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Global Warming: Engineering Solutions

Springer

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Preface

Global warming is considered an average increase in the Earth's temperature due to greenhouse effect as a result of both natural and human activities. In common usage, "global warming" often refers to the warming that can occur as a result of increased emissions of greenhouse gases from human activities, e.g., carbon dioxide, methane, water vapor, and fluorinated gases, which act like a greenhouse around the earth, trapping the heat from the sun into the earth's atmosphere and increasing the Earth's temperature.

Catastrophic events around the world have brought a desperate picture to forefront! The Global Conference on Global Warming 2008 (GCGW-08) was initiated to bring all disciplines together for local and global solutions to combat global warming. It is a multi-disciplinary global conference on global warming (and climate change), not only in engineering and science but also in all other disciplines (e.g., ecology, education, social sciences, economics, management, political sciences, and information technology). It covers a broad range of topics on energy and environment policies, energy resources, energy conversion technologies, energy management and conservation, energy security, renewables, green technologies, emission reduction and abatement, carbon tax, sustainable development, pollution control and measures, policy development, etc.

Intensifying global environmental problems require internationally coordinated responses, which must balance the goals of energy security, environmental protection, and economic growth. The adoption of a comprehensive approach to energy and environment issues and the integration of energy and environment policies have become central activities of several countries. National and global solutions to reduce pollutants and greenhouse gas emissions have implications for energy security, energy trade, economic growth, etc. To some extend the global climate change is still perceived by many as a debatable issue. For example, despite the policy measures taken to date, unless the rapid establishment and implementation of further effective policies and programs to reduce emissions are conducted, greenhouse gas emissions would continue increasing unless the right cure is underway. Of course, this requires the full range of possible areas for action and policy instruments.

This book is a unique collection of 45 selected papers out of the papers presented in the GCGW-08 in Istanbul, Turkey, on July 6–10, 2008, to cover a wide variety of topics from the main principles of thermodynamics and their role in design, analysis, and performance improvement of energy systems to the potential impact of global warming on human health and welfare.

Although the main focus of this book is engineering solutions to combat global warming, there is a diverse coverage from carbon sequestration to risk management, from sustainable construction to waste management, and many more to serve as a sustainable source of knowledge and information for researchers, scientists, engineers, practitioners, etc.

As mentioned above, global warming is one of the major concerns of the human beings in this century. A significant part of global warming comes from the human activities, such as consuming fossil energy sources, e.g., oil, coal, and natural gas. In the solution of global warming, engineering approaches play a key role. These approaches are linked to many areas including energy and environment policies, energy conversion technologies, energy management and conservation, energy saving, energy security, renewable and sustainable energy technologies, emission reduction, sustainable development, pollution control and measures, policy development, global energy stability and sustainability, carbon tax, and waste management. Innovative engineering solutions are needed to reduce the effects of global warming and also to obtain better efficiency, better cost effectiveness, better use of energy and resources, better energy security, better environment, and better sustainability. In this book, several engineering approaches and potential solutions from renewables to hydrogen, including data analysis, modeling, simulation, assessment, optimization studies, that reduce the effects of global warming are discussed in detail.

Incorporated through this book are many wide-ranging practical examples, case studies, and policy and strategy development which provide useful information for practical applications. Complete references are included with each chapter to direct the curious and interested reader to further information.

We hope this volume allows unique solutions for combating global warming to be more widely applied and the benefits of such efforts more broadly derived, so that the future can be made more efficient, clean, and sustainable.

Last, but not the least, we gratefully acknowledge the assistance provided by several individuals, including Dr. Can-Ozgur Colpan, Dr. Anand Joshi, Mr. M. Fatih Orhan, Mr. M. Tolga Balta, Dr. Nirmal Vijay Gnanapragasam in reviewing and revising several chapters, checking for consistency, and finalizing them for publication.

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1

Global Warming – Where Is the Cure?

Romney B. Duffey and Ibrahim Dincer

1.1 Introduction: The Health of the Planet

As the world proceeds into the 21st century, international dimensions of environmental problems have become more apparent and increasingly important. Globalization of the economy, emergence of worldwide communication and information networks, and rapid development of bio- and nanotechnologies all have important consequences for the environment. One may expect that by the middle of this century about 10 billion people will be placing stresses on the world's natural resources which will lead to further environmental problems (Dincer 2003). In fact, future environmental problems arise not only from the exhaustion of natural resources but also from how those resources are consumed. New technologies can and will lessen damaging environmental impacts if they are employed wisely, guided by the market system under some main pillars, such as better efficiency, better cost-effectiveness, better use of energy resources, better environment, better energy security, and better sustainable development.

Environmental impact is now certain to be one of the most important political issues in this century, but one that will not have the urgency (born of novelty) voiced in the late 1960s/early 1970s. Many nations have made much progress, but experience has brought recognition of numerous deficiencies dealing with environmental problems. As the complexity of many environmental problems becomes increasingly apparent, the focus may shift from identifying needs to identifying and applying new methods for solving problems and providing effective long-term care.

Intensifying global environmental problems require internationally coordinated responses, which must balance the goals of energy security, environmental protection, and economic growth. The adoption of a comprehensive approach to energy and environment issues and the integration of energy and environment policies have become central activities of several countries. National and global solutions to reduce pollutants and greenhouse gas emissions have implications for energy security, energy trade, economic growth, etc. The global climate

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change issue poses for energy policy makers is the focus of continuing international debate. For example, despite the policy measures taken to date, unless the rapid establishment and implementation of further effective policies and programs to reduce emissions are conducted, greenhouse gas emissions would continue increasing unless the right cure is underway. Of course, this requires the full range of possible areas for action and policy instruments.

