding areas.[100] In September 2008 along the Siberian continental shelf, scientists discovered methane chimneys — areas with methane bubbling up through holes in the melting submarine permafrost below.[101] Scientists estimate that these and the previously discovered areas with elevated atmospheric methane levels represent the release of millions of tons of methane into the atmosphere. What's causing this methane release? Among other possible factors, Siberian researcher Igor Semiletov speculates on a possible feedback mechanism. Relatively warm water from the melting Siberian tundra is pouring into rivers that empty into and warm the shallow coastal sea on the continental shelf. The warming sea is, in turn, starting to melt the undersea permafrost, causing the release of methane.[102]

Simultaneously, scientists analyzing 2007 data at the U.S. National Oceanic and Atmospheric Administration (NOAA) noted a sharp rise in methane and carbon dioxide.[103] Interviewed before the discovery of methane chimneys, NOAA scientist Ed Dlugokencky said the rise was likely due to the rapid increase in Asian industrialization and rising wetland emissions from the Arctic and tropics. It was too soon to know whether this was the start of a trend due to melting permafrost releases of methane, but they were keeping alert for the first signs of such releases, he added.

Methane has a much shorter "lifetime" in the atmosphere than carbon dioxide, so over a long time period, such as a century, the warming effect of our carbon dioxide emissions is greater than that of our methane emissions. But methane molecules are more potent at heating the Earth than carbon dioxide molecules, so over a shorter period such as a decade or two, the effect of methane emissions is greater than that of carbon dioxide emissions. This makes methane a far more potent agent of rapid positive feedback. Furthermore, this ongoing release of methane from the Siberian continental shelf is likely to increase as the undersea permafrost continues to melt, adding even more to the heating effect of methane. Thus, over at least the next 20 years the effect of the additional release of methane described above is cause for alarm. NOAA data indicate methane emissions are increasing from both the Arctic and tropic regions, citing the unusually warmer and wetter conditions there.[104]

Ultimately, however, we just don't have enough information yet about the increased Arctic methane emissions to know its origin (wetlands, permafrost, subcontinental shelf), how much more is being released, and how fast the process is accelerating. Will the additional methane release that we're starting to observe be a potent punch to the global climate system, contributing to a dangerous acceleration of global warming? Whether we like it or not, we're about to find out over the next two decades.

While we do not understand all the details of what causes the positive feedbacks seen in the Vostok core data and current ecosystems on Earth, the message is clear. And this full combination of feedback mechanisms is not currently incorporated in our climate models. If it were, we would be predicting an even greater increase in global warming than is currently forecast.[105] These feedback mechanisms have not been incorporated into current IPCC assessment reports either, so the big ominous story here is that IPCC projections are probably significantly underestimating the amount of global warming that will occur in the future.

The carbon sinks are filling up.[106] From the perspective of global warming, ecosystems and oceans have a very important function: they have acted as carbon sinks, taking CO_2 out of the atmosphere and storing it. When CO_2 increases in the atmosphere, the amount absorbed into the ocean also increases. This has been good, since some of our generated CO_2 has been absorbed by the oceans, preventing the planet from heating up even more than it has. But raising water temperature also lowers the water's ability to absorb CO_2, decreasing the ultimate size of the oceanic carbon sink. Recent observations indicate that our levels of CO_2 in the atmosphere have actually been increasing much faster in the past decade than expected[107] — in fact, 35% faster than our models have predicted.[108] Some of this has to do with the many inefficient coal plants operating worldwide and increasing in the populous, rapidly developing countries of China and India, and a general increase in global populations. But somewhere out there, some carbon sinks are approaching their limits, slowing down, or decreasing, as our example of northern forests in the positive feedback section above shows. Not good news. We depend on our ecosystems for clean air, water, food and shelter. So, anything that damages our ecosystems, damages our chances to prosper as a species. Why are we waiting?

Damaged ecosystems are more susceptible to global warming. This brings us to yet one more biological factor that is contributing to the effects of global warming: damaged ecosystems. Damage that we have already inflicted on them in our haste to exploit them for our convenience — damage in the form of physical destruction or through introduction of invasive species, whether accidental or intentional. Indeed, as much as 80% of the world's endangered species could suffer further losses due to invasive species alone.[109] In the marine realm, a map constructed from 17 global data sets of climate drivers shows that 41% of Earth's oceans are heavily impacted by us, and that no marine place is untouched.[110] On a pragmatic level, this is illustrated by over-exploited fish stocks that have been replaced by exploding populations of jellyfish,[111] which, in turn, eat fish eggs. And jellyfish have been shown to proliferate when seas warm.[112] Just as a person is more vulnerable to other infections when already sick, our damaged ecosystems are vulnerable to additional damage from global warming. Thus, damage invites more damage.

In some ecosystems, the resulting damage decreases the ability of the ecosystem to either store or absorb carbon dioxide and becomes another positive feedback to global warming. For example, people have destroyed significant parts of the Amazonian rainforest to exploit it for its wood, minerals, and other products, and to use the land for crops or grazing. Remember, from a functional perspective, this is a vast storage area of big, carbon-rich cylinders called trees. Historically, this ancient rainforest has maintained itself through reseeding and recycling its water. Evaporation from the massive forest rises in such large volume to the atmosphere that it creates large clouds, which promptly rain down on the forest again. But destroy enough of the forest, and you can destroy this self-perpetuating mechanism. As it is, enough of the forest has been destroyed so that scientists fear it is at a 'critical resiliency threshold,' beyond which the forest could disintegrate under the load of environmental stresses. With just a small degree of warming, the interior of the Amazon Basin could become essentially deforested. [113]

Global warming exacerbates the water crisis. Droughts have always been a part of our existence. Because of our large populations and consumption patterns, however, we have been using our water supplies faster than they can be replenished, whether they be rivers, lakes, aquifers, or reservoir systems. Farming and other human pressures have increased desertification worldwide, further disrupting water cycles and contributing to water shortages. In the future, unchecked global warming will likely increase the intensity of droughts and floods, and may already be doing so; that, in turn, will continue to increase the strain on global water supplies. In the U.S., we see many aspects of this water crisis playing out: growing western cities are fighting over finite river supplies, California farmers are selling their water to cities instead of growing crops,[114] major aquifers such as the Ogalala Aquifer are being slowly drained by agriculture, and both the southwest and southeast are experiencing uncommon drought.

In other parts of the world, this heady mix of increasing human population, climate change and decreasing water sources has led to a global water crisis that contributes to social instability in many poor countries. This has led the Secretary General of the United Nations to urge the world to put the global water crisis at the top of its global agenda in 2008.[115] Indeed, the global food giant company Nestle SA has advocated an international water market to encourage conservation and a true pricing of this increasingly scarce resource.[116]

Population size contributes to global warming. As hinted in the above section, one of the underlying causes of global warming, as well as all other environmental problems that we face, is human overpopulation of our planet. The Earth is only so big, and it can support only so many people without affecting the rest of biodiversity and our ultimate survival. A growing population fuels a growing global demand for energy, a demand met by an ever-increasing combustion of fossil fuels that, in turn, increase atmospheric carbon dioxide levels. Some argue that concerns about the size of the human population reflect an underlying dislike of people. In fact, we care enough about the unborn, the future generations, so that we do not want to leave them a world devastated from overuse by too many people.

There is also an often unstated implication that without population growth, there can be no economic growth. This implies an unchanging definition of “a healthy economy” that can quickly become irrelevant under changing circumstances. A new, clear, dynamic definition of a healthy economy is needed, one in which economic growth is tied to the quality and survival of life on Earth for humanity — not to its numerical growth, which is economically unsustainable at current levels.

In many parts of the world, population growth is checked through access to family planning methods. Many people elsewhere do not have this access. Additionally, there are relatively rich, high-consumption families in the developed and developing world that feel they can afford to breed many high consumers like themselves. The overall effect is an exploding global population that is competing for limited resources. In some areas, populations are being limited by starvation, disease, and resource wars that are either obvious or wear the mask of "religious/cultural differences." Thus, humanity is not living sustainably, and all of Earth's life is being damaged. The stark message is that at least for now, no one — either rich or poor — can in reality "afford" to have more than one child per couple. The price we are paying in terms of our ultimate survival is too high.

The latest United Nations Environment Programme's Global Environmental Outlook Report (No. 4, October 2007) observes that our continuing destruction of the natural world, a destruction first highlighted in its initial report twenty years ago, is decreasing our own health and well-being. Living far beyond our means, we are damaging the environment possibly beyond points of no return, and political leaders are not showing enough interest or alarm about it. It names climate change and species extinction as two of the main risks to humanity.[117] Let's change our ways. If we do not stop population growth, all our efforts to halt the climate crisis will ultimately be to no avail. Too many people are eating up too many resources and destroying the ecosystems that sustain us.

How fast is the planet reacting? MUCH faster than we thought. More bad news. As noted previously, many biological feedbacks from the ecosystems described above have not been incorporated into IPCC projections. And even some physical observations indicate that our computer models are not incorporating all of the important physical factors. Our arctic icecap, for example, is melting much faster than previously predicted;[118] so is the Greenland ice sheet — about 30 years ahead of our climate model predictions.[119] At least one arctic climate change scientist, Scott Lamoreux of Queen's University at Kingston, Canada, after observing the changes he's seen in the Arctic during the 2007 summer, estimated that the climate change occurring there is a decade ahead of the worst case scenario.[120] Satellite data indicate that Antarctic glaciers are also melting much faster than anticipated, nearly matching the ice loss of Greenland.[121] Meanwhile, accelerating sources of CO_2 emissions are coming from two giant nations, India and China,[122] which are ramping up their development to approach our standard of living.

Are we approaching a tipping point? Some world-class climate scientists have brought attention to the possibility of an environmental threshold or tipping point.[123] The tipping point can be likened to a stone rolling down the hill towards a cliff — at some point-of-no-return, dramatic change is unstoppable. The climatic tipping point is a point at which these scientists do not see humanity as capable of responding fast enough to accelerated warming in time to prevent some catastrophic effects to us — and there is concern that we are already near such a tipping point. For example, the rate at which ice is melting on the planet is accelerating; at what point will the rate result in an irreversible, complete meltdown of, say, the Greenland ice sheet? In some areas of the world, winters have become warm enough to let economically damaging insects survive them, devastating forests that cannot withstand the increased, constant onslaught; how long can such forests last under these conditions?[124] Scientists are warning that despite the uncertainty, perhaps even because of the uncertainty, we must be aware that there are many little-understood thresholds in nature. Once passed, these thresholds could cause abrupt shifts in our world and climate, with most of them probably being irreversible on a human timescale — and we might be close to some of these thresholds. Their examples include the projected drying of the Amazon basin, which might result in the dieback of the Amazon rainforest, and the complete disappearance of summer arctic ice and delay in winter ice formation, both of which might contribute to the melting of the Greenland ice sheet.[125] We are truly embarked on a sea of unintended consequences that will literally change the map of Earth.

How Predictable Is All This? Scientists are not all-knowing. Contrary to popular myth, the scientific process does not seek to prove a single hypothesis, but rather to disprove competing hypotheses. Like a boxing match, the last idea standing wins: by disproving all other alternatives, the remaining alternatives become the probable explanations. A more accurate motto for science is, "Science doesn't prove; it **im**proves." Scientists can make general predictions about climate, but can't tell you exactly when each event will happen, or all the events that will happen, or necessarily how fast events will develop, as our melting arctic ice cap illustrates. Our past experiences in affecting climate have shown that nature can produce nasty and unexpected surprises. (Remember how surprised everyone was initially by the ozone hole?) This alone should be a warning to us to clean up our act — and fast — before any other, much nastier surprises turn up.

Big Sticks — But Big Carrots, Too!

If the effects of global warming loom over us like big sticks urging us to act, the big carrots are that the needed solutions also solve an interconnected web of associated, important problems. Solving the climate crisis will solve some big economic problems, by solving our energy crisis of dwindling oil[126] and natural gas resources. It will also solve problems associated with those resources (e.g., oil spills, strip mining, mining accidents, acid rain, smog and other forms of air pollution and their resulting health problems), especially the cost of maintaining access to fossil fuels, as in the form of foreign wars. To paraphrase Gretchen Daily of Stanford University, we would not be fighting in Iraq, at a cost of many lives and hundreds of billions of dollars, if the main export of that nation was broccoli.

The proverb "A stitch in time saves nine" has never rung so true. As all of the above illustrates, the more we let global warming occur, the faster it's going to do so, and the more it will damage our ecosystems and our civilization. And we don't know when the problem will explode into a scale that becomes unmanageable, beyond the limits of a relatively easy, practical, technological solution. We do know that if we act now, it still can be managed this way. Acting now in a seriously coherent effort to solve the climate crisis will save millions of human lives, hundreds of billions of dollars, and much of our valuable biodiversity.

Our national security and our global security hinge on our acting as soon as possible. The 2007 IPCC report depicts an alarming picture. The IPCC Chairman and Nobel Laureate, Rajendra Pachauri, has already acknowledged that the effects from global warming are developing so much faster that if there is no action by 2012 to curb emissions, it will be too late to prevent some serious consequences.[127] The threat, in terms of potential devastation to our society, is just as real and even more global than the one faced in World War II, and thus warrants at least the same magnitude of focus, urgency and resources that our society contributed towards that last great war.

Many valuable human and material resources are being wasted instead on wars being fought over the very fuels that are causing global warming, and distracting us from solving the climate crisis.

We should not only fear weapons of mass destruction, we should fear methods of mass distraction. In our competition for fossil fuel sources, we are like rival groups of ants fighting over the same dwindling crumbs of bread as the anteater approaches. It's time to stop fighting among ourselves, and deal with the anteater.

But what are we going to do?

Chapter 3: An EASY Plan

Here we present an overview of the EASY plan, with the details to follow in subsequent chapters.

General Criteria

Any proposed energy policy should include these two components:

- **Technical/Behavioral:** What resources and technologies are to be used to supply energy? On the demand side, what technologies and lifestyle changes are being proposed to consumers?
- **Incentives/Economic Policy:** How are the desired supply and demand options to be encouraged or forced? Here the options include taxes, subsidies, regulations, permits, research and development, and education.

And a successful energy policy should satisfy the AAA criteria:

- ✓ **Availability.** The climate crisis will rapidly become costly to society if we do not take action expeditiously. We need to adopt now those technologies that are currently available, provided they meet the following two additional criteria:
- ✓ **Affordability.** Because of the central role of energy in our society, its cost to consumers should not increase significantly. In fact, a successful energy policy could ultimately save consumers money.
- ✓ **Acceptability.** All energy strategies have environmental, land use, and health and safety implications; these must be acceptable to the public. Moreover, while some interest groups will undoubtedly oppose any particular energy policy, political acceptability at a broad scale is necessary.

An Overview of the Blueprint

Our strategy for preventing climate catastrophe and achieving energy independence includes:

- **Energy Efficient Technology** at home and at the workplace. Huge reductions in home energy use can be achieved with available technologies, including more efficient appliances such as refrigerators, water heaters, and light bulbs. Home retrofits and new home design features such as “smart” window coatings, lighter-colored roofs where there are hot summers, better home insulation, and passive solar designs can also reduce energy use. Together, energy efficiency in home and industry can save the U.S. up to approximately half of the energy currently consumed in those sectors, and at no net cost — just by making different choices. Sounds good, doesn’t it?

- **Automobile Fuel Efficiency.** Phase in higher Corporate Average Fuel Economy (CAFE) standards for automobiles, SUVs and light trucks by requiring vehicles to go 35 miles per gallon of gas (mpg) by 2015, 45 mpg by 2020, and 60 mpg by 2030. This would rapidly wipe out our dependence on foreign oil and cut emissions from the vehicle sector by two-thirds. A combination of plug-in hybrid, lighter car body materials, re-design and other innovations could readily achieve these standards. This sounds good, too!
- **Solar and Wind Energy.** Rooftop photovoltaic panels and solar water heating units should be phased in over the next 20 years, with the goal of solar installation on 75% of U.S. homes and commercial buildings by 2030. (Not all roofs receive sufficient sunlight to make solar panels practical for them.) Large wind farms, solar photovoltaic

stations, and solar thermal stations should also be phased in so that by 2030, <u>all</u> U.S. electricity demand will be supplied by existing hydroelectric, existing and possibly some new nuclear, and, most importantly, new solar and wind units. This will require investment in expansion of the grid to bring the new supply to the demand, and in research and development to improve overnight storage systems. Achieving this goal would reduce our dependence on coal to practically zero. More good news!

- **You are part of the answer.** Voting wisely for leaders who promote the first three components is one of the most important individual actions one can make. Other actions help, too. Just as molecules make up mountains, individual actions taken collectively have huge impacts. Improved driving skills, automobile maintenance, reusing and recycling, walking and biking, wearing sweaters in winter and light clothing in summer, installing timers on thermostats and insulating houses, carpooling, paying attention to energy efficiency labels on appliances, and many other simple practices and behaviors hugely influence energy consumption. A major education campaign, both in schools for youngsters and by the media for everyone, should be mounted to promote these consumer practices.

No part of EASY can be left out; all parts are closely integrated. Some parts might create much larger changes — for example, more efficient home appliances and automobiles — but all parts are essential. If, for example, we do not achieve the decrease in electricity demand that can be brought about with the E of EASY, then it is extremely doubtful that we could meet our electricity needs with the S of EASY.

It is equally urgent that once we start implementing the plan, we aggressively export it to other major emitting nations. We can reduce our own emissions all we want, but the planet will continue to warm if we can’t convince other major global emitters to reduce their emissions substantially, too.

What EASY will achieve. If no actions are taken to reduce carbon dioxide emissions, in the year 2030 the U.S. will be emitting about 2.2 billion tons of carbon in the form of carbon dioxide. This will be an increase of 25% from today's emission rate of about 1.75 billion tons per year of carbon. By following the EASY plan, the U.S. share in a global effort to solve the climate crisis (that is, prevent catastrophic warming) will result in U.S emissions of only about 0.4 billion tons of carbon by 2030, which represents a little less than 25% of 2007 carbon dioxide emissions.[128] Stated differently, the plan provides a way to eliminate 1.8 billion tons per year of carbon by that date.[129]

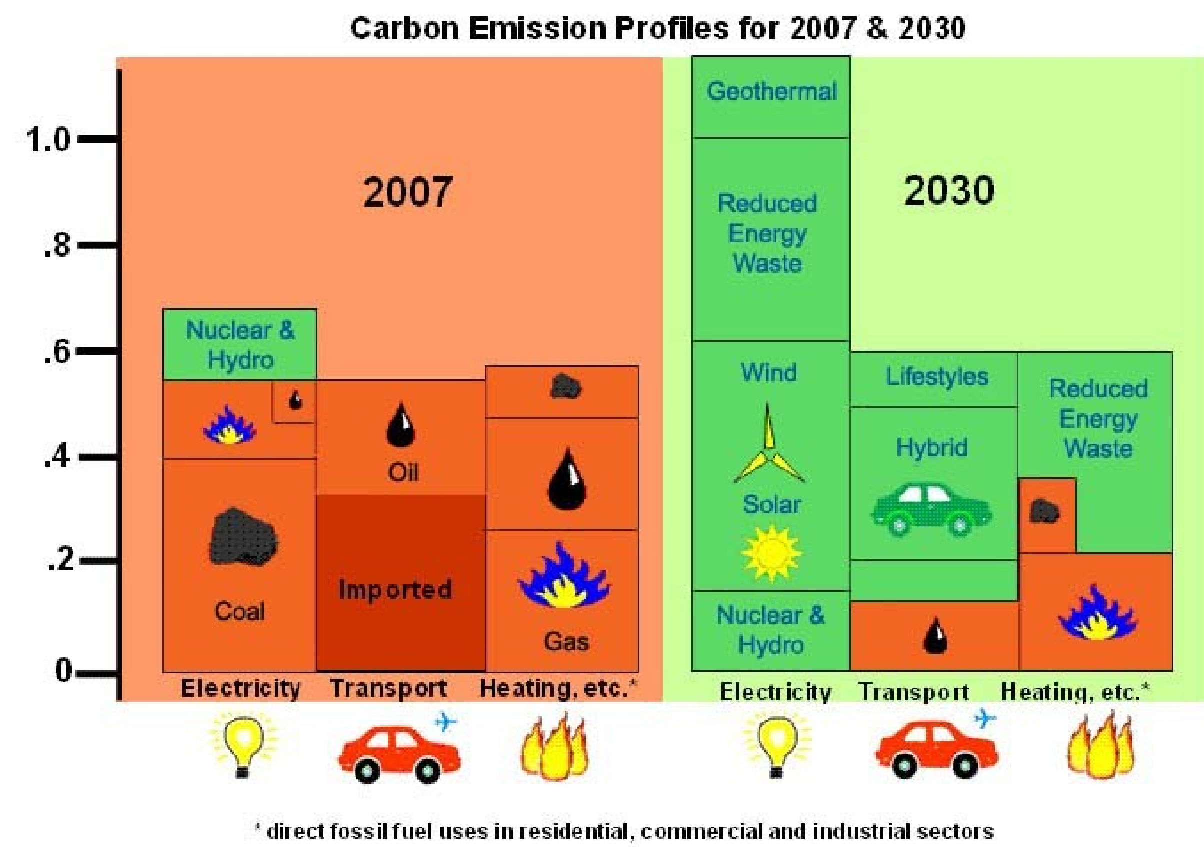
Want to talk in terms of tons of carbon dioxide?

1 ton of carbon = 3.67 tons of CO_2

We must act urgently: in the 14 months it took us to write this book, atmospheric CO_2 levels rose by several billion tons of carbon, and more climatic consequences have been observed.

Let's assume that we conserve our forests and other natural carbon reservoirs at our current levels, as well as maintain our current nuclear and hydroelectric plants (or replace them with more solar and wind generators). Here's what implementing EASY will achieve, as illustrated by Figure 3.1 on the next page.

Figure 3.1



Orange (the problem) signifies the carbon emissions (or their equivalent from other greenhouse gases) produced in billions of tons of carbon per year (vertical axis).

Green (the solution) signifies the equivalent amount of carbon emissions (created by the average mix of fossil fuels used to generate electricity) avoided through clean energy and energy efficiency. The bars in 2030 include the extra energy needed for projected increases due to expected population growth and increased per capita energy use, as well as increased electrical demand from plug-in hybrid vehicles. See the Appendix, Section A, for how we estimated the bars.

We will be coming back to Figure 3.1 again. Note that it focuses on the three main categories of energy consumption:

- the energy needed to produce electricity,
- the energy needed by the transport sector, and
- the energy needed for generating heat, whether in a factory, home, or commercial building.

Figure 3.1 also focuses on **three main avenues of solutions:**

* **solar and wind technology;**
* **plug-in hybrid or fully electric cars;**
* **reducing energy waste through improving energy efficiency and conservation.**

These avenues focus on two processes, promoted by the International Energy Agency[130]:

- **making current processes less demanding of energy;**
- **getting our energy from low/no-carbon-emitting sources.**

Determining how much energy savings we will get from each sector can become a messy business. In Figure 3.1 above, we have arbitrarily put carbon emissions savings that occur because of the use of efficient autos into the transport bar under the rubric “hybrid.” With equal justification, however, we could have put those savings into the electricity bar, because we will need less electricity to charge our rechargeables if they are more fuel efficient.

Why an emissions target? Energy policies that address the climate crisis can be designed to satisfy a variety of different targets or goals. One frequently stated target is to keep the future increase in globally averaged temperatures below some acceptable level, such as 4° F. Another target would be to keep the level of carbon dioxide in the atmosphere below an acceptable level, such as 450 parts per million. These two types of targets are often promoted because they are expressed in terms that relate to the damage that is done by fossil fuel burning. On the other hand, they both suffer from the same inherent problems. First, we do not know how to accurately predict the precise amount of temperature rise that will accompany a given rise in the atmospheric concentrations of greenhouse gases. This is because climate is complex and our best climate models can only predict a range of future temperatures that will result from a specified increase in atmospheric greenhouse gases. Secondly, we are not even able to make very accurate predictions of future levels of GHG concentrations, even if the rate of fossil fuel burning is specified. This is because of uncertainties in the future magnitude of carbon sinks, as well as in feedback mechanisms that can cause future releases of additional carbon dioxide from the oceans, forests, and soils into the atmosphere.

What we propose for a goal is quite different: let's target the thing we CAN control. The target that we use to define our energy plan and have adopted in the EASY plan is to specify limits on GHG emissions. Emissions targets relate directly to what we have control over — the total amount of energy we consume and the mix of energy sources we employ to supply that energy. Thus, regulations and other policy instruments can be constructed in a way that will achieve emissions targets more reliably than warming or gas concentration targets. The ideal emissions target is to reduce greenhouse gases as much as we can, as rapidly as we can, and as smartly as we can so that the economy benefits rather than suffers. This is precisely what we strive to do in this book. Our target is to reduce U.S. carbon dioxide emissions from energy consumption so that by the year 2030 they are no more than 25% of the level that they were in 2007.

A note on "wedges." It is widely accepted that there is no single technical "fix" to our energy and climate problems. Rather, a successful solution will have at least several components, as expressed by some in the concept of multiple "wedges." The idea is simple. Just take the energy demand pie and cut it up into relatively small slices. Each slice represents an option from a pool of numerous options that fall roughly into the following categories: solar, nuclear, wind, geothermal, hydro, oceanic, and biofuels energy sources; shifting from coal to gas; carbon sequestration; energy efficiency; maintaining and expanding forests as important carbon reservoirs; and conservative tillage of cropland.[131]

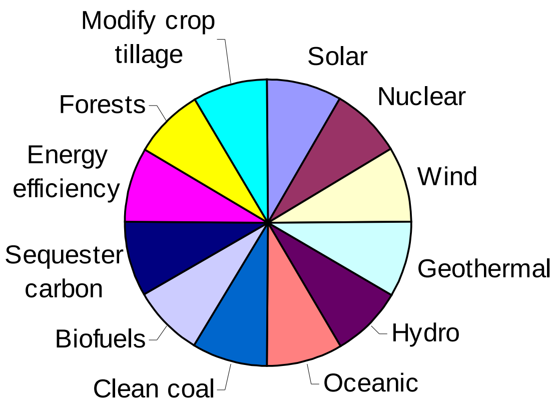


Figure 3.2

"Wedge" Solutions to the Climate Crisis

What's wrong with this diagram? Not all wedges are created equal! Not all solutions are equally available, effective, or acceptable, as we discuss in Chapter 8. Furthermore, the available time and money to solve this crisis are limited. That is why the EASY plan focuses on just the three major avenues mentioned above (solar/wind technology, electric auto technology, and improved energy efficiency/conservation), and relegates the rest as possible, but not necessary, supplements.

Some more warming is inevitable. The rest of the book is going to present a solution for the U.S., but achieving this goal will not prevent further global warming immediately. The phenomenon is so massive that our actions over the past two centuries have already "bought" a commitment to a certain amount of future warming that we cannot stop. Rather, our goal is to slow global warming to a point where we will starve the process, allowing it to peter out over the remainder of this century with a minimum number of resulting negative effects.

How Feasible Is Our Plan?

As the rest of the book shows, it is quite feasible, and its goal is not too different from similar goals already promoted by experts and some policymakers. Climate scientists and the IPCC have been calling for a roughly 70% reduction of current (2007) CO_2 emissions by 2050,[132] and even a Senate panel approved a bill, the Lieberman-Warner "America's Security Act of 2007" that aims to cut current GHG emissions by more than half by 2050.[133] In step with this is an increasingly popular grassroots movement from across the U.S. that is putting pressure on the U.S. Congress to enact legislation that will effectively reduce current (2008) CO_2 emissions by 80% by 2050.[134] Investment fund giants have called on the U.S. government to enact a national mandatory policy that will reduce greenhouse gases by 90% from the levels present in 1990 (called the benchmark year) by 2050.[135] Even large businesses want to address the climate crisis, endorsing a 50% global reduction of carbon dioxide emissions from current (2008) levels by 2050, pledging to reduce their emissions, and urging other businesses to do so, too.[136] An Australian plan developed by a respected international economic consultancy illustrates how that nation can bring its emissions down to 60% of 1990 levels without a dramatic shift in quality of life for a mere 80 cents a day per household.[137] And their plan involves technology not as fully matured as ours, although its core principle is the same — a major change in the mix of energy sources and increased efficiency.

The International Energy Agency is urging the U.S. to move faster on the basic tenets of our plan: cutting carbon emissions with energy efficiency and promoting solar and wind power.[138] In light of data that show the effects of global warming are increasing much faster than predicted, as noted in Chapter 2, we must act as fast as we can.[139] We propose here a faster, yet still achievable goal: by 2030, our annual emissions of GHG will be roughly 25% of the amount we emitted in 2007.

Underlying our plan, and any other solution that others might propose, is one essential, challenging, yet achievable action: we must change our behavior. We are energy addicts, and effective leadership will mean guiding our society away from wasteful, energy-consuming habits. We have been taught that human and economic (e.g., Gross National Product) growth is good, but we now must learn new lessons and develop new attitudes to survive in a new world. We can change our way of life into one that is sustainable and just as enjoyable and gratifying as our present one. The great news is that as one of the biggest energy users on the planet, our United States is in a position to make the biggest dent in global warming. We can control significantly the fate of the planet and our nation from the climate crisis, and provide a valuable role model to other big users.

What Are the Benefits of a Successful U.S. EASY Energy Plan?

While a major goal of the EASY plan is to vastly reduce the threat of catastrophic global warming, it will also bring many other benefits to our lives. Here is a summary:

- **Strengthening the Economy.** In the long run, it will reduce the price we pay for energy, given anticipated higher prices for petroleum and natural gas due to shrinking reserves. In the short run, shifts in incentives and subsidies will lead to only minor energy cost increases for consumers, and this will be balanced by savings resulting from reduced energy consumption brought about by increasing the efficiency of energy use and by behavioral changes. Moreover, a successful policy will ensure that U.S. automotive and clean, renewable energy companies are among the economic leaders of the 21st century.

- **Climate Mitigation.** We will be doing our share as a nation to avert a climatic catastrophe. By reducing U.S. emissions to a level that does not exceed 0.4 billion tons of carbon per year by 2030, we will be doing our nation's share of what is needed to prevent atmospheric carbon levels from doubling, relative to the safe level present at the start of the Industrial Revolution.
- **Energy Independence and Security.** We will not need to import any foreign oil, nor will we need to rely on shrinking worldwide oil resources.
- **Environmental and Health Benefits.** We will see health care costs decrease and many of our ecosystems recover as various forms of pollution and damage from extracting, processing, and burning fossil fuels disappear.

How Much Investment Will This Plan Require?

As with any major plan, the best anyone can do is make approximate projections of costs based on current values and consumption patterns. Already the economic community is starting to recognize that cutting carbon emissions isn't going to be as expensive as once thought. One study, for example, details how the U.S. could reduce its GHG emissions by 28% at relatively little cost or technological change.[140] So, let's compare the costs to the U.S. public of ramping up to the EASY plan versus the costs of our business-as-usual plan over the next 22 years, using conservative estimates of things like the future price of oil, conventional electricity and the cost of maintaining access to foreign oil supplies. Keep in mind that this is a comparison of inaction and action over 22 years, not of ultimate annual costs or levels of consumption in the year 2030 or beyond, which would be a much starker contrast — by 2030, the savings of the EASY plan are much greater than business-as-usual, once most of the upfront costs of making the transition to clean energy have been expended. See Table 3.1, next page.

Although the costs of both scenarios are roughly equal, what this table does not include are the costs of doing nothing to address the climate crisis. A recent study by Tufts University economists indicates that the effects of global warming by 2100, left unchecked, would cost the U.S. annually about $2 trillion in today's dollars.[141] These economic losses are just those due to real estate losses from coastal flooding, increased damage from hurricanes, increased energy costs, and agricultural and water losses, and it is possible that the costs could be significantly higher from other, as yet unaccounted effects.

How much will it cost to modify and expand the grid? Most experts agree that our national electrical grid is aging and in need of modification and expansion, just to keep up with rising demand. The new smart grid will have smart technology, enabling it to transfer both power and information in two directions — to AND from consumers — that allows for efficient use and distribution of power when and where needed.[142] This new grid will receive power from a variety of distributed energy sources, including clean energy sources both large (wind or solar farms) and small (photovoltaic roof systems). Storage of electricity will utilize equally diverse technologies, such as electrical car batteries and pressurized underground caverns.

Table 3.1

EASY Plan Costs, 2007-2030*		**Business-as-Usual Costs, 2007-2030***	
Photovoltaic panels on home roofs Solar thermal & wind power Residual conventional electricity	~ **$1.6** ~ **$3.5** ~ **$3.7**	Conventional electricity	~ **$7.3**
Hybrid car costs Other appliances and devices	~ **$6.0** **~ 0.048**	Conventional car costs Other appliances and devices	~ **$4.5** **~ $0.040**
Oil & coal federal subsidies Reimbursement of construction costs for coal power plants closed before their standard lifetime elapses Funds needed to retrain fossil fuel workers	**~ $0.7** **~ $0.2** ~ $**0.01**	Oil & coal federal subsidies	**~ $1.1**
Oil for transportation	~ **$5.8**	Oil for transportation (assuming today's prices)	~ **$9.2**
Total: + energy storage & grid expansion costs	**$21.6 trillion**	Total: + increasing prices for oil, for constructing fossil fuel and nuclear power plants; the health and environmental costs of climate change, air pollution and acid rain, oil spills, strip mining; and the military expenditures needed to protect foreign oil sources	**$22.1 trillion**

* In trillions of dollars. See Appendix, Section B, for how the estimated costs to the U.S. public are calculated.

Transmission will involve, at least in some cases, high voltage direct current lines that are already in use in some areas. Power will need to be transmitted from wind turbines populating the vast central corridor of the U.S., which is especially windy,[143] and from solar farms located in the particularly sunny southwestern U.S.

