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**Climate Change, Climate Science and Economics.
Prospects for an Alternative Energy Future:
Preface and Abstracts**

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Climate Change, Climate Science and Economics. Prospects for an Alternative Energy Future: Preface and Abstracts

This working paper constitutes the preface and chapter abstracts for the book:

van Kooten, G. Cornelis, 2013. [*Climate Change, Climate Science and Economics: Prospects for an Alternative Energy Future*](#). Dordrecht, NL: Springer.

Climate Change, Climate Science and Economics: Prospects for an Alternative Energy Future is a comprehensive examination of why this is the case, enabling readers to understand the complexity associated with climate change policy and the science behind it. For example, the author describes the criticism and defense of the widely known “hockey stick” temperature graph derived from combining instrumental data and proxy temperature indications using tree ring, ice core and other paleo-climatic data.

Readers will also learn that global warming cannot easily be avoided by reducing CO₂ and other greenhouse gas emissions in rich countries. Not only is emissions reduction extremely difficult in rich countries, but demands such as the UN mandate to improve the lives of the poorest global citizens cannot be satisfied without significantly increasing global energy use, and CO₂ emissions. Therefore, the author asserts that climate engineering and adaptation are preferable to mitigation, particularly since the science is less than adequate for making firm statements about the Earth’s future climate.

The purpose of the book is not only to inform but to get the reader thinking critically about what may well be the most important environmental issue currently facing humankind.

Preface

My exposure to climate related research actually began as a doctoral student in Agricultural and Resource Economics at Oregon State University. In a research methods course, one of my advisors, Dr. John ('Jack') Edwards, commented upon his efforts to complete his PhD dissertation in Economics from the University of Chicago. He was examining the effects of climate on agriculture and, after running numerous regressions that confounded cause and effect, he finally completed the research by applying a large dose of economic theory and a simple regression model. But it was not until I had taken a position in Agricultural Economics at the University of Saskatchewan that, in the mid-1980s, the question of climate change and global warming came to my attention.

Elaine Wheaton of the Saskatchewan Research Council in Saskatoon put together a team of researchers to examine the effect of anthropogenic climate change on Canada's boreal forests, potential strategies for forest-sector adaptation, and the role that Canada's forests might play in mitigating climate change. We completed Phase I of the research for Environment Canada by 1987 and put together a larger team of researchers for the promised Phase II, but then the Canadian government backed away from climate research and there was no Phase II. During this period, I also worked with Louise Arthur who was at the University of Manitoba, where her research focused on the impacts of climate change on prairie agriculture. We combined our talents and published several papers on climate change related to agriculture and forestry in western Canada. The research was unfunded for the most part and, by the early 1990s, we were overtaken by well-funded American researchers, who had the ability to develop large-scale, national-level models of the forest and agricultural sectors – our research was relegated to the periphery.

During the 1990s and until recently, I focused primarily on the economics of mitigating climate change through carbon sequestration in terrestrial ecosystems. I discuss this line of research in Chapter 9. It led to my appointment in 2002 as the Canada Research Chair in Environmental Studies and Climate in the Department of Economics at the University of Victoria (UVic), and to my involvement as a contributing author to the chapter on forestry in the 2007 report of the United Nations' Intergovernmental Panel on Climate Change (IPCC). At UVic, I was surprised at the politicization of climate research and the lack of focus, despite ongoing efforts in a number of areas. I found that the best venue for participating in climate research on campus was through the Institute for Integrated Energy Systems (or IESVic), which was an offshoot of the Department of Mechanical Engineering – essentially a think tank founded by David Scott. Although IESVic's primary focus was on fuel cell research, there was a spirit of openness and questioning regarding climate change and the means to address it. In this regard, I am grateful to IESVic's second director, Ged McLean (who to my dismay left academic life for industry), and subsequent directors Ned Djilali and Peter Wild, for encouraging me to engage with IESVic. I benefitted as well from many discussions with Lawrence Pitt (who has some of the best insights into climate change and renewable energy), Andrew Rowe, and many graduate students at IESVic, all of whom opened a door to the wonderful world of energy systems analysis in the context of reducing carbon dioxide emissions and enhancing energy efficiency. I am also grateful to my own graduate students during this period, including, among many, Jesse Maddaloni, Ryan Prescott, Julia Zhu, Geerte Cotteleer, Alison Eagle and Linda Wong.