As a consequence we are faced with major decisions that potentially cover our entire social structure and well-being, including

- change in lifestyle and habits to become more conscious;
- environmentally benign technologies;
- global energy sustainability;
- economic competitiveness of industries and nations;
- energy technology dimensions;
- health and welfare of people;
- energy security nationally and internationally;
- rights and privileges of a few and of the many;
- allowable energy and greenhouse gas emissions;
- managing emissions and wastes;
- radical shift in use of energy resources;
- implementation of right energy strategies and policies; and
- many other ramifications of social and environmental importance.

Many countries (e.g., Canada, the USA, Japan, the European Union) have taken initiatives to develop energy–environment technologies, particularly for the integration of the existing energy and environment-related projects. This move is based on the understanding that energy and environmental problems represent two sides of the same coin, and technological breakthroughs are expected to provide means to overcome limits imposed by such problems and provide sustainable growth. The integration of the existing projects will make possible the incorporation of environmental viewpoint in the development of energy technologies and vice versa.

This chapter aims to bring a new dimension to energy policies and provides a kind of prescription for better policies and strategies to current energetic and environmental issues.

1.2 The Planetary Patient

Uncontrolled human activities since the industrial revolution have brought the planet up to a level that the amount of emissions and the magnitude of global environmental impact are indigestible. So, we have finally figured out that the planet has the symptoms of inadvertently catching a disease. This is a kind of disease with both high fever, referring to the increasing Earth's surface temperature (i.e., global warming) and diarrhea, referring to the wastes disposed into the planet. The question we can pose here is "Is it global warming and global warning?" If

one looks at what is happening around us, it confirms that it has gone beyond warning!

The symptoms have of course slowly become more apparent as a slight rise in the global atmospheric temperature. There is no agreement on the cause or the consequence. Some ascribe this rise as due to an addiction to uncontrolled energy use, and moreover carbon-based energy and the emissions of infrared absorbing gases. The so-called "climate change," we are literally burning up a fever with a giant bonfire, a respirable disease of carbon-based fuels that we are literally steadily breathing out as an added atmospheric pollution, CO_2 and CH_4 burden. By having a measurable effect by altering global surface temperatures, it perhaps influences many to otherwise previously normal or accepted behaviors or lifestyles. Of course, like with any disease, the diagnosis depends highly on the experience of the physician, the exactness on the presence of recognizable symptoms, and the precise recommended medicine, surgery, or cure on who and which specialist one is consulting. But we need to beware of the false claims, wrong diagnoses, ineffective treatments, and "snake oil" that are being peddled as easier or cheaper alternatives to really effective cures. We now look at the actual clinical data available to date and show that this simple medical analogy helps us to understand and explain the large difference between the claims and the real cures for what may ail the planet.

The planet's symptoms, given the uncertainty or lack of conclusive evidence, raise a fundamental question and a huge issue: given the patient's apparent ills: should we be running a climate change experiment on the planet? Our answer to that question must also consider rejecting experimental therapies and unproven treatment regimes, dismissing plainly fake remedies, and deciding whether to seek lifestyle changes over emergency triage.

1.3 The Doctor

So we now have our planet as a severely infected patient and need to find the right doctor, a procedure which is not really an easy task. There are so many doctors, consultants, and specialists around in every discipline ranging from engineering to science, from sociology to economy, from geology to psychology, and all claim to be the best doctors. This is something creating a kind of dilemma on even whom to see and consult. So, this is not something we can check with friends or relatives to find out who is the best in the neighborhood. The smart idea here is to find a group of doctors comprising the engineers, scientists, economists, sociologists, policy and strategy makers and try to bring their professional opinions together.

Since economic wealth and personal health are both tied to energy and electricity use, the carbon fuel ladder to any country's future is measured and predicted by how much is used per person, and that relates directly to how much income each person has. Wealthy countries are usually healthier and free of the diseases due to poverty. In a country using lots of carbon energy (e.g., the USA) income is about $30,000 per person: for the carbon energy poor it is more like

$1000. No wonder everyone wants more energy to drive forward and to improve: it is a matter of human well-being, human health, and social and economic development (Duffey and Miller, 2006).

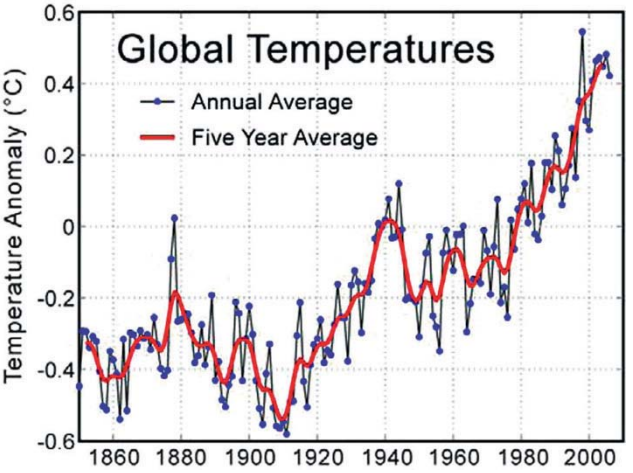

Fig. 1.1 Instrumental record of global average temperatures taken from Brohan et al. (2006) (as a record of surface temperatures collected from land-and ocean-based stations).

In fact, energy use could even be considered a right, just like breathing, and perhaps it is even unethical to deny or restrict energy use. Symptoms of malnutrition exist from those in energy poverty. As humans, who are we to deny anyone's ability or our fellow humans' desire to improve their personal health, to use light bulbs, build factories, computers, and have well-paying jobs? Even if it is causing some problems! So we cannot at all consciously restrict energy growth for those who now really need it, who also wish to share in the world's wealth, and improve their lives. We cannot divide the world into those who have the right to use energy and those who have not. But as with any doctor, the prescribing of any treatment regime must depend also on the chances of survival and success.