The Electric Power and Research Institute has estimated that a net additional investment of approximately $170 billion over the next two decades will be necessary, but will more than pay for itself in terms of the electricity it delivers.[144] This added investment represents about a 50% increase, i.e., an extra annual $8.5 billion over the current annual investment of $18 billion. But even that net estimate does not take into account the much greater expansion of the grid needed to transfer the solar and wind power from their sources to their consuming destinations, if solar and wind play major roles in producing power for the grid. So let’s assume another $200 billion will be needed. This amounts to a total investment of $370 billion to maintain, expand and upgrade the grid over the next two decades.

While the costs of storing clean energy and of modifying the national energy grid specifically to adapt to solar and wind power are difficult to estimate, the good news is that we will probably have much more than $400 billion to invest in it. According to our table above, we will have about $1 trillion in savings to develop the necessary technology and infrastructure. And there could be much more, when you factor in the uncalculated savings from oil price increases, the environmental and health costs associated with fossil fuel extraction, processing and burning, and the price of protecting our foreign sources of oil.

These uncalculated savings could indeed prove massive. Air pollution from traffic and electrical plants, for example, is a major contributor to health problems, especially in children and people with respiratory disease. Estimating the health costs to society from fossil fuel pollution is an ambiguous and complex process, but estimating the number of deaths, or of people with serious health consequences, is possible. In 2002, the World Health Organization reported that health deaths from air pollution topped three million, more than triple the deaths from traffic fatalities.[145] As for protecting foreign sources of oil, our military expenditure for the Iraq war of $200 billion in 2007 alone indicates that an EASY versus business-as-usual approach could potentially save us $2 trillion or more over the next two decades.[146] Overall, the investment indicates substantial savings to our economy.

A Caveat

What we are doing here is just the beginning of what will have to be a continuing process of “decarbonization” of our economy and indeed, the global economy. If economies and human populations on Earth continue to grow and consume resources at current rates, we will have to eliminate virtually all global CO_2 emissions by 2050 to prevent more than a 3-4° F rise in temperature globally,[147] with all the inherent destruction such a rise entails for us and all other living creatures through environmental destabilization. Ultimately, we have to recognize our reproductive responsibility on Earth, and redefine what constitutes a healthy economy.

Okay, we’ve got a plan. Now let’s take a look at the details, step by step.

Chapter 4: Energy Efficient Technology

Improving efficiency is one of the easiest and cheapest ways we can quickly reduce CO_2 emissions significantly.[148] It is the lowest hanging fruit on the tree of opportunity. The technology to do so exists and is constantly progressing. Improving efficiency can be done in both the public and private sectors, and doesn't entail a decrease in our quality of life — in fact, just the opposite, since improving efficiency helps saves money and decrease the destructive effects of global warming. New York State's Energy Smart Program provides a holistic approach. It offers free home energy audits, suggesting ways that people can improve their overall energy efficiency through both house and appliance improvements, and offering information and financial incentives to encourage the homeowners to implement those suggestions.[149]

Energy Efficient Appliances

At the public level, we can decrease energy consumption by increasing the energy efficiency of appliances, manufacturing processes (both using and wasting fewer resources), and the energy efficiency and insulation of homes and buildings. For appliances, it is important to focus on the big energy users: refrigerators, washers, dryers, dishwashers, air conditioners, heaters, furnaces, computers and accessories. Google and Intel, for example, are working on improving the energy efficiency of their computers.[150] California leads the nation in energy efficiency, and one of that state's energy commissioners, Arthur Rosenfeld, is an ardent promoter.[151] Dr. Rosenfeld notes that small but steady yearly improvements of a few percent in the efficiency of our appliances can reduce every home's energy use significantly over the long run. The resulting cut in energy bills makes this a sure-fire investment on a private scale that encourages the economy on a public scale.

The proof is in California's track record: efficiency programs legislated in the 1970s continue to save California a whopping 30% in energy needs every year. The treasures are in the details. For example, one of the home's energy-guzzling appliances, the refrigerator, came under legislated standards of energy efficiency in the 1970s by California. Since that time, energy consumption by California's refrigerators has decreased by 75%, even as individual refrigerator capacity has increased. Examples like this convey the plausibility of the EASY plan to reduce the average home's energy use up to 40% by 2030.

Compact fluorescent light bulbs (CFLs) are another good example of what can be done with appliances. Compact fluorescent bulbs today use 70% less energy than incandescent ones, last up to ten times longer, and are economically competitive. The downsides? They must be recycled carefully because they contain a small amount of mercury;[152] dissatisfaction has been expressed over the quality of CFL light; some can produce an annoying buzz; and at least some have been blamed for causing pain, dizziness, and skin rashes among those with health problems.[153] On the other hand, there are now relatively accessible places, such as IKEA stores, that recycle CFLs, and those that might experience health problems with the bulbs are relatively few. If every household in the U.S. immediately switched over to compact fluorescent bulbs, we would immediately reduce the equivalent of 300 million tons of carbon emissions per year into the atmosphere.[154]

Furthermore, CFLs have come a long way from their infancy. The quality of light in later models has improved; based on light alone, we could not distinguish between a compact fluorescent and an incandescent bulb in a friend's house one evening. How you choose and use CFLs also influences their efficiency and your satisfaction.[155] The diversity and availability of CFLs have greatly increased and will probably continue to do so. Changethelight.org, for example, is a nonprofit organization that sells CFLs and other energy saving devices at wholesale prices with no minimum order to encourage their adoption.[156] The U.S. Congress has recently passed legislation that will phase out the sale of current incandescent bulbs over the next several years, mandating a transition to 25-30% more energy efficient lighting. While this will spur the development of more energy-efficient halogen and incandescent bulbs, the legislation will probably also accelerate development of far more efficient CFLs with lighting quality that meets all needs.[157]

The savings are reflected not just in energy and durability, but in economics. As energy efficiency expert Amory Lovins notes:[158]

> "Consider, for example, a good compact fluorescent lamp. It emits the same light as an incandescent lamp but uses 4–5 times less electricity and lasts 8–13 times longer, saving tens of dollars more than it costs... In suitable volume—about a billion are now made each year—it can cut by a fifth the evening peak load that causes blackouts in overloaded Mumbai, can boost poor American chicken farmers' profits by a fourth, or can raise destitute Haitian households' disposable cash income by up to a third... [It] cuts power needs to levels that make solar-generated power affordable, so girls in rural huts can learn to read at night, advancing the role of women. One light bulb does all that. You can buy it at the supermarket and install it yourself. One light bulb at a time, we can make the world safer."

The Alliance to Save Energy website[159] lists several more examples of energy-saving opportunities with efficient lighting, such as installing photocells that adjust light levels to what is needed and occupancy detectors that automatically turn lights off when people leave. Replacing incandescent exit sign lights with much longer lasting CFLs or light emitting diodes (LEDs) saves both energy and labor costs associated with occasional replacements. Indeed, the development of much more energy-efficient white LEDs has allowed the development of an array of energy efficient light products for the developing world.[160] Although LEDs are significantly more energy efficient and last longer than CFLs, the first and latest mass-produced LED bulb is only as bright as an incandescent 40 watt bulb. Nonetheless, continuing improvements hold out the possibility that mass-produced LEDs will eventually replace CFLs.[161]

Yet another type of appliance is influencing energy efficiency — energy meters or “smart meters” that tell people what the changing electrical rates are throughout the day, and how much energy their household is using. In Pennsylvania, for example, so many people are having difficulty keeping up with recent hikes in energy costs, that the state senate is considering legislation to mandate the installation of these energy meters in private homes.[162]

Energy Efficient Manufacturing

Making manufacturing processes more energy efficient benefits the manufacturer, the consumer, the economy, and society as a whole. This is recognized by manufacturers: the National Association of Manufacturers teamed up with the Alliance to Save Energy to produce a booklet for manufacturers interested in saving money through improving their energy efficiency. “Efficiency and Innovation In U.S. Energy Manufacturing Use” notes that U.S. industry uses more than one-third of the energy consumed in the U.S. and that U.S. Department of Energy figures indicate that industry can reduce its current energy consumption by 20%.[163] A third of that reduction can be achieved without capital investment, simply through changes in behavior and procedures. The booklet outlines many opportunities in which manufacturers can reduce their energy consumption, utilizing case studies as examples, and points to successes that have already saved money for companies such as Frito-Lay, DuPont and others. Adobe Systems Inc. invested $1.1 million in upgrading lighting and appliances, and correcting energy inefficient practices at its corporate headquarters; now it saves just over $1 million per year in energy expenses.[164] At the federal level, the Save Energy Now initiative has a record of successfully identifying immediate energy savings for businesses.[165] This win-win effect benefits both industry and society.

An important way to increase energy efficiency is through recycling waste heat generated from one process for direct use in another. In Denmark, for example, over 50% of their electricity is cogenerated — the waste heat created through burning fossil fuels in their power plants is channeled into nearby industrial plants for heating purposes. Energy cogeneration (also known as combined heat and power, CHP) at power plants can greatly increase overall energy efficiency and decrease water usage, but less than 10% of U.S. electricity is cogenerated.[166]

A second way is just the inverse: take energy waste and reconvert it into electricity. Waste heat from power plants often doesn’t have enough energy to be worth turning into electricity, since the conversion itself isn’t very efficient. But it does make sense to do so for industrially-produced high quality energy, such as gas that isn’t flared, hot exhaust or high-pressure gas or steam. Here the industrially created waste energy is channeled into an on-site power plant for conversion to electricity. This is then sold back to

the industrial host, avoiding the need to distribute the electricity elsewhere and lose some of it during long-distance transmission.[167]
An important component for either method of recycling waste energy is locating power plants close to partnering industries. How much impact could this have in the U.S.? The potential impact is rooted in fact that the U.S. economy currently wastes 55% of the energy it consumes.[168]

Enhancing energy efficiency through recycling creates new business. Recycled Energy Development is banking on the profitability of recycling waste energy in industry.[169] The principals of this U.S. company have already improved the energy efficiency of some U.S. power plants and are trying to do so in the metallurgical industry. An important policy key towards recycling or cogenerating energy, however, is that current regulations in many states must be modified so that utilities are allowed to sell recycled waste heat. This, then, becomes an incentive for utilities to increase their energy efficiency.

For power plants operating on the aging U.S. grid, energy efficiency is also being promoted in the form of consumer conservation programs. An increasing number of U.S. utilities are adopting “smart grid” strategies that will give customers price signals — substantial increases in usage rates — and that will cut off large appliances when the grid is stressed to prevent blackouts.[170]

Energy Efficient Buildings

Finally, improving the insulation and energy efficiency of homes and buildings is another important part of the answer. Leon Glicksman of the Massachusetts Institute of Technology (MIT) notes that buildings use almost 40% of the country’s energy, and about two-thirds of the electricity.[171]

Building design techniques already exist to save a lot of energy, he notes, and architects must be trained in them, since builders have no economic incentive to do so, and consumers are often ignorant of them. For example, naturally ventilated buildings use half the energy of artificially ventilated ones, although this is not feasible for humid climates. Houses, even in cold climates, can be designed without central heating systems. Optic fiber and other technologies can now collect and transmit sunlight farther into rooms, lighting up areas that would otherwise be using electric lighting. In Sweden, the government has plans to use the body heat generated by people in a rail station to help heat a nearby building under construction.[172]

Glicksman and others have developed a computer program to help architects design energy efficient buildings, but even he notes that often simple fixes in current buildings can significantly save energy — it's just a question of finding the problems and remedying them. The American Institute of Architects admits that buildings can be built to use far less energy than they currently do, and at little or no additional cost.[173] In collaboration with Architecture2030, they advocate an ambitious goal: buildings will no longer require fossil fuel consumption in either their construction or maintenance by 2030. The subtitle of their plan, The 2030 Blueprint, is a great motto to inspire everyone about tackling climate change: "Solving Climate Change Saves Billions."[174]

There is also a cornucopia of biomimetic (mimicking nature) ideas being incorporated into architectural design, as architects recognize that nature's processes can be both efficient and aesthetically pleasing. Such designs include buildings that have ventilation systems based on those found in termite mounds, mechanical irises that regulate light and heat into buildings, and vents made of materials that flex in response to changes in temperature and moisture, much the way pine cones do.[175]

Amory Lovins has demonstrated that integrating existing energy efficiency technology into the structure, insulation, windows and appliances of a house or building can dramatically reduce the energy needed to maintain it.[176] Around half the heat in typical homes is lost through walls and lofts. Insulation of these areas in both new and standing homes, as well as draft-proofing, insulating tanks and pipes, and energy-saving glazing of windows in every present and future household could dramatically lower energy consumption on a national scale during the winter. This has been pointed out by the Energy Saving Trust, established by the United Kingdom to help them reduce carbon emissions nationally.[177] A challenge to be addressed is how to preserve the air quality as one reduces air flow to decrease heat loss.

Another source of energy savings lies in the type of materials going into building construction. Drywall production, for example, is normally an energy intensive process normally, using 1% of all the energy consumed in the U.S. annually. Now, a new drywall has been developed that is essentially emissions-free.[178] And new production methods that incorporate using recycled ingredients and renewable energy sources for creating cement, another significant source of energy consumption in the building sector, can be developed to cut down emissions.[179]

Energy efficient modular homes cut energy use both at the manufacturing level and the construction of the houses themselves. One modular home producer estimates that off-site construction can cut waste materials by 50-75%, and finished on-site construction takes much less time than regular construction, saving energy through cutting worker transport to the site.[180] Additionally, modern modular homes can incorporate many energy efficient features.

To incorporate energy efficiency into the building sector, a set of formal standards for building “green” houses and buildings has rapidly evolved within the industry. Based on standards of improved energy efficiency, water and resource efficiency, and indoor air quality, these buildings are not just healthier for the planet, but for their inhabitants. Today, for example, about 5% of U.S. buildings are Leadership in Energy and Environmental Design (LEED) certified.[181] The U.S. Green Building Council, a nonprofit organization of construction and building maintenance firms dedicated to sustainable building and design construction, created LEED as a national accreditation program to certify building projects that are environmentally responsible, profitable, and a healthy place to inhabit.[182] Such certified buildings reflect an average of 25-30% in energy savings while reducing environmental and public health impacts.[183] Here, not just the construction but the entire life of the building is taken into account in its overall cost, and this is where energy efficient designs can dramatically reduce lifetime operational costs.

A good example of what can be accomplished with green building is the Bank of America building in New York City, expected to be completed in 2008.[184] Built partly of recycled slag, a byproduct of blast furnaces that reduces the need for energy costly cement, the skyscraper features floor-to-ceiling insulating glass to capture heat and maximize natural light, an automatic daylight dimming system, a greywater system that captures and uses rainwater, waterless urinals, a 4.6 megawatt cogeneration plant, and an ice cooling system. (For more about watts, see the What’s Watt box, Chapter 6.) Similar to ice batteries, the IceBanks[185] cooling system used there produces and stores ice during off-peak hours, and then uses the ice phase transition to help cool the building during peak load. The building was the first skyscraper to win a LEED platinum award, the highest level available.

“Zero energy” homes combine energy efficient design and renewable energy technology to generate as much energy as they use. Habitat for Humanity has shown that such homes can be affordable. Across the U.S., the message is getting through to state and local governments, which are developing programs to provide incentives for the construction of essentially zero energy homes.[186]

How Much Do We Save?

What kind of savings are we looking at here in the U.S.? The U.S. Environmental Protection Agency estimates that computer servers and communication data centers in the U.S. alone could save $4 billion in annual electrical costs through more energy efficient equipment and practices.[187] Through its Save Energy Now initiative, the U.S. Department of Energy found a potential 10% savings in energy costs for the many manufacturing plants it assessed over the past two years; the savings averaged $2.5 million per plant.[188] Amory Lovins estimates that for the year 2000 alone, the U.S. experienced energy savings worth $365 billion;[189] he contends that increasing energy efficiency is the nation’s largest and fastest growing effective energy source. A 2008 report by the McKinsey Global Institute contends that we could halve the annual global energy demand growth just by investing in energy efficient technology, and that by 2020 these investments would reflect annual energy savings of $900 billion.[190]

Overall, improving efficiency can potentially save us as much as 40% of current energy use — a huge step towards decreasing energy use, even with increasing population. It’s been estimated that of the total energy efficiency savings, 40% comes from improving buildings and houses, while 30% each comes from the manufacturing and transport sectors.[191] Figure 3.1 in Chapter 3 divides the energy pie into somewhat different sectors. The take-home message in all of this, however, is the same: there are huge opportunities to save energy in all energy consuming sectors of our society — no one sector by itself has a much bigger potential than the others. So, our energy efficiency efforts must be distributed more or less equally throughout all sectors.

We’ve covered improving the energy efficiency of appliances, buildings and houses, and the manufacturing sector. Now let’s tackle the transport sector: vehicles.

Chapter 5: Automotive and Transport Efficiency — CAFE, Hybrids, and More

A huge improvement in overall energy efficiency at the public level can be achieved through improving efficiency of our vehicles and our public transport systems, dramatically decreasing energy consumption across the transport sector. How, you ask?

CAFE Standards

Let's start with CAFE (Corporate Average Fuel Economy) standards. Energy efficiency expert Amory Lovins notes that 70% of U.S. oil consumption is from vehicles. Not too long ago, in the wake of a 1970s oil embargo, we were very close to adopting legislative CAFE standards that would have significantly limited carbon dioxide levels in our atmosphere. We can still do so; we have the technology. We could legislate a CAFE standard of 60 mpg, phased in so that the average car (light trucks, SUVs, and cars) sold by 2015 would get 35 mpg; sold by 2020 it would get 45 mpg; and sold by 2030 it would get 60 mpg. In fact, presidential candidates have proposed similar goals.[192] Beyond 2030 we can do even better, perhaps boosting the U.S. fleet average fuel efficiency to 100 mpg.

This advance would also boost our automotive manufacturers out of the economic doldrums, since we would be able to sell cars to one of the largest potential markets on Earth, China. Presently, U.S. cars are not fuel efficient enough to pass new Chinese import standards.[193] With more energy efficient models we would also be competitive with foreign manufacturers that are currently outselling our companies. It is no accident that Toyota surpassed General Motors in global car sales for the first time in 2006.[194]

Fuel Efficient Cars

One of the ways to achieve this more stringent CAFE standard is with a popular type of car already out on the market — the hybrid car, of which there are different types. The ordinary hybrid uses a mix of fossil fuel and electric generation — mechanical motion of the car, as it slows or goes downhill, recharges the battery. These hybrids can attain a fuel efficiency level of 50+ mpg in the city. If hybrid SUVs were built out of new advanced ultralight materials such as carbon fiber thermoplastic composites (which, incidentally, have the added advantage of springing back rather than denting upon collision), the car would be as big, comfortable, and safe as today's SUVs — and get 67 mpg. "Think of this as finding a Saudi Arabia under Detroit," said Amory Lovins at the April 2007 meeting of the American Physical Society.[195]

A second type of hybrid vehicle, the plug-in hybrid, is currently being made ready for commercialization. It is recharged by being plugged into an electrical outlet when not in use. At least one company, AFS Trinity Power Corporation, is looking into using more advanced energy storage systems to create an extreme plug-in hybrid that can get 150-250 mpg, using mostly electricity.[196] General Motors has plans to introduce a mass market plug-in hybrid within the next few years, and to introduce several other new hybrid models.[197] Others are converting their hybrid cars, as well as trucks and even military vehicles, to plug-in hybrids with the help of Calcars, a nonprofit organization promoting plug-in vehicles.[198] These plug-in hybrids are getting more than 100 mpg[199] when using their plug-in feature, which essentially converts the car to an electrical one with a gas tank backup. Thus, the car can go much farther without touching the gas reserve, so you end up using little or no gas for long distances. Another way to look at it is that the "fuel" costs less than $1 per gallon, because these cars can go the same distance, 27 miles, as a moderately fuel efficient car on a single $3 gallon of gas, using an equivalent amount of electricity that costs less than $1.

And this is just the beginning. Combining hybrid technology with other technological advances can significantly increase mileage. Compressed air cars, for example, planned for 2010, allow hybrid cars to get more than 800 miles on a single four hour electrical charge, or over 100 mpg.[200] Energy heats up air in a fixed space and thus compresses the air, which is used to drive the engine. Aptera Motors has created a far more aerodynamically efficient hybrid car that gets 300 mpg. Made of super lightweight but super strong composite materials, it is a small, three-wheeled two-seater that will be sold in both hybrid electric and purely electric models by 2009.[201] Even something as simple as an accelerator pedal that resists unnecessary pressure, planned by Nissan, can increase fuel efficiency by 5-10%.[202]

Although some argue that a switch to plug-in hybrid electric vehicles would actually create more pollution since much of our electricity is produced from coal combustion, an analysis done by the Electric Power Research Institute in 2001 indicates just the opposite.[203] Furthermore, our plan advocates switching to clean energy sources as fast as possible: as the electrical grid relies more on clean energy, these cars will be cleaner. The California Cars Initiative (www.calcars.org) is lobbying to get these cars made commercially. The Internet giant Google has dispersed over $1 million in grants to encourage the development and deployment of plug-in hybrids, and will be investing millions more to demonstrate their feasibility with the company's own fleet.[204]

Yet another example of an alternative energy car in the prototype stage is the Honda FCX Concept,[205] a hydrogen fuel cell car. In the fuel cell, hydrogen combines with oxygen to create water vapor, releasing energy used to power the car, which reportedly gets up to 270 miles per tank of hydrogen. Honda hopes to sell the car commercially in 2008, along with a home hydrogen fuel station, which uses natural gas (methane, a potent greenhouse gas) to produce the hydrogen and the byproduct CO_2 — alas, just what we want to get away from. If this were to be scaled up commercially, we would also find ourselves limited by the amount of natural gas needed to fuel so many cars. Production of hydrogen from bacteria feeding on waste[206] cannot meet current automotive fuel needs because we do not generate enough organic waste each day. With increasing fuel efficiency, however, production of hydrogen from wastes could contribute, but the only possible method of cleanly producing hydrogen at a scale that could meet transportation needs is electrolysis of water, which uses electricity, and, at this point in time, is not a zero-carbon-emissions process.

The U.S. Department of Energy started in 2003 to explore hydrogen production via all sorts of energy sources, most of them carbon-emitting. From a technical point of view, hydrogen production today costs approximately five times the cost of the electricity needed to produce it, but some are optimistic that with enough research and development, we will be able to bring the price down to little more than the cost of that same electricity.[207] Under such a scenario, hydrogen fuel cells could play a role in hybrid car technology, in which solar or wind electricity could power the production of hydrogen for hybrid fuel cell cars. Although fuel cells, such as those that use hydrogen as fuel to run a car, are a tantalizing technology, the ultimate weak link is that energy must be used to create the hydrogen. Directly using electricity derived from a clean source, such as sunlight or wind, is likely to be a more efficient and cheaper way to achieve the same goal.

Vehicular Solutions

Daimler's SmartForTwo:
A small car

The Aptera:
Small, aerodynamically smart, & a smart energy source

The Plug-in Hybrid:
Aerodynamically smart and a smart energy source

Indeed, the ultimate and feasible goal is the development of a purely electrical car, utilizing wind and solar energy to create the electricity. In the electric car future, gas stations will be replaced by electric battery stations, where, in the time it takes to currently fill up your gas tank, your depleted electrical battery will be removed and replaced with a fully charged one. A current challenge is to power an all-electric vehicle using a self-recharging battery that enables a car to travel 100-200 miles without recharging externally or needing gasoline. As in a hybrid, such a battery would recharge when the car goes downhill or brakes.

Requirements for satisfactory electric car batteries include substantial use (100-200 miles) between recharges or replacements, ability to sustain hard use, long service life and modest replacement value. The most promising line for such batteries comes from the latest generation of lithium polymer batteries.[208] The prototype electric Blue Car, produced by the French company Bolloré, is powered by a lithium polymer battery, and is able to go 124-155 miles between recharges, attaining a maximum speed of 84 mph.[209] The company, owned by French billionaire Vincent Bolloré, is building a factory to manufacture lithium polymer batteries for electric cars; he is not alone.[210] Renault, Pininfarina, and Toyota all have plans to make or incorporate lithium ion batteries in planned electric or hybrid models.

Meanwhile, Shai Agassi, a Silicon Valley technologist and entrepreneur who is raising $200 million in venture capital, is currently developing plans to create an infrastructure of battery charging and swapping stations in the U.S., Europe and the developing world for all-electric cars.[211] Agassi has collaborated with a Denmark power utility, DONG Energy A/S, to set up an electric car network by 2011. It will include an electric grid that will service about 20,000 electrical recharging stations throughout Denmark, using the surplus energy from DONG’s wind turbines. The French company Renault will be supplying the fleet of battery-driven electric vehicles, once the service stations are completed at parking lots and outside homes. Japan's Nissan will be supplying the lithium car batteries.[212]

How feasible is this for the U.S.? Our current electric power generation system has the capacity to support 84% of all U.S. vehicles if we suddenly shifted them to electric and charged them at night time, according to an analysis by the U.S. Department of Energy's Pacific Northwest National Laboratory.[213] The analysis further notes that if one opted for plug-in hybrids, the cars would pay for themselves over five to eight years, depending on regional electricity prices. According to our own estimates under this scenario, we would need an extra capacity of 250 million kilowatts.[214] Twenty years from now, following the EASY plan we will have more capacity due to improvement in both overall and automotive efficiency.

Initial electrical cars have proved to be durable beyond 100,000 miles, and produce none of the asthma-inducing pollution that gas cars emit. Under current conditions, the pollution would be produced at the power plants, which are much more efficient at capturing such pollution. Of course, if the electricity comes from a solar plant, there will be no air pollution at all.

The Transport Sector

Transport of trade goods involves cargo ships, rail, jets and trucks. Here is another sector where energy and fuel efficiency can play an important role. Perhaps one of the most promising outlooks for the transport sector involves Wal-Mart, which is investing in doubling the fuel efficiency of its fleet by 2015.[215] It may well provide a model for the rest of the U.S. transport fleet. Improving truck aerodynamics has been proposed as one key to increasing energy efficiency,[216] but as mentioned above there are many others, including converting trucks to plug-in hybrids.

Better yet, there's a good argument for shifting much land transport of freight from trucks to rail systems. A freight train can move a ton of freight 436 miles on a gallon of fuel[217] — and if the system is upgraded to run on electricity supplied by sunlight and wind, it becomes a carbon neutral avenue. Upgrading our intercity and interstate transport to electric rail (as proposed below for the public sector) will also reduce emissions from the human transport sector. We will still need liquid fuels for airlines, whether it is from crops or fossil fuels, but that amount contributes relatively little to global warming. And we have enough oil resources or potential sources of biofuels to keep our planes flying, as long as flying becomes the sole major use for them.

Improving the energy and fuel efficiency of cargo ships is possible as well. An imaginative, promising technology illustrates how we can increase the fuel efficiency of merchant ships by harking back to an old idea, sails. German engineers have invented giant computer-steered kites, called SkySails, which can tug along merchant ships by catching oceanic winds, substantially increasing fuel efficiency by 30-50%. In principle, it could be applied to 60% of the global fleet. A maiden voyage from Germany to Venezuela and the U.S. successfully tested the feasibility of this technology.[218] A smaller, wave-power driven three ton catamaran also completed a maiden 2.5 month voyage between Hawaii and Japan, illustrating the ability to literally let the waves move the boat an average of 1.5 knots per hour.[219] Solar and solar hybrid boats are also under construction.[220] Although these technologies are in their relative infancies, they indicate ways in which oceanic transport can become much less dependent on fossil fuels.

Empowering Human Locomotion

Beyond improved vehicular efficiency, we can guide our society towards a substantial change in attitude towards transport. We should promote walking and bicycling whenever possible. Some cities have managed to do so with policies that help and encourage pedestrians and bicyclists. Copenhagen has created attractive pedestrian public spaces, and designated pedestrian-only streets and pedestrian-priority streets on which one-way vehicles must yield to two-way bicyclists and pedestrians sharing the street. The city has also created a “City Bike” program that has more than 2,000 bicycles available for a coin deposit at 100 racks across the city. A bicycle can be returned to any rack where one can reclaim the coin deposit. The result of all this? Of all trips taken in Danish urban areas today, 41% of those are human-powered.

Portland, Oregon is an example of a U.S. city that has invested over decades to create a bicycle friendly city. Investments included wide bicycle ways, bicycle racks on buses and light rail systems, bicycle parking places around the city, and neighborhood bicycling promotional programs. Results include an overall decrease of global warming emissions from the transport sector since 1990 and a vigorously growing sub-economy devoted to bicycles.[221]

Time to Go Public

We should also promote mass transit over private transport whenever possible and invest in creating efficient public transport systems that make this change attractive. In some cities we are already encouraging carpooling with dedicated carpooling highway lanes, and carpooling pickup spots at commuting centers. As the price of gasoline increases, more people are taking Amtrak, the national rail system, overtaxing it, and more congressional subsidies are flowing into it,[222] but we must do much more. It's time for government to invest in energy-saving transport infrastructure: an efficient national rail system for commuters, for example, that isn't sabotaged by having to share tracks with industrial transport and its overriding needs; a national bus system that integrates well with the municipal systems of cities. Every city should have an efficient and affordable municipal transport system. If Mexico City, a huge metropolis in a relatively poor country, can develop an effective mass transit system and other large cities in developing nations start similar projects with help from a U.S. think tank,[223] why can't Los Angeles? Even if we only implement the CAFE standards proposed above, however, we will be saving 400 million tons of carbon from going into the atmosphere, as shown by Figure 3.1 in Chapter 3 and calculated in Appendix A.2.

Now imagine what we could do with just a little help from the Sun….

Chapter 6: Solar, Wind, and More: Make No-Carb Electricity

"I'd put my money on the sun and solar energy. What a source of power! I hope we don't have to wait til oil and coal run out before we tackle that."

-Thomas Edison, 1931, in conversation with Henry Ford and Harvey Firestone[224]

In order to reduce atmospheric carbon emissions, we must go on a planetary no-carb diet, devising ways of producing electricity that do not release carbon to the atmosphere — truly clean energy.[225] While the air and ocean travel sectors of our economy will always need some fossil fuel or fossil fuel substitute, the good news is that fossil fuels can be a very small part of the electricity sector of our economy. The most economical and effective way to produce no-carbon electricity is through exploiting two energy sources — the Sun and the Sun-driven wind. Although either source alone could probably meet U.S. electricity needs, we do not attempt to predict how much each source will actually contribute to meeting overall electricity demand in 2030, leaving that to be determined by market forces.[226]

Solar Energy

Solar energy technology taps directly into Earth's primary energy source, the Sun, a giant nuclear reactor that broadcasts energy continuously to Earth. Solar energy technology for generating electricity already has more than a century of research and development behind it, emits no pollution during operation, requires relatively little maintenance, taps into an inexhaustible energy source, and is capable of becoming directly competitive with conventional technologies in most locations. Solar technology development began in the 1860s, and by the early 1900s, plans for its widespread use had already been conceived. But in the ensuing decades, the rush to use fossil fuels pushed these plans aside.[227]

In its simplest form, solar energy has been harnessed thermally by allowing sunlight to heat water in a network of pipes. The heated water can then be used directly, or cycled throughout a house to heat the home. Scaled up, the same basic technology can be used to generate electricity at a cost that is competitive with conventional fossil fuel power generation. The idea is simple — sunlight, rather than fuel combustion, heats water, and the steam that is produced spins a turbine, which generates electricity.[228] This process, known as solar thermal power production, requires a cooling system so that the turbines can operate efficiently. The amount of cooling water required will depend on the cooling technology deployed. Since water is more efficient than air at absorbing heat, wet cooling towers are generally less expensive to use than dry cooling towers. The waste heat produced here, however, could be recycled as described in Chapter 4, enhancing the energy efficiency of the operation.

Recent engineering advances have greatly improved the efficiency of solar thermal power production by improving the design of both turbines and reflector arrays. These improved arrays include solar tracking parabolic troughs; dishes; and “power tower” systems, in which sunlight is reflected from hundreds to thousands of sun-tracking mirrors onto a central receiver-tower.

Another important facet of this process is the ability to store the solar energy for use when sunlight is interrupted by clouds or night time. To deal with this variability and provide flexibility in the schedule of electricity production, heat energy can be stored in substances that can store large amounts of heat, such as molten salts.

Solar technology also encompasses photovoltaics (PVs), a means of converting sunlight directly into electricity. The technology is based on solar cells, in which light hits a light-absorbing material, called a semiconductor, creating energetic electrons. The spaces between the negatively charged electrons act like positively charged particles and the two types of charge effectively flow to opposite electrical contacts to create an electrical current. This transfer of energy from light to an electric charge is the basis for the term “photovoltaic”, applied to the cells.[229] Many solar cells can be combined to form a solar panel, and many panels can comprise large power production facilities.

Solar cells have allowed the development of a broad array of solar technologies: solar panels on rooftops, architectural solar panels in which the panels are incorporated into roofing materials, large central-station solar photovoltaic (PV) power plants, solar powered communications in remote areas, and solar portable appliances, such as flashlights and calculators.[230] More efficient, less expensive forms of photovoltaic cells are evolving rapidly. Plastic solar cells are being developed with the potential to provide cheap, competitively priced solar energy in every household.[231] Yet another promising breakthrough is the creation of “organic solar concentrators”, developed by scientists at the Massachusetts Institute of Technology.[232] Organic dyes applied in a thin film upon a glass pane collect, concentrate, and redirect solar energy to a narrow strip of solar cells placed along the edges. This means that far fewer of the relatively expensive solar cells are needed to create an efficient solar panel. Relatively simple in design, the device should be in commercial production within three years, and can be produced inexpensively, says one of the inventors.[233]

In a related technological advance, researchers at the U.S. Department of Energy have developed an inexpensive way to produce plastic sheets with arrays of billions of nanoantennas that collect heat energy from sunlight and other sources, such as the waste heat of industrial processes; conversely, they could be used to direct excess heat away from structures.[234] Although more work needs to be done, such arrays could ultimately be used to keep buildings cool, absorbing heat energy and then re-emitting it at harmless wavelengths, for example.

