

No Miracles Needed

The world needs to switch away from using fossil fuels to using clean, renewable sources of energy as soon as possible. Failure to do so will lead to accelerated and catastrophic climate damage, loss of biodiversity, and economic, social, and political instability. This book describes how to solve the climate crisis, and at the same time eliminate air pollution and safely secure energy supplies for all – without using “miracle” technologies. It explains how to use existing technologies to harness, store, and transmit energy from wind, water, and solar sources to ensure reliable electricity and heat supplies. It also discusses which technologies are not needed, including natural gas, carbon capture, direct air capture, blue hydrogen, bioenergy, and nuclear energy. Written for everyone, *No Miracles Needed* advises individuals, communities, and nations on what they can do to solve the problems, including the economic, health, climate, and land benefits of the solutions.

Mark Z. Jacobson is a professor of Civil and Environmental Engineering and Director of the Atmosphere/Energy Program at Stanford University. He has published six books and over 175 peer-reviewed papers. His work forms the scientific basis of the Green New Deal and many laws and commitments for cities, states, and countries to transition to 100 percent renewable electricity and heat generation. He received the 2018 Judi Friedman Lifetime Achievement Award, and in 2019 was selected as “one of the world’s 100 most influential people in climate policy” by Apolitical. In 2022, he was chosen as the World Visionary CleanTech Influencer of the Year. He has served on an advisory committee to the U.S. Secretary of Energy, appeared in a TED talk, appeared on the David Letterman Show, and cofounded The Solutions Project.

“To those who wrongly insist we lack the tools to decarbonize our economy today, I say: read energy systems expert Mark Jacobson’s amazing new book. In *No Miracles Needed*, Jacobson presents a comprehensive and detailed, yet highly accessible and readable blueprint for the options we have right now to address the climate crisis by taking advantage of existing renewable energy, storage, and smart grid technology combined with electrification of transportation systems, and efficiency measures. Read this book and be informed and engaged to help tackle the defining challenge of our time.”

Michael Mann, Distinguished Professor of Atmospheric Science at
Penn State University and author of
The New Climate War

“Many people believe or fear that we can’t solve the climate crisis, because we just don’t have the technologies in hand to do so. This book should lay that fear to rest, once and for all.”

Naomi Oreskes, co-author (with Erik M Conway) of
*The Big Myth: How American Business Taught Us to Loathe
Government and Love the Free Market*

“... shows impressively that numerous crises can be killed with one stone, without us having to wait for miracles: the energy, economic, health, and biodiversity crises can be solved by transitioning to a smart and complete supply of renewable energies. Let’s not wait for miracles: let’s simply implement it as soon as possible. Well worth reading!”

Claudia Kemfert, German Institute for Economic Research and
Professor of Energy Economics and Energy Policy at
Leuphana University

“... a highly compelling and accessible book laying out the best path for [our] energy future, one that is achievable with currently available technologies, with no need for some new miraculous breakthrough. This is a must read for all who care about the future of our society and our planet, written by the world’s premier thinker on energy futures.”

Bob Howarth, Cornell University

“... blends science, engineering and history into a readable cornucopia of information ... Mark’s style is to present approachable depth on dozens of major topics: everything you need to understand, and to join the fight against, the peril of our time.”

Anthony R. Ingraffea, Cornell University

“Forget future miracle technologies promised by snake oil salespeople. This book offers a practical and real-world solution today. It is a must read for everyone concerned about climate change and air pollution and interested in the transition to a more sustainable all-purpose renewable energy future. It is sure to be one of the most important books that you will read this decade.”

Peter Strachan, Aberdeen Business School,
Robert Gordon University

“Mark Jacobson’s essential book, *No Miracles Needed*, offers clean, safe, and efficient solutions for our energy needs in this time of ever-growing climate chaos and disaster ... The tools for producing, storing, and transmitting affordable and safe clean energy exist here and now with wind, water, and solar. *No miracles are needed*. A tireless and brilliant advocate for the environment, Professor Mark Jacobson’s voice must be read, heard, and acted upon —now.”

Heidi Hutner, Stony Brook University

No Miracles Needed

How Today's Technology Can Save Our
Climate and Clean Our Air

Mark Z. Jacobson
Stanford University

Cambridge University Press & Assessment
978-1-009-24954-6 – No Miracles Needed
Mark Z. Jacobson
Frontmatter
[More Information](#)

CAMBRIDGE UNIVERSITY PRESS

University Printing House, Cambridge CB2 8BS, United Kingdom
One Liberty Plaza, 20th Floor, New York, NY 10006, USA
477 Williamstown Road, Port Melbourne, VIC 3207, Australia
314-321, 3rd Floor, Plot 3, Splendor Forum, Jasola District Centre,
New Delhi – 110025, India
103 Penang Road, #05-06/07, Visioncrest Commercial, Singapore 238467

Cambridge University Press is part of the University of Cambridge.