1.4 The Symptoms

In any illness, the doctor(s) must first look for the symptoms in order to make a diagnosis, test the vital signs and overall well-being, and ask the patient how they feel. It is well known that somehow the Earth's atmosphere is showing signs of a rising fever and this has even been the subject of movies (Gore, 2006) as well as extensive international study (e.g., IPCC, 2007). The average global temperature and indeed in some places the local temperatures are seemingly rising (see Fig. 1.1), some say by one or more degrees over the last century, as documented by several sources (e.g., IPCC, 2007). It is slow and almost imperceptible among other fluctuations, but it is there. It is easier to see in the history and records of land temperature readings taken regularly over the last 100 years using calibrated thermometers in

places like in Europe. Similar measurements all show that the last few years have been the warmest ever recorded in many places. The remaining clinical and genetic record is sketchy, derived using indirect measurements to forensically deduce (detective like) the global temperatures from ice core composition going back millions of years, tree ring growths covering thousands of years, and historical accounts for a few centuries. The reconstructed inferences and images of our past temperature (what are called surrogates because they are implied) tell us two things. First, the past is uncertain and had strongly varying temperatures too, due to natural causes; second the relationship between carbon dioxide in the atmosphere and temperature fluctuates, but implies a link or correlation– higher levels are associated with higher temperatures.

Now in any diagnosis we must also seek the presence or absence of multiple symptoms, so just one observation is not sufficient. There are other symptoms too that have been observed or implied all over the world as due to a rising fever. The geologists see that more obviously in colder Arctic, Antarctic, and mountainous regions, where shrinking sea ice, retreating glaciers, splitting ice shelves, and melting snow caps seem to happen in some regions. Perhaps as a result, sea levels are slowly rising. We could only be certain that the recent trends appear to be ominous. In addition, oceanographers report changes in global (corporal) circulation where in warmer regions near the equator, more hurricanes and changing sea currents might be occurring; geophysicists increasing acidity in the patient's water that is potentially harmful to the food chain; biologists adverse trends in species lifetime and habitat; meteorologists possible or potential changes in precipitation patterns; and zoologists alterations in species habitat and migration patterns. As for any disease, none of these symptoms are by themselves conclusive. As has been well argued by Singer and others (Singer, 2008) entirely natural variations can account for many of the symptoms, and some even seem to repeat. But that argument begs the uncertainty question: we cannot wait until we have complete certainty, or until the patient exhibits potentially fatal or life-threatening condition, but must take precautionary measures, remedies, and cures now if the risk of a worsening condition is significant. As always in science, medicine, and society, this treatment decision is a matter of informed judgment.

Taken together, the prognosis is indeed of a worsening condition if there is no treatment and no cure (IPCC, 2007), since global energy use and emissions will rise unabatedly and so will the resulting fever. As always, this prognosis is not exact but uncertain, the knowledge imperfect, the modeling approximate, the data imperfect, some signals conflicting, but the potential consequences of avoiding or delaying treatment are both dire and potentially irreversible. The patient feels and looks sick, and may be getting worse – but we are not yet sure exactly what to do.

1.5 The Cure

In the current circumstances what we need is the appropriate effective cure. If one looks at the dictionary, the short definition for "cure" is "successful remedial

treatment." In our search for a cure we must distinguish between real cures and false claims. So the medical practice and analogy helps us again here.

- Cure: successful remedial treatment
- Snake oil: any of various concoctions of questionable value, sold as an all-purpose curative, especially by traveling hucksters

There is a need to distinguish successful cures from others that are not so effective, despite the claims. Specifically, "snake oil" was infamous in the US wild west during the 19th century, when doctors were few and illnesses were many in the developing states. They have clearly been defined too, in more recent times by Herbert (2006): "Products promoted for profit to the public without passing peer process are almost without exception ineffective …"

We need to find the right doctor to get the right prescription for cure, and right implementation of the prescription will cure the problem. We find not one but many treatment options. The prescription may be as long as the following:

- changing lifestyle and habits
- making systems and applications more efficient, cost-efficient, and environmentally benign
- developing cleaner technologies
- using renewable and green energy
- implementing hydrogen and fuel cell technologies
- conserving energy
- diversifying energy options
- purchasing more efficient appliances
- giving priority to district energy systems and cogeneration
- providing proper education and training
- using more cost-effective energy systems and applications
- seeking alternative energy dimensions for transportation
- using sustainable fuels
- increasing public awareness
- taking necessary energy security measures
- monitoring and evaluating energy indicators
- implementing right energy strategies and policies (avoid side effects!)
- and many more socio-economic activities
- with a target to achieve some of the following main pillars:
- better efficiency
- better cost-effectiveness
- better resources use
- better design and analysis
- better environment
- better sustainability
- better energy security

Of course, we should expect and will find many of these listed cures offered to us in varying amounts. Whom should we believe? What is real, tested, and actually works? We must be on our guard: and we will carefully reject cures that are not

supported by data or real clinical trials under known conditions, and reported by reputable means. We must be particularly wary of alternative treatments, regimes, and overclaiming, and those where easy money is to be made, or we are offered a panacea or cure-all. We have only one Earth: we had better treat it right and with due and diligent care. Let us look at the fragile situation through what is going on around us now as the disease progressively seems to be gaining hold. Figure 1.2 is an example, showing the latest size variation in the Arctic sea. It exhibits a steady average decline as a blue line since measurements were available.

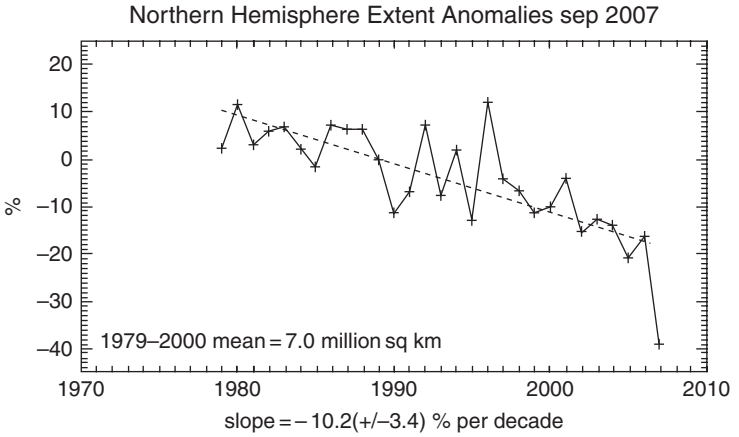

Fig. 1.2 The latest size variation in sea ice in the Arctic for 1977–2008, showing the decline as a *dotted line* since measurements were available (NASA, 2008 and NOAA, 2008).