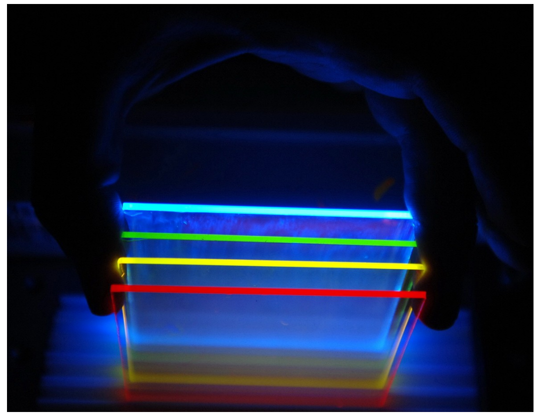
Currently, solar thermal plants have several advantages over PV plants, including lower construction costs and greater efficiency in converting energy into electricity. Unlike solar thermal plants, however, PV plants require no coolants. This is a big advantage, since solar power plants are often located in places with lots of sunlight and little water, such as much of the southwestern U.S. But solar thermal plants are meeting the water challenge with cooling processes that minimize water usage.

One of the most popular forms of producing solar energy is through solar panels installed on an ever-increasing number of private home roofs. The energy it takes to make a solar panel is offset by what the panel produces in only about two years of operation.[235] The panels not only produce electricity, but act as a buffer, reflecting sunlight back to space or absorbing heat in the summertime that would otherwise overheat the house, which might then require more energy use through air conditioning. A typical solar panel manages to convert about 25% of the sunlight that hits it to electricity; some sunlight is reflected back to space, but some dissipates as waste heat energy. In a further development, engineers at PVT Solar have devised a way of collecting heat energy from the panels, which could double or even triple the harnessed energy.[236] This new modification redirects the heat energy towards household use: water heating, home heating, and pool heating, for example. They expect to start commercial production of this new setup soon.

The number of households in the U.S. with solar panels is exploding, and California leads with a visionary Million Solar Roofs Initiative for the state.[237]

Depending on the energy footprint of a household, its rooftop solar panels can supply all the electricity needed for the house, and sometimes can even

Sunny Solutions



Organic solar concentrators (Donna Crowley/MIT)

Solar Dish Concentrator Array, Hermannsburg, NT, Australia (Curtis Morton)

Bogolight, a solar flashlight used in Africa

feed extra energy back into the grid. Another option is to be independent of the national energy grid and store the energy in batteries. Currently, such batteries are cumbersome, and more work is needed to create more efficient ways of storing extra energy. One way being explored involves storing produced energy in a quiet, low-friction fly wheel [238] that could be buried in the backyard.

As part of the EASY plan, we propose that solar panels be installed on every private rooftop in the U.S. with adequate sunlight (roughly 75% of all U.S. homes — about 60 million homes) and on commercial building rooftops. Spreading PV rooftop panels across the country spreads the risk of clouds, and also decreases the cost of distributing electricity, which can be significant. The installations could be financed in various ways via governmental "leasing" to the property owner. This could be accomplished through elevated taxes, rate structures, or a subsidy structure that enables the owner to purchase the solar panels, according to the economic capacity of the owner. (See Chapter 9 for more details.) This should be considered an investment in our national security and our economy. The installations on private homes alone would provide jobs for 180,000 people[239] — coincidentally, about the number of military personnel we now have in Iraq. What a great way to provide employment for our homecoming troops!!

Reform of utility regulations and barriers are needed across the country to help make this a reality. The Citizenrē Company, for example, is trying to make it far easier for homeowners. It proposes leasing out PV roof systems under a monthly payment system, whether the contract is for one or 25 years, taking care of all the arrangements: installation, permitting, maintenance, and updating. But regulatory barriers, especially ones that prevent sale of excess generated energy to utilities, stymie this sort of enterprise. [240]

Beyond rooftop solar production, there are myriad ways of using solar energy to meet a home's energy demand, as shown by the 2007 Solar Decathlon entries.[241] Sponsored by the U.S. Department of Energy this contest invites teams of students from universities around the world to design and construct solar houses that produce enough electricity to power not only the house but an electric car, as well. The 2007 winner, created by a team from the German Technische Universität Darmstadt, featured solar paneled louvers programmed to continuously track the maximum available sunlight. Each house was unique, and showed the possibilities that exist for solar architecture.

There are other increasingly popular uses of solar panels. One is as solar canopies over parking lots: these can produce needed energy and keep cars cool on hot days.[242] Google headquarters, for example, has installed solar canopies over its parking lots that produce 30% of the energy used by the center. Another use is starting up in Oregon, where solar panels are being installed along highways to help fuel highway lights.[243]

The solar message has already been heard in many places around the world. Major solar power plants exist in Spain, Algeria and Israel.[244] Globally, grid-connected photovoltaic systems increased 50% in 2006 and another 50% again in 2007 to a cumulative 1.5 million rooftops feeding into the global energy grid. Roughly 50 million households worldwide now have rooftop solar heat collectors that provide hot water, and a growing number of households are utilizing solar space heaters.[245] The first Chinese billionaire, Shi Zhengrong, made his money from producing solar panels; [246] since then at least four others have joined the solar billionaires club: a German, another Chinese, and two Americans.[247] A Chinese utility is planning the largest solar power station in Australia, with plans to incorporate the technology within China as well.[248] Japan leads the world in thin film photovoltaic module manufacturing and is a leading solar module exporter.[249]

The potential of solar technology in addressing national energy needs is amply illustrated in Germany, which committed itself in 2000 to a massive decrease in fossil fuel emissions and to a massive increase in solar energy production. Its 100,000 solar roof program pays the homeowner about $.70 per kilowatt hour of solar generated electricity.[250] Relatively cloudy Germany now produces half of all solar power produced worldwide through solar power plants and rooftop solar panels. This not only reduces Germany's GHG emissions, but also promotes its economic goal of becoming a leader in producing and exporting solar technology –– Germany is well on its way towards doing so. What spurred this transition and resulting economic boom was a 2000 law mandating that existing utilities subsidize solar upstarts by buying their electricity at marked-up rates that made it easy for the new companies to profit.[251] In Europe, a consortium of politicians, scientists and renewable energy experts have formed the Trans-Mediterranean Renewable Energy Cooperation (TREC). This consortium is backing a project that would create enough solar thermal plants, covering less than 0.3% of the Sahara, to meet the electricity demand of Europe, the Middle East and North Africa, and slash current (2008) European carbon emissions by 70% by the year 2050.[252]

Worldwide, solar energy production has surged 20-25% per year for the past two decades, and in the U.S., solar energy production grew 33% in 2006 alone.[253] Even though solar and wind energy supply only a small percentage of current U.S. electricity, at a 20% rate of increase per year in production, these clean energy sources can supply all of the projected U.S. electrical demands in 20 years, eliminating the need for any coal-fired plants. A solar thermal plant now delivers electricity to Las Vegas during peak power demand.[254] As we write, Bright Source Energy, a private solar energy company, is planning to construct a 400 megawatt solar power plant that will cover up to 3,500 acres of land managed by the Bureau of Land Management (BLM) in the Mojave Desert in California near the Nevada border. The BLM has already received right-of-way requests for the development of over 30 solar plants, whose combined output would total

What's watt

A watt is a RATE of energy usage: 1 watt = 1 joule per second.
A joule is a unit of energy —
about what's needed to lift a quart of water (32 oz) four inches.

An average lamp has a 60-100 watt bulb or 20 watt compact fluorescent lightbulb in it.
An average U.S. household uses over 1,000 watts —
that's right, over 1,000 joules per second.

1 thousand watts = 1,000 watts = 1 kilowatt.
1 million watts = 1,000,000 watts = 1 megawatt.
1 billion watts = 1,000,000,000 watts = 1 gigawatt.
1 kilowatt-hour (kWh) = 3,600,000 joules.

The U.S. currently consumes roughly 400 gigawatts of electricity.

24,000 megawatts, about half the amount of electricity consumed by California on a hot day.[255] Florida Power & Light, which already owns controlling interests in solar energy generating systems in the Mojave that produce 141 megawatts,[256] has committed to build a 300 megawatt solar power plant as part of a $2.4 billion clean energy program. This program will also include Smart Meters, allowing people to manage their energy use and monitor their daily energy consumption and utility rates online.[257]

Perhaps the most ambitious U.S. energy plan yet, however, is the Solar Grand Plan proposed by three photovoltaic experts on how to replace all our coal and much of the rest of our fossil fuel use with solar power. The plan is to invest about $420 billion in the installation of photovoltaic panels on 30,000 square miles of land in the southwest, create pressurized underground air reservoirs to store excess power, and modify the electric grid to transport the power along a main spine of high voltage direct current lines. The authors claim that such a plan could supply 3,000 billion watts of electricity by 2050, which could fulfill 69% of the U.S. electrical demand in 2050, representing 35% of the total U.S. energy demand.[258] Increasing efficiency in solar panels and decreasing installation costs as the production was scaled up would help to make this affordable by 2020. The $420 billion subsidy would come from a carbon tax of 0.5 cent for every kilowatt-hour (kWh) of power consumed as we make the change. Millions of new jobs would be created in the clean energy sector to enact the plan. The current rate of efficiency increase in photovoltaic panels indicates that this is feasible. These experts further predict that such a commitment to solar voltaic power generation would fulfill total U.S. energy demands by 2100. It’s an intriguing plan that goes a long way towards outlining how photovoltaic farms could fulfill a substantial part of U.S. energy demands.[259]

The big question is: When will the cost of solar thermal electricity become competitive with that of fossil fuel generated electricity? Table 6.1 on the following page gives a useful comparison.[260]

Table 6.1

Source of Energy	Cost *	Advantage
Coal, from old power plants	4.8	• Cheap • Common • Easy to transport
Nuclear	39.6	• Does not emit CO_2 • Efficiency & safety have improved much since 1980s • Reactor could co-produce electricity and hydrogen fuel
Wind	4-6	• Does not emit CO_2 • Fuel is free • Available at night
Solar	12-14 thermal 15-40 photovoltaic	• Does not emit CO_2 • Marginal operating costs near zero • Fuel is free • Output is easier to predict than wind
Biofuels	Same as gasoline**	• Potentially replace foreign oil sources
Efficiency	4 or less	• Lower carbon emissions without R & D • No need to build new infrastructures

* estimated cents per kilowatt-hour (kWh), except for biofuels

** for corn ethanol, not including its subsidy

Solar photovoltaic energy prices have declined an average of 4% per year for the past 15 years. If that rate of improvement continues, by the year 2030 the price of solar-generated electricity will be 9-18 cents per kilowatt-hour. With the subsidy plan advocated in Chapter 9, the cost of electricity from sunlight will be competitive with that of electricity from coal well before 2030.

The take-home message is that with further improvements in policy, manufacturing, and technology, we can achieve solar electricity pricing that is competitive with fossil fuel electricity. The current technological challenges are to create clean, renewable energy when the sun doesn't shine, and/or to devise efficient storage of solar-generated energy, on both a retail and commercial scale. Wind energy is an important answer to the first challenge, and promising technological avenues exist as potential answers to both challenges.

Solar technology is also having an impact in many other smaller but equally important ways in developing countries. For example, where cooking fuel is expensive and forests are being depleted, cheap solar thermal cookers are making an important difference.[261] In 1992, China alone reported using 100,000 of them. The demand for them in the U.S. is increasing as well, as people recognize that they are not only preferable on a hot sunny day, but significantly decrease their electricity bills. Solar stations power communications for remote Amazonian villages, and individual cells mounted on grass shacks charge cell phones used by inhabitants along that river. Solar calculators have existed for years, and solar charged flashlights provide an affordable and important source of light at night in villages throughout Africa.[262]

Recent advances in solar technology include spray-on solar panel cells — like a solar paint that might someday be applied to roofs.[263] Silicon ink, composed of silicon nanocrystals, is being used to create thin, lightweight solar panels, and Innovalight CEO Conrad Burke says this next generation of more efficient solar panels will be produced at a tenth of the cost and take up half the space of current solar panels.[264]

Other advances include solar concentrated collectors that greatly improve the efficiency of solar collection at solar thermal power plants. Scientists continue to create new and better solar cells. Improving solar energy production will be the next big surge in energy technology over the coming decades. The question is whether overseas corporations will get there first and leave the U.S. in the dust, or whether we will profit by becoming a competitive producer soon. In the early 20th century, we made the profitable leap into producing cars and left the horse drawn buggies behind. We must make a similar leap again, leaving behind outmoded fossil fuels and producing solar energy instead.

A common myth is that too much land is needed to harness significant amounts of solar energy. How much land *would* have to be devoted to solar thermal farms to meet its 30% share of the projected U.S. electricity demand in 2030? The answer has to take into account growth in population, increased per-capita consumption in the absence of gains in efficiency, efficiency gains, and an assumed new demand for electricity for plug-in hybrids and all-electric cars. In Appendix C.3 we show that for the EASY plan the land needed to produce electricity from solar thermal farms is approximately 7,000 square miles, which is roughly 2% of the combined areas of Nevada, Arizona and New Mexico. You might have noticed that this is about one-sixth the land requirement of the Solar Grand Plan described above. The difference is that they are assuming that the photovoltaic panels will be supplying 100% of their estimated 2050 U.S. electrical demand, and that demand is about twice our 2030 estimate; their doubled projection, however, might not reflect the savings in energy efficiency that we project as a result of the E, A, and Y of our plan.

Here’s another way to express the EASY plan land requirement: it is approximately two and a half times the combined areas of the U.S. military’s Yuma and Dugway Proving Grounds (roughly 1500 and 1200 square miles, respectively) for testing weapons in Arizona and Utah. In other words, if we devote two and a half times as much western land to producing solar energy as we have devoted to testing weapons at these two proving grounds, we could meet the 2030 electricity demand, including that for electric vehicles. We would establish energy independence and we would hugely reduce the U.S. contribution to global warming by eliminating our use of coal and of foreign oil. While a panel should be established to explore which government lands are suitable for producing solar or wind power, we leave it to the reader to weigh the effects on our national security of using those two areas to test weapons or produce solar power.

What about Wind?

Wind generated electricity will also occupy a very significant part of the no-carb electricity pie and, like solar technology, is gaining attention around the world. The idea is pretty simple: mount a large turbine in a windy area, and, like a windmill, the wind turns the blades, which powers the turbine, generating electricity. The idea is so simple, in fact, that a self-taught young Malawi man, William Kamkwamba, has constructed successful windmills using parts of blue gum trees, plastic pipes, and spare bicycle parts for his energy-starved country.[265] He plans to build more.

Wind power supplies 20% of the electricity used in Denmark, 9% in Spain, and 7% in Germany, while the U.S. lags behind with less than 1%.[266] Globally, wind power increased by 28% in 2007 alone.[267] China built 33 wind turbines to partially power the 2008 Olympics, and is considering government subsidies to encourage its citizens to buy wind power. Wind power's cost is comparable to that of coal, which makes it substantially cheaper than most solar power sources, and it comes without the destructive mining and pollution. Because of its low cost, both in deployment and use of turbines, and abundant wind resources in the U.S., it is one of the fastest growing clean energy sources in the U.S. In his overarching plan to transition the U.S. to a clean energy economy by 2020, renowned sustainability expert Lester Brown places wind at the top of his list as the major clean energy source.[268]

Increasing numbers of homeowners in windy locales are installing their own wind turbines, 33-100 foot structures that produce 2-10 kilowatts and cost between $12,000 and $50,000, often partly defrayed by state incentives.[269]

In some areas, a near gold-rush mentality has set in as farmers start to view wind as a cash crop, either through leasing part of their cropland to wind turbine operators, or installing wind turbines themselves.[270] Rooftop wind turbines, a little more conspicuous than satellite dishes, were initially developed in Scotland a few years ago, where the government offered subsidies to bring the cost below $2000 for homeowners, as part of a much larger plan to cut emissions.[271] Since then, improved models have appeared,[272] a San Francisco supervisor is encouraging their use in his windy urban district,[273] and New Jersey is contemplating locating mini-wind turbines along its turnpike.[274] At the other end of the scale, commercial wind turbines average 1 megawatt in output but have been increasing in efficiency and power generation. The largest one so far generates over six megawatts, enough to power over 1,000 U.S. homes[275] — it's Danish.

The amount of wind-generated electricity has been increasing fast both in the U.S. and globally, tripling in the U.S. since 1998. The American Wind Energy Association projected a 63% increase in wind power installations for the year 2007.[276] The U.S. now produces over 10,000 megawatts[277] from wind, with a quarter of that installed just in 2005.[278] This is enough to meet the present domestic electrical needs of ten million people, — roughly 20 million people, if the E of EASY is implemented. Deployment is concentrated in the mountain ranges of the lower 48 states, as well as on the Great Plains, the vast flat area east of the Rocky Mountains. Perhaps the largest planned project is a large desert wind farm being constructed by Southern California Edison. The company predicts that it will be the largest wind power facility in the country, potentially supplying 4,500 billion watts of electricity to three million homes by 2013.[279]

Savvy European wind power companies are building wind turbine manufacturing plants and selling turbines in the U.S. Why aren't the U.S. companies doing this? Fluctuating federal support for tax credit plans over the past several years have hampered homegrown wind power industries in the U.S. As Ron Pernick, a wind power researcher noted, “We could have had our own homegrown wind-power companies competing for these new wind-farm developments and manufacturing (plants) had we had the right policies in place.”[280] As it is, technical advances could push U.S. wind power up to a 5% share of U.S. electricity production by 2010, especially if the current federal wind tax credit is maintained continuously, and the demand for clean electricity by local state governments (21 states as of 2006) remains steady or increases. Additionally, the nonprofit organization, 25x’25[281] is a collection of farm leaders who are working towards supplying 25% of the U.S. total electricity by 2025, in part by committing farm, ranch, and forest areas to wind farming. According to the American Wind Energy Association, if the U.S. utilized its maximum capacity for generating wind energy, it could produce three times the total electricity generated from all sources in the U.S. today.[282]

The advantage of wind is that it can be there when the sun goes down, so it can partially fill the supply gap left by solar at night, eliminating the need to store solar energy. The disadvantage is that winds are not steady, so neither is the flow of power. One Pacific Gas and Electric energy procurer, Vice President Fong Wan, notes that winds die down when the midday sun heats a community up, which is when people switch on air conditioners.[283] Thus, he reasons, wind power can’t cover peak usage periods, and is limited to supplying only 15-20% of overall electricity needs. Of course, if we follow the

Solutions from Wind and Earth

Wind Turbine Arrays in California and Pennsylvania


Nerissa Lindenfelser

Wind Turbine on the Thames Estuary


Phillip Hollman


Nerissa Lindenfelser

A Geothermal Plant in Nevada


DOE/NRE

EASY plan and all those houses have rooftop solar panels, the national energy grid will not be experiencing a peak in demand during that time.

Significant concern exists about the impact of turbines on flying wildlife, especially birds. Possible solutions may be to modify turbines, or site them more carefully so as to minimize the number of birds killed from flying into them.[284] This number pales, however, in comparison to the number of birds killed from loss of habitat or by cats, both feral and domestic.[285] In California, a large wind facility at Altamont Pass is starting to reduce bird mortality through measures such as partial shut down during migration, dismantling the most poorly sited turbines, and replacing old ones with taller, fewer and more powerful ones that work above the flying altitude of most birds. [286]

As in solar energy, emerging technological improvements have decreased the cost of producing wind energy, and will continue to do so, while tax breaks and green pricing programs have encouraged the growth of this industry. While they are an unusual sight to many who see a wind farm for the first time, wind turbines are a welcome alternative to power plants that spew air pollution, coal mines that devour land, and rupturing oil tankers that smother marine life.

The Promise of Wave Energy

Another indirect solar source of energy is from waves, which are driven by wind that is, in turn, created by solar heat. Compared to wind or solar technologies, technology that harnesses wave, tidal, or water-current energy is still in its infancy. Wave patterns and land formations will constrain where such technology can be used, but the field shows promise. There are over 1,000 wave energy patents, and many different types of wave energy devices already exist.[287]

Attenuators are long, multi-segment structures that lie parallel to the wave direction. The changing height of the waves rolling through one causes flexing, which is harnessed as energy.[288] Wave energy snakes, known as Anacondas, also lie parallel to the wave direction, but these consist of completely closed, long rubber tubes filled with water. A wave, hitting the seaward end, creates a “bulge” wave within the tube that increases in size as it continues to be pushed landward by the external wave. At the end of the tube, the bulge wave passes through a turbine, generating energy that is transmitted to shore via cable.[289]

Terminator devices are a category of wave energy machines that are oriented perpendicular to waves.[290] An example is an Oscillating Water Column (OWC), which is a partially submerged box with a seaward opening at the bottom and a landward opening at the top. Wave action forces the enclosed water column and overlying air to move up and down, causing air to be pushed and drawn through a turbine at a landward outlet. Pendulum or flap devices consist of a box with a seaward opening. Waves rush in, causing a flap or pendulum to move back and forth, driving a hydraulic motor. This, then, powers a generator.

Overtopping devices include setups such as tapered channel devices. These have walls above the water that funnel waves higher and higher through a progressively narrower channel. At the end, the wave spills into a storage area, and the water runs through a turbine out to sea again. Point absorbers take advantage of components that move relative to each other because of wave action. For example, one type of wave energy converter is a floating buoy attached to a submerged, movable casing containing magnets that surround a firmly tethered, relatively motionless metal coil.[291] When a wave forces the buoy up and down, the motion of the magnets around the coil changes the magnetic field, generating electricity. Placed 2-3 miles off the northwest coast of the U.S., where strong waves arrive because of the westerly winds, wave buoys have the potential to deliver far more power than similar buoys placed off the U.S. Atlantic coast. There are also tidal energy devices, placed singly or in sets, such as tidal fences with turnstile-type turbines, to harness tidal energy.

Although wave energy is estimated to possibly supply as much as 10% of the nation’s energy demand eventually, there are significant financial and technological hurdles to overcome. There are also concerns to address, such as whether buoy placement might interfere with fishing or the movement of marine animals.[292] At this point, its potential contribution appears to be too little, and too far into the future, to significantly help towards solving the climate crisis. But, with demonstration pilot projects in the works, the situation might change. Exploiting the energy of the Gulf Stream with underwater turbines is an avenue that is just beginning to be explored, and is even further away from making a significant contribution.[293]

The Geothermal Boost

Geothermal sources currently supply less than 1% of the world’s energy,[294] and will likely never be as important as solar or wind power in addressing the climate crisis. With enough time and investment, however, geothermal energy could eventually comprise an important part of the pool of clean energy sources. There are three different ways to generate geothermal electricity: hydrothermal, binary, and enhanced geothermal. All three involve tapping into hot regions below the ground; the first two methods use and return geothermal fluids. In hydrothermal systems, naturally occurring superheated, pressurized underground water reservoirs are tapped, which supply steam (dry steam method) or depressurized water that instantly converts to steam (flash method) on its way to the turbines that it will drive at the electrical plant.[295] Binary systems tap somewhat cooler geothermal fluids and use a heat exchange system to superheat other fluids. These other fluids have much lower boiling points that vaporize to power turbines. Enhanced geothermal or hot-dry-rock systems pump water onto hot rocks underground, using the hot fluids to similarly drive turbines, as outlined in the previous methods. This particular method opens up many more locations for geothermal power production.

Enough geothermal resources exist to replace a substantial fraction of current fossil fuel demand,[296] but several obstacles block large-scale use of these resources. The geologic characteristics of specific drill sites can pose unique challenges to economic production. Minor earthquakes can be stimulated by drilling,[297] and relatively small amounts of greenhouse gases and toxic hydrogen sulfide can be emitted, although various methods can reduce these emissions.[298] Additionally, hydrothermal sources have been known to cool after several decades, so the sources are not necessarily reliable in the long term. An MIT study estimated that enhanced geothermal systems could possibly supply up to 100 billion watts of electricity to the U.S. grid by 2050 if we invested $1 billion over 15 years of research and development .[299] By way of comparison, today the U.S. uses electricity at the rate of 450 billion watts. Even if just one third of the MIT goal could be achieved by 2030, and we think that is very likely, it would be a significant contribution to the EASY plan.

What Are the Challenges?

We already noted above that erratic U.S. government incentives for the development of wind power have given the wind turbine manufacturing edge to already developed European companies. Obviously, we need to create a stable U.S. governmental source of incentives for both wind and solar power. But this also points to a much broader issue: creating an efficient planning process that does not get new clean energy projects entangled in local bureaucratic restrictions. Britain has already seen something happen similar to this.[300]

Our federal government has demonstrated how far-reaching its power can be when exercised in the name of national security. The old threats to our national security were loss of control over needed oil supplies and the terror promulgated by our wars over these supplies. The new threat is global warming, and the new answer must include clean energy sources, which will negate our old threats. Thus, in light of our new threat, our government needs to redefine our national security goals and exercise federal power appropriately and with similar forcefulness to facilitate the development of clean energy sources. A start is to recognize that our national security rests in great part on energy security. A major national security goal, then, should be to develop clean, affordable, sustainable, and abundant sources of energy that are easily defensible, and to do so as soon as possible.

There are all sorts of policy experts who simply conclude that we cannot do enough, fast enough.[301] When faced with the threat of Hitler, however, our country didn't debate whether we could conquer this threat. We simply marshaled our resources — mental, physical, and financial — into a concerted effort, and we conquered. Global warming also threatens our planet, and we need to meet it with the same urgency and commitment that we mustered in World War II.

The Challenge of Energy Storage

An important technological challenge we face is to develop energy storage systems for the energy produced from sunlight and wind. We could produce enough solar electricity to take care of daytime needs and night time but we lack adequate storage capacity store solar electricity for night time use. Similarly, we could produce enough wind based electricity to power our nation if it could be stored. Dealing with fluctuating supply from solar- and wind-generated electricity is the biggest technological impediment to EASY, but fortunately there are promising ideas for addressing it. The major approaches to dealing with the intermittence of solar- and wind-generated electricity can be grouped in nine categories:

- battery storage
- flywheel storage
- hydrogen
- pumped storage
- compressed air
- supplementary supply
- grid expansion
- stored heat
- policy measures to manage timing of demand

Batteries are being used for some rooftop photovoltaic systems so that the houses can operate independently of the national energy grid. These batteries are cumbersome, however, and add considerably to the cost of a home solar unit. The technical challenge is to create better cheaper batteries for home electricity storage. There is considerable research happening here, but much of it is focused on batteries for hybrids, all-electric vehicles, and power plants. We are reluctant to even estimate what the characteristics of batteries for home electric storage will be by 2030. The city of Austin, Texas, envisions plugging in plug-in hybrid cars during peak usage hours to use their stored battery power to supplement peak supply.[302] The batteries would then be recharged during off-peak hours.

On the scale of a large power plant, megawatt (MW) batteries have been developed as a cheaper alternative to building backup plants and grid substations, and as a way to begin storing the energy produced from wind farms.[303] Operating through a variety of chemical systems such as sodium sulfur, zinc bromine, and vanadium-based, MW batteries can be charged whenever electricity supply exceeds demand, and when extra energy is needed, be accessed for energy much faster than generators or power plants. Storing one billion watts of energy each, these double-decker-bus-sized batteries cost half as much to make as building a peaker plant, according to one battery maker, Altair Nanotechnologies, Inc. Peaker plants are methane-fueled facilities that only run at peak hours to supplement coal-fired plants. Altair Nanotechnologies, Inc. recently created a $1 million 2 MW battery system for a utility, and is also developing hybrid vehicle batteries. The cost of these MW batteries is expected to decrease as production increases. Japan’s NGK Insulators is creating sodium sulfur MW batteries that last about 15 years, longer than its rivals. As we write, the Xcel Company is testing the ability of its MW battery to store energy from a Minnesota wind farm. A disadvantage of these MW batteries is that once used up, the battery must be disposed carefully, especially its toxic components.

Flywheel storage systems are intriguing alternatives to batteries. Flywheel energy storage involves using generated electricity to create a magnetic field that turns and suspends a flywheel in a partial vacuum, storing the energy as moving (known as kinetic) energy in a nearly frictionless heavy rotating wheel.[304] A commonly voiced concern is that they could fly apart and cause injury, which is why we suggest that home units be buried in the backyard. Theoretically, a buried flywheel in your backyard could store solar energy produced from your rooftop photovoltaic system. Such flywheel systems are already used in datacenters and other applications that require uninterrupted power supply. Various companies, such as Active Power and Hitec Power Protection Company, for example, use them to prevent interruptions to power supplies for airports, hospitals, and other industries.[305] Beacon Power Corp is building its first flywheel plant in New York State and hopes to have it operating by the end of 2008. Under this operation, the company will make money by selling power stored in its flywheels to utilities when they need it.[306]

If we deployed both home- and industrial-scale flywheel storage systems for all solar and wind power systems, this would remove the major hurdle for producing clean energy. Home-scale units that could meet home electricity demand for several consecutive sunless days — assuming the E of EASY is implemented in the home — would probably be cylindrical in shape, no larger than about three feet in diameter and three feet tall, made of composite high-strength materials, weigh upwards of half a ton, and spin at perhaps 10,000 revolutions per minute. Today the cost of such a system would be prohibitive but were they mass-produced, they could be highly cost-effective. Whether the optimum scale at which to deploy them is the home, the neighborhood, or an even larger scale remains to be seen. Advantages of flywheels over battery storage include the absence of toxic materials in their manufacture, their much longer lifetime, and their relative insensitivity to temperature changes. We also suspect that within a decade they will be more cost-effective than batteries.

Hydrogen can be produced from electricity by electrolyzing water, as described in Chapter 5. Hydrogen produced during times of ample sunlight or wind can then be used when the solar and wind supply is low to regenerate electricity. This last step can either be accomplished with hydrogen fuel cells or by combusting the hydrogen to produce steam-generated electricity.

Pumped storage is already in use, both domestically and abroad. The idea is simple: use excess electricity to pump water uphill to a reservoir and then let it flow back down to generate electricity when extra supply is needed. It is cost-effective, but available sites are limited, and creating new sites would trigger all the environmental concerns that hydroelectric power generation creates. It might fill in perhaps 5-10% of the additional needed storage under the EASY plan, but attempting to do more than that would probably be environmentally unacceptable.

Compressed air is yet another way to temporarily store excess electric energy. Electric-powered compressors produce the high-pressured air that is stored in abandoned mines, empty aquifers, vacant underground caverns, and depleted gas wells. This stored compressed air can be used upon subsequent expansion to turn a turbine and regenerate electricity. In the Solar Grand Plan mentioned above, the authors observe that such compressed-air energy storage plants have been operating reliably in Germany since 1978, and in Alabama since 1991.[307] The disadvantage is that the turbines still need at least 40% of their original natural gas fuel requirements to aid in their operation, although the authors believe that heat recovery technology would lower this to 30%. The cost of this form of storage today is estimated to be about half that of lead acid batteries.

Supplementary supplies of electricity beyond use of solar and wind can also be used to alleviate the problem of fluctuating supply. Geothermal production and existing hydroelectric production can be operated primarily at night when solar power is unavailable, and existing nuclear power generating capacity can help supply steady or baseline power.

The national electricity grid provides another means of dealing with fluctuations in supply. It is rarely windless and cloudy over most of the nation at the same time. If, at any particular time, electricity generated from sunny Arizona could fill in for electricity not generated in windless Maine, we could avoid the problem of fluctuating local supply. But the current electricity grid is not adequate to dealing with this challenge; it would need to be upgraded and expanded, and the means of operating it most effectively will need to be worked out — a wonderful and solvable problem for network engineers. The extensive direct current grid network proposed by the authors of the Solar Grand Plan mentioned above is quite different from today’s current grid, but illustrates the breadth of possible solutions that exist. National leadership could facilitate grid upgrading and there is no major reason why we can't adjust our energy grid to accept and distribute clean energy. As it is, a lack of transmission lines is impeding renewable energy development in the U.S. today.[308]

Stored heat could be a very effective way to deal with fluctuation in the supply of electricity produced by solar thermal plants. The idea is simple: solar thermal electric generation typically works by focusing solar energy to produce steam that then spins a turbine. The heat energy can be stored for hours or days in molten salts, provided the salts are well insulated, and then converted to electricity when needed. This appears to be one of the most promising ways to deal with a fluctuating solar energy supply.

Policy and technical measures to manage timing of demand can also alleviate the problem of fluctuating supply. For example, people can be encouraged, at least to some extent, to choose sunny periods to charge their plug-in hybrids or to use electricity with the help of Smart Meters, as mentioned previously. Operators of "electric stations", where people will go to have their automobile battery replaced with a charged battery as described in Chapter 5, can certainly be encouraged with pricing policies to recharge drained batteries during sunny periods. People can use dishwashers to wash tonight's dinner dishes tomorrow afternoon rather than in the dark of the evening.

It is unlikely that just one of these nine storage approaches to fluctuating supply will suffice, but by using some combination of improved versions of these options, the problem of storage has a very good chance of being solved. Certain approaches such as flywheels, air compression, grid modification, thermal storage and demand management hold particular promise in our opinion. We advocate a large infusion of research and development money to further perfect and implement these approaches. An especially deserving area of more research is determining the appropriate scale (home, neighborhood, district, etc.) at which different storage technologies can be most cost-effectively deployed.