But I was really dragged into the climate change morass (for that is what it truly is) when I provided pre-publication comments for the book *Taken by Storm*, written by Christopher Essex and Ross McKittrick. I had been asked to provide comments by Ross McKittrick of the University of Guelph, whom I had known at the University of British Columbia where, as a member of faculty, I had been a member of his PhD supervisory committee. It was my first exposure to some of the issues concerning the theory of catastrophic anthropogenic global warming. My comments on the rear jacket of the book read as follows: “Any politician who failed to read this book and yet is willing to commit society’s resources to avert global warming has been derelict in his or her duty to the public. Professors Essex and McKittrick present a powerful case.” At that point, I still had reservations about the view taken by the book, but my dust jacket rendition stoked up the ire of the environmentalists, who subsequently sent me numerous emails requesting intimate details about my research funding (particularly if any research, regardless of the subject area, had ever been funded by an oil company), my employment history and so on, much of which was readily available on the internet.

I also had lunch with Dr. Timothy Ball, a retired professor of climate science at the University of Winnipeg now living in Victoria. Professor Ball indicated that, as a result of research that questioned whether carbon dioxide was a principal driver of climate change, he had been the object of vitriolic attacks on his person and felt he had been denied promotion on several occasions because of his views. As a leading thorn in the side of climate scientists, Ross also confided to me that he too had been the object of malicious attacks. McKittrick is often dismissed as an economist, unfit to comment on climate science, except that he is expert in statistical analysis and has extensive experience constructing models that predict economic outcomes – models of the kind that form the foundation of the emission scenarios used to drive climate model projections.

In July 2009, just as my study leave began, Dr. Calvin Beisner telephoned to ask if I would write a synopsis of the current state of economics related to climate change for his Cornwall Alliance for the Stewardship of Creation. A previous version had been written by Ross, who had probably suggested my name to Calvin, so I agreed that this would be a good way to begin my sabbatical, given that I had already agreed to teach a new course on the topic for a minor in Climate Studies at my UVic. The underlying document and associated research marked the beginning of this book. During the rest of 2009 and during 2010 and 2011, I discovered that economists were working on aspects related to almost all of the topics of climate science presented in this book, particularly climate reconstructions, paleoclimatology and climate modeling, as well as topics normally considered the purview of economists.

In this book, I attempt to address the science of climate change as objectively as possible. However, based solely on my choice of topics and the scientific literature I cite, it is unavoidable that I will be accused of bias. Therefore, it behooves me to be clear about my own stance. Until my encounter with the environmental movement (attributable to what I had written about *Taken by Storm*), a meeting with David Anderson (then Canada’s Minister of the Environment under Jean Chretien’s Liberal government) around the same time, and subsequent discussions with climate scientists at the University of Victoria, I had no specific view on what might be causing climate change. I was content to confine my research to economic issues relating to the uptake of carbon in forest ecosystems. It was only after much reflection, particularly during my 2009-2010 sabbatical leave that coincided, in late 2009, with the release of the so-called ‘climategate’

material (see Chapter 5), that I determined the case being made by climate modelers to be weak one, and not entirely supported by the empirical evidence. I simply could not understand how climate change could be an irreversible catastrophe that would put an end to the human race, how CEOs of energy companies had committed crimes against humanity (equivalent to Hitler, Pol Pot and other mass murders), or that rising temperatures were the greatest security threat to the United States – all claims made by climate scientists. Scientists had, in my mind, oversold their case.

The main obstacle that I could not get around, which potentially could prove to have involved one of the greatest science cover-ups ever (although the verdict is probably still out), concerned the Medieval Warm Period. Historical writings and anthropological evidence gathered and/or reported by Ian Plimer, Brian Fagan, Jared Diamond, Bjørn Lomborg and many others indicate that there was a period between about 900 and 1300 AD when the earth was warmer than today. Until recently, no one questioned the existence of the Medieval Warm Period, but climate scientists did just that in making the case that present temperatures are the warmest humans have ever experienced. The attempt to exorcise the Medieval Warm Period from the scientific record makes fascinating reading, and is discussed in Chapter 3. As carbon dioxide was not the culprit, what could explain this warming?