Lastly, we cannot be sure that this type of temperature variation (Fig. 1.2) has not occurred sometime before man even appeared; perhaps it is an even natural pattern of the patient itself. We may never know, we may never be able to properly measure and analyze everything, and we may never be totally sure.

1.6 The Diagnosis of the Cause: Is It Stupidity of Humans?

Given the symptoms of an apparently rising temperature, we needed to find out what can additionally warm the atmosphere, apart from more sunlight and city streets, and despite the shading by trees and clouds. Thinking of the atmosphere not as what we just breathe but what also helps provide the weather conditions, it has long been known that there is also a corresponding rise in CO_2 gas in the atmosphere, which acts as an absorber of the radiative heat from the Earth itself. In fact, the term greenhouse gas arises from the action of water vapor and carbon dioxide resonantly absorbing the re-radiated heat in the infra-red spectrum from the Earth which the Earth has already absorbed the visible and ultraviolet light from the Sun, just as in a garden greenhouse. The clearest trend is the increases since the industrial revolution, or about 1790 onward, when carbon (coal) burning,

gasoline (petrol) use, and natural gas (methane) combustion have been essential in many sectors and drastic use. Although varying, there is a possible link between the increase in carbon dioxide emitted by humans activity and increasing temperatures. But the cause is clouded by the fact that only about half of the CO_2 we emit from our factories, power plants, and cars appears in the atmosphere. Half of it goes missing. We think the other half is absorbed by the oceans, lakes, and seas, which are full of dissolved gases anyway just like we see as bubbling bubbles rise up when we warm water in a saucepan, and in the growth of trees and shellfish.

Direct symptomatic measurements, taken daily, of the gases in the atmosphere have only been made in many places over the last 20–40 years, as pioneered by Charles Keeling (Keeling et al. 2005). Looking at this "breathalyzer test" for the atmosphere, the trend is an almost straight line increase with time, with a superimposed cycle though the year as seasons change. Current levels are some 380 ppm by volume, which is seemingly small. But more importantly the present concentration levels are higher than before 1790 (about 280 ppm), and higher today than ever before in the ice core history of about half a million years (Petit et al. 1999). We are indeed on an historic "high," so just perhaps this is a cause of the symptoms!

Understanding the warming phenomena and modeling of the entire patients, including the atmosphere, industrial emissions, and the global circulations, are crucial. This is all too complex to be exact, but gives some feedback to the ideas and diagnosis that there is a link. It is clear that the same trends of increasing temperature with increasing gases in the atmosphere, of course, are subject to the same kind of uncertainties as the measurements prove themselves! So it does not hold that the models are exact or true, nor do they have to be: since the trends are correctly recovered this implies the link. Absence of evidence is not evidence of absence.

The initial and preliminary diagnosis is simple: emissions that are man-made and come from our industrial and transport activity are causing the increase. Not everyone agrees, nor do they need to, since we can now seek a second opinion from other specialists, which is natural if we are suffering from a potentially deadly or poorly diagnosed, controversial malady.

1.6.1 A second opinion confirms the fears

Specialists are experts who have become an authority in their area through experience, practice, and studies carried out. They may be highly specialized in certain diseases, or just especially knowledgeable about the particular topic. Generally, an expert, specialist, or consultant is someone who knows what it is they do not know, what does not work, and what cannot be occurring, as well as what might be happening and its cause. They are also independent, so they should not be unduly influenced by business, fiscal, and unscientific factors.

Nowadays, specialists and their tests can also often delicately distinguish genetic or in-built traits from acquired trends, the mental from the physical, and the curable from the treatable, and what might be a successful or unsuccessful and ineffective treatment. In our case this specialist role is performed by the UN's Intergovernmental Panel on Climate Change (IPCC) which is a body of specialists

armed with the latest models, data, experience, and records that are globally available. This does not mean infallibility or that certainty is achieved: that can only be from data which as we know may never be fully available (i.e., from a postmortem only can we truly give the cause of death). Although its independence and integrity have been questioned, and even how they interpret and select the available symptoms challenged (see, e.g., Singer, 2008), the panel does provide detailed written records and reports as to how their opinion was derived. One should avoid that contingency and degree of certainty at least as far as the Earth is concerned.
Now medicine is an experimental science and the human body is an extremely complicated system. In conjunction with this, we can say that the planet is not an easy laboratory and no cadavers are available. But many IPCC specialists are involved and available, so the IPCC have produced extensive compendia, diagnoses, studies, and predictions (IPCC, 2007). As with all specialists, as more evidence is accumulated so the opinion becomes firmer. Presumably not easily convinced, and hopefully impartial and technical in their judgment, the latest report IPCC is not happy reading (IPCC, 2007). In the recent report, seven major measures are described that reflect actual changes in climate other than temperature, from warm spells to droughts to sea levels. They went further in their consultation, ascribing whether the symptoms were likely or not, whether human in cause, and a glimpse of the future prognosis. This summary of the latest IPCC is shown in Table 1.1. The analysis is typical of a critical standard whereby no one symptom is conclusive, but whether or not multiple items are likely present, may become more convincing. They are described as likely, and also likely to be human caused, where likely is about a 90% certainty, or odds of 10 to one of holding true in a bet. Moreover, not only do the historical symptoms suggest this human contribution but also dire prognosis of things are getting even worse. Still not everyone is convinced – the arguments include that perhaps the natural variations dominate the symptoms, and human activity is really not that significant (Singer, 2008). So, the question we now pose is, why such a dire worsening prognosis?