The Manufacturing Challenge

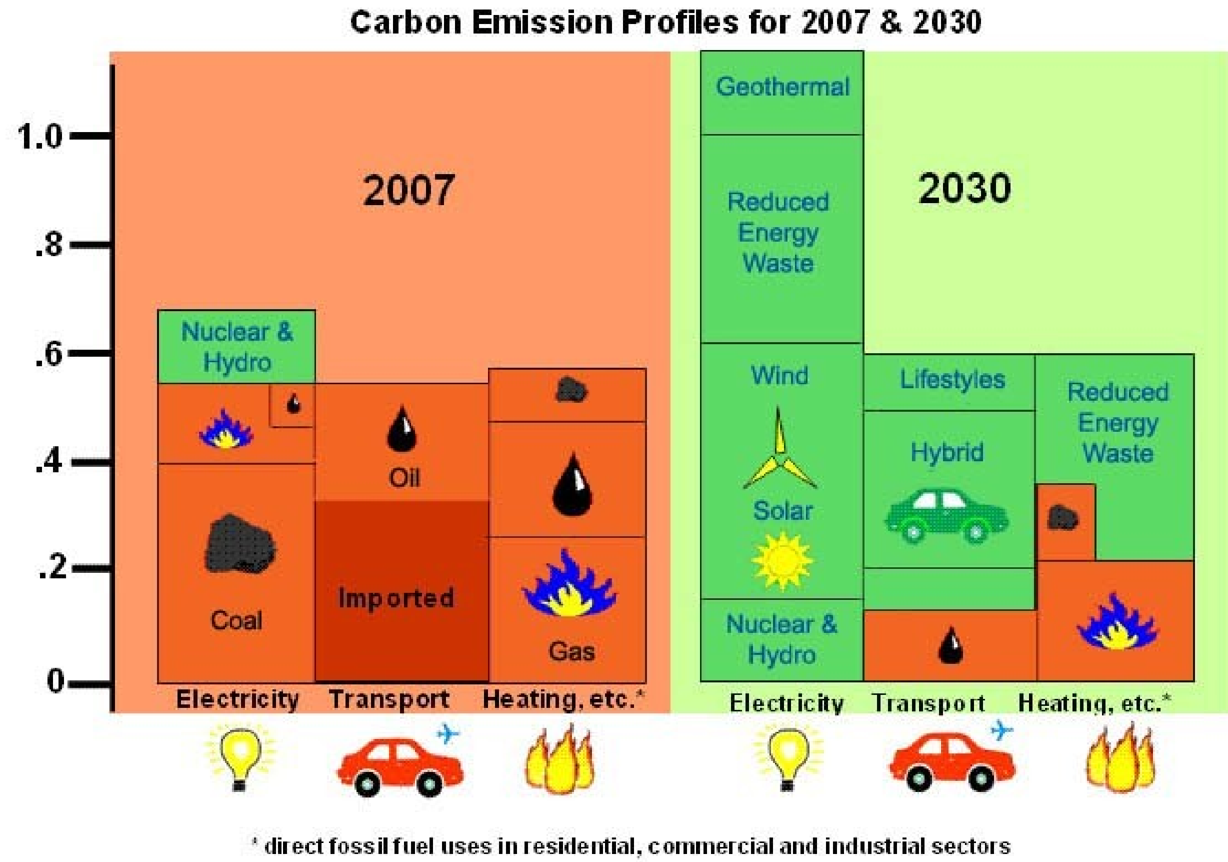
For both solar and wind power, the manufacturing challenge will be to accelerate production of the needed infrastructure sustainably[309] and fast enough to meet the goals of the EASY plan:

* photovoltaic panels;
* wind turbines;
* solar thermal plants;
* energy storage systems;
* transmission structures;
* adequately trained workers.

Already, supplies of vital parts for wind turbines and solar panels have run out temporarily, forcing expensive projects to halt.[310] Solar workers are in demand.[311] In part, this has been driven by the lack of political commitment by our government. If our government doesn't create long term incentives for promoting wind and solar energy development, manufacturers don't make long term investments in the production of the technology. The results so far are that we have been paying foreigners to help make the needed energy transition — foreigners whose governments create the economic conditions needed to grow clean energy companies.

As the building needs of developing countries explode, we will compete for basic resources such as steel;[312] this must be factored into preparations for the manufacturing surge necessary for our transition to clean energy. The U.S. has been able to make a similar industrial surge in the past, notably during World War II. Between 1940 and 1945, for example, the U.S. produced over 300,000 fighter planes,[313] machines more complex and resource-intensive than industrial wind turbines. We have more human resources now, and with proper federal commitment we could manufacture the same number of one megawatt industrial wind turbines, fulfilling most of our electricity needs. As noted above, the security stakes here are just as great as in World War II, even though the source of instability is quite different. We simply need leaders with the necessary vision and commitment.

Let’s take another look at our energy transition blueprint again, previously outlined in Figure 3.1 and reprinted on the following page. We can reduce CO_2 emissions from the production of electricity, and practically wipe out our use of coal, just by adopting solar and wind technologies.



Orange (the problem) signifies the carbon emissions (or their equivalent from other greenhouse gases) produced in billions of tons of carbon per year (vertical axis).

Green (the solution) signifies the equivalent amount of carbon emissions avoided through clean energy and energy efficiency. The upper bars in 2030 include the extra energy needed for projected increases due to an increase in population and per capita energy use, and increased electrical demand from plug-in hybrid vehicles. See the Appendix, Section A, for how we estimated the bars.

As discussed above and illustrated by other countries, solar and wind technologies are feasible, accessible avenues. Now let’s tackle the last part of this plan — ourselves.

Chapter 7: You Are Part of the Answer

Every time you buy, you are voting for or against the Earth, Green Consumer expert Julia Hailes notes.[314] Yes, it's true that changes enacted at the public level will be the major avenue through which we as a nation will solve the climate crisis by reducing energy consumption and producing clean energy. Nonetheless, through our collective will, we as individuals can move mountains, even by enacting only some of the changes discussed below — and we can **save money** doing so! At this point, most people are ready to make personal sacrifices to address global warming,[315] but "sacrifice" is a relative term. When we compare the consequences of doing nothing about climate change to those of addressing climate change by making personal money-saving changes that impinge little on our quality of life, suddenly the word "sacrifice" morphs into the phrase "common sense." The most obvious way to change is to make smart choices by following the three R's: **Reduce** wasteful consumption, **Reuse,** and **Recycle** resources. Here, changing our behavior occurs at a very personal level.

Smart Choice 1: Reduce Wasteful Consumption — and Save Money!

Reducing consumption means that we have to re-examine our material needs, and separate them from our often wasteful desires. Our advertising industry plants consumptive expectations and desires within us and our children, exerting pressure through relentless advertising to consume impulsively — buy or expect to receive more, the latest, the best, as much as possible, and as soon as possible for all possible holidays and occasions, and at the same level as your peers, or higher. Many insist that this is the only way to drive a healthy economy, but just the opposite is true. When we consume beyond a sustainable level — beyond the ability of our remaining resources to meet our desires — families go into debt, economies will ultimately crash, and we rob the futures of our children. Some may be tempted to justify their consumption when the products are considered green, and others might see it as a way to ease into a more sustainable lifestyle. But wasteful consumption is wasteful consumption, no matter how green we buy.[316]

This wasteful consumptive behavior is a recent phenomenon; before World War II, for example, fancy parties and gifts for all sorts of holidays and occasions were not the norm. Rather than consumption, parties then were based on fun and engaging activities: lively conversation, readings of poetry or play scripts, games, singing and dancing. Why not revive these valuable traditions? You save money, and have even more fun socializing! You can save money, save energy and save the planet by eliminating wasteful consumption from our behavior, teaching your children to do so, and leading by example. Center for a New American Dream (www.newdream.org) focuses on ways to save money by reducing consumption and waste, i.e., by being thrifty. The recently released book, “The Live Earth Global Warming Survival Handbook: 77 Essential Skills To Stop Climate Change” by David de Rothschild (2007, Rodale Press), gives many tips on how to reduce energy consumption. So does the Environmental Protection Agency, the Department of Energy, and Flex Your Power, an online organization funded by the state of California.[317]

Here are some further smart choices to reduce wasteful consumption. Set an example — when possible, let friends and relations know that you do not need material gifts. Sounds revolutionary, doesn’t it? But there are many advantages. One is that if everyone does it, we all save money. Another is that this can go a long way towards easing tensions around the holidays, especially when people can feel obligated to give gifts that they cannot afford, or others are disappointed by unfulfilled gift expectations. It also can go a long way toward uncluttering your house. Want to give a gift? You can give the gift of time and service to your loved ones, as some are starting to do for Christmas.[318] The most important gifts are not material ones, as many religions teach.

If your current wardrobe and equipment are still usable, resisting the latest fashions or electronic toys will save you more money. Another saver for you and the planet is to buy reusables rather than disposables, from batteries to cameras to water bottles, and more. Following the venerable Japanese tradition, wrap presents in colorful scarves, which you can reclaim upon presentation and reuse again; ditto for colorful paper bags. Go to the library instead of the bookstore. Unless you really read them regularly, don't subscribe to magazines and newspapers. If you do, share your old magazines with friends, neighbors, or local schools and recycle the newspapers.

Want to support a cause? Your money will go farther if you simply give them money, and not buy their fund-raising products. Avoid buying excessively packaged products, and reuse shopping bags. Stop junk mail effectively by signing up at www.greendimes.com , www.stopthejunkmail.com , the free service www.catalogchoice.org , or similar websites. Replace energy consumptive activities with non-consumptive ones: jog and bicycle rather than drive. Walk with friends on trails, in safe neighborhoods, in parks, and in museums, rather than in malls, to nourish your physical and mental health rather than your material desires.

For the household, buying energy efficient appliances will save you money; look for the Environmental Protection Agency's energy rating Energy Star label on products, which guarantees payback on the product within five years from energy savings alone.[319] When choosing a product model, from cell phone to refrigerator, buy one that meets your needs most energy efficiently; extra features often consume extra energy and can even shorten the usable life of the appliance. Even when turned off, plugged in TV, VCR, printers, computers, and chargers for cell phone and other appliances suck energy from their sockets. This wasted energy is known as standby or vampire energy. Devices that contain recharging batteries, such as cordless phones, will leach more standby power than corded versions that have no batteries. Buy appliances that suck minimal amounts of standby energy; peruse the Federal Energy Management Program appliance buying guide[320] and search their database for appropriate brands and models (http://oahu.lbl.gov/cgi-bin/search_data.pl).

The savings can be significant; one study indicated that you could save 5-25% on household electricity by eliminating standby energy.[321] When you consider that the U.S. national residential consumption of electricity in 2001 was 1,140 billion kWh,[322] 5% of that tremendous amount of electricity equals the output of about 100 typical coal-fired power plants. The standby power of a single TV can cost the consumer as much as $10 annually; a Cornell energy expert in 2002 noted that nationwide, the energy wasted as standby power amounts to $3 billion worth of electricity.[323] To reduce standby energy, unplug any appliance not in use continuously. To make unplugging easier, plug your appliances into power surge strips and turn those strips off when not in use.

Use appliances efficiently: wash your clothes in cold water when possible; wash only full loads of dishes or clothes. Urge your children to make smart choices when playing games — video and computer games consume energy, while board and outdoor games do not. Change your incandescent bulbs to compact fluorescent ones. New energy legislation passed by Congress will mandate much more efficient light bulbs within the coming decade. So why not do it now? Don’t wait for the government to tell you that you have to.

The kitchen is a great place to curb energy consumption. When cooking little, cook small: use a toaster oven and microwave rather than firing up the energy-hungry conventional oven. One cooking expert offers further tips:[324]

- *Keep your burner at the lowest possible setting to boil or steam.* The temperature — 212° F — is the same, whether the water simmers or boils vigorously.
- *Use induction cooktops*. Renovating? Under typical cooking conditions, these are the most efficient cooktops: 90% of the heat gets transferred to the pot, compared to the 35-40% transferred with a gas burner, or the 70% transferred via an electric element. The more efficient the transfer, the better the resulting food — vegetables steam faster, retaining more vitamins, and fried foods cook faster, absorbing less oil.
- *Cook with a lid on.* Lids help retain heat and prevent escaping steam, so that the energy and humidity stays in the pot.
- *Pre-soak grains, legumes (beans), and even hard pasta.* This can cut down cooking time by as much as two-thirds, since much of the normal cook time is spent transferring moisture into these foods.
- *Cook at two levels to cook meats or fish.* Cook a cold roast at 400-500° F for 10-15 minutes, for example, then reduce the heat to 250° F to cook the rest of the roast. This results in a browned exterior and a moist interior.

Replacing an electric water heater with a solar one can reduce your electric bill by 25%, and pays for itself in 4-8 years. Turning down your water heater to the warm setting, 120° F, will save you more energy. Hang your clothes outside to dry in the sun, or on an indoor drying rack if your house is not air conditioned. If you must use your energy-hungry dryer, make sure the clothes have been spun dry in the washer and use the dryer’s sensor button, which stops the drying as soon as the clothes are dry. When away from your home for more than a few days, turn your house and water heater thermostats to the lowest safest energy setting — if this means turning a gas pilot off, first make sure you know how to relight it. Ultimately, we need more computer controlled appliances with electronic ignition rather than pilot lights. The American Council for an Energy Efficient Economy website supplies many more guidelines and tips.[325]

Health care and cleaning up chemical pollution also cost energy. Avoid excess chemicals in your environment, such as unnecessary fragrances, brighteners, fertilizers, pesticides, or unnecessarily strong cleaners. A U.S. website lists 5 basic ingredients as the building blocks for all types of nontoxic cleanser: baking soda, borax, soap, washing soda, and vinegar or lemon juice.[326] Green cleaning expert Anne B. Bond uses five common Australian ingredients to make a basic, non-toxic cleaning kit: white distilled vinegar, baking soda, washing soda, tea tree oil, and a good liquid dish detergent; just a 5% solution of vinegar — i.e., the concentration of vinegar sold in supermarkets — kills most bacteria, viruses and molds, she notes.[327] She offers several cleanser recipes derived from these.

When remodeling, choose products that have no or low volatile organic compounds (VOCs), which can pollute the air inside your home. Many of these chemicals ultimately end up in our rivers and bays, and have not been screened for possible health hazards.

Getting your family psyched to help reduce energy can be a challenge. Here’s one way to make it an encouraging activity for all:

Getting the Family on Board

1. ***Hold a family pow-wow. Discuss and agree on all the ways everyone can help reduce energy and material consumption.***
2. ***Start comparing monthly bills, and keep track when members forego consumption through reuse, recycle, and reduce.***
3. ***At the end of a month, add up the savings, put it into a special awards account, and keep the progress of the account posted on the fridge.***
4. ***Use the savings as a reward to everyone – an ice cream party, a vacation? Start saving now!***

Make your house more energy efficient. To reduce your energy bills on your current home, properly insulate all your walls and attic spaces, plug up heat leaks, and install glazed windows. Energy efficiency building consultants are now being employed by all levels of government, industry and even in the private sector to accomplish this for all types of buildings. Innovative housing construction such as energy efficient straw bale houses, for example, should be promoted.

During the summer in areas with relatively low humidity, houses can be cooled in a natural, energy efficient way through several methods. One method is to create ambient shade areas around the house (trees and bushes, awnings, window shades), especially on the hot east and west sides of an exposed house. Ventilate the house during the coolest parts of the day and the night by opening both the interior doors and the lowest and highest windows to create a cooling airflow. This can be helped, if necessary, by an energy-efficient window fan in the highest house window blowing hot air out, which is much easier than sucking cooler air in. Seal the house during the hottest parts of the day.[328] All this can decrease summer energy consumption dominated by air conditioning systems.

In a longer term, the next time you replace your roof, replace dark shingles with light colored ones to reduce the amount of summer heat absorbed by the house. (This will have little effect on the solar heat retained in winter, by the way, since the lower angle of the winter sun then causes most solar heat to be absorbed by the sides of the house, not its roof.) Still getting high energy bills? Ask your local utility to help you set up a professional energy audit, which can help save you money, and even secure rebates for energy-saving remodeling such as weatherization.

Small lifestyle changes can also add up to significant increases on money savings and energy consumption. Kick the “car is my ego” habit. Walk, bicycle, use public mass transit, or carpool whenever you can. Also, depending on where you live and how much you drive, there are car-sharing programs and companies, such as Carpool Expert, Greenride or Zipcar, which can be much cheaper than owning a car.[329] Don’t drive a car or other motor vehicle more often than necessary. Telecommute to work as often as possible. Many people now choose their work based on how near it is to their home, or vice versa, or work from home to minimize their commute to work. Avoid the hassle and expense of extensive business travel by teleconferencing when possible. When you must fly, choose a direct route when you can, since take-offs are particularly fuel consuming. For trips shorter than 300 miles, consider taking the train or bus, which allows you to relax or work and spares you the stress of driving.

When you do drive a car, make it an energy efficient one no larger than necessary. Then, drive it efficiently. Developing efficient driving habits may be challenging, but are worth it. For example, many people do not know that slowly decelerating towards and slowly accelerating away from stop signs can significantly improve gas mileage — so does keeping tires properly inflated; keep a tire gauge handy.

On a daily level, re-examine how much water and food you really waste, since both require energy to supply. When drought conditions occur, our society illustrates how much we all can do to conserve water; try implementing those measures as often as possible. One easy way is to install greywater systems that recycle lightly used bath or dish water to the garden or toilet. Install low-flow showerheads (with knobs for easy temporary turn off while you soap), low-flow aerated faucets and low-flush toilets, all of which save water and money. You can significantly reduce the flush of existing toilets by placing a brick or two in the toilet tank.

Our diet — what we eat and how much we waste — is an important way in which we can influence global warming. How much food do we waste? If England is to be considered a typical developed country, then people in the developed world end up throwing out up to one-third of the food they buy.[330] Our consumption of imported sugar and beef, especially through fast food chains, indirectly fuels the destruction of tropical forests, which are converted into cane fields and ranches. Furthermore, cows contribute over a quarter of the total methane released by human activities to the atmosphere.[331] Thus, our very diet undermines our climate security, not to mention our health, as the current obesity and diabetes epidemics in the U.S. illustrate. Eating less imported beef and sugar will promote both, and is an important change people can institute immediately on an individual basis.

Vegetarian protein (e.g., beans, nuts, tofu, tempeh or seitan) is healthier and cheaper, and requires much less energy and land to produce than meat, simply because you don’t have to feed animals. You save in three ways with vegetarianism by decreasing health costs, food bills, and environmental costs. Consider having some vegetarian meals on a regular basis. Vegetarianism is increasing as people recognize how much healthier it is for themselves and the planet. Consider growing your own organic fruits and vegetables, as many are starting to do,[332] and use your own compost. Fruit trees are an easy way to begin. You'll save money and carbon dioxide emissions, and get exercise.

The cheapest item may hide the very real environmental and social costs of its production and transport. "Buy local" means buying locally produced items, which sustains local employment and the local economy. This saves your entire community money by keeping employment and local revenues up. It often also reduces unnecessary transportation, the emissions of which add significantly to global warming. A fairly straightforward example is flowers. Typically, they are grown and packaged in another country and flown into ours, a process that consumes quite a lot of energy. It would be best to grow your own, or buy locally grown living plants. Check your local community for farmers markets. Look into organizations such as LocalHarvest that helps people buy from their local farms.[333]

All of this might sound like a thousand little changes of behavior, and overwhelming at times. To counter this feeling, remember that after a while, it will feel like your normal routine and become second nature to you. It also helps to remind yourself and your family regularly why you are changing your behavior. It is all part of a very grand, very real plan to save money, save energy and save the Earth for our children. The options to do so are available and often easy to do.

Smart Choice 2: Reuse

One way of reducing wasteful consumption leads to our second R. Reusing resources has been a social tradition, even a necessity for much of society until recently, as any middle class survivor of the 20th century's Great Depression will tell you. Reusing comes in many forms. One form is to repair rather than replace. Another is to find new uses for old items. Yet another popular form of reuse is to buy used instead of new. This last tradition has kept pace with technological advances: besides the old standbys of antique, consignment and thrift shops, yard sales and flea markets, Generation X has added eBay, Craigslist, and Freecycle.[334] The challenge is to make "buying used" a habit. Investing in reuse saves money and prevents further unnecessary production and recycling.

Giving and acquiring used items can be as simple as putting a "FREE" sign on an unwanted item and placing it in front of your house. Even when we have been tempted to dispose of various items, our family has been amazed at how even very worn, broken or used items placed with a "FREE" sign outside our home get taken away by grateful people. In turn, we like trading stories among our friends and family about the bargains we have picked up from free piles outside other houses.

Smart Choice 3: Recycle

Recycling, another venerable tradition, has also undergone a revolution in our society.[335] As landfills fill up, and garbage disposal and resources become more expensive, people are recognizing that their communities can save money through recycling. In 1980, the U.S. recycled only 10% of its municipal trash — today it recycles 32%. Not to be confused with reuse, recycling refers to breaking down an object or building to its basic components, and redistributing those components for new use in other objects/buildings. The European outlook is even more dramatic. Countries such as Austria and the Netherlands recycle 60% or more of their waste. And Britain's recycling rate, though low, is improving fast, having nearly doubled in just the past three years. There is much more room for improvement if every U.S. community develops good curbside recycling programs and every household takes the time to conscientiously participate in those programs.

Not having enough time is not an excuse. It's all part of the plan to save Earth, and everyone has to help.

Expanding recycling is just a question of economic demand and creativity. For example, copper has become so valuable that people in the U.S. and elsewhere not only make money recycling scrap copper, but stealing copper pipes and other fixtures has unfortunately become more common. The scrap industry includes recycling the components of old houses and office buildings, which allows people to incorporate antique elements of bygone structures into new ones. Further still, rising landfill costs and tighter recycling guidelines coupled with an increasing awareness of green building practices, has given rise to the house "deconstruction" industry. Here, a house is carefully taken apart and the parts used once again to build another house or recycled.[336] Recycling also has a place in the fine arts, where many artists and craftsmen make their creations with discarded items.

Carbon Footprint

"Carbon footprint" refers to the amount of carbon emissions a person or family creates by their style of living. It is also a measure of how much money we spend, since we pay in some way for every unit of carbon that is emitted, either through buying goods or services. Americans are notorious for creating some of the largest carbon footprints on the planet. How much could we reduce our footprints?

A Boulder, Colorado family of four took on the carbon footprint reduction challenge.[337] They reduced their electrical use more than 60% by installing compact fluorescent bulbs, buying an energy efficient refrigerator, and using wind and sunlight to dry their clothes on a line when possible. The parents made a conscious decision to live close to work and school. Will Toor, a county commissioner, rides his bicycle to work when he can, and public transport when he can't. Their one car, a 13 year-old Honda civic, gets 40 mpg, and is driven a little over 5,000 miles per year; the average U.S. car gets 25 mpg and is driven over 12,000 miles per year.[338] Toor's wife is a stay-at-home mom and environmental activist. Both of them installed solar panels on their garage. And as part of a major remodeling project on their 1928 house, they installed insulating windows, extra insulation in their walls and under their roof, and a heat-recovering ventilation system. They plan to install a solar water-heating system to cut emissions further.

Toor figures that they now produce only a quarter of the carbon emissions of a typical Colorado household. The big news is that, overall, these steps will save them money in the long run and changed their lifestyle very little — and the house is now more comfortable. The energy-efficient retrofits were part of a major house remodel that had been planned anyway. "It's not rocket science," says David Hawkins, head of the Natural Resources Defense Council's Climate Center. "The tools are in the toolbox. The challenge is to get them out of the toolbox and into peoples' hands." Considering your carbon footprint is another way of reviewing your smart choices for saving money and energy. It can be done at home, in the office, when traveling, and throughout your daily life.

Flex Your Voice for the Forests

We have already mentioned several ways in which our buying power influences the climate crisis — through diet and consumption patterns, for example. Another way to promote change is to use your voices, as well as buying and voting power, to preserve our global forests, which act as carbon sinks and reservoirs, both absorbing carbon dioxide and storing it. A hidden assumption of Figure 3.1 in Chapter 3 is that we will continue to maintain and expand our global carbon reservoirs. The continued destruction of our global (especially tropical) forest ecosystems for our exploitation and consumption contributes about 20% of manmade carbon emissions to the atmosphere each year.[339]

Among forests, primary or “old growth” forests are the largest carbon reservoirs per acre. An old growth forest has larger, denser trees (think giant carbon cylinders) than regenerated forests or forest plantations, which have smaller, younger, less dense trees. The U.S. has the 7th highest rate of primary forest loss in the world.[340] The lumber produced from cutting old-growth forest can store carbon for many decades. The huge amount of forest debris left over from the timber cutting represents much of the carbon stored in the forest, however. When this debris decomposes or burns, its carbon is emitted into the atmosphere as carbon dioxide. For the sake of exporting timber or constructing homes out of the finest wood, we are undercutting our carbon storage capabilities, robbing the carbon bank of our descendants. This is clearly a case of our nation’s climate security suffering for the benefits of the entrepreneurial few, and must be stopped as soon as possible. Furthermore, as we destroy primary forest we are causing numerous plant and animals species to go extinct through loss of habitat, thus leaving a biologically poorer Earth for our descendants.

Instead of primary forest lumber, we should be substituting composite wood products made from plantation trees, sawdust, and wood scraps. Several websites exist that offer suggestions for reducing wood consumption when building new structures.[341] Similarly, whether at the individual or business level, refusing to buy wood products made from primary forests also helps discourage their exploitation. The challenge becomes: are we willing to use fewer and different products to bolster our climate security?

The World Bank has recognized the importance of forest conservation; a planned $250 million fund that encourages developing nations to stop deforestation and in some cases pays them to do so is attracting strong international interest.[342] To our north, the destruction of intact boreal forest in Canada is being recognized as a driving force fueling the climate crisis. We can choose through our wallets not to support that, and to support non-governmental organizations, such as Rainforest Action Network, Forestry Ethics, and Pacific Forest Trust[343], that are trying to promote their conservation. If you really need wood, buy it from businesses certified through the Forest Stewardship Council;[344] these businesses get lumber from sustainable forestry enterprises. But beware of industrial “greenwashing” organizations that appear to support sustainable forestry, but really do not.[345]

Opportunities to Make a Personal Difference

Each of us can make a personal difference just by thinking more consciously about how we can consume fewer goods and services, and conserve energy on a daily basis. We can also lobby political candidates or representatives to offer specific plans on how to address it, and support those who we think can make the necessary changes. Our different occupations offer different opportunities, as well.

If you are a homemaker, we’ve already talked about some of the ways you can improve your home environment through better energy conservation and efficiency in Chapter 4. But there are always new products and ideas that are popping up. Consider creating an “Ecotime” club with your friends that includes a monthly “Ecotime” gathering, where you exchange information about new ideas on how to decrease the carbon footprint of your home, and perhaps even set up some friendly contests. There are already groups you can join, such as the EcoMom Alliance, or Eco-chicks.[346] And when you get involved, it rubs off on the kids. Getting married? Check out the web-based Center for a New American Dream.[347] It has ideas on how to have a beautiful, but less consumptive, wedding of your dreams and other tips for responsible consumption.

Here's an idea for everyone. Try out a new kind of party — get together with friends for a festive "swap-meet." Have everyone bring unwanted clothes, accessories, books or other treasures, and let the swapping begin! You can walk away with a whole new wardrobe and more without paying a penny or consuming new goods. It's a great way to make recycling fun and meaningful. And, you have the satisfaction of knowing that former treasures of yours are going to find a new life with your friends. An offshoot of this is practiced by some 20-something friends of ours: don't buy — share. When one of them has to go to an important event, they will email among their circle of friends, asking what they have in their closets — pictures (a phone-click away for some) get sent, items shipped, and ultimately the favor is returned or passed forward. It eliminates purchases of expensive clothes or accessories for rare uses, and one's own "virtual" wardrobe is greatly expanded through the network.

If you are a student — elementary, high school, or college — the climate crisis will affect your generation more than the previous one, so learn as much as you can about it, and then do your best to create ways to prevent it as much as possible. Graduate students are already starting to make a difference through programs such as Campus Climate Challenge, committed to creating carbon neutral campuses across the country as models of sustainable living.[348] Climate Campus Neutral, a project sponsored by the National Association of Environmental Law Societies, is committed towards leveraging the resources of U.S. graduate students to help educate, train, and mobilize the next generation of world leaders, across political affiliations and disciplines in support of cost-effective, long term climate solutions.[349]

If you are a younger students, you can figure out how to reduce your own energy consumption: start a carbon footprint club at school, create Internet presentations for others, host recycling parties, start an after-school store that recycles used items (prom dresses from former alumni could become a niche market here), and learn about the political process. Efforts like these are steps in the right direction, and eventually you will be able to participate as a voter, community leader, or politician. You are never too young to make a difference.

If you are a teacher, you can have a big influence by educating students about the climate crisis and the many ways they can make a difference. You can encourage them to reduce their family's carbon footprint through a class project or competition, or create a school club with that as its goal.

If you are a parent, lead by example in the numerous ways already mentioned and introduce your children to our democracy. Talk about how it works, educate them about current issues, bring them with you when you vote, and when they are old enough, encourage them to register as voters.

If you are a leader in the economic or political arena at any level of society, you have a great opportunity to make a difference simply by taking into account global warming when contemplating new enterprises and policies. The most progressive ideas for addressing the climate crisis in the U.S. are actually occurring at local government levels. State governors nationwide, for example, are starting to leapfrog ahead of the federal government in establishing GHG emission regulations, as the governors of California and Florida[350] have already done. Many state governments are now reconsidering plans for a new wave of coal plants, after concluding that the old plants are too dirty to operate and the new, cleaner ones are too expensive to build.[351] Local governments have even signed onto the Kyoto Protocol.[352] This dovetails with the major political concerns of voters today — addressing the climate crisis through public policy. This will also improve our economy, provide more employment, improve our general health and negate any rationale for going to war to preserve our energy sources.

There are numerous opportunities at the community government level to make a difference. Create a bicycle-friendly city.[353] Get your community to join the Climate Neutral Network, a group that includes Norway, Vancouver and other nations and cities committed to becoming "zero emissions" economies and communities.[354] Start or improve the community curbside recycling program. Stipulate that all new development, including commercial, governmental, or private, have mandatory standards for energy efficiency and every new roof include solar heating water pipes and solar panels, and/or if appropriate, a roof wind turbine. Stipulate that some portion of your electricity come from clean energy. How do you get such statutes or ordinances instituted? Every community has a set of guidelines for development. Determine where in your local government those guidelines exist. Find out who makes building code decisions and who influences them. Then start organizing your neighbors to pressure them to create green statutes.

If you are a scientist, consider getting involved politically to make a difference. More scientists are needed at the legislative level to develop effective legislation for addressing the climate crisis.[355] Not ready for the big leap? Even giving a community talk at a local library or community organization can make a difference.

Into philanthropy at the mega-level? What about starting a foundation to stimulate solar panel installations and home weatherizations for the needy, or help subsidize growth of the clean energy industry? Or focus on saving forests from deforestation? And those ideas are just starters.

If you are a business leader, seriously consider the opportunities for decreasing the carbon footprint in your businesses by selling green products, encouraging green practices in your businesses and media outlets, and investing in green solutions (although invest carefully![356]). You stand to profit from consumers willing to pay more for green products,[357] and from energy savings.[358] Nearly 50 major investors, led by activist pension funds, have already pledged to invest $10 billion in clean technology over the next two years.[359] Some of the biggest businesses in the country — Wal-Mart, Google, and even the military[360] — are investing in solar and wind power systems and other energy efficiency measures to cut their energy costs. Consider investing in a clean power system to cut your energy costs, or buy renewable energy to power your businesses, as Intel has done.[361] Indeed, some experts now say that going green will be the only economically feasible route for retailers as energy costs skyrocket and future governmental energy regulations kick in.[362]

As part of investment, participate in the Carbon Disclosure Project, which seeks to inform shareholders about the carbon footprints of the businesses that they assess for investment.[363] Several of the world's largest corporations have united to work with their suppliers to see how they can cut carbon emissions through their supply chains, as part of the Carbon Disclosure Project.[364] The Chicago Climate Exchange is another opportunity to manage the carbon footprint of your investments. It is North America's only global marketplace for integrating legally binding emissions reductions with emissions trading and offsets for all six greenhouse gases.[365] University of Idaho business students who participate and manage their carbon credits are being gobbled up by industry while they test out the feasibility of a carbon trading system.[366]

Besides the U.S. Department of Energy website mentioned in Chapter 4, the Climate Action program is devoted to helping businesses decrease their carbon footprint.[367] Wal-Mart, for example, has recently joined with the Clinton Climate Initiative to find ways, using purchasing power, to lower the prices of products connected with energy efficient building materials and lighting.[368] It's another win-win situation: making greener technology more accessible, and competing successfully in a promising market. Also weigh carbon footprints when considering suppliers and their products.[369] A good business model is illustrated by the sensible steps that insurance companies are taking: making green investments, and rewarding customers with discounts when they shrink their carbon footprints by driving hybrid cars, for example.[370]

If you are a business owner, offer incentives to your employees for going green and saving energy at work and at home,[371] such as taking mass transit or bicycling to work, for example. To maintain high indoor air quality — because it's better for all and because unhealthy employees cost the company — use energy-saving air-exchange systems that exchange dirty indoor air with outdoor air, but don't let the heat in winter or the coolness in summer mix with the outdoor air. If you are an office worker, conduct your own energy and waste audits. Use less paper, and when you do, use recycled: when possible, print on both sides or re-use paper already printed on one side. Set up recycle bins. Drink at the sink or water fountain, or re-use your own water bottle rather than disposable cups. Turn off power strips at the end of the day when possible.

What kind of savings can a business realize? The Boston law firm of Breakstone, White & Gluck was able to reduce its energy bill by 10% just by installing motion detector lighting, energy efficient bulbs, and encouraging both professional and janitorial staff to turn off lights.[372] But the potential savings can be much greater. Michael MacCracken notes that the energy use per square foot of the Lawrence Livermore National Laboratory atmospheric sciences building built in the 1990s was 10% that of the lab's similarly functioning main administration building built 20-25 years earlier — a 90% reduction in energy use![373]

As Chapter 10 will emphasize, there are plenty of opportunities for the business world to prosper while on the path of sustainability and combating global warming. A 2007 report to the UK treasury notes that climate change represents the largest market failure ever made, since the emitters of greenhouse gases are not being held accountable for the planetary damage inflicted by their consequences.[374] The world's second largest re-insurer, Munich Re, has noted the frequency and cost of natural catastrophes are increasing and predicts that future catastrophes will be costlier due to climate change.[375] In this light, business leaders have a vital role to play in balancing resource exploitation with REAL sustainability, even at the cost of short term gain. The descendants of Rupert Murdoch, Bill Gates and other corporate giants stand to suffer as greatly as the rest of humanity from climate change, as the ruins of past empires attest.