Another issue that stands out in my mind concerns the role of observation. Science has always been observation based: scientific theories are tested against the empirical evidence (deductive reasoning) or observations lead to ‘generalizations’ or theories (inductive reasoning). In contrast, ‘predictions’ of climate change are based on climate models that are not tested against observation, except through back-casting exercises as a form of validation. Back-casting as a means of validating models has not had much success in terms of predicting the future, as McKittrick well understood, and this is just as true for climate models as economic and other models. Knowing this, climate scientists validate their models by comparing them with other climate models that essentially share the same biases. A particular bias is that human activities are presumed to be the main drivers responsible for climate change. It is not surprising that not all scientists accept the outcomes of climate models, and it is not surprising to find scientists who propose alternative theories of how climate changes. It is important, even for the purposes of this book, to examine some of the questions surrounding the science of climate change. After all, economic prescriptions for addressing climate change can only be as good as the underlying science, and where the underlying science casts doubt, such doubt must be taken into account in developing policy.

Finally, I am disappointed by the climate debate. Very few people appear to know much about the nuances of climate change, yet they are willing to make all sorts of pronouncements regarding what governments must do to prevent global catastrophe. For example, in 2011 I presented a seminar in Geography at UVic focusing on weather index insurance. The seminar was hijacked when so-called climate experts in the audience took me to task for not understanding the science, issues of causality, and how science works. One questioned my knowledge of the ‘urban heat island’ (Chapter 2) suggesting that it only referred to the increase in nighttime temperature caused by the radiation of heat from pavement and other ‘black bodies’ that had been absorbed during the day. He was wrong, of course, because black bodies radiate heat at all times (see Chapter 4). Another claimed it is impossible to determine whether economic activity as measured by GDP causes temperature to rise or vice versa (see Chapter 2) –

I thought causality in this case is rather obvious! A third person claimed that the research of some scientists was suspect because of their religious beliefs and/or political leanings. And these are individuals who are influential in teaching students and/or bringing UVic's scientific climate expertise to the general public. Rather shocking in my opinion. I can only hope that this book will enlighten them and others.

Finally, some acknowledgements are in order. I want to acknowledge many national and international non-governmental organizations and government agencies, publishers, and individuals who granted permission to use their material in whole or part. Permission to use historical surface temperature data was kindly granted by: (1) the United Kingdom's Meteorological Office at the Hadley Centre/Climate Research Centre at the University of East Anglia, whose web site (www.metoffice.gov.uk/hadobs) contains public sector information licensed under the Open Government Licence v1.0; (2) the U.S. National Atmospheric Space Administration's Goddard Institute for Space Studies (<http://data.giss.nasa.gov/>); (3) the U.S. National Oceanic and Atmospheric Administration, which also provided information on weather stations (<http://www.ncdc.noaa.gov/ghcnm/>); (4) the Berkeley Earth Surface Temperature project at the University of California, Berkeley (<http://www.berkeleyearth.org>); and (5) Environment Canada for Canadian data. Permission to use temperature data derived from NASA satellites was provided by Dr. John Christy, who indicated that such data were in the public domain.

Paleoclimatic proxy data (e.g., tree ring data) and temperature reconstructions based on ice core, tree ring and other proxy data are stored electronically with the World Data Center for Paleoclimatology in Boulder, Colorado, and are available from their website <http://www.ncdc.noaa.gov/paleo/paleo.html>. These are open access data and a statement to that effect, "NOAA/National Climatic Data Center Open Access to Physical Climate Data Policy, December 2009," appears on their website.

Stephen McIntyre granted permission to use any material found on his website <http://ClimateAudit.org>. Likewise, Anthony Watts granted permission to use material from his website <http://wattsupwiththat.com/>. Watts' material included information about the quality of U.S. weather stations and the hockey stick <http://wattsupwiththat.com/2009/10/05/united-nations-pulls-hockey-stick-from-climate-report/>. Indur Goklany also granted permission to use any data found in his many reports and papers. Data on atmospheric carbon dioxide content are found at <http://cdiac.ornl.gov/trends/co2/contents.htm> and are used with permission. Arctic sea ice extent data used in this book were derived from AMSR-E sensor and provided by Japan Aerospace Exploration Agency (JAXA) through the IARC-JAXA Information System (IJIS).

