BEYOND SMOKE AND MIRRORS

SECOND EDITION

What are the practical options for addressing global climate change?

How do we provide sustainable energy and electricity for a rapidly growing world population?

Which energy provision options are good, bad, or indifferent?

One of the most important issues facing humanity today is the prospect of global climate change, brought about primarily by our prolific energy use and heavy dependence on fossil fuels. Continuing on our present course as the world economy and population grow will lead to very serious consequences. There are many claims and counterclaims about what to do to avert dire consequences. This has generated a fog of truths, half-truths, and exaggerations, and many people are understandably confused about these issues. The aim of this book is to help dispel the fog, and allow citizens to come to their own conclusions concerning the best options to avert dangerous climate change by switching to more sustainable and affordable energy options.

The book begins with a composed and balanced discussion of the basics of climate change: what we know, how we know it, what the uncertainties are, and what causes it. There is no doubt that global warming is real; the question is how bad we will allow things to get. The main part of the book discusses how to reduce greenhouse gas emissions and limit the global temperature rise, including what the upper limit on greenhouse gases should be, how fast we should go to cut emissions, and all of the energy options being advocated to reduce those emissions. The many sensible, senseless, and self-serving proposals are assessed.

Beyond Smoke and Mirrors provides an accessible and concise overview of climate change science and current energy demand and supply patterns. It presents a balanced view of how our heavy reliance on fossil fuels can be changed over time so that we have a much more sustainable energy system going forward into the twenty-first century and beyond. The book is written in a non-technical style so that it is accessible to a wide range of readers without scientific backgrounds: students, policymakers, and concerned citizens.

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Prize from the American Association for the Advancement of Science, and the Fermi Award for lifetime achievement. Over the past decade, he has turned his attention from high-energy physics to climate change and energy issues, and has earned a strong reputation in this field as well. He has served on many national and international review committees, but his most direct involvement is with nuclear energy where he chaired an advisory committee to the US Department of Energy. He was also chairman of a recent American Physical Society study on energy efficiency, and a member of the "Blue Ribbon Panel" that oversaw the final edit of the US climate impact assessment that was released in 2000. He has written over 300 papers in scientific journals and op-ed articles for the *New York Times*, *Washington Post*, and *LA Times*.

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CLIMATE CHANGE AND ENERGY IN THE 21ST CENTURY

SECOND EDITION

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PREFACE TO THE SECOND EDITION

This second edition of this book is aimed at the general public, as was the first edition. It is not intended to be a textbook, but rather an accessible overview of what we know and don't know about energy and climate change, what options we have to reduce greenhouse gas emissions in the energy sector of our economy, and what policies we should and should not adopt to make progress. I have also come to realize that climate change is not the only reason we have to change the energy sources that drive the economies of the world, and will discuss the others.

I am a latecomer to the climate and energy field. My career has been in physics. I received my PhD in 1956 and my Nobel Prize in 1976 at the relatively young age of 45. Many Nobel Laureates continue research, but some look for other mountains to climb, and I was one of those. I took on the job of directing a large Department of Energy scientific laboratory at Stanford University in 1984. During my 15 years as director we expanded opportunities in many areas; the number of users from outside Stanford that came to the laboratory rose from about 1000 to nearly 3000, and the facilities that we pioneered were reproduced in many parts of the world.

Like many scientists, I had followed the growing debate on climate change from a distance, though I did have some peripheral involvement in related areas having to do with energy options. I became seriously interested in climate and energy issues in the mid-1990s, partly because it was clear that this would be a critical issue for the future and partly because of the lure of another mountain range. Since stepping down as a laboratory director in 1999, I have devoted most of my time to various aspects of the issue.

Having a Nobel Prize is a great advantage when moving into a new area. Besides being one of the highest scientific honors, it is a great door opener. Nobel Laureate Richter had a much easier time getting appointments with high-level officials in government and industry in the United States and abroad than would have scientist Richter. I have served on many review committees, both national and international, ranging from the US government's analysis of the effects of climate change on the economy, to the nuclear energy programs of both the United States and France, to the role of efficiency in the reduction of greenhouse gas emissions.

The original 2006 outline for this book devoted much space to the reality of global warming. The pendulum has swung since then and a majority of the general public now seems convinced of its reality. Much credit for the change goes to former Vice President Al Gore, and to his movie and book *An Inconvenient Truth*. His Academy Award and Nobel Peace Prize are testaments to the influence of his work. His dramas have been important in getting people to pay attention, but for appropriate decisions to be taken, we need a more realistic view than his about the dangers, the uncertainties, and the opportunities for action.

The public needs and deserves an honest science-based explanation of what we know, how we know it, what the uncertainties are, how long it will take to reduce those uncertainties, and what we can do to reduce the risk of long-term changes to the world climate that make the Earth less hospitable to society. If I do my job well, the reader will have enough information to come to his or her own conclusion.