If you are a religious leader, consider using your influence to educate your community about the moral obligations we incur to help the less fortunate combat climate change, to protect God's creation, and to provide examples of good citizenship.[376] The current pope has added polluting the environment to the Catholic Church's lists of sins,[377] and carbon atmospheric emissions can be considered one of the most destructive forms of pollution. Such pollution is also a violation of Koranic principles, which prohibit the waste of natural resources and their unsustainable use.[378] As far back as 2001, the U.S. Conference of Catholic Bishops noted that global climate change "is about the future of God's creation and the one human family. It is about protecting both 'the human environment' and the natural environment."[379]

Indeed, many branches of Judeo-Christian faith are realizing the importance of this statement.[380]

From an ethical perspective, the climate crisis affects the human rights of all global citizens. Christian evangelical leaders have called it not only “an offense against God” but “the civil-rights movement of the 21st century.”[381] Indeed, the Alaskan town of Kivalina, which is being eroded away because of the loss of protective shore ice due to global warming effects, has filed suit against 24 energy companies as perpetrators of the damage to their village.[382]

Since consumption fuels global warming, guide your community on how to live contentedly with far less consumption. In the United Kingdom in 2008, for example, the Christian leadership promoted a “carbon fast” that encouraged people to decrease their carbon footprint rather than their intake of favorite foods for Lent, the season leading up to Easter.[383] Consider similar opportunities for your own religion.

If you are a farmer, you have many opportunities to reduce CO_2 emissions and still profit, just by making your operation more energy efficient, recycling and reducing wastes, and running your farm on solar or wind generated energy. Even plowing can make a difference. Minimum tillage keeps more carbon in the soil, and Congress is beginning to recognize it[384]— a bipartisan bill has been proposed to give carbon credits to farmers who leave organic waste behind after harvest, and practice no- or low-till farming. These credits could then be sold to industrial polluters. Contemplate committing some of your land to wind power generation rather than biofuels (see Chapters 8 and 9) by leasing land to wind turbine operators or installing wind turbines yourselves to generate power to sell to the local utilities yourselves.

If you own or work in the media, you also have a very important and responsible role to play: you have the opportunity to educate people on the relevance of many newsworthy events to the climate crisis, well beyond what is usually reported. Whenever there is a story about the effects or causes of climate change, or the use of energy or its production, there is a chance to point out a very important aspect — i.e., how it relates to global warming. For example, a recent New York Times article devoted much space to how a new cheap car will make cars far more affordable to the people of India.[385] The article devoted little space to the polluting aspects of the car, and no space about its efficiency. What could be argued plausibly as the biggest story in all of this wasn't even mentioned: the impact that millions of these new cars will have on increasing the atmospheric carbon dioxide emissions from India.[386] This leads to another opportunity to get involved — monitor the media. Write letter or emails to the editors and producers when news pieces fail to mention how a news piece is significantly related to the climate crisis.

If we fail to educate the public on a daily basis about how human actions impact our climate and, as a result, our well-being and that of our descendants, it will be that much more difficult to convince powerful political and business figures to do anything significant about it and in a timely manner. And there are still powerful heads of state that are either skeptical,[387] or simply not worried enough to take necessary actions.

Yet another important way we can influence the effects of global warming individually is in the political arena, through political activism and participation in our democracy. We discuss those opportunities in our last chapter, however, so we won't go into them here.

Exercise Reproductive Responsibility

Finally, a very important way that we can, as individuals, influence the effects of global warming on our descendants is by exercising our individual reproductive responsibilities for the public good. We are all programmed in our genes to love babies, and for good reason, so this message is a really tough sell. Beyond the cuteness factor and instinctual parental urges, most human societies promote having babies, often for commercial reasons. So, we are going against the main marketing messages aimed at us. “Limit our Reproduction” is not a popular message — but then, neither is the overall impact of our numbers on this planet: global warming, toxic pollution, the loss of biodiversity, spreading disease, and increasing scarcity of resources like water and arable land.

Huge families in the past were promoted as a way of our species to simply survive the brutal realities of life. Now, the inverse is true: we must decrease our family sizes to survive into the distant future. Only by willfully agreeing to have families of two or fewer children will we be able to humanely rein in the exploding global human population and the catastrophic after-effects of its consumptive needs, climate change and the decimation of our life supporting ecosystems. Perhaps one of the most direct links between population growth and global warming is that when populations increase in the developing nations, the forests there disappear. This not only decreases everyone’s chances of stopping global warming, but decreases the safety and well-being of the people living where forests once were, as soil erosion increases and drier local weather decreases the ability to grow needed crops.[388]

***Fertility rate* refers to the number of live births per 1,000 women of reproductive age (ages 15-44 usually) in a given year.**

Even more damaging is the growing number of high-powered consumers in the U.S. This growth spurs global warming and unsustainable exploitation of global ecosystems. Every additional child born to a U.S. family represents the resource consumption of 32 new children in developing countries.[389] In this respect, the recent observation of the U.S. fertility rate hitting its highest level in 35 years — enough to keep the population at its current level — is a cause for concern, not jubilation.[390] That this fertility rate is described as stabilizing the population is ironic, since our current, unsustainable population level both domestically and globally undermines the future stability of our species. It borders on absurdity —indeed, it is just a cruel hoax when our country promotes the myth that everyone on Earth can practice the same unsustainable rate of human proliferation.

It is probably not a coincidence that in Australia, a continent particularly feeling the effects of global warming, the Medical Journal of Australia published a proposal by one of their medical experts. He proposes levying a climate change tax on parents for every extra child that parents produce beyond their first two.[391] Optimum Population Trust (OPT), the leading UK think tank on the effects of population growth on the environment, estimates that the "climate cost" of each new Briton over an average lifetime, assuming a "social cost" of about $85 per ton of carbon, is roughly $60,000.[392] Multiply that by the ten million increase expected in the UK population over the next 70 years, and that soars to approximately $600 billion. As OPT's latest published research briefing, "A Population-Based Climate Strategy," succinctly puts it:

> "The most effective *personal* climate change strategy is limiting the number of children one has. The most effective *national* and *global* climate change strategy is limiting the size of the population." [393]

As a future solution to further climate change, it continues, it is "easier… cheaper, freer and greener" than all other solutions.

Again, we have the tools, in this case for humanely regulating our population growth; we just have to use them. Experience has shown that on a global scale, one of the most effective ways to bring down the birth rate is to educate young women and provide them with access to family planning resources. Improving women’s rights, providing a secure social safety net, and encouraging later childbirth can also help. “The report, Youthquake, published by the Optimum Population Trust and written by Prof. John Guillebaud, a leading authority on family planning, points out that voluntary population stabilization programs, centering on education, awareness and removing the barriers to women’s control of their own fertility, have a proven record of success. A voluntary “two-child” population policy in Iran, for example, succeeded in halving fertility in eight years, as fast a rate of decrease as that of China, whose much-criticised one-child policy began in 1980.” *— OPT news release, July 11, 2007*

What would be the cumulative effects of all this improved efficiency at the public and individual levels, the E, A, and Y of EASY? As Figure 3.1 in Chapter 3 shows, the U.S. could be reducing its current carbon emissions by almost a billion tons per year, or almost half of current emissions, by 2030. Thus, improving efficiency will significantly reduce our current energy consumption through a few big technological changes and many smaller ones. All of it is attainable and doesn’t require any dramatic technological leap to do so, or any significant decrease in quality of living.

The Earth is worth it, and so are all of us and our descendants.

Chapter 8: Other Solutions Have Problems

Considering the urgency of the climate problem and the exciting possibility of making huge amounts of money by selling attractive alternatives to current energy practices, it is not surprising that a great many creative and speculative suggestions for reducing global warming have been proposed. Through their political attractiveness or sheer imagination, many of the more speculative proposed solutions act as entertaining distractions, garnering precious press coverage. Some of the other suggestions, such as energy efficiency and conservation in the home and in transportation, as well as solar and wind energy production, comprise the core of our EASY solution.

But we purposely have not incorporated many other currently discussed ideas. Why not? Because time and economic resources are limited, so we are presenting those ideas which appear to be the smartest choices, in terms of reducing carbon emissions most effectively and quickly with the least amount of capital investment. Because, while we support continuing research into some of the other ideas as possible supplements to the EASY plan, we do not believe that we will have to rely on these other alternatives to solve the climate crisis. Some, like methane production from landfills,[394] will never constitute a large enough source or efficient enough method to seriously address the problem, although they might help. Others look like they should be major players, but aren't. These proposed supplements include: expansion of nuclear power, biofuels, clean coal (including carbon sequestration), and geoengineering (e.g., iron filings in the oceans and orbiting aerosol or tiny mirrors into the atmosphere). What are the problems? Let's go over these proposed supplements, one by one.

Expansion of Nuclear Power

There is deep distrust in the U.S. today about nuclear power, and fear of its environmental consequences. This distrust stems in part from a sense people have that the nuclear power industry and its governmental backers have not "come clean" with the public. Additional distrust stems from the horrors associated with the cities of Hiroshima, Nagasaki, and Chernobyl, and even more from the inherent mysteriousness of nuclear phenomena. Actually, we have no deep, unyielding reasons for opposing the expansion of nuclear power in the U.S. Indeed, the science behind the technology is a most remarkable achievement. In countries such as France, where nuclear power plays a major role in energy production, the technology is elegant and beneficial in preventing the carbon dioxide emissions that would result from coal burning. So, why not expand it here? The reasons are purely pragmatic, political, economic, and technical in nature.

An emerging pragmatic reason is drought, which threatens to at least partly shut down current nuclear reactors throughout the U.S. later in 2008, as the water needed for them gets shunted to higher priorities.[395] Nuclear plants require vast amounts of water to keep them cool during operation.

The political reason is simply that the technology is not wanted here, for the reasons mentioned above, as well as the concern of nuclear-related terrorism. It is probably not possible to erase the legacy of numerous political and communicational missteps by the industry and our government. France did it right, we did it wrong, and now we must pay the political price.

But the economic reasons are also compelling. Even with the major subsidies allocated to the nuclear power industry, the cost of electricity from nuclear power is currently greater than that from wind and solar thermal and it is comparable to or greater than that from photovoltaics, depending on how you do the bookkeeping. The subsidies take the form of government-backed insurance for the industry in the event of a serious accident, as well as the public bearing much of the cost of waste disposal and anti-terrorism policies needed to deal with the vulnerability of radioactive materials to theft and misuse. If these subsidies were withdrawn, the price of nuclear power would probably exceed that of photovoltaic electricity today and certainly would exceed it in the near future, as the cost of solar declines and additional concerns add to the cost of nuclear power.

From a technical perspective, no good technological (or, for that matter, politically popular) answers for dealing with nuclear waste have been developed, even with subsidies specifically targeted for that purpose. Another technical reason has to do with international security and concerns about the proliferation of nuclear materials that can be used as weapons by terrorists or so-called rogue nations. The more nuclear material that circulates through the US, from mines to fuel processing plants, from fuel processing plants to nuclear power plants, and from nuclear power plants to waste disposal sites, the more likely it becomes that some of that material will be intercepted by those who would use it for harmful purposes.

For all these pragmatic reasons, we do not expect nuclear power to play a major expanded role in electricity generation in the U.S. during the coming decades. Research should continue, however, on the safety of nuclear power, the waste disposal issues, and maintaining the integrity of our existing nuclear plants, as well as on the planning of their ultimate de-commissioning and replacement with energy efficiency or clean energy sources.

Biofuels

The idea behind biofuels is, on the surface, quite attractive. Green plants grow by taking carbon dioxide, the primary global warming culprit, out of the atmosphere and incorporating it into new plant biomass through the process of photosynthesis. If a dead plant is combusted, the carbon it incorporated during its lifetime is largely released back to the atmosphere as carbon dioxide. If we exploit this cycle, there is a big benefit: energy is obtained with no net increase in the carbon dioxide level in the air. The same carbon dioxide that last year's grass removed from the atmosphere is returned this year when we convert the grass to fuel and burn it. In contrast, when we burn fossil fuels, we are burning the remains of plants that grew hundreds of millions of years ago, and so the carbon dioxide level in our current atmosphere rises. Biofuels sound like a good deal. And in a sense it's a "green" solution, with a sort of "back to nature" feel to it. So, what's not to like? Plenty.

First and foremost is the issue of the land needed to grow enough energy crops to meet our demands. Photosynthesis may be a marvelous process, but one thing it is not, is efficient. We can measure the photosynthetic efficiency of a crop by comparing, over a year, the amount of sunlight energy that falls on an acre of land with the maximum amount of energy that we can get from a crop grown on that acre. Crop plants grown today achieve at best approximately 1% efficiency, and more typically photosynthesis operates at about 0.2% efficiency. Efficiencies of 1% or better only occur under the most favorable conditions, with plenty of water, herbicides, pesticides, and soil nutrients, usually applied as fertilizers. The energy used to supply irrigation water, produce the needed chemicals, operate the farm equipment, transport the biomass, and produce a useful fuel from it does not enter into that efficiency calculation; if it did, biofuels become much less efficient, as we'll see below. In contrast, today's photovoltaic panels and solar thermal plants can capture and convert to electricity up to about 25% of the solar energy falling on them, and the next generation of solar panels will probably do much better. So, even if an acre of solar energy "farm" is not entirely covered with panels, because of the need for maintenance alleys, the land requirement for solar panels or solar thermal plants is much less than what is needed to grow biofuels — in fact, because of the difference in efficiency, it is less than 10% of the land required to obtain the same amount of energy from green plants.

Moreover, the land needed to grow corn or grasses (e.g., switchgrass) that have been proposed for biofuel production must have good soils and suitable climate; in other words, biofuel and food demands compete for the same land. In contrast, we can place solar panels on unproductive lands, such as those currently used by the U.S. military for weapons testing in the southwestern deserts. These lands are of no possible value for food production, and the military uses of these lands have somewhat precluded their value as wildlife habitat. (There are a few species, however, such as the endangered desert tortoise, whose needs should constrain any uses, for energy or otherwise, of these lands.) Even more importantly, we can place solar panels on rooftops, a category of "land" that is otherwise not useful. So, solar photovoltaics have a major advantage over biofuels: it requires a tenth or less as much land, and the land needed has fewer requirements.

The prohibitive magnitude of the land needed to grow biofuels in the U.S. can be best illustrated by considering their primary proposed use: to replace most or all of our gasoline use. Currently, U.S. citizens burn 140 billion gallons of gasoline each year for transportation. Ethanol is a popular biofuel substitute for gasoline produced by extracting starches and sugars from corn and other plants through fermentation. Let's first look at the land required to derive that much energy in the form of ethanol derived from corn.[396] As shown in the Appendix C.4, it would take an area the equivalent of six states of Iowa to grow enough corn to make 140 billion gallons of ethanol each year. Not just any area six times that of the entire state of Iowa, but land with the agricultural quality of Iowa's fertile soils! For those of you who haven't traversed the heartland of the U.S. lately, we don't have six spare Iowas sitting around idly, waiting to be plowed.

Now, ethanol is not as efficient a fuel as gasoline, and so it will actually require about 15-20% more than 140 billion gallons of ethanol. So fine, find yet another Iowa. But the story is much grimmer than that. It takes energy to grow, harvest, transport, and convert corn to ethanol. And if conventional fossil energy is used for that purpose, then the savings in carbon dioxide production drops dramatically. Let's say we put the energy equivalent of a gallon of gasoline in the form of ethanol into our gas tank. Using this gasoline substitute results in the same amount of emitted carbon dioxide that results from burning roughly ¾ of a gallon of gasoline. In other words, the carbon dioxide reduction from replacing gasoline with ethanol is not 100% — it's only about 25%.

Of course, we could avoid this huge penalty by using ethanol not just in our automobiles, but also for the energy needed to produce the ethanol. But now we would need 24 Iowas — six to yield the ethanol for our cars and 18 to grow the additional corn needed to produce the additional ethanol. Can it get worse? Yes, it can. The demand for corn ethanol in the U.S. has pushed corn production to its highest level ever, and the resulting runoff of nitrogen from the fertilizers travels over a thousand miles down the Mississippi River and into the Gulf of Mexico, where it helps enlarge the "dead zone" there.[397] If ever there was a bad deal, this is it.

Proponents of biofuels will reply to the above problem of land needs by stating we needn't use corn. We could grow switchgrass or Miscanthus grass in the U.S. In other countries, we could grow palm oil, sugar cane, or

Jatropha, a newly touted scruffy plant that grows in India and whose seeds produce an oil that can be converted to usable fuels. True enough, we could grow these alternative plants. Biofuel grass or similar crops would be much more attractive if we could devise a practical way to derive ethanol or some better fuel from cellulose, an abundant plant component that is difficult to break down. Such crops would then have the advantage that most of the harvested plant could be used, rather than just the starches and sugars in it. But, we still face the 10:1 land disadvantage of biofuels relative to photovoltaics. Moreover, while some of the crops listed above do not require the prime land that corn requires for high yields, the water and fertilizer requirements will continue to be a concern for some of these crops. And other crop plants have such low yields that the land requirements will be even greater than that estimated above.

Furthermore, valuable carbon reservoirs (i.e., tropical forests and peatlands) would likely be destroyed to produce these crops, resulting in loss of ecosystem services, such as watershed services, and soil and biodiversity preservation. Taking into account these environmental losses has led scientists to conclude that some biofuels are actually worse than fossil fuels in terms of atmospheric carbon dioxide emissions.[398] Indeed, in Asia and South America, production of palm oils and sugar cane has already led to the destruction of forests that are not only important carbon reservoirs, but also valuable habitats for wildlife and home to indigenous societies whose livelihoods are being destroyed.[399]

Another poignant example is orangutans, our primate cousins, who are now threatened in one of their last strongholds, Borneo. Palm oil plantations are wiping out their rainforest habitat and destroying peatlands, one of the most effective carbon reservoirs on Earth. Indeed, one report estimates that over 27 million acres of Indonesian peatlands have already been destroyed for cropland, and that current peatland destruction accounts for 4% of the current GHG emissions globally.[400] Little improvement has come from the Roundtable on Sustainable Palm Oil, an industrial consortium of companies that fuel the demand for these plantations.[401] If production of these fuel sources is expanded to the point where they could largely replace gasoline use, we would face the likely destruction of a large fraction of our remaining forests in the tropics. This destruction would result in an overall increase in carbon dioxide emissions to our atmosphere.

Consider the following example. In order to grow an energy crop in the Midwest, a farmer diverts an acre of soy from food to ethanol. That will yield a net saving of no more than two tons of carbon emissions each year. But now, with the price of soy slightly higher, it pays for a farmer in Brazil to cut an acre of forest to grow the soy for food. Clearing that forest will release 100 tons of carbon emission to the atmosphere! How many years of ethanol production in the Midwest will it take to reach the break-even point, when the benefit of reduced carbon dioxide emissions from the produced biofuels just equals the harm of increased carbon dioxide emissions from deforestation? The answer is about 50 years. After that, there is a net benefit because carbon dioxide emissions will begin to be reduced. The catch is, we cannot afford 50 years of increased, rather than reduced, carbon dioxide emissions, even if there is a promised reduction afterwards.[402] And this is not simply an academic exercise: recent reports detail accelerating loss of the Amazon due to pressures to farm food and biofuels.[403]

Now in all fairness, two counter arguments often made by biofuels advocates should be mentioned. One is that solar electricity production is intermittent, and cannot be produced at night. So, without adequate storage, as discussed in Chapter 6, solar electricity cannot meet all our needs. It is indeed true that at any given location solar or wind energy is subject to interruptions because of cloudy or windless conditions. To prevent massive shortages, solar energy facilities must be distributed over many locations, so that shade here will be balanced out by sunlight there. The same is true for wind farm locations. But biofuels production also may face interruptions — indeed, possibly much more serious ones and over longer time scales, for it, too, is highly vulnerable to the vagaries of climate. For example, in the spring and summer of 2007, drought in several southeastern states, especially Georgia and the Carolinas, resulted in significantly reduced yields of ethanol corn and other crops. The long-term climate projection in the U.S. is for both increasingly severe droughts and deluges in its heartland. So, shortfalls in energy crop yields can be anticipated. Our transportation fuel supply may be no more reliable, if we replace vulnerability to the political uncertainties in the Middle East with vulnerability to the climate uncertainties in our Midwest.

A second argument made by biofuels advocates is that we can make transportation fuels out of biomass but we can only convert solar or wind energy to electricity, or directly to heat; solar or wind energy do not directly produce liquid fuels that we can use for transportation. This and the first argument are related in the sense that liquid fuels are a fine way to store energy. It's true that biomass can be converted into substitutes for gasoline, while the direct product of solar or wind energy is electricity or heat. However, electricity can be used to split water into hydrogen and oxygen, with the hydrogen available as a potential transportation fuel. Furthermore, automobiles of the future will probably be either all-electric or plug-in hybrid. If the former is true, liquid fuels will not be needed. With rechargeable hybrids that get 60 mpg or better, the amount of liquid fuel needed will be so small that the biofuels industry necessary to supply those automobiles would not eat up vast amounts of land, and could be sustainable.

It is also possible that with such highly efficient automobiles, we could stretch out our domestic oil supplies far into the future, keeping carbon emissions low enough to allow us to achieve our goal, by 2030, of no more than 25% of 2007 emissions. In fact, the scenario shown by Figure 3.1 in Chapter 3 assumes that this will be the case.

In any event, solar energy will almost certainly be needed to supply carbon-free electricity in the future. To use biomass as a substitute for coal to generate electricity would be the height of foolishness, because in combusting biomass to generate electricity, we would lose roughly two-thirds of the photosynthetic chemical energy. This loss is due to the intrinsic inefficiency of electricity generation — burning a fuel to create steam to drive turbines that then create electricity. Because of this added inefficiency, biomass would require 30 times, not just 10 times, more land than solar thermal or photovoltaic technology to produce our electricity. We suspect that once solar energy production is up and running on a large scale, the momentum for using it to power all-electric vehicles and to recharge hybrids will become unstoppable.

We can summarize the transportation fuels situation as follows: at best, biofuels make sense only if our automobiles get very high mileage, and in that case, biofuels may not even be necessary if we go the route of all-electric vehicles, or if we use domestic oil supplies to meet the small liquid fuels requirements of plug-in hybrids. What we must avoid, however, is the replacement of gas guzzlers with grass guzzlers.

As it is, studies by the Washington D. C.-based International Food Policy Research Institute and the Geneva-based International Institute for Sustainable Development's Global Subsidies Initiative (GSI) are now indicating that biofuels are not contributing much to solving the climate crisis, and that they have several serious drawbacks.[404] Biofuel subsidies are expensive and not sustainable. The production of food crop biofuels has not only already spiked prices of basic food crops of the poor in developing countries, but will raise world food prices 20-40% higher by 2020, using precious water supplies while enriching agribusinesses. The increased farming augments both deforestation and the troubling cropland runoff of fertilizer nitrogen and toxics into coastal waters, where the runoff is considered a factor in creating coastal dead zones that impact our marine food supplies. Ronald Steenblik, GSI director and author of two reports in a new series entitled, "Biofuels at What Cost? Government Support for Ethanol and Biodiesel", notes, "Fuel made from food is a dumb idea, to put it succinctly … [Biofuels are] also a distraction from dealing with the real problem of reducing GHG emissions."[405] Apparently the European Union is also beginning to have misgivings, and has rolled back massive subsidies, noting that the environmental benefits of biofuels have been overstated.

Despite all these concerns about energy from biomass, there are two good arguments for continuing research on cellulose conversion to biofuels. One is that cellulose biofuels may well be needed to meet the energy requirements of aircraft. A second, long term use for crop-based fuels is in the petrochemical industry, as an eventual replacement for petroleum and coal.

Algae as a Fuel

Some researchers are exploring the possibility of using marine algae as a fuel source, since certain strains are made up of as much as 50% oil, which can be converted into a type of diesel fuel.[406] Unfortunately, on a large scale, this could damage huge areas of valuable coastal marine ecosystems. It would also take many years to develop this into, at best, a very limited energy source.

Hydropower

Our planet is peppered with thousands of dams that convert moving water into energy through gigantic turbines. Most of the rivers in our country already have dams in the most economically favorable locations. Should we build more? On the surface, this sounds as good a non-CO_2 emitting energy source as wind or solar energy generation. Why is it not? Part of the problem lies in their location. Dams drastically alter important, overlooked ecosystems: our rivers. Dams flood riverbank and nearby habitat, interrupt migration routes of important food fish, and increasingly displace human populations.

In addition, relatively new data indicate that many dams, in fact, emit significant amounts of the potent global warming gas, methane.[407] The decomposition of submerged plant and animal matter or sewage at the bottom produces methane, much of which may, in the course of a slow natural drift to the surface, become further broken down into the less harmful CO_2. But when bottom water is sucked through power turbines, the methane gets forced out directly into the atmosphere. A study by Ivan Lima of Brazil's National Institute for Space Research shows that worldwide dams could be emitting methane that equals 20% of all other global sources combined. Depending on their design, some dams might be emitting more global warming gas than even some fossil fuel options. What makes this problem even more serious is that China, beset with water quality problems and containing about half of the world's large dams, probably already has many high-emitting dams, and is racing to build many more dams to decrease its dependence on foreign fuel sources. Lima notes that dams could be designed to decrease these emissions and even "mine" the remaining methane for fuel use. But ultimately, dams are not sources of clean energy.

One further disadvantage of dams is that they require water, and the increasing frequency of droughts, which global warming is predicted to worsen, will cause some to fail, creating power outages, as Costa Rica, a heavily hydroelectric-powered economy, found out in 2007.[408]

Carbon Sequestration

Here is another interesting idea that would be wonderful to implement, were it possible. The concept is straightforward: figure out a way to take the carbon dioxide emitted when oil, and in particular, coal are burned, and sequester (i.e. inject) the CO_2 somewhere. It can be injected at the bottom of the deep ocean or in underground spaces, such as those vacated when oil and natural gas are extracted. When they are combined with carbon sequestration, coal and oil are referred to as "clean" fossil fuels by some. But this still ignores the other hazards of coal and oil usage, such as smog in our cities, acid rain in our countryside, soot in our atmosphere, oil spills on our oceans and bays, accidents in our coal mines, and the devastation of our mountains and streams when coal is mined. If sequestration were possible, <u>and</u> <u>if</u> the other hazards of coal and oil usage could be resolved, <u>then</u> we could rightly speak of "clean coal" and "clean oil."

Could all of those advances in fossil fuel technology be achieved? And, achieved at a cost that was competitive with the costs of solar energy, wind energy, and improving energy efficiency? We know the cost of all those environmental advances in fossil fuel usage will not be small, and so efficiency, with its intermediate and long-term negligible costs, is a clear winner. But while efficiency can accomplish a great deal, we do need new clean energy. So, we should compare the costs of clean coal or oil with that of solar and wind. Sequestration of carbon dioxide will add to the cost of energy because it requires energy to shove carbon underground, making the process less energy efficient. So, power from coal with sequestration will cost more than conventional coal-derived power.

Will the reduced efficiency make this technology for electricity production more expensive than solar and wind? We cannot, of course, even begin to answer that with any confidence until two things happen: 1) clean fossil fuel is demonstrated to be applicable on a commercial scale and its costs are assessed, and 2) the costs of solar and wind energy, which are rapidly decreasing (as noted earlier), settle down. The first is still a distant goal,[409] and would have to include all the costs associated with the remaining hazards from extraction, transportation, processing, and burning of coal.

Currently, advocates of carbon sequestration cite estimates that suggest the cost of electricity from this technology will be somewhat greater than the cost of wind-generated electricity today, and somewhat less than that from solar panels. Neither we nor anyone else knows how the latter comparison will look if 1) the costs of solar panels come down, as most analysts and many investors expect, and 2) the costs of remedying all the environmental hazards of coal mining and consumption, as well as of solar panel fabrication and installation, are included in the calculation. If carbon sequestration still looks like the cheaper technology, then by all means we should consider carbon sequestration in our future energy supply mix. And we should certainly continue the basic research on, and testing of, sequestration technology. But energy efficiency and wind energy are already proving to be a better deal. Solar energy is also likely to be so, simply because it does not carry with it all the other hazards of coal mining and burning. Thus, our educated guess is that 25 years from now far more electricity will be generated from solar panels and wind than from truly clean coal.

Geoengineering Ideas

Wouldn't it be wonderful if we could do something cheap to our atmosphere or our oceans that would cool down the planet? Changing the climate on such a large scale is an example of what is called geoengineering. Loading the atmosphere with carbon dioxide is also an example of geoengineering. If we could engineer a cooling trend to cancel the warming from greenhouse gases, then we could continue on our merry way importing and burning oil — at least until it runs out, at which point we might be able to derive sufficient liquid fuels from coal, tar sands, or oil shales. But is there practical hope of a geoengineering solution to the climate crisis? Two ideas have been suggested.

Putting phytoplankton to work for us. The first idea is a bioengineered carbon sequestration process: put something in the oceans that will accelerate the rate at which marine phytoplankton pull CO_2 out of the atmosphere. Simultaneously, something must be done to slow their decomposition, so that the carbon stays in the dead or living phytoplankton cells and thus remains stored in the oceans. How do phytoplankton absorb carbon dioxide? Phytoplankton live in the shallow waters of the oceans, where the amounts of CO_2 there and in the atmosphere are in approximate balance with each other: add some carbon dioxide to the air, and some of it will flow into the sea to restore the balance. When marine phytoplankton photosynthesize, they extract dissolved carbon dioxide from seawater, incorporating the carbon from it into their cells. As the amount of carbon dioxide in seawater decreases from this incorporation, more carbon dioxide passes from the atmosphere to the sea to restore the balance. So, we just have to provide the phytoplankton with some essential nutrient that speeds up their photosynthesis. And a substance has been identified that could do just that: iron. In at least some parts of the ocean, the growth of phytoplankton appears to be limited by iron. So, if we could pour tons of iron into the sea, perhaps we could speed up phytoplankton growth.

There is one little problem, however. When phytoplankton die, they eventually decompose, releasing carbon dioxide back into the seawater. This causes the balance to be restored the other way — carbon dioxide passes from the oceans back to the atmosphere.

To win at this game, you have to do one of two things:

1) somehow cause much more living plankton to exist simultaneously so that the additional living cells store much of the carbon that is now in the atmosphere, or
2) somehow slow down the decomposition of the phytoplankton.

As to the first option, it is virtually inconceivable. Today, the amount of carbon in living marine phytoplankton equals no more than 1% of the carbon present in the atmosphere as carbon dioxide. So, we would have to multiply the amount of living phytoplankton in the sea by about a factor of 100 over the next 50 years to have a significant impact on the atmosphere. Nobody thinks we could even increase it by a factor of two, and even doing just that could have a detrimental effect on the rest of marine life. So, that option is out.

The other option would be to get the newly dying phytoplankton cells to decompose more slowly. As yet, no one has thought of a mechanism to bring that about. Enriching the seas with iron will speed up the life and death cycle of the phytoplankton, but available research suggests it will not make a serious dent in the climate crisis problem.

Smoke and mirrors. This second geoengineering idea is to put particles high in the atmosphere that will either block sunlight from reaching Earth by absorbing it high above the ground, or will reflect the sunlight back to space before it can strike the ground. Blocking sunlight takes its inspiration from the particles and aerosol that form when coal is burned (i.e., smoke) or large volcanoes erupt, for we know that the sooty particles emitted from coal burning and volcanic eruptions do indeed block sunlight. The second approach, reflecting sunlight, could be achieved if we could put a huge number of small reflecting objects (mirrors) high in the atmosphere.

Canceling the climatic effects of increasing greenhouse gases with the climatic effects of smoke or mirrors is not straightforward. For one thing, the objects we place high in the atmosphere, i.e., the stratosphere, will disperse, so that even if rockets release them over the mid-latitudes, a considerable amount of the stuff will end up over the Arctic. There, aerosols and other light-absorbing particles could generate warming rather than cooling, augmenting the greenhouse gas effects on melting Arctic ice — further eliminating polar bear habitat, and so forth. This is a serious concern for two reasons. First, the polar regions are warming the most and the fastest today, so where we need to counter warming the most, we would actually either do very little to counter it (with mirrors), or actually make the problem worse (with smoke). The second concern is that, in many respects, the polar climate is a driving force, influencing climate all around the world. So, by letting the polar regions continue to warm, we should expect unpredictable climatic effects where most of us live in the mid-latitudes.

Even if smoke or mirrors were a feasible way to roughly balance the temperature warming from greenhouse gases with the cooling effect of intercepting sunlight, we should not forget that temperature is just one of many climate variables. Average precipitation, storminess, likelihood of drought, and variability in temperature all play a huge role in determining crop yields on our farms, availability of water for domestic use, frequency and intensity of hurricanes, and many other climatic factors that affect our well-being. As yet, there has been little convincing analysis of the overall climatic effects of combining greenhouse gas increases with interception of sunlight high in the atmosphere. We do know that the combination will alter both the vertical and the equator-to-poles distributions of temperature. By altering these temperature profiles, we will be influencing the flows of air and ocean water that are driven by them. It would be foolhardy in the extreme to blindly assume that the climate that ensues will be any less catastrophic for us than would be the greenhouse climate we are creating.

Finally and most importantly, even if smoke or mirrors could counter the warming effects of increasing atmospheric carbon dioxide, they will not prevent ocean acidification that pre-existing excess carbon dioxide causes, nor all the other harms to human health and the environment that result from coal mining, oil transport and fossil fuel burning. We simply have to stop atmospheric carbon dioxide build-up — and soon!