1.6.2 The prognosis about the future: carbon fuel dependency syndrome

The logic is simple and based on a lifestyle addiction or habit. Presuming the rise in emissions to be from energy use, which is linked directly to a nation's GDP (Duffey, 1999), then the burning of carbon-based fuels like coal, oil, and natural gas explains within a factor of 2 the rise in atmospheric amounts of CO_2. So increased energy use will and does cause worse symptoms, since such a large fraction ends up in the atmosphere and could and will raise the temperature. Since energy is used for making things like goods and chemicals and electricity, and this grows a nation's economy by providing jobs and products to sell, energy use is inextricably linked to economic growth if, any only if, carbon-based fuels are used without restricting the resulting CO_2 emissions. So unless we reduce emissions by reducing our carbon fuel use emissions, the temperature will presumably rise more. It is all in lock step: unless the habit changes, the symptoms will persist.
The global "habit' in this case is burning carbon-based fuels for energy, power, heating, and transportation as they are both easy to use and plentiful. The artificial

neural network (ANN) projection data of consumptions of world primary energy, fossil fuels, and green energy from 1965 to 2050 are displayed in Fig. 1.3. The past dependency on carbon-based fuels continues into the future, supplying over 90% of the demand. So carbon fuel use is a habit that is hard to kick without feeling major withdrawal symptoms and without a substitute helping out. It can be called carbon fuel dependency syndrome (CFDS) and acts like a drug.

Table 1.1 A summary of symptoms as identified by the IPCC.

Symptoms	Prior (1060+) symptoms	Human causation	Future (21st century) prognosis
Warmer and fewer cold days and nights over most land areas	Very likely	Likely	Virtually certain
Warmer and more frequent hot days and nights over most land areas	Very likely	Likely	Virtually certain
Warm spells/heat waves (with an increasing frequency in most land areas)	Likely	More likely than not	Very likely
Heavy precipitation events (with an increasing frequency in most land areas)	Likely	More likely than not	Very likely
Increased droughts affecting areas	Likely in many regions since 1970	More likely than not	Likely
Increased tropical cyclone activities	Likely in some regions since 1970	More likely than not	Likely
Increased incidence of extreme high sea level (with no tsunamis)	Likely	More likely than not	Likely

Source: IPCC (2007).

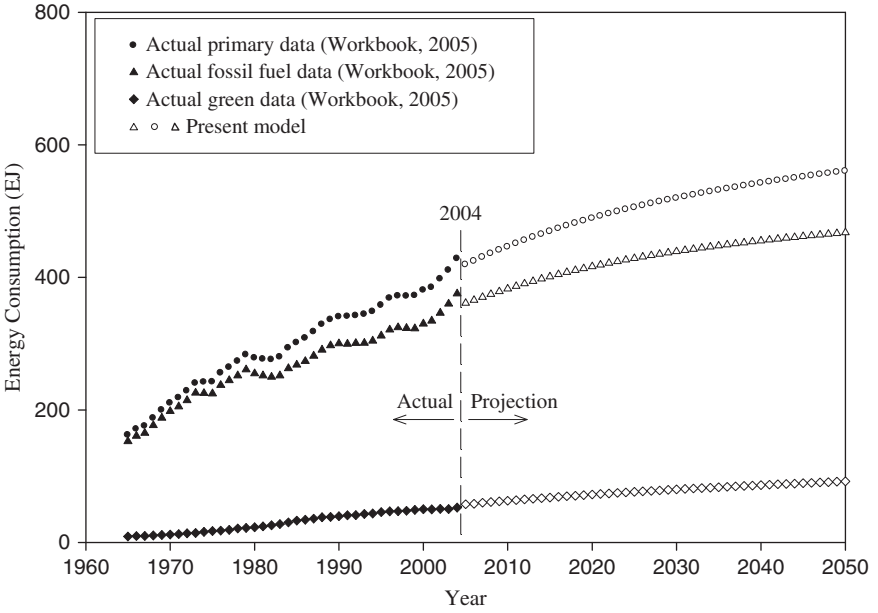

Fig. 1.3 Variation of actual and projected total world primary energy, fossil (carbon) fuel, and green energy consumption with time (adapted from Ermis et al., 2007).

Let us further elaborate on Fig. 1.3 as carried out by Ermis et al. (2007). The world primary energy consumption, fossil (carbon) fuel consumption, and green energy consumption exhibit a sigmoidal increase after 2004. World primary energy consumption is expected to reach 560 exajoules (EJ) by 2050, made up of 468 EJ of fossil fuel and 92 EJ of green energy. The dependency also grows as the population grows, and world population now exceeds 6 billion, doubling that of 40 years ago and is likely to double again by the middle of the 21st century. Even if birth rates decline so that world population becomes stable by 2050, the population will still be about 10 billion. Population, social equality, and wealth aspiration increases are all expected to lead to increasing price of fossil fuel resources with the shortfall of cheap conventional new supply with ever-increasing demand, as originally predicted by Hubbert (1956). The picture is even more complex today. In fact, there is a gap between theory and reality and changes depending on the phenomena. In regard to green energy, essentially wind power, such options will become increasingly needed to compensate for shortages of conventional resources. The ANN projection for world primary energy sources rises asymptotically to 590 EJ from 1984 to 2050 as follows, rounding off the numbers:

$$E_{wpc}\,(EJ) = 590\left[1+\exp\left[-\left(\frac{Y-1984}{22}\right)\right]\right]^{-1} \quad and \quad (R^2 = 0.999) \tag{1.1}$$

where E_{wpc} denotes world primary energy consumption in EJ. Other (Edmonds et al., 2007; IEA, 2005; IPCC, 2007) projections all show dependency increases depending on the scenario of about three to seven times by 2050 or so.

This increase indicates not only our dependence on the fossil fuels. If the increase of fossil fuel consumption continues in this manner, it is likely that the world will be affected by many negative symptoms and problems. Therefore, it is expected that the green (non-carbon) energy consumption will increase at the same trend as in Fig. 1.3. In the near future, green energy will likely become increasingly important to compensate for shortages of conventional energy resources.