Personally, I should tell you that I do believe in beginning to invest in reducing greenhouse emissions as a kind of environmental insurance for my two young granddaughters (ages 9 and 6.5 as I write this in early 2014). A beginning now will cost much less than we are spending on the bailout of the world's financial institutions. If later information says that things are better or worse than we now expect, we can change our program, but the earlier we start the easier it will be to do some good.

UNITS

The book uses a combination of American and metric units. Almost all data on greenhouse gas emissions are given in metric units. Most electric power units are metric also. In this list I give some of the conversion factors.

Temperature

1 degree centigrade (ºC) = 1.8 degrees Fahrenheit (ºF)

Large Numbers

kilo (k) = thousand
mega (M) = million
giga (G) = billion (US) or thousand million (Europe)
tera (T) = thousand billion or a million million
Examples: kilowatt (kW), gigatonnes (Gt), etc.

Weight

tonne (t) = 1000 kilograms (kg) = 2200 pounds (lb)
ton = 2000 pounds

Distance

1 meter = 39.4 inches
1 kilometer = 1000 meters = 0.62 miles

List of Units

Volume

1 barrel (bbl) = 42 gallons (US)
1 liter = 1.056 quarts = 0.264 gallon

Power

1 watt = basic unit of electrical power = 1 joule per second
1 gigawatt (GW) = one billion (or 1000 million) watts

Energy

Energy = power × time
1 kWh = 1 kilowatt-hour = 3 600 000 joules
1 BTU = 1054 joules
1 Quad = 1×10^{15} BTU = 1.054×10^{18} joules
1 TJ = 1×10^{12} joules

CONVERSION FACTORS

Energy conversion factors

To:	TJ	Mtoe	MBTU	GWh
From:				
TJ	1	2.388×10^{-5}	947.8	0.2778
Mtoe*	4.1868×10^{4}	1	3.968×10^{7}	11 630
MBTU	1.0551×10^{-3}	2.52×10^{-8}	1	2.931×10^{-4}
GWh	3.6	8.6×10^{-5}	3412	1

Multiply *from* by *to* for number of units
* Million tonnes of oil equivalent

Mass conversion factors

To:	kg	t	ton	lb
From:				
kilogram (kg)	1	0.001	1.102×10^{-3}	2.2
tonne (t)	1000	1	1.1023	2204.6
ton	907.2	0.9072	1	2000.0
pound (lb)	0.454	4.54×10^{-4}	5.0×10^{-4}	1

Multiply *from* by *to* for number of units

List of Conversion Factors

Volume conversion factors

To:	gal US	gal UK	bbl	ft³	l	m³
From:						
US gallon (gal)	1	0.8327	0.02381	0.1337	3.785	0.0038
UK gallon (gal)	1.201	1	0.02859	0.1605	4.546	0.0015
barrel (bbl)	42.0	34.97	1	5.615	159.0	0.159
cubic foot (ft³)	7.48	6.229	0.1781	1	28.3	0.0283
liter (l)	0.2642	0.220	0.0063	0.0353	1	0.001
cubic meter (m³)	264.2	220.0	6.289	35.3147	1000.0	1

Multiply *from* by *to* for number of units

ABBREVIATIONS

ACEEE	American Council for an Energy Efficient Economy
AOGCM	atmosphere–ocean general circulation model
APS	American Physical Society
BAU	business as usual
BEV	battery-powered electric vehicle
CAFE	corporate average fuel economy
CCS	carbon capture and storage (sometimes sequestration)
CO_2	carbon dioxide, the main human-caused greenhouse gas
CO_2e	carbon dioxide equivalent
DOE	US Department of Energy
DSM	demand side management
E_i	energy intensity (energy divided by GDP)
EGS	enhanced geothermal systems
EIA	Energy Information Administration (a division of the DOE)
EPA	US Environmental Protection Agency
EU	European Union
FF	fission fragments
GDP	gross domestic product
GNEP	Global Nuclear Energy Partnership

List of Abbreviations

GRS	greenhouse gas reduction standard
HEU	highly enriched uranium (suitable for weapons)
IAEA	International Atomic Energy Agency
ICE	internal combustion engine
ICSU	International Council for Science
IEA	International Energy Agency (division of the OECD)
IIASA	International Institute of Applied Systems Analysis
IPCC	Intergovernmental Panel on Climate Change
LWR	light water reactor
NAS	National Academy of Sciences
NPT	Treaty on the Non-Proliferation of Nuclear Weapons
NRC	US Nuclear Regulatory Commission
OECD	Organization for Economic Co-operation and Development
OPEC	Organization of Petroleum Exporting Countries
OTA	Office of Technology Assessment
PHEV	plug-in hybrid electric vehicle
PPP	purchasing power parity
PV	photovoltaic
R&D	research and development
RPS	renewable portfolio standard
TCM	trillion cubic meters
TMI	Three Mile Island
TPES	total primary energy supply
TRU	transuranic elements
UK	United Kingdom

UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
VMT	vehicle miles traveled
WEC	World Economic Council
WMO	World Meteorological Organization
ZNE	zero net energy