So, we’ve outlined a plan, showing how it can work and what won’t work. But how can we make the EASY plan a reality in our economy?

Chapter 9: Carrots and Sticks for the Energy Economy

Although some companies are beginning to take important steps to reduce their carbon footprint and emissions, the overall picture is one of little movement, especially in the area of reducing carbon emissions.[410] Thus, to achieve the EASY plan, we need a national program of economic incentives and regulations. Here is where the rubber hits the road — we hope with well-inflated tires! How do we propel the United States down the EASY path?

The politics will not be easy, as we know from the dismal history of failed efforts in the U.S. to solve the problem of health care delivery. We are optimistic, however, that with the right proposals for incentives, energy policy will not be similarly obstructed, if for no other reason than that economic competitiveness and the survival instinct will overcome political dogmatism. Congress has already passed the Energy Independence and Security Act of 2007 that begins to address the climate crisis.[411] Although it does little to actually reduce GHG emissions, it is a beginning.

Designing policy instruments that will promote the EASY path is not a trivial matter. We don't have much time to get a grip on greenhouse gases, so we have to act expeditiously but consistently with our nation's traditions. Our goal for the U.S., you may recall, is to achieve a level of carbon emissions that is no more than 25% of current emissions by the year 2030. We have described in Chapters 4 through 7 an energy strategy that will accomplish this. Now, we must describe the actual economic and regulatory policies that will allow us to achieve that strategy. Here's how we can do it.

Promoting a U.S. Energy Economy That Serves the Public Interest

There are five major policy components to our proposed strategy for propelling the U.S. along the EASY path:

1. **Revise tax policy to reward clean-energy winners** by redirecting some of the Bush administration tax breaks for the wealthiest individuals and fossil fuel industrial profits toward tax breaks on the profits from the sale of clean energy and energy-efficient devices.
2. **Shift energy subsidies** from fossil fuels to clean energy, energy-efficiency, electric grid expansion and mass transit.
3. **Regulate the energy efficiency** of vehicles, appliances, and industry.
4. **Provide public land** for solar and wind energy, grid expansion, and mass transit.
5. **Redirect military spending** for maintaining oil supplies in the Middle East.

1. Revising tax policy to reward clean-energy winners. There are two ways that taxation can be used to promote a social goal: 1. we can increase taxes on a bad thing; 2. reduce taxes on the good alternative. Here, we can make dirty energy more expensive, or clean energy cheaper. Thus, in the case of electricity generation, or any other energy consumption sector, we can tax electricity production and/or consumption that create carbon dioxide emissions directly, or indirectly. Or, we can reduce taxes on the profits from the sale of clean energy technologies.

The energy taxation policy most likely to succeed will have to be:

- politically acceptable,
- equitable, in the sense that it reduces, rather than exacerbates, the gap in wealth between the richest and the poorest among us,

- designed to encourage research and development of new clean energy technologies.

A carbon tax may not meet any of these criteria. Politicians and their constituents hate new taxes. And low-income people will spend a larger proportion of their income on the carbon tax than will the rich, because more of the poor's income is spent on the necessities of life, some of which are currently carbon-intensive, such as old cars. Finally, the influence of a carbon tax on technological innovation will be indirect at best, with the strong possibility that we will continue to use fossil fuels, but just pay more to do so.

Consider instead that tool beloved by all politicians, the tax break — in this case, on future corporate profits from the sales of clean energy electricity generation systems, highly efficient automobiles and appliances, and energy-saving homes. If the money to do this came from rescinding some of the Bush Administration's tax break for the richest individuals and on the windfall profits of the fossil fuel industries and shifting it towards encouraging clean energy generation, this transition would not require additional government funds, and thus, would not exacerbate our budget deficit. By making clean energy cheaper, rather than dirty energy more expensive, this tax policy would be progressive, uplifting the poor as everyone benefits. And by directly leading to lower corporate costs for desired outcomes, it provides more motivation for industry to provide society with cleaner energy options.

Under such a "Reward the Winners" policy, investment capital would flow to all firms, large or small, that invest in:

- successful research and development of clean, no carbon-emitting energy sources, such as solar and wind, or
- the development and introduction to the market of more energy-efficient devices.

And the government need not attempt to choose winners and losers in advance — only the eventual winners with marketable clean energy systems will be rewarded, because only they will make tax-exempt profits.
Why not simply offer consumers a tax break if they purchase clean energy systems for their homes? One could, but this would primarily benefit wealthier Americans, who already have enough money to make the transition. Ultimately, the way to reduce costs to all consumers of clean energy is to encourage development and reduce costs of that energy, with targeted tax incentives for the producers.

A clean energy tax break is quite different in spirit from carbon taxes or imposed caps on fossil fuel use — it is based on promoting opportunity, inventiveness, competition, and rewarding success. The U.S. opposition to the Kyoto Protocol to protect the global environment is based on a fear of imposing excessive costs on U.S. taxpayers. This proposal removes that obstacle and goes further by setting a sound economic foundation for climate-friendly innovation that other nations could follow. One possible obstacle does remain: setting forth tax criteria that do not require a bloated bureaucracy to implement. We suggest that a task force be appointed to explore the options for a relatively simple and unambiguous codification of a clean-energy tax break.

The corporate energy giants 50 to 75 years from now are not likely to be companies that mine and sell oil and coal. Who they will be actually depends on who invests the most money in the best ideas, just as was true in the early stages of biotechnology and information technology revolutions in the recent past. For the sake of our future quality of life, why don't we promote this process with a sensible tax cut and let the market for innovation pick the winners? Both major political parties profess a commitment to the principles of tax relief, economic fairness, and reliance on market forces to create a decent future for all of us. Here is an opportunity to put these principles into practice, and at the same time greatly reduce the threat of what is the greatest environmental problem of our time — the climate crisis.

In summary, the current government's tax breaks for the wealthy and the fossil fuel industries should be repealed, and some of that saved revenue should be redirected as a tax break towards reducing taxes on profits from the sale of high-efficiency vehicles and home appliances, and from carbon-free energy supply systems (e.g., solar and wind generated electricity, manufacture of wind mills and solar panels, installation of solar panels on rooftops). In contrast to carbon taxes, which regressively raise the cost of current energy supplies to consumers, making clean energy systems cheaper will make them available to the less wealthy and immediately encourage investment in the appropriate manufacturing sectors. Moreover, this plan would reward the naturally occurring market winners, not pick them in advance.

2. Shift energy subsidies by ending subsidies for the fossil fuel industries and redirecting them toward further easing the cost to the public of clean, renewable electricity supply. Such a shift would create jobs as the clean energy industry grows, build our economy and improve the environment. The shifted subsidies would also help pay for energy storage systems, more efficient wind and solar energy conversion systems, efficient automobiles, and mass transit systems in our cities. Energy subsidies expert Douglas Koplow created a list of distorted energy subsidies for the world that, if corrected, would create more realistic prices for the various energy sources.[412] These subsidies would, in turn, drive the market to promote the best renewable energy sources. His list includes the oil security subsidy, which we address partly in the section "Redirect military spending" below.

Non-military U.S. energy subsidies discussed by Koplow include:

- public funding devoted to maintaining oil stockpiles in the U.S.,
- subsidizing nuclear industrial accident liabilities,
- more than 200 U.S. policy-generated biofuel subsidies that amount to more than $500 per metric ton of CO_2 displaced by biofuels,
- averaging costs of electricity so that important variation is masked in terms of the costs to supply specific consumers specific energy at specific times,
- nuclear waste management subsidies, probably amounting to billions of dollars annually,
- tax credits for "new" U.S. coal production, about $3 billion annually.

We think that nuclear waste and accident subsidies are, unfortunately, necessary for existing structures, but should not be extended to new plants. Averaging costs of electricity is an indirect subsidy: if both high and lower users pay the same rate, the low users end up partially subsidizing high users. New electricity price structures should be implemented that equitably reflect real usage by consumers; this would also indicate niche opportunities for new technologies to grow. The other subsidies on this list could be redirected towards clean energy sources.

What could we do with these redirected subsidies? Help subsidize a national rooftop solar plan and a national energy efficiency plan for all private and public buildings, for starters, and encourage the production of more solar- and wind-generated electricity. Then, rather than invest in a national bus transit system that runs on oil (as has been proposed in Congress), invest in an electric rail system. Unlike most European nations, the U.S. lacks a national or even a regional electric rail system. What we do have is not modern, efficient, or comprehensive. New, successful, light rail systems are restricted to a dozen of our major cities. Creating a national and regional electric rail system, powered by solar- or wind-generated electricity, would improve human transport efficiency significantly, be carbon-free, and has always made sense, even as a defense against another oil embargo. What could be done to create this system? Two congressional actions have been proposed:[413]

1. "Provide Amtrak, or whatever succeeding agency replaces it, with enough money to create a modern passenger rail system— $20-30 billion…
2. Change the federal Surface Transportation Act so cities and transit agencies don't have to put up matching funds to get federal funds for transit system construction. This is something local governments don't need to do when they ask for federal money for highways. Make it easier for local governments to build rail systems, or expand existing rail systems and get more rail lines built. This change would also stop local transit agencies from having to make a terrible choice: under the current system transit boards often have to choose between building new rail systems and operating bus systems. If matching funds were not required, transit agencies could do both."

Federal research and development funding for building technologies is especially needed in this fragmented and competitive economic sector. But, as pointed out in Chapters 5 and 6, we also face challenges in developing electric cars and significant solar and wind energy sources, and our federal research and development funds should be refocused to reflect that. The focus should lie not only in making them cheaper and more energy efficient, but also developing a manufacturing infrastructure that will allow us to expand these industries and adapt our energy grid to them as fast as possible.

3. Regulate efficiency. The most straightforward component of our recommended policy entails regulation. Where appliance energy efficiency standards have been implemented, and combined with efficiency labels so that consumers know the energy implications of what they are buying, they have been generally welcomed both by consumers and manufacturers. Markets cannot function effectively without the flow of information, and that is precisely what efficiency labels promote.

Automobile fuel efficiency can be vastly improved, as we have discussed in Chapter 5, and it will take new regulations that go well beyond the Energy Independence and Security Act of 2007 to achieve this. Central to our energy strategy is the passage of legislation mandating fuel efficiency standards that ramp-up to a new-vehicle fleet average of no less than 60 mpg by the year 2030, starting with a standard of 35 mpg by the year 2015. As discussed in Chapter 5, it is technologically feasible to do even better than this; we suspect that once industry catches on to the technologies that get us to 60 mpg, the race will begin to improve further. A major improvement in efficiency will come from switching ultimately to electric cars, and this will improve car performance, reduce costs, and improve the environment. The taxation policies we recommend next will reward automakers for compliance with fuel efficiency standards and even over-compliance with such regulations, and achieve an important additional goal that goes way beyond the transportation sector — reducing fossil fuel emissions even further.

Building codes requiring at least a minimum level of energy efficiency for new structures can be enacted at any government level and take advantage of the fact that the best opportunity to make a building energy efficient is during its construction. Moreover, appliance and equipment efficiency standards that require a minimum level of energy efficiency should be required for all energy-consuming household appliances and industrial equipment.

Regulatory barriers that prevent the sale of cogenerated or recycled energy back to utilities should be broken down so that utilities can make money as they increase their energy efficiency. It’s another win-win situation for the utilities and the customers to whom savings are passed.

A portfolio approach by government at all levels is needed here. For each area within the fields of energy efficiency and renewable energy development, different approaches (regulations, subsidies, taxes, permits, incentives, etc.) need to be chosen so as to optimize development in that particular area.

4. Provide public land for the generation of clean energy. A commonly repeated argument is that solar- and wind-generated electricity plants will take up an unacceptable amount of land. As we showed in Chapter 6, the numbers tell a different story. Under the EASY plan, all electricity demand in the year 2030 could be generated from sunlight at current solar panel efficiencies, using a combination of rooftops and 7,000 square miles of suitable land. The Department of Defense controls about 19,000 square miles of land in Nevada, Utah, Arizona, and New Mexico. These lands are currently off-limits to the public and reserved for weapons testing and other purposes that are justified as being in the interests of national security. We recommend that a portion of those lands be re-assigned to a different national security agenda: energy independence. Some of those lands are probably best used for wind energy, others for solar, and perhaps some for geothermal. A report prepared by a combination of federal and state government, industry, academic, and nongovernmental organizations’ scientists should be commissioned to determine which portions of all that land could be best devoted to each of these energy generation technologies.

5. Redirect military spending for maintaining oil supplies. The final component of our proposed national energy policy is the redirection of money, spent largely by the military, to insure the import of foreign oil to the U.S. By shifting to clean energy generation, we will be

- investing money --not lives-- into developing our energy independence,
- reducing our vulnerability to foreign disruption of our energy supply,
- improving our national security and reducing the chance of our money, in the form of oil payments, ends up in the hands of terrorists,
- generating savings — energy savings, savings on reducing the military costs of maintaining foreign oil supplies, savings from a reduced trade deficit and a strengthening of the U.S. dollar.

By the end of the Bush Administration, our total expenses associated with the Iraq war will surpass one trillion dollars, and the long-term cost will be twice that or more. What could we have bought with the amount of money spent in Iraq? With a trillion dollars, we could have subsidized nearly two thirds of the cost of solar panels for the estimated 75% of U.S. residences on which sufficient sunlight falls to make solar energy practical (see Appendix B.1). That would leave property owners with a residual payment that, under typical conditions, would have a payback period of less than five years at current electricity rates, making it a sound investment. Of course that trillion is already spent or committed to being spent — but let's redirect some of the next trillion! After all, we won't have to spend it defending future oil supplies if our automobiles are getting 60 mmpg or more. We might even recoup our war expenditures from the savings resulting from the transition to clean energy independence.

With this strategy, we could free up our National Guard from overseas oil wars and redeploy them here in the U.S. Their role would be a very large and important one: utilize their manpower for installing solar panels (see Appendix C.2) on all rooftops in the housing sector, both public and private. We could similarly mobilize national youth corps programs to augment the efforts of the National Guard. This would bring down installation costs significantly, thereby making it accessible to virtually all homeowners. It would also increase economic security at the family level, as well as ensuring energy security, in a way that all our military might is incapable of providing presently.

Indeed, at least one organization is already thinking along those lines.[414] Mr. Van Jones of the Ella Baker Center for Human Rights in Oakland, California, in conjunction with the local electrical union, started the Oakland Apollo Alliance, raising $250,000 from local government to train young people in “green collar” retrofitting jobs — specifically, learning how to install solar panels and weatherize buildings. He has also launched the Green for All campaign, which seeks to “help build a green economy strong enough to lift people out of poverty”, at the 2007 Clinton Global Initiatives event in New York.[415] The Green for All organization is working in collaboration with other organizations to form a Clean Energy Corps, which would “be a combined service, training and job creation effort to combat global warming, grow local and regional economies and demonstrate the equity and employment promise of a clean energy economy.”[416] It is an ambitious but plausible plan: build the right kind of sustainable economy by training the underprivileged part of the next generation appropriately. These people both need the jobs required for that type of economy and the motivation to get involved in addressing the climate crisis. Mr. Jones recognizes that creating a healthy green economy means including everyone possible in an economically sustainable occupation as part of it. He hopes to secure $1 billion dollars by 2012 to create a “green pathway” out of poverty by training 250,000 urban youth from all over the U.S.

To summarize, the Iraq war will end up costing taxpayers over a trillion dollars. Future conflicts to maintain our oil supplies would entail comparable or larger costs. Spending a trillion dollars to subsidize the cost of rooftop solar units would be a much sounder investment.

What Can We Do with an Extra $500 Billion?

The Table in Chapter 3 shows that under the EASY plan, a national savings of approximately $500 billion will be accumulated by the year 2030. Of course we could be off, in either direction, by a substantial chunk of cash, but let's imagine for a moment that we do have that much savings as a result of changes in our energy policy. What could we do with it to help expedite the EASY Plan? With just $10 billion per year over the period from now until 2030, we could finance electric grid improvement and a crash research and development program to improve technology for storing solar- and wind-generated electricity. Improving the grid would allow electricity produced from sunlight in New Mexico to be consumed in Seattle. Simultaneously, it would improve the means of storage necessary for the eventual transition, by the year 2030, of our entire electricity generation system to solar and wind. And we would still have a sizeable amount of money left over to spend on health care and education. What a deal!

Additional and Important Policy Carrots for the Portfolio

We've outlined the major policy moves above, but there are many other policy options that can encourage significant development of the EASY plan at all levels of government. Carrots and sticks can come in the form of regulations, incentives (subsidies, rebates, tax credits), and education. Our federal and local governments already incorporate some of them, but we need to expand them much more. Some are outlined in "Tackling Climate Change in the U. S.", a study produced by the American Solar Energy Society:[417]

- The **Energy Star program** introduced by the Environmental Protection Agency in 1992 functions to:
  1. clearly identify with labels which products, practices, new homes, and buildings are energy efficient for the consumer;
  2. provide decision makers with energy performance assessment tools and project guidelines for efficiency improvements,
  3. assist companies to easily offer energy-efficient products and services, and
  4. collaborate with other energy-efficiency programs to maximize resource use and impacts.

- **Utility-based financial incentive programs** operate on the idea of offering incentives for using less energy and have been operating since the 1980s. An example is a sliding rate scale for water or energy, with the price per unit increasing as individual homes use more than an established baseline needed amount. The carrot here is that you are rewarded with cheap rates when you don’t use more water than is absolutely necessary for an average lifestyle.

- Another carrot is **time-of-use metering**: you are charged a higher rate for using energy during peak usage hours, during peak energy usage months. This provides a huge incentive to homeowners contemplating putting solar panels on their roofs. Solar producers get a bigger monetary credit for feeding electricity into the grid at times of peak power use because those times tend to be summer afternoons, when air conditioning demand is high and solar power production is greatest. This substantially brings down the payback time for solar installation.

- The **Federal Energy Management Program** (FEMP) was developed in 1973 to increase the energy efficiency and decrease the environmental impact of the operations of our federal government. Congress and the President impose energy use reduction and renewable energy goals for the various agencies, and FEMP provides specialized tools and assistance to help the agencies attain their goals to conserve water, energy, promote renewable energy, and improve utility management. This program could be improved to promote not merely renewable, but clean, carbon-free energy.

Besides these, there are other carrots that exist for clean energy:

Tax credits for both solar and wind installations exist from the federal government. Here, individuals get a tax break by being able to deduct a percentage of the purchase and installation costs from their taxes, usually up to a specified limit. As currently written, the solar tax credit for industry decreases to 10% in 2008 and for residences ends in 2008.[418] This credit should be increased and made permanent, then phased out when U.S. energy demands are met solely through clean energy, efficiency, and conservation. Doing this will pay for itself when the clean energy transition generates savings through helping the trade balance, generating jobs, eliminating the need to build expensive coal powered plants, and helping the environment.

According to the American Wind Energy Association (AWEA), the federal wind tax credit is currently an income tax credit of 1.5 cents per kWh of electricity produced by qualified wind energy facilities, and is useful only at the industrial scale.[419] As noted in Chapter 6, the short-lived nature of this credit within the past several years discouraged a robust growth of wind power manufacturers in the U.S. and allowed foreign wind manufacturers to fill our needs. This wind tax credit should be made permanent and then phased out when U.S. energy demands are met solely through clean energy, efficiency, and conservation, as with solar electrical generation.

AWEA urges citizens to ask their representatives and senators to create legislation that provides tax credits for the installation of small wind systems (100 kilowatts and under) on farms, private residences, or the buildings of individual businesses.[420] Again, we believe such tax credits should exist until electricity in the U.S. is generated solely through clean energy.

Renewable portfolio standards (RPS) are currently in place with 22 state governments and the District of Columbia currently, and require that a certain percentage of power purchased by utilities come from renewable energy. According to AWEA, the benefits of RPS are that:

- by diversifying our energy sources, we are less vulnerable to energy price spikes from fossil fuel sources;
- it allows the market to pick the "winners" by encouraging competition among renewable energy technologies, driving down costs;
- it creates jobs and income in rural areas, since the establishment of each large scale wind turbine has been shown to generate over $1.5 million in economic activity;
- further local income is generated through long-term lease payments to farmers and landowners hosting wind turbines;
- both the resulting diversification and decentralization of our energy sources increase our national energy security; and
- the resulting expansion of clean renewable energy decreases harmful air pollution.

What's not to like? We should be going federal with this. As it is, Representative Tom Udall (D-NM) introduced H.R. 969 to create a national RPS, requiring utilities to generate or buy 20% clean, renewable energy by 2020.[421] Under the EASY plan, we think this should be increased to 50% by 2020.

The U.S. Department of Energy has also started a **Solar America Initiative** program to make solar electricity competitive with conventional electricity by 2015 through a sustained research and development effort in partnership with industry, universities, state governments, other federal agencies, and non-governmental organizations, and eliminating market barriers to deployment. Sounds good, doesn't it? But the maximum funding that could be allocated to this under the current federal budget is $168 million.[422] This is the equivalent of two months of U.S. aid to Columbia. Or compare it to the $3.2 billion allocated in California for solar power rebates under the California Solar Initiative.[423] Until the federal government gets real about financing solar energy, such initiatives are window dressing and misleading at best.

What else are we doing? The U.S. Department of Agriculture runs the **Conservation Reserve Program**, supplying incentives to farmers to convert highly erodible or otherwise environmentally sensitive cropland to vegetative cover, which increases their carbon sink capacity. The program also encourages other environmentally healthy practices, such as letting croplands rest unused for a few years.[424] It has done much to help preserve ecosystems such as prairie potholes, important habitat for wild ducks and grasslands.[425] As cash incentives for biofuels cropland have soared, however, voluntary enrollment in this program has decreased; program incentives should be increased to keep up enrollment.

Given what is now known about the relative environmental merits of biofuels versus wind power, we should modify our current farming cash incentives. Why not subsidize the installation of wind turbines on farmland, rather than subsidizing the diversion of food cropland to energy crops? Instead of producing ethanol to feed today's energy-inefficient vehicles, they could be simultaneously producing the wind-generated electricity to feed tomorrow's efficient all-electric vehicles and the crops to feed a world that will increasingly be forced to deal with the threat of hunger.

We can go further, however. Let's **create an Energy Innovation Council**, an interagency government group that would develop a multi-year National Energy Research and Development strategy for the U.S. This has already been proposed as part of an overall strategy for boosting energy innovation in the U.S.[426]

Carrots at the Community Level: The California Example

Innovation at the local and state government level is at least partly addressing the vacuum of vision at the federal level. Curbside recycling in some form, for example, occurs in most U.S. communities. Many states, such as Florida and California, have established energy and CO_2 emission goals. So have some cities outside these states.

Ah, California, land of all those annoying liberals, but also of innovative ideas. Where the Republican governor is truly acting like a conservative, trying to conserve energy and environmental resources. And it's paying off. Let's see what California is doing, and why other states are starting to emulate it.

We've already talked in Chapter 4 about the mid-1970s energy efficiency legislation that continues to save California about 30% of its energy needs yearly, and helps make it the leading state in energy efficiency. Various other states in the next three decades developed special incentive programs to improve energy efficiency, energy conservation and promote renewable energy options.[427]

The twenty-first century dawned with an increasing belief in the phenomenon of global warming and its effects on the planet. In June 2005, California's governor had vowed to cut the state's GHG emissions 80% by 2050, and by December the state's Climate Action Team had laid out a series of proposals.[428] By August 2006, Governor Schwarzenegger had signed into existence the $3.3 billion Million Solar Roofs bill, a plan he had already directed the California Public Utilities Commission to implement.[429] The result was the establishment in January 2006 of the California Solar Initiative (CSI), which is committed to creating 3,000 megawatts of new, solar electricity by 2017 with a million new solar roofs. [430]

The CSI is offering an array of incentives over the next decade for establishing photovoltaic panels on the roofs of new and existing residential, commercial and industrial buildings. This will help create jobs and new products, thus helping the future economy. The CSI collaborates with the California Energy Commission's New Solar Homes Partnership, a $400 million decade-long program to encourage solar in new home construction.[431] This model has encouraged others. The Western Climate Initiative was started in February 2007 by Arizona, California, New Mexico, Oregon, and Washington. Its mission is to identify, evaluate, and implement collective and collaborative ways to reduce greenhouse gases in the region; it vows to cut emissions at the 2005 levels by 15% by 2020. By April 2007, the Canadian province British Columbia had joined, and several other states have joined as observers.

What has happened in California since then? Despite complaints by businesses and consumers alike, legislation has been passed to improve air quality and develop alternative transportation fuels and vehicles — and more progress is on the way. Business groups, who warned a year ago that businesses would flee California, are now actively engaged in the plan. Perhaps one of the most important social lessons from all of this is that if a leader with vision sets out to implement a decent plan to address the climate crisis, other diverse sectors of society, from businesses to environmentalists, from liberals to conservatives, will be anxious to learn and follow.[432]

California provides extensive examples of what could be created at the community level through the right mix of state and local statutes and incentives. For example, the Million Solar Roofs Initiative is buttressed by tax rebates for solar panel installations, while several tax credit incentives exist for insulating existing homes, energy efficient or hybrid passenger vehicles, renewable energy and solar water heater systems, and energy efficient cooling and heating systems.[433] In 2002, California enacted Community Choice Law AB117, which allows communities to choose alternative energy electricity providers, locally control the content of the energy they buy, set their own rates, and lets local residents, businesses and public agencies for local energy efficiency programs control millions of dollars per year in available funds.[434] Within the San Francisco Bay area, the nonprofit Local Power has created an implementation plan for San Francisco to buy more than 50% of its electricity at competitive prices from renewable energy sources by 2017 through development of wind and solar power sources, as well as energy conservation infrastructure. Local Power has also created an alliance of environmental organizations, experts, and local community groups to promote its plan in surrounding cities, as well.[435]

Examples of local community initiatives abound. The city of Berkeley, California, for example, has approved a measure to reduce GHG emissions by 80% by 2050, and as part of the answer has developed an innovative “loan” plan to facilitate the purchase of rooftop solar panels by residents, a plan that is attracting attention nationwide.[436] For every participating residence, the city will pay for rooftop solar panel installations, and then conduct a 20 year assessment audit. Owners will pay the new property taxes over the next two decades, at a rate that equals or is less than the money they will save on energy bills. The big advantage is that it allows homeowners to conquer the most challenging obstacle to installing rooftop solar panels: paying the upfront costs. The city's website also offers a link to a local nonprofit organization that offers free household energy assessment audits, training of young people as energy specialists, installation services of efficient energy technology, and educational workshops on resource literacy.[437]

The good news is that California is not an oddity in this. As noted previously, many states have signed on to limit greenhouse gases, and many mayors and communities are now involved in various ways to cut down on GHG emissions through clean energy or energy efficiency. Both northeastern and western governors have gotten together in a bipartisan way to push climate change control efforts.

International Carrots

Although this book focuses on the U.S., we are inextricably linked to the rest of the world through trade, scientific exchanges, atmospheric concerns, and competition for resources. Here, we propose some international initiatives whose time has come.

Initiate an International Clean Energy Plan akin to the highly successful Marshall Plan, with the same urgency that went into the Manhattan Project, sharing our energy efficiency technology and our solar and wind technologies quickly wherever there is a huge upsurge of carbon emissions occurring. We have already started on this path by entering into a non-binding agreement with China, a major global warming gas emitter, to help improve energy efficiency in their industries.[438] We must do much more with them and expand to other major emitters around the world. China has stated bluntly that it would do more to curb emissions if rich nations would supply technical help.[439] The U.S. government made an encouraging move in that direction, announcing the intention to form, and be a leading contributor to, an international "clean technology fund" in 2008 to help China and other developing countries transition to clean energy solutions.[440] This was a concept promoted by China during climate talks in Bali,[441] and a United Nations (UN) climate chief hailed the U.S. announcement as a "Marshall Plan" for climate change.[442] Now, we must follow up our grand intentions with grand actions. Our plan must be coherent and comprehensive in content and outreach, involving as many of our international aid institutions as possible.

Helping to subsidize the energy transition of developing countries should be an essential part of our aid packages, and even programs as small as the Peace Corps should be devoted towards spreading energy efficiency and clean energy. When the Indian Ministry of Power says that coal "is the only fuel that they can afford at the moment",[443] we have to give them alternatives to contemplate, as well as a constructive diplomatic dialogue with such questions as: Can India or China "afford" further effects of global warming, such as more droughts or mega-typhoons? Can they "afford" mass starvation brought on by crop failures? In this light, is coal truly "affordable"? Alternatives should include subsidies and incentives that make it cheaper to build a wind farm or solar thermal plant than to mine and burn coal. Calling for a moratorium on building and operating coal plants is heroic,[444] but not feasible without adequate support.

As Thomas Friedman put it after observing two cities, Doha of Qatar and Dalia of China, exploding with highrises, there are now new "Americans" with the same dangerous consumptive appetites popping up all over the globe, [445] and if they are not directed towards alternative energy sources to keep down their carbon emissions, they will swamp all of our efforts to address the climate crisis in the U.S.[446] The UN notes that progress in the poorer developing nations will be countered by the destructive effects of the climate crisis, unless richer nations not only cut emissions but also provide aid allowing developing nations to leapfrog to cleaner energy sources.[447] We have been effective in exporting our habits of consumption. Now it's time to export another blueprint. The most effective role the U.S. can play now in addressing the climate crisis is to develop a good model for drastically cutting GHG emissions, then export it as quickly as possible to all others — especially the other major global warming gas emitters on Earth, India and China. Indeed, China is looking to the U.S. to lead by example.[448]

One of the best hopes of doing so lies with the RE < C Initiative (Renewable Energy Cheaper than Coal) announced by Google.[449] The Internet giant will be investing hundreds of millions of dollars into reducing the price of clean renewable energy below that of coal. One motivation is to save money on powering their massive data systems. But as their philanthropic head, Dr. Larry Brilliant, noted, poorer countries' first priority is removing poverty, not addressing the climate crisis and cheap, clean renewable energy will accomplish both.[450] As it is, this is a drop in the bucket, but it's a start.[451]

Subsidize the preservation of natural carbon reservoirs. Complementing the above plan should be a policy that encourages developed nations to subsidize developing nations for preserving their natural carbon reservoirs, such as rainforests, for the planetary good, as has already been suggested by Indonesia and Brazil.[452] Indonesia's vice president has insisted that countries who are major consumers of their timber pay now for the upkeep of remaining forests.[453] He should also insist, however, that his own government cleanup the corruption that allows companies to destroy forests and massive peat bogs, both important carbon reservoirs, on Kalimantan, the Indonesian part of Borneo[454] and anywhere else in Indonesia.

Indeed, conservation organizations have already helped create “debt for nature swaps”, in which developing nations such as Costa Rica, Bolivia, Madagascar, and the Philippines are forgiven part of their accrued foreign debts in exchange for preserving their rainforests.[455] Conservation organizations such as World Wildlife Fund and the Nature Conservancy often arrange the financial buyouts of parts of these debts; this frees up funds within the countries for local conservation.[456] But these efforts must be greatly expanded to adequately address the continuing loss of carbon reservoirs through deforestation and other habitat destruction.

Consuming nations are part of the problem and should be part of the solution:some countries, such as Norway, are starting to fund forest conservation in developing nations.[457] But perhaps more precisely, it is also time that the UN get all nations to agree to an international ban on the destruction of natural forests (not timber farms) and peat bogs for any reason. Enforce it on countries that fail to prevent further deforestation with economic sanctions. Enforce other sanctions on international or other companies that continue to deforest, such as boycotts and freezing their accounts. Sounds radical, doesn’t it? But so are the consequences that are happening to our planet from global warming.

Some contend that deforestation cannot be stopped abruptly. Brazil’s Agricultural Minister has stated, for example, that the fast-growing farming sector, which is responsible for destroying much of the Amazon rainforest, would probably need ten years to stop its encroachment into the rainforest.[458] To its credit, Brazil has announced new measures to slow the surge of Amazonian deforestation: 1) putting a hold on any new deforestation permits for an area where half of the latest deforestation has occurred; 2) making sure that preservation areas created in compensation are maintained by the responsible landowners; 3) enlisting its army in facilitating inspections; and 4) holding the companies who buy commodities grown on the land of destroyed forests equally responsible for deforestation.[459] The UN should monitor whether the program is enforced and effective, and encourage Brazil to halt deforestation entirely. The world can help by boycotting the purchase of crops or cattle raised on deforested lands. Ending deforestation does not mean an end to harvesting wood, however. Brazil is also starting sustainable forestry endeavors that manage the forest, so that wood is harvested and the forest is perpetuated sustainably.[460]

In addition, the UN should insist that the companies or people who are responsible for past destruction of forests for whatever reason, or who have benefited from selling forest resource rights to exploitive companies, should also be made to pay for the preservation of remaining forests. They should also pay for reforestation efforts and sponsor the development of timber farms that do not impinge on already existing forests.[461] Again, the UN should enforce this with economic sanctions. Deforestation has been the result of complicity on many fronts, and shifting blame solely to consumers will not be very productive.

One company involved in using palm oil to produce biofuels is, in fact, trying to restore peatlands, and buy only certifiably sustainable palm oil. BioX, a Dutch firm, has teamed with the nonprofit organization Wetlands International to restore about 1.24 million acres of peatlands. Maintenance of peatlands is cheap — it involves ensuring that no fires occur and a certain level of water is maintained — and represents one of the most cost-effective ways to curb carbon emissions.[462] Many more firms should be given incentives to do likewise for both peatlands and forests. The devastation of the peatlands has convinced the Netherlands to go even further: it will stop the subsidization of imported palm oil.[463] In concert with the REDD (Reducing carbon Emissions from Deforestation in Developing countries) project developed at the international climate Bali talks, the World Bank is starting to take steps in that direction, launching plans for a $300 million Forest Carbon fund to turn forest management into a tradable commodity on the carbon credit markets.[464] The caveats are that carbon credits have yet to prove useful in this respect, and indigenous forest peoples have to be included in any plans. It also falls far short of the estimated $5 billion needed to stop deforestation.