Some material found in Chapters 10, 11 and 12 are published as Chapter 2.20, entitled "Wind Energy Policy," in *Comprehensive Renewable Energy*, edited by Ali Sayigh, Copyright Elsevier 2012, and are used with permission. Some figures and tables in Chapter 10 were created using data from *Key World Energy Statistics 2009* published in 2010 by the International Energy Agency of the OECD and used with permission.

CHAPTER ABSTRACTS

CHAPTER 1: INTRODUCTION

Climate change constitutes a particularly tricky policy dilemma as noted by the rhetoric that surrounds both the science and potential response to the threat of global warming. In addition to a brief discussion of the rhetoric surrounding the opposing views of global warming, whether it is unprecedented and anthropogenic in origin – there is clearly no consensus – this chapter provides an introduction to climate science, the issues pertaining to global warming, and the economics of climate change.

Key words: science policy; funding climate change research and lobbying; climate change organizations

CHAPTER 2: WEATHER AND THE INSTRUMENTAL RECORD

Climate scientists use instrumental data from numerous weather stations to develop summary measures of regional and global temperatures. The difficulties of doing this are illustrated using both hypothetical data and information from two weather monitoring stations, where one of the stations is clearly influenced by non-climate factors to a greater extent than the other. Instrumental records are available from numerous weather stations around the globe, but whose numbers and quality have varied over time, and from satellite data. However, as demonstrated using simple data, efforts to remove non-climatic factors (such as the so-called urban heat island effect) from the surface temperature reconstructions prove to be unsuccessful. Statistical analyses indicate that, since the late 1970s, some 50% of the temperature increase in the reconstructed data is attributable to socioeconomic factors, but that this is not true of temperatures derived from satellite data. The chapter ends by examining the potential for replacing traditional crop insurance, and its inherent drawbacks (adverse selection and moral hazard), with financial weather-based derivatives.

Key words: aggregating weather data; urban heat island effect; surface versus satellite data; financial weather derivatives

CHAPTER 3: CLIMATE SCIENCE AND PALEOCLIMATOLOGY

Although individual instrumental records from various places in North America and Europe are examined to determine trends, including the identification of the warmest and coldest years in the records, the main focus of this chapter is on proxy records. Proxy temperature records are constructed from tree ring, ice core and other paleoclimatic data using statistical methods that link the proxies to observed (instrumental) temperature data. The statistical methods are briefly discussed. Climate scientists use the proxy temperature reconstructions to show that global average temperatures remained constant for upwards of two millennia before rising dramatically beginning in the 20th century – the temperature reconstructions effectively eliminate the Medieval Warm Period and the Little Ice Age or relegate them to local phenomena. This reconstruction became known as the hockey stick, with the long-run period of constant temperatures constituting the shaft and the recent dramatic upturn the blade of the stick. Along with a similar trend in the concentration of atmospheric carbon dioxide, the hockey stick is the key empirical evidence of global warming used by the IPCC. The criticism and defense of the hockey stick graph are discussed in detail, as are some of the other issues regarding the use of instrumental and proxy temperature reconstructions.

Key words: historical temperature reconstruction; ice cores; tree rings; paleoclimate; hockey stick controversy

CHAPTER 4: EMISSION SCENARIOS AND CLIMATE MODELING

Given weak empirical evidence for global warming, climate scientists fall back on climate models to provide the strongest case for climate change. Although computer models of the atmosphere and oceans are solidly grounded in physics, there remains too much that is arbitrary. It is necessary to provide a path of future carbon dioxide emissions before climate models can forecast a future climate scenario. Emission scenarios rely on projections of population and income growth, convergence of per capita incomes between rich and poor countries, technological change, resource availability, et cetera. Not only are the assessment models used to develop emission scenarios spotty, but they assume significant convergence in incomes; indeed, for scenarios that lead to the highest temperature forecasts, the least well off on Earth have per capita incomes that exceed those of rich countries today. Then four types of climate models are

described, and a simple energy balance model is used to demonstrate the sensitivity of results to model parameters. Finally, the validity of climate models is considered in greater detail with answers provided to the following questions: How sensitive are numerical solutions of nonlinear models to changes in starting values, solution algorithms and so on? Do climate modelers follow standard guidelines for making forecasts? Do predictions from climate models accord with observation?