Figure 1.4 shows the variations of the fossil fuel consumption ratio as a function of the green energy consumption ratio over time based on actual data (Workbook, 2005) and ANN projection data. As shown in the figure, the world fossil fuel consumption ratio was decreases with time while the world green energy consumption ratio increases. The world green energy consumption ratio was 5.58% and the world fossil fuel utilization ratio was 94.42% in 1965 based upon the actual data. The world green energy utilization ratio increased to 12.31% in 2004 while the fossil fuel consumption ratio decreased to 87.69% or at about 0.2% per year. Based on the projected data (see Ermis et al., 2007 for assumptions and their details) it is expected that the world green energy consumption ratio will reach 16.48% and the world fossil fuel consumption ratio will decrease to 83.69% in 2050 or a rate of ratio reduction of now only 0.1% a year. Thus, to increase the world green energy consumption ratio to the value needed for sustainable development (or a ~50% ratio reduction from c. 2010 values) and to reduce the harmful effects of fossil fuels, green energy substitution strategies must and should be put into practice at a rate of at least (83.69−50)/(2050−2010) = 0.84% a year, or five to ten times faster than the historic rate. The required dependency substitution or addiction reduction rate is then a 40-year average of (590/2)×0.08 ~ 23 EJ per year. The ANN projection of world green energy consumption is expected to play a key role in developing sustainable energy and global stability strategies in the future.

Just like cigarette smoking, the dependency or CFDS happened so easily because it made life easier and more pleasurable. It made money for the drug suppliers who made it; the governments who taxed it, the auto makers who made cars to use it; from the power plant owners who burnt it to sell power; to the consumer who felt better because of all the good things it made available, plus the money to spend from all the factory and office jobs created. Whole countries suddenly became immensely rich on selling carbon fuels around the world, from the UK to Saudi Arabia, from Columbia to Russia, from Norway to North America, from Australia to Iran, from Scotland to Morocco. Vast networks of pipelines grew up, connecting oil and gas supplies from those who made it or where it was found, to those who used it or needed energy for their factories and automobiles notably in Europe and the USA. We are all hooked on carbon. Even those without it want it, from China to South Africa, and it makes everyone happy. Except the Earth, which it appears to become sicker and sicker. Perhaps then, so we can all feel good, is not the best way forward to find a way treat the symptoms and not the cause? Then we can all feel better, even if the disease is not cured.

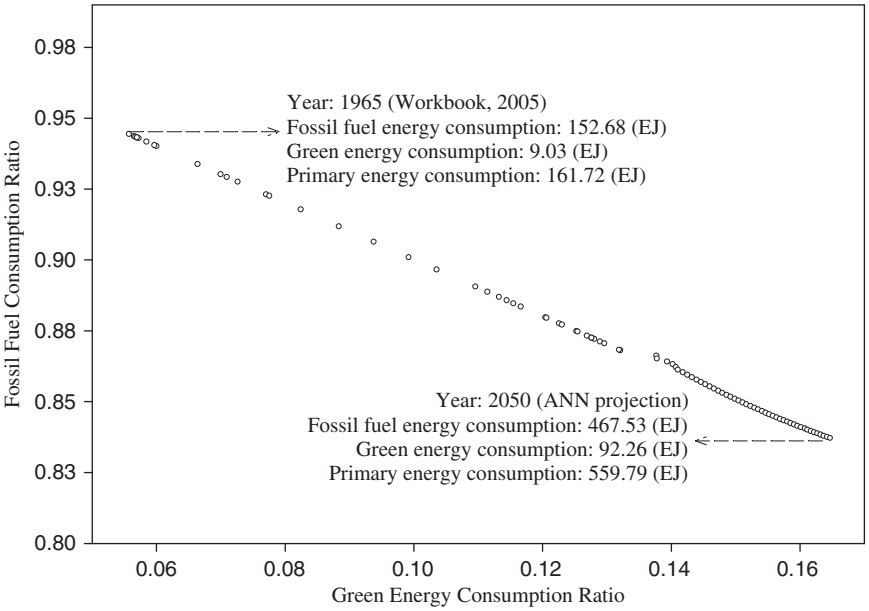

Fig. 1.4 The world fossil fuel consumption ratios as a function of the world green energy consumption ratios (adapted from Ermis et al., 2007).

1.6.3 Panaceas, painkillers, and procrastination

True to our medical analogy, there are many such "feel good" treatments available. It is obvious that we are clearly suffering typical global and human symptoms:

Rising fever + Chemical dependency syndrome + Carbon fuel addiction + Poor diagnosis + Delays in treatment = Continuing problem (1.2)

We share the human desire to look for a "quick fix" solution so as a result we have a confusing menu of short-term panaceas and ineffective painkillers that treat symptoms:

- Kyoto Protocol aimed to reduce and carbon pricing mechanisms but which has actually not decreased emissions worldwide.
- Seeking alternative medicines and supplements – windmills, biofuels, and efficiency improvement which sound good to do even if they do not necessarily work well.
- Denial of problem – putting off real treatment until major surgery required, which is an effective means to avoid unpleasant truths.

- Need for "lifestyle" and feel-good cures – unqualified "offsets," "carbon neutral," and "allowances' that allow the energy rich to feel good with unsustainable lifestyle.
- Shortage of key/real specialists – living in an era with information pollution in world of unqualified knowledge and with many unqualified specialists we turn to instant judgments and views of self-anointed witch doctors, who have almost magical insights.
- Long waiting times – insufficient funding for real cures means that long-term treatment is hard to find even after waiting in line for emergency help.
- Unbalanced coverage – media looking for headlines, social issues, celebrities, and awards providing the sensational but not the solution.
- Business opportunities – out of such a complex disease there is money to be made from peddling cures in the rush to profit from the ailments of the masses.