The World Bank is also promising to increase funding for forestry reform in the Democratic Republic of Congo, which contains the world's second largest tropical forest.[465] Unfortunately and much more relevantly, however, the World Bank is also a key backer behind the development of Amazonian basin cattle ranches. The expansion of these is a major threat to the Amazon forests, which are experiencing sharply accelerating losses from biofuel farm pressures and soybean production as well.[466] Clearly, it is time for the World Bank to refuse to fund any endeavor that fuels deforestation, and to make funds available for reforestation projects instead, especially as development pressures mount on the Amazon forest. Indeed, since the World Bank's mission is to reduce poverty and studies have shown that the poor will suffer the most from global warming, the World Bank should be prohibited from funding any green house gas emitting project, especially coal-fired plants.[467]

Encourage farmers to practice environmentally sustainable farming. We should be encouraging the UN Food and Agricultural Organization (FAO) to move forward with a plan to do this, along the lines of our own nation's Conservation Reserve Program. Give incentives to farmers to keep carbon in their soil with appropriate practices, such as:

- minimum tillage or plowing crop remains back in to the soil;
- growing crops that maintain root systems in the soil to prevent erosion; and
- preserving natural areas around croplands to prevent flooding and help carbon storage.

The FAO recognizes that it makes sense to do so worldwide, since a huge portion of the planet's population depends on farming for their direct livelihoods and thus strongly influences land usage around the globe.[468]

Learn from other countries. Germany is a good example of how fast we could be turning our economy green. A major European polluter and environmental laggard in the 1980s, Germany started its clean energy revolution in 2000.[469] Working in tandem with industry, it decoupled energy use from economic growth, with long term plans that gave industry time to adapt, while slowly tightening standards. One key was to create markets and businesses that profit from environmental standards. Germany federally encouraged a surge in renewable energy use nationwide by mandating that utilities buy renewable energy at marked up rates from anyone who produces it. Today its green technology and standards are being profitably exported and adapted globally. It has just pledged to cut its carbon emissions from 1990 levels by 36% by 2020 through the use of incentives to encourage energy efficiency and further development of renewable energy. If Germany can do this, why can't we?

Norway is aiming to go carbon neutral by 2030.[470] China is on a fast track with wind and solar, as noted above. Hong Kong has embarked on an innovative regulatory program with their power utilities that sets the utilities' rate of profit partly on the basis of how much pollution they emit.[471] Britain has also created a national renewable energy plan to reduce CO_2 emissions through wind turbines, and improved efficiency.[472] It has already instituted a hefty tax when buying new gas-guzzling cars. Ireland is going further, penalizing existing high-emission vehicles by 2008 and banning incandescent light bulbs by 2009, in favor of energy-saving ones.[473] France is following with a similar system penalizing car emissions.[474] What are they doing? Are any of their carrots transferable to us? We should be finding out.

We can learn from their successes and mistakes in crafting successful strategies for ourselves. Then we can act, and lead.

We can also learn from their growing pains. The European steel industry, for example, has warned the European Union (EU) that their climate plan would send steel industries overseas to stay competitive. This is because the plan would make steel production more expensive in Europe than in other nations, such as Russia or China, in the absence of an international climate treaty.[475] Their point is valid, and invites consideration of an import tariff system that includes the true environmental price of foreign steel production, where equivalent carbon-emissions curbs are not in effect.

Participate in and support international efforts. Former UN Secretary Kofi Annan, for example, has launched a Global Humanitarian Forum to focus on coordinating international efforts to counter the effects of climate change.[476] A global carbon partnership to slow global warming through an international carbon trading market has recently been formed by European countries, individual states within the U.S., Canadian provinces and New Zealand.[477] Brazil wants to create incentives to curb deforestation of the Amazon.[478] The European Union and the World Bank are discussing the creation of a long-term loan to poor countries to help combat climate change by limiting their emissions.[479] We should contribute to these efforts.

The IPCC has warned that bold carbon-emission curbs are needed now to keep GHG emissions from peaking beyond 2012, beyond which, it warned, higher sea levels and more droughts and floods are practically inevitable. It is still possible for us to rein in rising levels, said the World Wildlife Fund representative director at the World Economic Forum in Davos, Switzerland in early 2008.[480] We should be doing everything we can to help achieve that goal. We should exert our influence in the UN and World Monetary Fund to support clean energy projects, and discourage projects that contribute to global warming, such as dams and deforestation. We should be encouraging OPEC (Organization of the Petroleum Exporting Countries) to participate beyond funding research for carbon capture and storage,[481] and to invest in clean energy sources, for both the planet's and their own financial future. We should be supporting UN efforts to enable countries to rein in population growth, through family planning and women's education. We should be proposing bold, effective plans for addressing the climate crisis at international climate meetings.

"If They Aren't Doing It, Why Should We?"

A prominent reason given by the current U.S. administration in 2007 for not trying to enter into any international agreements to reduce carbon emissions was, "Why should we participate in reducing carbon emissions if China and India aren't doing so concurrently?" Then there are prominent scientists that doubt that we will be able to reduce emissions enough to prevent destructive rises in global temperature.[482] These are both non-starters. Developing, using, marketing and exporting an effective model to address the climate crisis are essential. The challenge and consequences face ALL of us, and there is no room for anyone to take their marbles and go home, because home is the same for all of us — the surface of a big ball in space called Earth.

What about a Carbon Tax, or Cap-and-Trade/Auction System?

Energy policy analysts, both in the U.S. and abroad, are currently debating the relative merits of two policy instruments for dealing with the climate crisis: carbon taxes and a cap-and-trade system.[483] Because so much intellectual, and in some cases economic, investment has gone into these ideas, it is particularly important that we carefully evaluate these governmental schemes here.

A carbon tax would encourage consumers to reduce energy waste and to choose efficient products, while a cap-and-trade system would place a cap on how much total carbon can be emitted by industry, allowing industries to trade allotted permits, or carbon credits, to emit below the cap. Two more variations of the cap system are: 1) cap-and-auction, in which a limited number of capped emissions permits are auctioned off, rather than sold at a fixed price; and 2) cap-and-dividend, whereby the permits are auctioned off and the dividends distributed to consumers, which at least partially mitigates the higher costs that permit winners pass onto the consumers.[484] Each of these has merit. They will certainly nudge us in the right direction. Let's examine these ideas.

But will a carbon tax that is big enough to quickly make a significant difference in GHG emissions be politically acceptable in the U.S.? Software executive, Jim Manzi, argues that carbon taxes could create a sizable global economic drag.[485] Furthermore, it has been justifiably pointed out that a carbon tax is a regressive tax — it negatively impacts the poor, because they spend a larger portion of their income on energy than do the more affluent. Others, however, assert that revenue from a carbon tax could, at least in principle, be redistributed, so that the poor do not suffer the most.

At best, the carbon tax has a mixed record overseas.[486] Norway imposed a stiff tax on GHG emissions in 1991. Although it forced the gas and oil sectors to curb energy waste, booming fossil energy prices worldwide encouraged even more fossil fuel development, which boosted emissions somewhat. The tax, placed on top of an already $10 per gallon price tag, was accepted by drivers, who bought more cars and drove more. Numerous industries obtained exemptions from the tax. This has resulted in an overall yearly increase in GHG emissions. In fact, the two Scandinavian carbon-taxing countries that showed any declines in GHG emissions had programs encouraging energy efficiency and renewable energy, which played a part in those declines, their economists note. These countries were Sweden and Denmark, demonstrating declines in GHG emissions of 14% and 8% since 1990, respectively.

We do strongly advocate a role for a carbon tax, however. As the Easy Plan begins to be implemented, oil exporters are likely to lower the price of oil in an attempt to encourage the U.S. back to using more fossil fuels. A carbon tax could be used to maintain current prices on oil and gasoline, to negate any such destructive incentives. The revenues of the tax could be used to further implement the EASY Plan.

Cap-and-auction/dividend is an improvement over cap-and-trade, because instead of giving away permits, or setting some arbitrary price on them, an auction with an appropriately high starting bid establishes a more equitable price for polluting and generates revenues. These revenues could then be distributed to consumers. Here again, the effects of passed-on costs will affect the poor more than the rich — the poor spend a higher percentage of their income on necessities. So, it will be important to devise a system that distributes revenues in an equitable way. This will not be a trivial task.

Community groups are already starting to protest a planned cap-and-trade system in California. They argue that allowing polluters to buy their way out of polluting allows continuing pollution to damage the public's health. They suggest, instead, that polluters be simply taxed for polluting, although others argue this is much more difficult, politically, to accomplish.[487] Moreover, when a tax on polluters gets passed onto the public in the form of higher prices, the poor again suffer the most.

Carbon credit exchanges already exist overseas and are proliferating.[488] In anticipation of a U.S. market, companies are reporting their emissions to the Climate Registry.[489] But even if a high price on carbon emissions is reached, it alone is inadequate to address the climate crisis, the Confederation of British Industry (CBI) told its government recently.[490] This view is echoed by U.S. financiers and think-tank people, as well. And, getting the system to work requires government creating a framework, business delivering, and people feeling empowered to act, said one CBI head.

Although carbon emission trading schemes are in their relative infancy, the record is not good. Britain, one of the pioneers in this, already admits that it will miss its stated target of cutting its current GHG emissions 26-32% by 2020, and has pushed back its target date to 2030.[491] In a further setback, Japan reports that the surplus UN tradable permits for carbon emissions between 2008 and 2012 under the Kyoto Protocol will probably far outweigh the demand by industrialized nations, significantly weakening the outlook for carbon exchanges.[492] Recognizing such flaws, the European Union is planning a major overhaul of its carbon trading system to reduce corporate influence and make polluting more expensive.[493] Here in the U.S., the experiment has already been set in motion at the state level. Ten states have already instituted some form of cap-and-trade system, although if New York is a typical example, the experiment is tepid at best, seeking to merely hold emissions steady until 2014, when it would start reducing emissions.[494] This is clearly not the dramatic action that is needed.

We are skeptical that the complexities of cap-and-trade, and agreed-upon solutions to problems of auctioning or giving away permits, can be achieved in a timely manner. It is true that the system was remarkably effective in reducing sulfur dioxide emissions by 40% over 17 years when inserted into the 1990 Clean Air Act, and thus helped reduce acid rain.[495] Cap-and-trade worked for sulfur dioxide emissions in the 1990s, however, because the necessary transition simply meant modifying existing infrastructure with already developed technology. Cap-and-trade is not working, as illustrated in Europe, because the transition is not trivial — it is not simply a case of modifying existing infrastructures, but replacing them, which is an extensive process. Trying to force such a transition on industry within an arbitrary period of time simply leads to extensive gaming of the process, rendering it ineffective.

Cheating and fraud have already been detected in carbon trading in Europe.[496] A good example is when large automobile companies claim carbon credits for cars that can run on biofuel-based ethanol, but in reality run mostly on the more accessible fuel, gasoline. We also wonder whether society has the will to impose a cap that is strict enough to REALLY deal with the climate problem in a timely manner.

The European Union’s climate change plan is a good illustration of our argument. The revised plan is a compromise of green and industrial interests, with environmentalists contending an overindulgence of oil and airline industries. The plan itself, of which their carbon trade system is part, calls for a 20% cut in the 1990 level of emissions by the year 2020, a boost in renewable energy use, and promotes mandatory use of biofuels in transport — too little, too late, say environmentalists,[497] and we concur.[498] Meanwhile, U.S. businesses are anticipating mandatory GHG emissions regulations in the near future and want to influence their formation.

Any cap-and-trade/auction system, with or without dividends, carries the same drawbacks: loopholes; cheating through allocation of exemptions or offsets; poor or selective enforcement; and, in the absence of socially equitable distribution of dividends, the regressive taxing of the poor as permit winners pass the costs onto consumers. Furthermore, the creation of any carbon trading system, whether they trade free or auctioned permits, involves the creation of carbon traders and markets. These entities are then motivated by self-survival instincts to prolong the system by slowing its process, since achieving the goal of the system (reducing carbon emissions to a negligible amount) renders the market and traders themselves obsolete. Although some of the biggest U.S. businesses support a cap-and-trade system, it has been admitted that it would be complex, have far-reaching economic consequences, and require monitoring for decades.[499] Do we have the time and resources to devote to such a system, when effective dramatic cuts in emissions are needed now?

At best, perhaps a cap-and-dividend system with a minimum starting bid might help, if:

- it is implemented to avoid all possible loopholes and reflect a real dramatic decrease in permits and emissions over time;
- the starting bid reflects a price that pushes the market toward quickly accelerating the development of non-carbon electricity sources; and
- a substantial part of the revenues is directed towards further subsidizing the “Reward the Winners” market of non-carbon electricity producers proposed in the first section of this chapter.

Such a system would be focused on what really counts: decreasing atmospheric carbon emissions dramatically over the next two decades. Quite frankly, though, its adoption is not likely, because such a truly effective system would probably be opposed by many business interests with influential government lobbies. Furthermore, the political battles associated with implementation of truly effective carbon taxes or cap-and-trade/auction will eat up precious time in our effort to deal effectively with the climate crisis.

Rather than waste the valuable time and resources needed to develop effective cap-and-trade schemes, we advocate the tried and tested process of tax breaks, subsidies and incentives that have already worked so well for fossil fuel industries, and that should simply be shifted to energy efficiency and clean energy industries.

This strategy skirts the political thickets associated with either of these schemes. It focuses on regulations (e.g., tightening CAFE standards and a mandated phasing-out of energy-wasteful lighting and home appliances), bringing down the price of clean renewable energy by reducing taxes on the profits from its sale, and ending subsidies for the fossil fuel industries. In short, our plan both mandates and rewards good behavior, and promotes economic justice, rather than exacerbating income inequalities. Furthermore, because our system is inherently simpler, it can be implemented sooner and more easily than cap-and-trade/auction systems. When we “Reward the Winners”, we all are winners — especially business, as the next chapter illustrates.

Chapter 10: Yes, Folks, You Too Can Profit from All This!

Contrary to the opinions of many doom-and-gloom naysayers, the economic opportunities to profit are many in transitioning to a clean energy world, spurred by the new motivation to develop energy efficiency and clean energy sources.[500] The employment opportunities associated with a clean energy transition are also forecast to significantly increase employment.

An Exploding Potential for Jobs

Indeed, former President Bill Clinton, who oversaw balancing the national budget and the creation of millions of jobs during his tenure,[501] said the shift to a green economy is the biggest economic opportunity facing the United States since the buildup to World War II.[502] A new United Nations Environment Programme report backs up his words on a global scale.[503] In 2005, the environmental industry generated more than 5.3 million jobs, more than those involved in the pharmaceutical industry. By 2020, Germany is predicted to have more jobs in the environmental sector than in the automobile industry. A 20% increase of energy efficiency in Europe could create a million new jobs. China is the global leader in solar heating, with 2005 revenues of $2.5 billion and an employment base of more than 150,000 people. And with increased solar deployments this could increase substantially. All in all, a net gain in jobs is predicted worldwide as we transition to a clean energy economy. One U.S. economist, Roger Bezdek, recently concluded that with the right federal incentives, clean energy industries could create 40 million U.S. jobs by 2030.[504]

The Green Collar Market: Business and Employment Opportunities

Many new companies — indeed, whole new industries — are sprouting up to address the climate crisis and meet the resulting new demand for clean renewable energy. One part of the green collar market, representing a whole new segment of U.S. job creation, involves addressing the climate crisis through planting trees and installing solar rooftop panels. Mayor Douglas Palmer of Trenton, New Jersey, for example, sees this annually $314 billion industry as having the potential to raise people out of poverty.[505] The diversity of new job sectors is expanding as more people recognize the scope of change necessary to create a sustainable, green, and more profitable economy.

Numerous opportunities exist in both service and manufacturing:

* resource recycling,
* energy efficient architects and contractors,
* energy efficiency consultancies,
* photovoltaic industries,
* retrofitting commercial and private structures with solar panels and efficient weatherization,
* greening and expanding rail and other public transport systems,
* designing and building solar and wind energy plants,
* designing and building electric cars and supporting infrastructure,
* modifying and expanding our national energy grid,
* research, development and manufacture of clean energy technologies from appliances to power plants, and,
* maintenance and repair.

These are just a few of those burgeoning areas. Indeed, the wind energy industry is growing so rapidly that it has many companies scrambling to find enough trained technicians to fill their needs.[506]

Can U.S. Businesses Afford to Invest in a Green Economy?

What is the risk of investing in these areas in the U. S? Some point to the emerging attempts in energy efficiency efforts after the 1975 oil embargo, which quickly withered away as the price of oil dropped again. Three facts make the current trends much more likely to endure:

1. a worldwide recognition that we will need clean energy to combat global warming;
2. the growing acceptance that because we are at or near peak production of conventional oil, future supplies of oil will dwindle and become ever more expensive; and
3. the huge technological advances in photovoltaic panels, wind turbine design, and energy efficiency.

Of course, if you use a cost-benefit analysis that excludes the long-term environmental advantage of addressing the climate crisis, you will often find more "cost-effective" short-term uses for your capital flow than advances in clean energy or energy efficiency. But excluding the climate crisis in your company equation means you're part of the problem, making a profit at the expense of the global community and ultimately the welfare of your descendants. It is certainly a moral theft of legacy and birthright if not legally so, assuming that all human beings have the right to clean air, water, natural resources, and a decently adequate climate. And legal liability is likely to become a bigger issue. Companies often make good faith attempts to compensate for damage that they might cause for short-term gain. But "compensation for short-term gain" here becomes irrelevant — there is no way to compensate in the short-term for the loss of an ecosystem, of species gone extinct, or of a "damaged" climate, losses that will take "forever" — from centuries to never — to recover.

We have seen the results of this false “costs and benefits” analysis throughout history: from the cutting of the trees on Easter Island or the cedars of Lebanon, to the loss of the lower Mississippi storm-buffering wetlands, humankind has suffered when nature has suffered. This situation is summarized by recognizing that the human economy is a wholly owned subsidiary of Nature. Forgetting this important and often stated relationship can create a policy peril for the business community. In its desire to influence energy legislation that benefits its short-term prosperity, business can lose sight of the goal that benefits business and humanity in the long term. Thus, a power plant might gain more time to pollute on a business-as-usual basis through influencing legislation to allow it to buy cheaper or fewer carbon credits. But, the resulting pollution undermines the more important goal: cutting carbon emissions. Ultimately, we all lose.

The need to cut emissions, however, is now clearly recognized as an important goal by the business sector. Recently, 150 leaders of global companies endorsed the idea of an international, legally binding framework that mandates cuts in GHG emissions globally.[507] A recent analysis of the top 40 global financial institutions show that more than half of them have set emissions reduction targets and are supporting alternative energy projects, while some are adding chief environmental officers to their staff.[508] Another analysis shows that banks worldwide are taking various steps in education, energy efficiency and investment to combat global warming; investments in renewables are now at $100 billion and represents 18% of the power sector.[509] Of course, much more remains to be done. Banks need to be transparent about how they incorporate climate change or carbon costs into their financing and investing decisions. This is especially true when considering energy-intensive projects that could pose financial risk as energy regulations increase.[510]

U.S. Businesses Already Profit in This Brave, New World

As noted in previous chapters, businesses and homeowners profit when they invest in energy efficient appliances, weatherizing, and solar panel installations, which add to the marketability of houses.[511] Existing businesses and government are investing in energy efficiency because they recognize the profit from it. Solara, a 2.5 acre, 56 unit housing complex in San Diego, California, is a good example of a profitable energy efficient housing project.[512] Touted as the largest energy efficient apartment complex in the U.S., it was made for low to middle-income families, and the features are many: enough carport and rooftop solar paneling to meet each unit's needs, natural lighting, energy efficient appliances, tankless water heaters, and edible landscaping. There is also a mandatory educational program for residents and staff on how to maintain the units and grounds. Leases immediately sold out, and there is a long waiting list.

Big Business Dives In

Can big businesses really profit from the transition to clean energy? The proof, of course, is that some have already profited. The sale of the Toyota hybrid Prius helped Toyota pass General Motors in global car sales in 2006.[513] As noted previously, China's first billionaire made his money in solar panels. We've already mentioned Google's energy-saving solar paneled parking lots. Wal-Mart is not only investing in solar panels to cut energy costs at its stores[514] — it is also opening more energy-efficient stores, and is on the way to doubling the fuel efficiency of its trucking fleet by 2015.[515] This is not an act of altruism, but of financial opportunism. Future trends point towards the solar energy industry as a good investment: 2007 marked the first year that more silicon in the U.S. went into solar panels than into computers, and

Silicon Valley entrepreneurs are investing in solar energy.[516] Southern California is becoming a hotspot for the solar energy industry.[517]

Perhaps the industry that has the biggest potential to cash in on the energy transition is the oil industry. These companies have experienced vast profits in the past few years, so they have the resources to invest in solar and wind farms — and stand to make even bigger profits in the future from a clean, sustainable source of energy that will be cheaper than the polluting resource they currently market. As it is, Jan-Peter Onstwedder, until recently a major executive and the most senior risk manager of the oil company BP, notes that oil companies currently spend about $50 billion a year on searching for new oil fields.[518] Burning the carbon contained in the current reserves, however, will warm the planet another 3.5° F. Beyond this threshold lies dangerous climate change, the European Union warns. Given this, Mr. Onstwedder wonders why they continue to search. Indeed, imagine what could be done if they invested $50 billion annually into developing clean energy sources instead!

China Accelerates Its Green Economic Growth

Not waiting for the U.S. to act, China has moved forward significantly on its own. Faced with an ominous picture of the ecological damage it is inflicting on itself through pollution, China is vowing that polluters will pay, and urging its own officials to balance economic growth with environmental concerns.[519] More substantially, its renewable energy industry is applying the same fast-business culture that drives the rest of China's economic engine. Already an exporting solar technology leader, it now is tackling wind power. With tempting wind turbine tariffs in place, China is expected to pass its 2010 wind turbine installation target by 2008, and move towards its 2020 target of 8% of all power coming from renewable energy. It is also laying economic groundwork, having persuaded local and foreign investors to the China Environment Fund to increase its clean energy fund to $250 million. And the message has filtered down to local officials, who are showing an increased interest in renewables projects, according to the director of a group of renewable energy investors, Azure International. Additionally, General Motors had announced that it would be producing a hybrid car in China — one of its major markets, with the model rolling off the assembly lines in time for the Olympics in August 2008.[520] As of October 2008, the authors could not glean from GM whether, in fact, this had actually taken place.

An Answer to Our Current Economic Crisis

In late September 2008, U.S. citizens watched as investment and loan companies started crumbling financially. On September 29, 2008, the stock market took its largest point dive ever, falling an ironically numbered 777.7 points. We watched the President and Congress rush to bolster the market by attempting to allocate $700 billion towards bailing out many of the affected companies. Many citizens had other ideas, and demanded that their representatives not use taxpayer dollars to bailout these failed risktakers.

Deafened by the mainstream media din of all this panic, our leaders might be missing out on a great opportunity here to both save the economy and cool the Earth by listening to a few green voices. "...we must consider environmental impacts to be economic impacts as we move forward," said Friends of the Earth (FOE) President Brent Blackwater.[521] FOE proposed that the U.S. government assume partial ownership of any bailed out companies, and in exchange modify their policies to reflect a redirection towards an energy sustainable future. For example, FOE proposed that the U.S. force the American Insurance Group to halt underwriting of any fossil fuel development endeavors, and concentrate on enabling a clean energy transformation. It also proposed that Fannie Mae and Freddie Mae (mortgage companies) require that an increasing number of the purchases they make be considered “green” in terms of the energy efficiency and sustainability of the building’s structure and location.

Carl Pope, President of the Sierra Club, notes that the bailout price tag of $700 billion is roughly what the U.S. pays for its oil every year.[522] Might not reducing that oil price tag create a higher rate of return for the U.S. Treasury than that of the bailout, through policies that encourage energy efficiency and renewable energy technology? he asks.

Coincidentally, as Wall Street firms started to fail over the last weekend of September 2008, across the U.S. huge rallies called for our government to jump-start a new clean energy economy. The rallying cry of the 100,000 participants was in the events’ title: “Green Jobs Now: A Day to Build the Economy.” Tom Friedman notes that our next president will have to launch an energy technology revolution “with the same urgency as this bailout. Otherwise, all we have done is bought ourselves a respite, not a future.”[523] We will rely more on U.S. creativity and less on foreign credit, he continues. Friedman proposes that we invest the ultimate profits from the bailout into new grid infrastructure or other “green” avenues.

Presidential candidate Barack Obama noted that the price of the bailout might take away his ability to go fully forward with his energy plan.[524] We have striven with this book to show that by shifting policies and subsidies he can pursue an effective energy plan without a net increase in governmental expenditures. The message is spreading to all of our society, backed by the studies of economists and scientists: Cooling the Earth WILL save our economy. But what if we don’t act to “green our economy”?

The Risks of Not Joining the Green Economy

Not only do companies have a great deal to gain by joining, if not leading, the energy transition, they have much to lose if we do not make the transition to a low-carb energy diet, and thus do not curb global warming. Some companies will suffer directly, and relatively soon, from the climate crisis, such as ski resorts.[525] Sea level rise will bring destruction to coastal beach resort owners. The rise will also cause incalculable damage to urban infrastructure, such as port facilities and industrial facilities that use cooling water from the sea. Some firms will find their operating costs rising as they require more and more air conditioning due to more frequent and intense heat waves, and pay more and more for the electricity to provide it. If the rest of the world passes tight auto-efficiency standards and we do not, then foreign auto markets will be closed to our manufacturers of gas guzzlers, and both company executives and workers will suffer. And all businesses stand to lose in myriad ways from flooding, drought and wildfires.

Perhaps the real question to ask is: what are the risks of the U.S. *not* investing in the transition to a clean energy economy? As noted above, the rest of the world is. Developing countries already have tariffs protecting their emerging clean energy industries, and the global export industry for the technology has grown at an annual rate of 15% since 2000. The U.S. is already trying to negotiate a decrease of those tariffs, recognizing the market potential. General Electric does. About 9% of General Electric's sales in 2007, for example, were those of clean technology, its fastest growing sector. Caterpillar Inc. successfully negotiated a lower Chinese tariff on its methane generators. These generators produce energy from methane emissions from mines and emit the less potent greenhouse gas, carbon dioxide.[526] So, the real risk is that U.S. companies could lose out to the international competition for the lucrative clean energy technology market developing globally. Nobel laureate and head of the IPCC Rajendra Pachauri concurs, noting that those companies and countries that do not take the lead in the direction of a low-carbon future will be left behind.[527]

The means to profit from this new transition is limited only by human imagination. But if we let global warming damage enough of our infrastructure, global warming itself could limit our profits in the future. It doesn't have to be that way. And this leads us to one of the most important ways that we can forge the change necessary.

Chapter 11: Vote Like Your Life Depended on It

As we write this, in the autumn of 2008, the largest obstacle to reining in global warming in the United States is lack of political vision and leadership. And since the U.S., the wealthiest nation on the planet, is viewed as a model for many other countries, what we do reverberates around the world. Politicians are more likely to address global warming when they recognize that they are in danger of losing their jobs. And they will recognize this only when the voter recognizes that our country is in danger from global warming, and decides it’s time to do something about it.

Needed: A Bold Leader with Good Green Judgment

We should do all we can as individuals to cut down on carbon emissions. But this will not significantly address the problem if we don’t collectively elect leaders that can address the problem boldly, urgently, and effectively on a large scale. The climate crisis is an illustration of how we are in a conflict with nature — one that we cannot win by force, but must resolve. And, unlike social conflicts, this one cannot be negotiated. Thus, we need leaders at all levels whose judgment and vision are not muddied by the political urge to please the polls or the biggest donors to their campaigns, and who can forcefully articulate to the public a bold, intelligent vision for the transition to a clean, affordable, and sustainable energy economy.

Ultimately, we need leaders who will mobilize the government and the electorate to participate fully in this transition, as quickly and as intensely as possible. We, as voters, must demand that our media and our politicians make this a top issue in our elections and in our legislation — at least on a par with national security, the economy, and health care, all of which hinge on our solving our energy and climate problems.

The good news is that the issue is gaining political headway. Both of the 2008 major presidential candidates recognize that global warming is an important issue that will have to be addressed by the next president. They are hearing that global warming is one of the major issues that voters bring up when meeting with them along the campaign trail. And the candidates have presented detailed plans of how to address the problem through federal energy policy. But the plans differ substantially, and now it's time to analyze them.[528] Find out if they are talking about palm oil or CAFE standards, clean coal or solar energy. Are they pushing drilling for oil and nuclear energy more than renewable energy sources? There are real differences here.

The Sleeping Top Political Priority

You might not believe that global warming should be a top priority. Perhaps you are unemployed or struggling economically, and looking for the leaders that you think will improve the economy most effectively. So, you put this priority ahead of global warming. In reality, they are the same priority. By effectively addressing global warming, we are pursuing the best possible course for warding off economic disasters from climate change now, and opening up new vistas of economic opportunity for our economy, as pointed out in Chapter 10 and previous chapters.

Perhaps you are swayed by a political party's stand on abortion or homosexuality. Both of these issues affect segments of our society — but the climate crisis affects, in the vernacular of Christian faiths, all of God's creation, and all of God's human family, as noted by the U.S. Catholic Bishops in Chapter 7, and supported by Evangelical and other religious faiths. The ramifications of the climate crisis engulf the unborn, and all people of all sexual orientations. If we allow our society to be devastated by the consequences of global warming, the importance of abortion and homosexuality will be drowned out by the desperation of billions simply trying to survive. Thus, even for those people concerned with these issues, our candidates' positions on addressing our climate crisis should be a top priority.

Vote for Green Leaders at ALL Levels

Voting for the right presidential candidate is important, but this is not enough. Congress plays a huge role in shaping and passing legislation that drives our policies. Good energy legislation in 2007 was made less effective, because the consent of 60 of the 100 senators in the Senate could not be mustered to pass the legislation in its most effective form. Many, for example, didn't want to end unnecessary subsidies to oil companies, who have profited the most from marketing a potent greenhouse gas-emitting source. So, we should be judging our candidates and politicians at ALL electoral levels on their knowledge of global warming, its problems and solutions. This includes judging the incumbents' and candidates' ideas of how to build a coherent, timely effort to address the climate crisis and how to export it, and how committed they really are to addressing the problem. Bucking fossil fuel lobbyists will require real political courage and determination.

Also check out where your candidates for governor and other state offices stand on solving the climate crisis. If your community is big enough, it should even come up as an issue at the mayoral and city council level. Once you know their positions and records, vote accordingly. Nothing less than the welfare of your descendants depends on it.

More Ways to Support Your Democracy

What to do when not actually voting? In the political arena, you can institute change in many ways. One is to become a true patriot and get involved with your democracy. Turn up at events where you get to question candidates and ask questions. A good one is, “Science informs us that the U.S. is going to have to reduce current annual carbon dioxide emissions to 25% of their current levels by the year 2030 to prevent catastrophic global warming. What do you plan to do to help our nation achieve this goal?” If the candidate can outline a good, plausible plan of what they will do, and displays a track record that indicates they would invoke this plan, help to elect them. Several candidates already have outlined climate plans; find out whether and where they have their plans on the internet, and critically review them.[529]

Demand that your current leaders at all levels of government address the problems of the climate crisis at the public policy level with effective legislation. Legislation should promote no-carb renewable energy, and better land use policies, such as conserving forested areas and discouraging urban sprawl, which decreases efficient use of public energy, as in municipal lighting. Demand that they take a leading role in the world to promote renewable clean energy sources, as well as improved efficiency to decrease global warming gas emissions everywhere. This is not a trivial point. China is starting to accelerate its carbon emissions as it seeks a higher standard of living for its citizens. The increasing flow of other pollutants emitted from its coal-fired smoke stacks reach us, like a perpetual storm, 5-10 days after being emitted.[530]

Vote out the politicians who don’t address the climate crisis effectively at their government level, and promote the ones who do. Support organizations that promote these green candidates. Join organizations that are pressuring our leaders to do something to reduce CO_2 emissions effectively. Step It Up 2007 has helped organize thousands of people and events.[531] Support the election process by volunteering to be a poll worker on a voting day. Become an activist and communicate with your representatives about which legislation you want them to promote or discourage. At the community level, get active: promote economic enterprises that help eliminate global warming and protest those that exacerbate it to your local leaders.

* * *

So, now we know: the enemy is us. But the choice is also up to us, and the sooner we start addressing the climate crisis boldly, urgently and seriously, the easier it is going to be to stop it.

A Time to Imagine

What would this new world of energy security look like? In the U.S., imagine each family creating enough energy to be independent of, or adding to, the national energy grid. Imagine each family not having to choose between feeding themselves or warming themselves. Imagine no American dying of excessive cold or heat. Imagine clear, smog-free skies, fine architecture free of grime, and clean, convenient public transport. Imagine children without asthma, and healthy elderly being able to roam freely outside without the threat of sickening pollution. Imagine your great grandchildren seeing polar bears in the wild, and the tropical forests full of brilliantly colored butterflies, beautiful furtive animals and botanical treasures, uncut and unburnt, far into the future. Imagine federal revenues, freed from protecting foreign energy sources, being devoted to education, health care, and social security for all.

Imagine a nation united by the hope and opportunity that clean energy provides, rather than by fear of unimagined destruction from intensifying global warming. Imagine a world free of foreign energy wars. Imagine… Now let's get to work.

Appendices: Let's Do the Numbers...and More!

If math makes you cry, don't read further. If it simply makes you wince a bit, you'll make it through the following units section. The main part is meant for the people who have not only a moderate ability in math, but a curiosity as well. It's for the people who, when reading through the chapters and coming across a table of figures or a statement based on a calculation, think, "Now how did they come up with THIS?" For those of you in this category, read on.

Explanation of Units Used in the Appendices

We try to use the units that people in the U.S. are most familiar with but occasionally we use metric units. Here we explain the relationships between these two types of units in so far as they are needed in the calculations that follow in Appendices A-C.