Key words: climate modeling assumptions; structure of climate models; quality of model forecasts

CHAPTER 5: ALTERNATIVE EXPLANATIONS

Surprisingly, there are many alternative explanations for observed changes in climate. In this chapter, these are categorized by whether they are cosmological in origin or not. Non-cosmological explanations include ocean events that impact the Earth's climate, such as the Pacific Decadal Oscillation, El Niño and Atlantic Multi-decadal Oscillation. The feedback effect of CO₂ warming on cloud formation is also important, as clouds reflect solar radiation back to space, which increases the Earth's albedo and lowers global temperatures. Although cloud formation is a complex process that is not considered in climate models, the feedback effect due to water vapor (the most important greenhouse gas) is much diminished by clouds. Of the cosmological explanations considered in this chapter, those related to the sun are most important. Solar cycles impact the amount of radiation reaching Earth – the energy balance that affects temperatures. But the sun's magnetic field also shields the Earth from cosmic rays that affect cloud formation – a reduction in the magnetic field has been shown to promote cloud formation, thereby cooling the globe. Also discussed in this chapter is the politicization of both climate science research (as found in the so-called climategate emails) and the IPCC process.

Key words: feedback effects in climate models; cloud formation; solar cycles; cosmic rays; ocean climate events; climategate

CHAPTER 6: HOW ECONOMISTS MEASURE WELLBEING: SOCIAL COST-BENEFIT ANALYSIS

This chapter constitutes a survey of economic measurement and social cost-benefit analysis.

Economic analysis employs many of the same criteria as financial analysis to determine whether a project or activity is worth undertaking – net present value (NPV), the benefit-benefit ratio (B/C) and internal rate of return (IRR). The main difference relates to what is counted. Economists measure net benefits as surpluses, namely, consumer surplus, producer surplus (or quasi-rent), and differential and scarcity rents. These measures are described in detail, as are techniques (e.g., hedonic pricing, contingent valuation) for measuring non-market or environmental costs and benefits that accrue to citizens and need to be included in a social evaluation of a policy or project. As discussed in this chapter, environmental costs and benefits can be significant and their measurement controversial, and sometimes incorrectly applied. Since costs are incurred and benefits accrue at different times, an aggregation of costs and benefits requires that they be discounted to the present period (or compounded to a common future time) using a discount rate. The controversy as to which discount rate (or rates) is most appropriate to use is examined. Finally, the precautionary principle for addressing extreme events and the possibility of irreversibility is discussed; indeed, a precautionary approach is evident in some cost-benefit analyses of anthropogenic global warming through assumptions of an extremely low discount rate, a high probability of catastrophic future damages, and very low costs of immediate mitigation (as discussed further in Chapter 7).

Key words: cost-benefit analysis; economic surplus measurement; discount rates; non-market valuation; precautionary principle

CHAPTER 7: ECONOMIC ASSESSMENT OF THE DAMAGES CAUSED BY GLOBAL WARMING

Damages avoided – the principal benefit of mitigating climate change – are investigated in this chapter, particularly the potential adverse impacts on the primary sectors, biodiversity and human health. A review of studies indicates that climate change is unlikely to have much impact on agriculture and forestry; projected climate change will increase productivity in some regions while reducing it in others, leading to a redistribution of land rents with little impact on overall output. When CO₂ fertilization is taken into account, there might even be an overall increase in primary sector productivity that results in more undisturbed land, thus protecting biodiversity. Other findings in this chapter also run counter to current shibboleths: The biggest threat to polar bears is hunting, not climate change; current trends in Arctic ice extent are not without historical