1.6.4 How much green is green? or is green really green?

Not surprisingly, the motivation of making money is quite appealing. Somehow, almost inexplicably, just being re-packaged "green" is now quite literally and almost magically considered a fashionable cure. Available at any checkout stand or health store, popular health gurus have appeared in numerous "green guide" articles, with political maneuvering and calls for energy use reduction. We would all like such a simple cure, and feel good about it, but of course not only a change of diet is needed but also a change of habit.

We must also, as usual in medical situations, divide the world into those who can afford the treatment, and those who certainly cannot. Those still having inadequate calories in their energy diet are most of the world's population, and a diet is not feasible as they simply want and still need more energy.

True to form, now on sale from many gurus are ideological and idealistic "cures" to reduce climate change impacts, industrial emissions, and damaging carbon fuel use for those affluent enough to consider and pay. Ideas and remedies are not only being proposed just by professional scientists and engineers but also by entrepreneurs and investors, and they are being pushed using media savvy techniques. Lectures, award winning documentaries, editorials, books, and consultancies are all now available that propose their own cures (Gore, 2007). Unfortunately, and as to be expected, much "snake oil" is now available. As usual this is apparently cheap, and cures all known ills without needing professional diagnosis, scientific testing, or a professionally written prescription. Unfortunately, selling the so-called "green" products is big business and leads to conspicuous consumption of 'green" products, without any sense of the energy use or emissions impact. The list of cures becomes longer and longer and the packaging slicker and slicker – recent quotes from a sample of magazines on sale at local North American supermarkets include self-proclaimed energy reducing "Green Guides" and descriptions of the new concepts and/or misconcepts:

- "Green is glam"
- "Green is the new black"

- "Reduce the use of planet's resources"
- "Green retail opportunity"
- "Green has become new fashion"
- "Next economy based on life values"
- "Making money by saving nature"
- "Green education"
- "Green justice"
- etc.

These are all quotes from recent articles and interviews with consumer, fashion and business experts in North America. Labels and products are now described and slanted as "Recycled," "Organic," "Reclaimed," "Eco-," and "Sustainable," giving the implied and vague suggestion that they are somehow kinder and more natural ways of making, using, and selling consumer goods while somehow helping to save the planet. This is big business and the so-called "Green Market" is now estimated at more than $250 B in North America. Confusing, yes; understandable, yes; global emissions reducing, no. Any increase in sales offsets any savings in emissions – as we shall see. Not everyone is taken in by the green repackaging.

Thus credibility is like energy, easy to use, and very easy to lose. Energy, like medicines and medications, is a profitably traded global commodity but in liquid (oil and LNG), gas, and solid (coal) forms, as well as in the form of electricity over wires between neighboring states and nations. Just as with drug makers and oil companies, unless subsidized or domestically price controlled, what we must pay for energy is whatever the highest bidder will pay anywhere in the world, and we compete for the energy resources to grow global and national economies.

Emissions are global too: so what one country exhales another breathes the effects. Thus although we need globally applied solutions, we must have locally taken and highly personal medicines. Many political leaders now understand the health of the planet does indeed depend on this "low carbon" cure approach, and also on the curative policies and actions they must take. But they are misled by many of the cures that are now literally "on sale," misled into believing, thinking, and supporting cures that are not.

1.6.5 Cure alls: the product range now on sale at your local store

Look carefully at the various cures we are all now offered, noting that many have not had real clinical testing or any peer review. We can make some real, painful, difficult, and technical judgments based on the actual clinical trials and the experience that we already have, and the prognosis that we can make. We can and must distinguish the local treatments of symptoms from the globally effective cures of cause. If we do not we may invest and pay for the wrong thing, in good faith and with good intentions. We need to consider rationally the claims made for, and look at the data for the effectiveness of the various cures and treatments. We may classify not conventionally but in medical terms as follows:

a) Pain killers for local and political relief of our individual and collective efficiency of energy use, ignoring whether this really will decrease the energy

use symptoms compared to the reality. These include efficiency improvements and conservation measures that attack personal and business use, from insulating the home to more efficient equipment, which although being more expensive up front may ultimately pay off in reduced energy bills. The concern here is whether this actually reduces global energy use and emissions, or just slows down the growth.

b) Palliatives or panaceas to calm fears by adopting "renewables," meaning massively deploying sources of energy like wind power, where the hope is that the non-emitting power productions will displace or replace emitting sources (like gas, oil, and coal) and the concern is whether this actually reduces the symptoms, or simply defers real treatments or worse implies only one solution or treatment option is needed.

c) Alternative medicines or curatives of "pricing," "permitting," or "trading" carbon emissions, which reduce emissions simply based on the idea that by pricing what was previously free the buyer or emitter will be discouraged from emitting, as it costs money for the ultimate consumer who ends up paying. The question here is simple – what is the incentive to actually reduce, and is it effective, or does this approach just "allow" emissions to occur, albeit at a price.

d) Public universal or managed care, where indirectly there are subsidies or insurance payments to non-carbon energy sources with guaranteed prices and power sales – almost a no-risk cure that we can buy if everyone pays the same. But realistically we must consider how socialized practices will work in a capitalist, competitive world market, The issue is whether such public care is unduly expensive, dependent on easy but false pricing, and does not really make energy affordable for those who actually need it and is a disincentive to innovative cures.

e) Health treatments or "feel good" remedies of reducing your personal consumption, so your individual contribution hopefully helps the collective good. But it may not make any actual difference to the global disease, so although the planet will not get better, ones self-image is improved Such approaches may be applicable to developed nations by substituting a specialized medication (like fluorescent lighting) but not for the energy needy, who require generic products of any type (say, just one or two light bulbs of any sort) and will apply whatever is not used or made available by others, especially if it is cheap and/or affordable (in this case implying a huge surge in electricity demand from the surplus manufacture of unwanted and cheaper bulbs)[1].