In some cases, it won't matter much which type of unit we use. For example, we express carbon emissions in units of tons of carbon per year. An English ton is 2,000 pounds, whereas a metric ton is 1,000 kilograms. Because a kilogram is 2.2 pounds, the two types of tons are the same to within 10%, and often the uncertainty in an estimated number of tons of carbon exceeds the difference between the two types of units. So, for our purposes here, we don't distinguish the English from the metric ton. Remember, also, that if you want to convert tons of carbon into tons of carbon dioxide, multiply the tons of carbon by 3.67.

We express areas of land in square meters (m^2) or square kilometers (km^2). Where we use "square meters", think "square yards", for they are the same to within about 10%. Where we use "square kilometers", keep in mind that a square mile (mi^2) contains about 2.6 square kilometers, so a square kilometer is about 1/2.6, or about 0.4 square miles, or in abbreviated units, 1 $km^2 \approx 0.4$ mi^2.

Readers are probably least familiar with energy-related units, such as those used to describe electric power, or the energy content of gasoline, or any other units that quantify energy supply and demand. So before we get to the calculations, let's review the units such as kilowatts or joules that frequently crop up in discussions of energy supply and demand.

Consider a 40-watt light bulb. When it is on, it is consuming energy at a rate of 40 watts. A watt is a basic unit of power, or equivalently a unit expressing the rate of flow of energy. Energy itself is frequently measured using the unit of "joule." The relation between the two is simple:

1 watt = 1 joule per second

Please note that this expression is simply a relationship between two definitions.

Suppose a 40-watt light bulb is on for 1 hour. An hour contains 3600 seconds, and so we can work out how much energy the bulb consumes during that hour:

40 joules/second x 3600 seconds = 14,400 joules of energy

To gain a sense of the size of the energy unit joule, it takes about 2.5 million joules of energy in the form of heat to bring 1 quart of water to a boil.

You can see that we often will have to deal with large numbers of joules, and so we use exponential notation. For example:

1 billion joules = 1,000,000,000 joules = 10^9 joules

1 thousand watts = 1,000 watts = 10^3 watts

[Remember that negative exponents refer to fractions of 1: 1/100 = 10^{-2}, for example.]

And to slightly simplify matters, we introduce prefixes for expressing big quantities:

10^3 watts = 1 thousand watts = 1 kilowatt

10^6 watts = 1 million watts = 1 megawatt

10^9 watts = 1 billion watts = 1 gigawatt

Note that “giga ” is used for billion.

We can invert the definition given above that states: “1 watt = 1 joule per second” and deduce that

1 joule of energy = 1 watt x 1 second.

Often we refer to “1 watt x 1 second” as 1 watt-second. If you look at your monthly electricity bill, you will see the energy unit “kilowatt-hour”, which is often abbreviated “kWh”. Let’s see how much energy a kWh is:

1 kWh = 1 kilowatt x 1 hour = 10^3 watts x 3,600 seconds

= 3.6 x 10^6 watt seconds

= 3.6 x 10^6 joules

From what we’ve explained above, you should be able to see why

1 gWh = 1 billion watts x 1 hour = 3.6 x 10^{12} joules

Next, let’s look at the energy content of fuels, such as gasoline. Here we usually consider the number of joules released when some convenient quantity of fuel is burned:

1 gallon of gasoline releases 0.015 x 10^{10} joules = 1.5 x 10^8 joules

1 ton of coal releases about 3 x 10^{10} joules

1 ton of dry wood releases about 1.5 x 10^{10} joules

Finally, let’s look at the amount of energy in sunlight. The Sun provides a flow of energy to the Earth and so it is natural to talk about the amount of power in sunlight. Consider an average square yard or meter of Earth’s surface. If we average over day and night and over the four seasons the sunlight striking that square, we find a flow of energy equal to about 170 watts. Because a year contains about 3 x 10^7 seconds (60 seconds x 60 minutes x 24 hours x 365 days ~ 3 x 10^7), each year the sunlight striking an average square yard of Earth’s surface contains about

(170 watts/square meter) x (3 x 10^7 seconds/year)
≈ 5 x 10^9 joules of solar energy per square meter per year

Recalling the energy content of gasoline, we see that the annual solar energy on a square meter is roughly equal to the energy content of 33 gallons of gasoline.[532]

A. Calculating the Carbon Consequences of the EASY Plan

Here we show the calculations that lead us to the estimated carbon emissions in 2007 and 2030 as portrayed in Figure 3.1 in Chapter 3.

A.1. Electricity. To work out the carbon emissions from electricity production today and in 2030, we consider a unit (1 kWh) of electricity production, so that the reader can then work out the answer for any amount of electricity production. We have seen that a kWh of electricity has an energy content of 3.6×10^6 joules. A modern coal-fired electric generation plant has an efficiency of about 40%, so that production of a unit of electric energy requires 2.5 units of thermal energy — roughly what you get from about a cup of coal. Hence, we need $3.6 \times 10^6 \times 2.5 = 9 \times 10^6$ joules of King penguins population threatened by southern ocean thermal energy. Recalling that the energy content of coal is 3×10^{10} joules/ton, we learn that the production of a kWh of electricity requires about

$$(9 \times 10^6 \text{ joules/kWh}) / (3 \times 10^{10} \text{ joules/ton of coal}) \approx 3 \times 10^{-4} \text{ tons of coal /kWh}$$

Coal is about 75% carbon, and 90% or more of that carbon forms CO_2 when the coal is burned, so electricity production emits carbon dioxide at approximately:

$$0.75 \times 0.90 \times 3 \times 10^{-4} \approx \mathbf{2 \times 10^{-4}} \textbf{ tons(C) from coal per kWh}$$

Similarly, when the following are burned, the carbon dioxide emissions are

$$\mathbf{1.5\ kg \times 10^{-4}} \textbf{ tons(C) from oil per kWh}$$

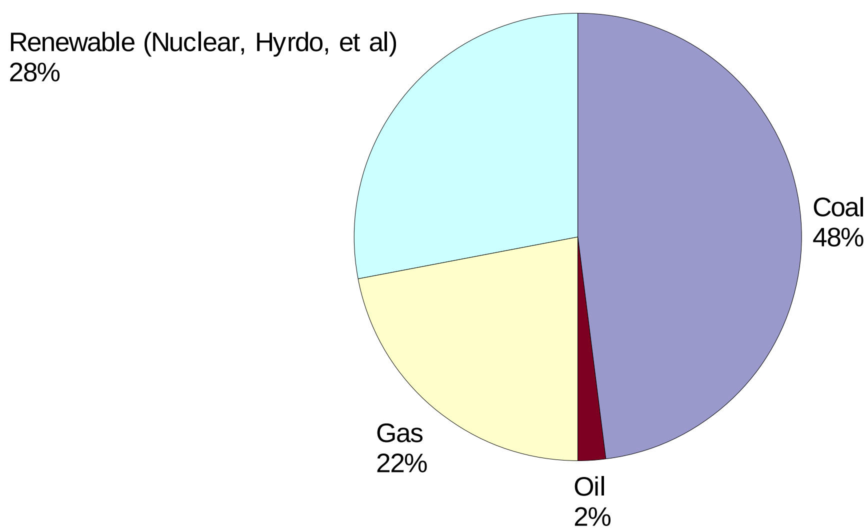
and

$$\mathbf{1 \times 10^{-4}} \textbf{ tons(C) from natural gas per kWh}$$

As we can see above, burning oil and natural gas results in lower emissions of CO_2 than from burning coal. We will ignore the relatively small amounts of carbon dioxide that result from building and operating nuclear, hydroelectric, solar and geothermal facilities.

Today we consume about 4 x 10^{12} kWh/year of electricity and it is derived in the following approximate proportions from these sources:

Energy Sources for U.S. Electricity 2007[533]



These proportions result in the value of 0.52 billion tons(C) /year as shown in Figure 3.1 in Chapter 3. If the electricity produced by nuclear, hydroelectric (hydro), and solar sources today were instead produced with fossil fuels in the same proportions as above, then an extra 0.13 billion tons(C) /year would be emitted, which in Figure 3.1 is the green rectangle in the electricity bar for the year 2007.

Under EASY, there will be reduced electricity demand because of gains in efficiency and changing consumer behavior, which we assume will result in a savings of 2 x 10^{12} kWh /year. If these savings result in less coal consumption, the reduction in carbon emissions is 0.4 billion tons(C)/year, as shown in Figure 3.1. But there will also be population growth and an increase in demand for electricity to charge plug-in hybrids and all-electric vehicles, which we assume will add 2.5×10^{12} kWh/year of new demand (see Appendix A.2), resulting in a total demand for electricity of $4 - 2 + 2.5 = 4.5 \times 10^{12}$ kWh/year. Assuming that nuclear and hydro production remains constant at roughly 1×10^{12} kWh/year, and that the remaining electricity demand of 3.5×10^{12} kWh/year is produced from fossil fuels, carbon emissions would soar to nearly 0.6 billion tons(C)/year. But under EASY, that demand will be met with solar and wind power and a small amount of geothermal. Thus, the additional renewable energy contribution to electricity production in 2030 saves 0.6 billion tons(C) as shown in Figure 3.1 and there is no carbon emissions from electricity production in 2030.

A.2 Transportation. In 2007, U.S. automobile and light truck transportation consumed the equivalent of 140 billion gallons of gasoline. Burning roughly 350 gallons of gasoline produces a quantity of carbon dioxide that contains one ton of carbon, and so 140 billion gallons produces $140/350 \times 10^9 = 0.4$ billion tons(C). Adding in the roughly 0.12 billion tons(C)/year for heavy trucking and aircraft and we obtain 0.52 billion tons(C) as shown in Figure 3.1 in Chapter 3. Under business-as-usual, we estimate that because of extra miles driven by a larger population, roughly 170 billion gallons/year of gasoline would be required for automobile and light truck transportation in 2030, which would produce 0.48 billion tons(C) in that year. Adding in a 25% increase from the transport trucking and aircraft sectors brings carbon emissions from those sectors to 0.15 billion tons(C)/year, we obtain 0.48 + 0.15 = 0.63 billion tons(C)/year as shown in Figure 3.1.

To calculate the 2030 carbon emissions from transportation under the EASY plan, we assume that increased car-pooling and other life-style changes — the Y of EASY (see Chapter 7) — and mass transit brings total fuel requirements for cars, SUVs and light trucks down from 170 billion gallons/year to 150 billion gallons/year, saving 0.06 billion tons(C)/year. Next, let’s look at the effect of improving vehicle efficiency. Today’s vehicles achieve an average fuel efficiency of approximately 20 mpg and propel us a total of nearly 3 trillion miles each year. We will assume that by 2030, all cars, SUVs, and light trucks are plug-in hybrids achieving a minimum of 60 mpg, which will raise the demand for electricity to recharge batteries, but at the same time increase liquid fuel efficiency to a minimum of 60 mpg and probably higher. After adjusting for reduced vehicle mileage because of life style changes and mass transit, we will be driving about 3.2×10^{12} miles. With current vehicles, we would be consuming

$$(3.2 \times 10^{12} \text{ miles}) / (20 \text{ miles/gallon}) = 160 \text{ billion gallons per year.}$$

At 60 mpg, this becomes

$$(3.2 \times 10^{12} \text{ miles})/60 \text{ mpg} = 54 \text{ billion gallons per year,}$$

and the savings becomes 160 – 54 = 106 billion gallons of liquid fuel per year. In carbon units, this is a savings of

$$(106 \times 10^{9} \text{ gallons/year}) / (350 \text{ gallons/ton(C)}) = 0.3 \text{ billion tons(C)/year}$$

Adding in the 0.06 billion tons(C) from the Y of EASY and from mass transit, we get a grand total savings in the transportation sector of 0.36 billion tons(C)/year. Hence, with these advances, total carbon emissions from transportation in 2030, will become

$$0.63 \text{ billion tons(C)/year} - 0.36 \text{ billion tons(C)/year} = 0.27 \text{ billion tons(C)/year.}$$

The share of those emissions resulting from heavy trucks and aircraft is 0.15 billion tons(C)/year. Large efficiency gains are less likely there, but if industry does develop the technological capacity to convert cellulose to a transportation fuel that could be used for heavy trucks and aircraft, then emissions will be substantially lower. We assume in the EASY plan that roughly half of the remaining fuel needs in the car, light truck, heavy truck, and aircraft sectors will, indeed, be satisfied with biofuels, and that as a result the total demand for petroleum-based fuels will be ~ 50×10^{9} gallons/

year in 2030. This then results in carbon emissions from the transportation sector of

$$(50 \times 10^9 \text{ gallons/year}) /(350 \text{ gallons/ton(C)}) = 0.14 \text{ billion tons(C)/year}$$

as shown in Figure 3.1 for 2030.

Note that if we switch to all-electric vehicles and if the electricity to supply these vehicles comes from sunlight or wind, then they would be emitting no carbon dioxide at all and the savings would be even greater.

A.3. Heat for residential, commercial, and industrial sectors. Total fossil-fuel-based energy consumption in these sectors in 2007 was about 18 trillion cubic feet of natural gas, 50 billion gallons of oil, and 0.12 billion tons of coal, yielding an amount of energy from each fuel equal to approximately 15×10^{18} joules, 11×10^{18} joules, and 4×10^{18} joules/year respectively. Taking into account the different yields of carbon dioxide per unit of energy derived from burning each of these fuels (see Appendix C, Question 6), natural gas, oil, and coal (mostly for industrial heat) contribute to carbon emission in the proportions of roughly 5:4:2. We assume in EASY that by 2030 oil is completely phased out in these sectors, coal use is halved, and natural gas use is reduced by 10%, leaving us with carbon emissions from gas and coal in the proportion of about 8:1. Moreover, we assume that total fossil fuel use is also halved due to increased energy efficiency (the E of EASY, Chapter 4).

B. Estimating the Economic Costs in Table 3.1

B.1. The electricity production sector. As noted above, we are assuming, conservatively, that the U.S. annual electrical demand would have increased from the current annual level of about 5×10^{12} kWh/year to approximately 6×10^{12} kWh/year by 2030 under "business-as-usual." Under EASY, there will be reduced demand because of gains in efficiency and changing consumer behavior, which we assume will result in a savings of 3×10^{12} kWh/year. But there will also be increased electric demand for recharging plug-in hybrids, which we estimate to be approximately 1.6×10^{12} kWh/year. If this additional generating capacity were to be produced from fossil fuel combustion, it would generate approximately 0.2 billion tons(C)/year, but in EASY it is produced from clean renewable electricity generation with virtually no carbon emissions. Thus the total amount of renewable energy capacity to be installed by 2030 must supply approximately

$$6 + 1.6 - 3 = 4.6 \times 10^{12} \text{ kWh/year.}$$

We assume that conventional fossil fuel-generated electricity costs \$0.06/kWh and that this cost will remain constant from now until 2030. Under business-as-usual, and assuming capacity ramps up steadily from 5×10^{12} kWh/year to 6×10^{12} kWh/year by 2030, the **total cost for conventional electricity** will be:

$$(5.5 \times 10^{12} \text{ kWh/year}) \times 22 \text{ years} \times \$0.06/\text{kWh} = \mathbf{\$7.3\ trillion}.$$

For the purpose of this calculation we assume that, under the EASY plan, by the year 2030 rooftop photovoltaics, wind, and central station solar thermal will provide 30%, 40% and 30% of the total new renewable generating capacity. The actual percentages will be determined by market forces and are difficult to predict, so this breakdown is intended to be illustrative. We also assume that conventional fossil-fuel generated electricity steadily declines to zero by 2030 (and that the relatively small contributions made by nuclear, hydro, and geothermal are as stated in Appendix A.1). The **total cost of** fossil-fuel generated **residual conventional electricity** between now and 2030 then becomes the average of the costs of the 2007 and 2030 end points — that is, half of the $7.3 trillion, or **$3.7 trillion.**

Today, the cost of a kilowatt of rooftop solar energy is about $15,000 per installed kilowatt; the trend in cost has been significantly downward and the industry goal over the coming decades is to reduce the cost to approximately $1,000 per kilowatt. We will, conservatively, assume an average cost between now and 2030 of $10,000 per kilowatt. This cost reduction will occur not only because of industrial innovation, as in the past, but also because in the EASY plan, distributors and installers of solar panels will have greatly reduced taxes on their profits (see Chapter 9). The EASY plan calls for the installation on home and commercial space rooftops of 160 million kilowatts of power between now and 2030. So the **total cost for photovoltaic roof panels** will be

$$160 \times 10^{6} \text{ kilowatts} \times \$10^{4}/\text{kilowatt} = \$1.6 \times 10^{12} = \mathbf{\$1.6\ trillion}.$$

The current cost of wind power is about $0.06/kWh and of solar thermal is about $0.14/kWh, so we take an average of $0.10/kWh for the remaining (non-rooftop) power generation. We further assume that deployment of these technologies will ramp up steadily between now and 2030, in which year these technologies will supply 70% of the total demand for clean energy electricity:

$$0.70 \times 4.6 \times 10^{12} = 3.2 \times 10^{12} \text{ kWh}$$

We multiply this by the average cost of clean energy to calculate an annual cost that year of:

$$(3.2 \times 10^{12} \text{ kWh}) \times (\$0.10/\text{kWh}) = \$3.2 \times 10^{11}.$$

Under the ramp-up assumption this means that the **total cost of solar thermal and wind power** over 22 years will be

$$(\$3.2 \times 10^{11})/2 \times 22 \text{ years} = \mathbf{\$3.5 \times 10^{12} = \$3.5 \text{ trillion.}}$$

We realize this calculation greatly oversimplifies the economics. In part, we have assumed that the price of fossil fuels and solar energy will remain constant. Furthermore we have ignored the economic discount rate, which values the money spent today more than the same amount of money spent in the future. These simplifying assumptions tend to skew our answers to favor the business-as-usual plan because if price changes occur, they are most likely to increase for fossil fuels and decrease for solar and wind energy. Moreover, because we're ramping up clean energy costs and ramping down fossil fuel costs, the actual future costs of solar and wind energy, when taking into account the economic discount rate, are not as much as they appear to be: we're spending more valuable money now on using fossil fuels, and less valuable money in the future on solar and wind energy.

B.2. The direct cost of efficient appliances and other devices. The dollar benefit of the energy savings that accrues from the use of more efficient appliances and other devices is already included in Table 3.1 in the rows describing energy costs. Here we estimate the added cost to the consumer between now and 2030 to buy the more efficient items that lower energy demand.

Conventional and hybrid car costs: Let's assume an average conventional car price of $20,000. Hybrid cars currently average an extra $4,000 — sticker shock, it's called. Let's assume that there are roughly 100 million (or 10^8) owners, and that they'll buy a new car every nine years or so — say, 2.5 cars over 22 years. The **cost of** buying regular cars, i.e., **conventional cars**, under business-as-usual becomes:

$$(\$20{,}000/\text{car}) \times 10^8 \times 2.5 \text{ cars} = \$4.5 \times 10^{12} = \mathbf{\$4.5 \text{ trillion,}}$$

while the **cost for hybrids** becomes:

$$\$24{,}000 \text{ car} \times 10^8 \times 2.5 \text{ cars} = \$6 \times 10^{12} = \mathbf{\$6 \text{ trillion.}}$$

Other appliances and devices: Lighting: Conventional incandescent bulbs typically cost about $0.50 apiece, while compact fluorescent bulbs (CFLs) cost about $5.00 apiece. On the other hand, a typical incandescent lasts for 1000 hours of use, while the energy-saving bulbs last for 10,000 hours of use. Hence the lifetime cost of the two types of bulbs are roughly equal and so there is no net increase in cost when buying CFLs rather than standard bulbs.

Refrigerators, air conditioners, dish washers, clothes washers and dryers, etc.: The brands of efficient appliances that are assumed in the electricity demand calculations typically cost the consumer from $50 to $200 more than poor-efficiency brands. We assume that 80 million households in the U.S. will each buy ten such devices between now and 2030, and the added cost per device will be $100. Then the total cost for energy efficient appliances is 10 x (80 x 10^6) x $100 = $0.08 trillion. We assume that each device will, on average, cost $500. So, roughly speaking, the **total cost of conventional appliances and devices will be**

$500 x (10 devices/household) x (80 x 10^6 households) = about **$0.4 trillion**

and **the total cost of efficient devices** about **$0.48 trillion.**

B.3. Oil & coal federal subsidies. Calculating this is an exercise in extreme complexity, since it involves taking into account all sorts of tax breaks, user fees, and other manipulations; a recent book prepared for and published by the Organization for Economic Co-operation and Development gives an estimate of $50 billion per year with a breakdown of roughly $40 billion for oil and $10 billion for coal, although it admits that estimates range up to 100 billion.[1] Let’s take the conservative estimate of $50 billion and multiply it by 22 years for **business-as-usual:**

$50 billion x 22 years = **$1.1 trillion**

Under the EASY plan, coal use will be virtually zero, and oil will have been reduced to about one third or 33% — and let's assume that so will necessary subsidies.

That leaves a remaining subsidy level by 2030 of: 0.33 x $40 billion x 22 years = $0.3 trillion. As in other calculations for the **EASY plan**, we'll take the average of this and the 2007 estimate, $1.1 trillion, to reflect the investment costs gradually decreasing over 22 years:

($1.1 trillion + $0.3 trillion) / 2 = **$0.7 trillion**

B.4. Reimbursement of construction costs for coal power plants closed before their standard lifetime elapses. Under the EASY plan, existing coal-fired fossil fuel plants will be shut down before their assumed lifetime has elapsed. Reimbursements to investors who paid for the up-front cost of construction of the plants can be estimated. A rough estimate of the cost of reimbursement can be obtained from the per-kilowatt sunken cost of such a plant. While a detailed calculation cannot be performed without examining actual ages and assumed lifetimes of the hundreds of such plants, we can get a ballpark figure by assuming 20 years of cancelled generation per power plant.

The total annual U.S. consumption of electricity is about 6 x 10^8 kW, of which coal is responsible for about half.[534] Thus, multiplying the average lost sunken cost[535] of $650/kW by (3 x 10^8) kW of the U.S. coal-fired capacity yields **a total amount owed investors** of approximately

$650/kW x (3 x 10^8 kW) = **$200 billion** at present value.

Under the EASY plan nuclear powered electric generation plants will not be phased out before their assumed lifetime elapses, so their much larger sunken cost of approximately $2,100/kW need not be considered. Similarly, the smaller per-kW sunken costs associated with gas turbine plants will be ignored because most such plants will be needed to meet demand while our renewable options are entering production. From this exercise we can conclude that the amount of money owed investors because of early retirement of existing power plants is a very small addition to the overall balance sheet, amounting to less than 1% of the total cost of the EASY plan (0.2 trillion/22 trillion).

B.5. Funds needed to retrain coal workers. There are about 100,000 coal workers in the U.S. Let's assume retraining takes 2 years, that it costs $10,000 per year for each worker, and that each is also given a salary of $50,000 per year during training, to retrain them for other jobs (such as installing solar panels or manufacturing more energy efficient devices). The total cost of retraining is then $120,000 for each worker and the total **retraining cost** is then:

10^5 workers x (\$1.2 x 10^5/worker) = **\$ 0.012 trillion.**

B.6. Oil for transportation. Currently, the U.S. consumes 140 billion gallons of oil-based fuels each year at a cost of approximately $3 per gallon. Assuming the price stays fixed, and ignoring growth in population and per-capita miles driven, even though costs and consumption would surely rise above that price in the next 22 years as supplies dwindle, a conservative estimate for the total cost of fueling transportation under **business-as-usual** for the next 22 years would be then:

(140 x 10^9 gallons/yr) x \$3/gallon x 22 years = **\$9.2 trillion.**

The EASY plan would decrease consumption of oil by at least 75% by 2030 (with the actual value dependent on the ratio of all-electric to plug-in hybrid vehicles on the road at that time), but since it will happen gradually, we must take an average decrease of ½ x 75% leaving us with a need over the next 22 years of

(100% - 37.5%) x \$9.2 trillion = **\$5.8 trillion.**

Addendum: **Military expenditures for protecting overseas oil sources.**

Based on requests for war expenditures for Iraq for 2007, let's assume an annual expenditure of $\$200 \times 10^9$ and multiply that by 22 yrs:

$$(\$200 \times 10^9)/\text{year} \times 22 \text{ years} = \$4.4 \text{ trillion.}$$

But let's be hopeful and say it'll only be **$4 trillion.** As we ramp down from $4 trillion in 2007 to zero in 2030, we will take the average of the two numbers to come up with the **Residual Military expenditure, $2 trillion.**

C. Miscellaneous Calculations

C.1. How many tons of CO_2 emissions would be saved each year by using compact fluorescent light bulbs just in all U.S. homes? Assume that each of the ~80 million residences in the U.S. has thirty 75 watt light bulbs that are on for three hours per day. If you prefer different assumptions you can scale our answer up or down as you please. Over the 365 days of the year our assumptions imply a total yearly electricity usage for that lighting of:

365 days/year x 75 watts/bulb x 30 bulbs/residence x 80 x 10^6 residences x 3 hours/day

$$= 19.8 \times 10^{10} \text{ kWh/year.}$$

If the bulbs are replaced by compact fluorescent ones consuming only 20 watts, then the energy consumption is 20/75 of the above, or 5.3 x 10^{10} kWh/year, and the savings are:

$$19.8 \times 10^{10} - 5.3 \times 10^{10} = 14.5 \times 10^{10} \text{ kWh/year.}$$

Using the figure from Appendix A.1 of 2 x 10^{-4} tons(C) per kWh of electricity produced from coal, and assuming the saved electricity results in saved coal, switching bulbs reduces carbon emissions by about 0.03 billion tons(C) per year. This would reduce current total U.S. carbon emissions by about 2%. Adding in commercial- and public-space lighting would save roughly another 2%. Of course, if the electricity that is saved had been produced by hydro or nuclear power, then there would be no carbon savings.

C.2. How many people are needed to install solar panels on all U.S. roofs by 2030? Assume 60 million homes are to have solar panels installed on their roofs over the 20 years from 2010 to 2030. That amounts to three million roofs per year, or assuming a 50-week year, 60,000 roofs per week. It takes three workers a week to do a roof. Hence we need a labor force of about

3 workers/week-roof x 60,000 roofs/week = **180,000 workers**.

C.3. How much land would have to be devoted to solar or to wind farms to meet the 2030 electricity demand in the U.S.? From Appendix A.1, we need to generate approximately 3.5 x 10^{12} kWh/year of electricity from solar, wind, and geothermal. Because there are 24 x 365 hours in a year, that is equivalent to an installed effective generating capacity of 400 million kilowatts. Suppose as an extreme case none of it is generated by wind and geothermal, so that only rooftop solar and central-station solar "farms" meet this demand. First, let's see how much of it could be produced from rooftops. Typical homes with today's rooftop solar panels (our own, for example) produce electricity at an average rate of about 1.4 kilowatts. If solar panels are installed on 60 million private homes in the US, we obtain 84 million kilowatts from our roofs. Further, assuming that half again as much is produced on commercial- and public-space roofs, we then have a remaining need for 400 - 84 - 42 = 274 million kilowatts.

How much land will be required to produce these remaining 274 million kilowatts? Let's assume that we locate our solar farms in really sunny places in the southwest, where average solar flux easily exceeds 200 watts per square meter. Although panels can achieve 25% efficiency under ideal conditions, we will assume a real-world efficiency of 15% and we take a lower estimate of 200 watts per square meter from the sun. Then we need (274 x 10^6 kilowatts) / (0.15 x 200 watts/square meter) = 9000 square kilometers or 3500 square miles. However, the actual land requirement will be as much as twice this to account for access roads and other facilities, so, conservatively, we require 7,000 square miles. How much area is that? It is approximately two and a half times the combined areas of just the U.S. military's Yuma and Dugway Proving Grounds (roughly 1500 and 1300 square miles, respectively) for testing weapons in Arizona and Utah. Expressed differently, it is **a little more than 5% of the land area of either Arizona or Nevada.**

Wind-generated electricity requires about twice as much land as solar photovoltaics or solar thermal because of the need to leave adequate space between wind turbines. Hence we require about 14,000 square miles of land if we are to meet all the 2030 non-rooftop-generated electricity from wind power.

C.4. How many Iowas are needed for enough biofuel production to fuel our cars?

Current U.S. gasoline consumption for all categories of vehicle = 140 billion gallons/year.

This yearly gasoline consumption has an energy content of 3 x 10^{19} joules. Equivalently, U.S. transportation consumes power at a level of 1 trillion watts.

On very productive land, with plenty of water, fertilizer, pesticides, and herbicides, corn can convert sunlight to chemical energy, averaged over the year, at an efficiency of around 1%. Annually averaged solar flux at the ground in the U.S. is about 170 watts per square meter.

At 1% conversion efficiency, this yields 1.7 watts per square meter. So obtaining 1 trillion watts requires

$$10^{12} \text{ watts}/\ 1.7 \text{ watts/m}^2 = 600 \text{ billion square meters}$$
$$= 600{,}000 \text{ km}^2 \text{ or } 232{,}000 \text{ square miles}$$

of very fertile land. This is six Iowas! But to grow, transport, and process the corn, we need 75% or more extra energy than what we derive from the corn. Hence, for every Iowa on which we produce ethanol, we need three more

Iowas to grow the corn to produce the energy to produce the ethanol from the first Iowa. **So altogether we need 24 Iowas.**

Note: If we cut transportation fuel use down to a third of current use (with more efficient vehicles averaging at least 60 mpg) and develop a way to derive ethanol or other fuels from cellulose, we can use Miscanthus grass or switch grass to provide the biomass and we could probably get by with one Iowa. There are three ways in which we save:

1. it takes less energy to grow miscanthus or switchgrass than it does to grow corn (perhaps one third of the amount needed for the same area of corn);
2. cellulose conversion, if it is attainable, would allow use of nearly all of the plant, rather than just the starch and sugar, leading up to a tripling in yield; and
3. we will need less fuel if we achieve the fuel efficiency standard (one third as much as today).

This gives an overall improvement factor of roughly 27 and so we would need 24/27, that is, about one Iowa. This is the value that we implicitly assumed at the end of Appendix A.2, where we estimated that 50 billion gallons of fuel per year could be ethanol derived from cellulose. Note, however, that without the increase in fuel efficiency we would still need three Iowas, which is more than we can spare.

C.5.What is the trade off between expanding crops and losing forest? Suppose a U.S. farmer takes an acre planted with soy for food, and instead uses the harvest, which might be either soy or some other biofuels crop, for ethanol. That acre will produce an amount of ethanol that will reduce U.S. carbon dioxide emissions by about two tons of carbon each year. But if many other U.S. farmers have followed this farmer’s example, then the world price for soy will go up because the supply has decreased. So, now a farmer in Brazil or Indonesia is motivated to cut down an acre of tropical forest to expand soy production; this is done to meet world soy demand and because the price of soy has gone up. An acre of tropical forest contains roughly 100 tons of carbon in the biomass that is cut and burned. Hence the destruction of the forest will result in 50 times more carbon dioxide released to the atmosphere than is saved by a year of production of biofuels from that acre of farmland. So only after 50 years does the biofuels option reach the break even point where its net benefit on climate begins to kick in. We don’t have the time to wait, or the wildlife habitat to lose.

C.6. How much additional electric-generating capacity will be required if all our automobiles are plug-in hybrid or all-electric? Let’s first work this out for the most electricity-hungry of these choices: all-electric vehicles. We assume that the all-electric vehicles will be built to efficiency standards so that if the same car used gasoline, it would be obtaining at least 60 mpg, as required by 2030 under the EASY plan. So we have to calculate how much electricity is needed to provide the same amount of energy as a U.S. fleet of gasoline-burning vehicles that obtain 60 mpg. As in A.2., we would be burning about 48 billion gallons of gasoline per year, which in energy units is about 10^{19} joules/year or about 300 million kilowatts.

The amount of electric capacity that will be needed to recharge the batteries of plug-in hybrids will be considerably less than this because liquid fuels will be providing some of the power. In Appendix A.1. we assumed a mix of plug-in hybrids and all-electric vehicles that results in an additional need for **250 million kilowatts**.

D. Useful Websites Noted in Text

This is a selection of websites referred to in the text, for easy access.

Stay informed about the climate crisis and emerging solutions:

Information

- www.realclimate.org
- www.worldviewofglobalwarming.org

Newsfeeds

- www.climatecrisiscoalition.org
- www.EnvironmentalHealthNews.org
- www.planetark.org

Consume less, save more:

- www.newdream.org (Center for a New American Dream)

Convert your hybrid to a plug-in electric:

- www.calcars.org

Stop junk mail:

- www.greendimes.com
- www.stopthejunkmail.com
- www.catalogchoice.org

Meet other eco-women and moms:

- www.eco-chick.com
- http://ecomomalliance.org/

Make your campus carbon neutral:

- www.climatechallenge.org

Search for appliances that waste little energy when not being used but plugged in:

- http://oahu.lbl.gov/cgi-bin/search_data.pl

Recycle and save money by using and disposing of used but serviceable products through:

- www.freecycle.org
- www.ebay.com

www.craigslist.com

Share cars:

http://www.ene.com/service/sustain/car-pooling.aspx?src=Google&cmp=ENE&adgroup=Green-Ride&kw=car%20sharing&gclid=CNSFiI7Q-ZUCFRxNagodjS3JEg

http://www.carpoolexpert.com/carpool-signup.php?gclid=CPGGxfDO-ZUCFRsRagodfh9OEQ

Make nontoxic cleansers:

http://www.ecocycle.org/hazwaste/recipes.cfm

Buy local organic food:

http://www.localharvest.org/organic-farms/

Buy Compact Fluorescent Lightbulbs (CFLs) at a bargain price:

www.changethelight.org

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Matthew Lindenfelser and Tony Vigil created an inviting and professional website on which to provide a free download of this work, and Matt continues to host the site. Amy Atkins helped us hone the message.

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(begin on next page)

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