precedent; sea level rise is not an imminent threat; extreme weather events are not increasing; malaria is not only a tropical disease; and human health is a function of income, not climate, with bottom-up models using UN data predicting that death rates from almost all causes will be lower with projected global warming than without it. Meanwhile, integrated assessment models (IAMs) simply assume damages are an arbitrary function of temperature; upon balancing discounted costs and benefits, IAMs can be used to find an optimal path (usually of a carbon tax or emissions cap) for mitigating climate change. It is shown that different assumptions regarding damages, the discount rate, and/or the probability of catastrophic damage can be used to justify completely different policies for addressing global warming. Therefore, a carbon tax that is contingent on the temperature in the troposphere above the tropics – where the earliest indication of global warming is predicted to occur – is considered to be the preferred policy strategy as it should appeal to global warming proponents and skeptics alike. Finally, the Kaya identity is used to demonstrate the policy dilemma that decision makers face in reducing CO₂ emissions.

Key words: costs and benefits of global warming; integrated assessment models; policy ramps; fat tails; Kaya identity and emissions intensity

CHAPTER 8: IMPLEMENTING POLICY

What policy instruments are available to governments wishing to mitigate climate change by reducing greenhouse gas emissions? What role can and should government play? How effective is government action likely to be in reducing emissions and mitigating climate change? These are the subjects of this chapter. One concern is that government intervention to correct the market failure associated with global emissions of greenhouse gases leads to policy failure that worsens rather than helps the situation. The strengths and weaknesses of the main instruments in the policy – regulation, carbon taxes, subsidies and emissions trading – are examined in detail. While mandates are regularly employed, market instruments (taxes and cap-and-trade) are shown to be more efficient. With respect to emissions trading, corruption can be endemic because of potential windfalls from accessing grandfathered permits, from profits accruing to financial intermediaries, and from sale of dubious certificates or carbon offsets. The European Union's Emissions Trading System, failed efforts by the U.S. Congress to agree on carbon legislation, and other cases are discussed. Regulation and subsidies play a dominant role, and are often

justified on the grounds that they create green jobs; however, mandates and subsidies have resulted in policy failure, high costs to the economy, fewer and not greater numbers of jobs, and little in the way of reduced emissions of greenhouse gases. Evidence provided in the chapter indicates that there is little appetite among the public for mitigating climate change if the costs of doing so are \$1000 or more; surveys of policy experts are even less optimistic in this regard.

Key words: market versus government failure; U.S.-EU climate mitigation policies; corruption; economic incentives; green jobs

CHAPTER 9: AVOIDING EMISSIONS REDUCTION: TERRESTRIAL CARBON SINKS

As noted in previous chapters, it is not easy to reduce carbon dioxide emissions – it is technically difficult and the public is willing to pay too little to do so. As a result, governments have looked to land use, land-use change and forestry (LULUCF) activities as a means of removing CO₂ from the atmosphere and sequestering it in terrestrial carbon sinks. This chapter considers economic issues related to, among others, discounting of carbon, questions pertaining to additionality and leakage, transaction costs, the process of certifying carbon offset credits, governance, and corruption. Available data suggest that, compared to emissions reductions, LULUCF activities are a costly alternative for mitigating climate change, although forestry activities in some regions might constitute an exception. Carbon sequestration and its costs are examined over a number of forest rotations encompassing 240 years; costs and carbon uptake depend on tree species, growth rates, the post-harvest use of fiber, and the discount rate. As shown in this chapter, tree-planting activities can be used to earn certified emission reduction (CER) credits under Kyoto's Clean Development Mechanism, but the approach used to determine the CER differs from the actual carbon flux. Finally, although currently not permitted under Kyoto, activities that Reduce Emissions from Deforestation and forest Degradation (REDD) are being promoted as eligible CER credits. This effort has gone even further, however, in the attempt to link the UN's Framework Convention on Climate Change (FCCC) and the Convention on Biological Conservation – the definition of REDD credits has been extended to include sustainable management of forests, forest conservation and the enhancement of forest carbon stocks, collectively known as REDD+.