f) Institutionalized exercises, proscribing existing known ineffective regimes, such as the Kyoto Protocol, using externally enforced therapeutic limits and bureaucratic measures. Here the value of the exercise regime appears to be in the exercise itself, but actually it may delay effective treatment and does not

[1] Also known as the "Law of Unintended Consequences," when in this case meddling with markets, products, taxes, and incentives produces an unexpected but totally understandable and often opposite result.

affect a real cure. The concern is that such approaches produce artificial "consensus" rules designed not to offend, damage, or deny any one sector, country, political grouping, or business sector, in some way or manner.

g) Experimental therapies, unproven and untried by true clinical trials, such as "intensity reductions" or "footprints," and "offsets," which do not produce emissions. We have made an apparent and willing effort by eliminating some past wasteful practices but we do not actually reduce emissions globally or in the full energy cycle, This therapy route should raise concerns with inadequate testing, unrealistic expectations, and unfulfilled hopes, while still actually enabling continued worsening symptoms and bad usage habits.

h) Faith healing, where believing in a cure is seen as the answer, such as a return to the unattainable historic "global village," the so-called ethical treatments and organic fuel use. These are usually based on dreams or beliefs that may not be directly or scientifically testable but they become almost dogma or accepted as truth, so the issue is that it is impossible to use rational approaches or change views since, by definition, all else is untrue or unacceptable.

i) Holistic treatments, herbal remedies, or popular movements, where concern and sharing are emphasized, appeal is made to simplicity and "natural" medications but no actual cure is affected. The issue here is wasted resources, and lack of research and of objective data on effectiveness since results are highly subjective, reflect personal behavior(s) and norms, and perhaps induce placebo effects (a cure that is not). While not actual working on the larger problem and population, such treatments may negatively counter or interact with accepted or conventional approaches.

Given these care options, no wonder we all may be confused and overwhelmed, and we clearly need a second, truly independent and professional opinion and prognosis. Given the quantities offered of snake oil, instant cures, and palliatives that have not and do not work, we examine and show what can be done to affect the real cure. This means large doses of non-carbon-based energy (some say as large as 80%) (IPCC, 2007; G8, 2009) must be deployed, displacing and removing the dependency on carbon-based fuels, energy sources, and products. The candidate medicines are few, and the surgery is targeted and must be done with care: it entails changing habits, cutting out the old views, and implanting new ideals.

1.6.6 Truly disabling treatments: does efficiency improvement work?

It should be intuitively obvious that if we improve the efficiency of energy use – make or do more with or using less – that should reduce our demand and need for energy. If that were also economic that would be another incentive. So this sounds like a true "no brainer" – use less, pay less, and emit less as in, for example, the many articles and opinions on the role of efficiency, which exploits the apparent accounting merit of cost avoidance in the present versus capital investment for the future (Lovins, 2005, 2007, 2008). But despite major reductions in energy intensity and large improvements in and "buying" more snake oil end-use efficiency, totally unmentioned is the fact that locally, nationally, and globally both energy use and GHG emissions still rise, as we now show.

In fact efficiency standards have become mandatory for some appliances like refrigerators and indeed they do use much less energy as a result. If the increased initial cost if any can be paid back by reduced energy bills and costs, then the "payback time" to recoup the expenditure can be defined, and we can prove that real money savings can be achieved. So, we discuss the concept behind this below.

In fact, we can show this for light bulbs, where fluorescent lights use less power than incandescent or standard types (one uses a gas discharge, the other filament heating), depending on the rate of interest on the money used up front to buy the more expensive light. Older inefficient refrigerators are used for storing other goods, and so the use doubles.

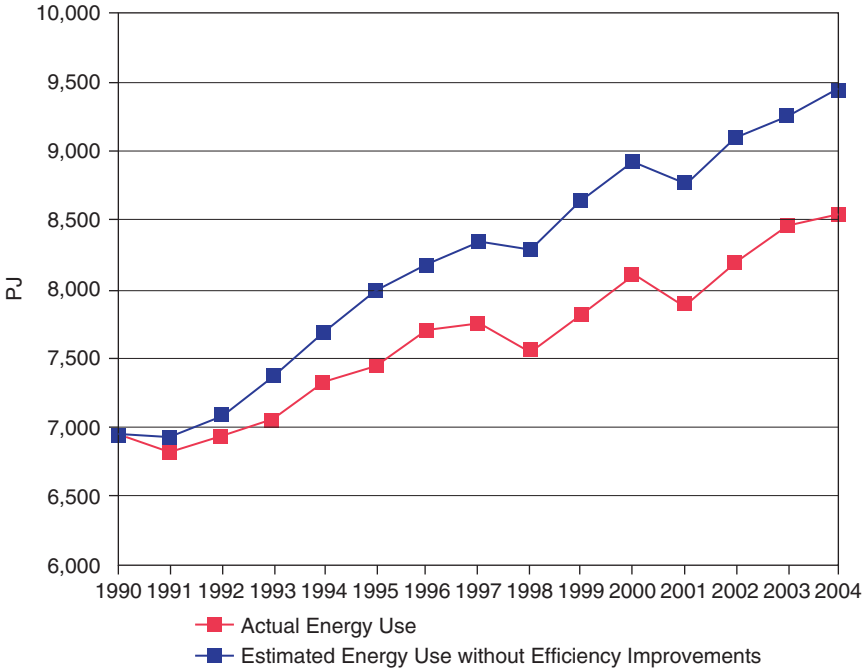

Fig. 1.5 Energy use growth in Canada from 1990, showing the impact with (*gray line*) and without (*dark line*) efficiency improvements (NRCan, 2008).

However, globally and especially nationally this has the opposite effect, in a perverse example of the law of unintended consequences. To illustrate this we show the data for Canada in Fig. 1.5 for the energy actually used compared to that estimated to be used without efficiency improvements. The rate of increase of energy use declines, but there is no real decrease in total amount used! The reasons are simple, and rather annoying.

First, and fundamentally, by making products cheaper by using less energy, more units are sold. So there is no incentive to actually reduce production com-