Key words: certifying carbon offset credits in forestry; ephemeral carbon uptake; deforestation

and biodiversity

CHAPTER 10: ECONOMIC GROWTH, ENERGY AND CLIMATE CHANGE

Fossil fuels account for more than three-quarters of global energy consumption with another ten percent or more coming from renewable and waste sources that emit carbon dioxide. Energy consumption is projected to grow by some 50% in the next quarter century, with the majority of this coming from sources that emit CO₂. While renewable sources of energy will play a greater role in the future, economic development will necessarily continue to rely on abundant and cheap fossil fuels, particularly coal and natural gas. In an era where climate change dominates the energy agenda, the prospects for expanding the use of CO₂-emitting sources of energy (oil, coal, natural gas) and relying more on hydroelectric, solar, wind, geothermal, biomass and nuclear sources are examined. Economic policies in many jurisdictions use a combination of mandates and subsidies to reduce overall reliance on fossil fuels and/or promote generation of electricity from renewable sources. Lessons from biofuel programs, and an economic analysis of feed-in tariffs for electricity, indicate that they are not only expensive but generally ineffective. Despite the setback caused by the near meltdown of the Fukushima nuclear power plant, it is argued that nuclear energy is a safe alternative to many other forms of energy, and that, given the rebound effect associated with conservation and physical limits to the use of renewable energy, a natural gas-to-nuclear scenario might not be unrealistic future course of action.

Key words: global energy trends; prospects for renewable energy; gas to nuclear future; energy conservation rebound and backfire effects

CHAPTER 11: ELECTRICITY MARKETS AND WIND ENERGY

The importance of reliable electricity to the economy continues to expand, and much of the focus of climate policy is on the generation of electricity from non-fossil fuel, non-nuclear sources. Global electricity use is expected to increase dramatically as a result of the information age, policies to electrify vehicles, and rapid economic growth in China, India, Brazil and other developing countries. However, with the exception of hydro and biomass sources, alternative renewable sources of energy are variable or intermittent. This imposes additional costs on electrical grids and creates problems for managing them. In this chapter, the operation of

electricity markets (grids) is described, as is the effect on electricity markets when an intermittent source of power is introduced into a grid. Because the largest increase in renewable generating capacity has come from wind turbines, wind power is used to illustrate the challenge of increasing reliance on intermittent energy sources. The need for extra reserves is discussed, and a grid model is used to evaluate the economic costs of integrating wind power into an existing electricity grid. If the system operator can invest or decommission generating assets and a carbon tax is employed, wind generation will not entirely replace coal until the tax becomes exorbitant; however, if investment in nuclear power is permitted, the analysis in this chapter indicates wind will have no role to play. Wind energy will provide an important contribution to future electricity supply, but its role will be limited by lack of storage and all the more so in regions lacking access to hydro reservoirs.

Key words: economics of integrating intermittent power into electricity grids; wind energy; nuclear, coal and natural gas electricity generation

CHAPTER 12: CLIMATE CHANGE POLICY ENCOUNTERS THE REAL WORLD

In this concluding chapter, the main issues developed throughout the book are briefly reviewed. The concern about climate change is then discussed in broader terms, viewing it in much the same way as earlier concerns about resource scarcity, population growth and the potential adverse impact that humans have on the environment. From this perspective, global warming is an environmental issue and much less a scientific one. The only real difference would seem to be the fact that it has the backing of the United Nations. UN involvement is a mixed blessing, because the UN must reconcile its climate agenda with its economic development goals, including its Millennium Development Goal (to halve the number of people living below \$1.25 per day by 2015). Economic development on that scale cannot occur without vast amounts of high-quality, high-density energy that is only available from fossil fuels. Rich countries have agreed to facilitate convergence of incomes in poor countries to those of the rich, but they have also agreed to de-carbonize the global economy. These objectives are incompatible, as illustrated by the rise in CO₂ emissions that accompanied economic growth in China. Mitigation is too costly, imposes a large burden on the poor, and is unlikely to prevent global warming – the concentration of CO₂ in the atmospheric keeps increasing and human emissions show no sign of

slowing. Therefore, climate engineering and adaptation are preferred to mitigation, particularly since the science is less than adequate for making firm statements about the Earth's future climate.

Key words: global warming as environmental catastrophe; Malthus; economic development versus de-carbonizing global economy; mitigation versus adaptation