It furthers the University's mission by disseminating knowledge in the pursuit of education, learning, and research at the highest international levels of excellence.

www.cambridge.org

Information on this title: www.cambridge.org/9781009249546

<https://doi.org/10.1017/9781009249553>

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First published 2023

Printed in the United Kingdom by TJ Books Limited, Padstow Cornwall

A catalogue record for this publication is available from the British Library.

ISBN 978-1-009-24954-6 Paperback

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978-1-009-24954-6 — No Miracles Needed
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**To the young people of today, who will take us to the finish line
tomorrow**

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FOREWORD

This is among the most important books you'll ever read, because it lays out in clear and frank terms the great problem of our age, and the great solution.

Burning things – coal, gas, oil, and biomass – has produced the prosperous world that we in the West inhabit. It has allowed us to heat and cool our buildings when the temperature is not to our liking, to light our spaces so as to extend our days, and to move ourselves and our stuff great distances with great ease. It has liberated us, that is, from many of the constraints that had traditionally governed human life.

But we now know that those liberations have come with unbearable cost. Breathing the smoky byproducts of all that burning kills more than 7 million of our brothers and sisters each year, far more than Covid, or HIV/AIDS, or malaria, or war. And that combustion has filled the air with invisible greenhouse gases that now threaten the very stability of our civilizations by raising the temperature and in the process melting the icecaps, destabilizing the jet stream and the Gulf Stream, raising the sea level, and sundry other catastrophes on a scale of destruction we'd previously imagined only in connection with atomic weapons.

So replace them we must – but with what? Mark Jacobson and his team have provided, after two decades of work, all the answers we need. Wind power, hydropower, and solar power – wind, water, and sun, or WWS to use his formulation – are sufficient to give us more than enough energy for our needs, and to do it at a cost that should

allow for quick transition. This book lays out those essential facts in interesting, accessible, and readable fashion: it is a user's manual for a planet in transition, and one that should settle the panic in anyone who thinks we lack the resources to do what needs doing.

To state it plainly: there is no longer any technical or economic obstacle to the swift transition of our energy system to something far cleaner, cheaper, and more rational. We have the miracle technologies we require firmly in hand. You can point a sheet of glass at the sun and out the back will come light, air conditioning, information, mobility: all the requirements of modernity. Jacobson dutifully considers the possible drawbacks – will it use up minerals we don't possess in sufficient quantity, or occupy too much land – and comes back with mathematical assurances. He has the data.

But of course winning the argument is not the same as winning the fight. Shifting in the short time that climate science requires will mean overcoming both inertia and vested interest, which means that all of us, even if we are not engineers, have a role to play in getting the job done. Indeed, some of the most interesting sections of this volume describe Jacobson's own evolution into an activist of sorts, or at least someone trying to make the case for change. If he can overcome the sweaty panic that overtook him in the seconds before his nationwide interview with David Letterman, the rest of us can learn to make this case in letters to the editor and to our elected leaders.

In fact, it would be a dereliction of intellectual duty to read this book and then not take some actions to change the debate. If we had no readily available answer to the twin crises of climate change and air pollution, then I suppose we could in conscience ignore them. But the solutions are readily at hand. This book should empower you – and with not a moment to spare!

Bill McKibben

PREFACE

On July 11, 2011, I was invited to a dinner at the Axis Café and Gallery in San Francisco to discuss the potential of renewable energy as an alternative to natural gas hydrofracking in New York State. Little did I know it at the time, but that dinner would set off a chain reaction of events that turned a scientific theory, that the world has the technical and economic ability to run on 100 percent clean, renewable energy and storage for all purposes, into a mass popular movement to do just that. The movement catalyzed an explosion of worldwide country, state, and city laws and proposed laws, including the Green New Deal, and business commitments. Ten years after that meeting, critics were no longer mocking our ideas as pie-in-the-sky and tooth-fairy-esque. They were no longer claiming that transitioning to more than 20 percent renewables would cripple power grids. Instead, the discussion had changed to what is the cost of 100 percent renewables, how fast can we get there, and should we leave a few percent for non-renewables?

Why do we want to transition our worldwide energy system entirely to clean, renewable energy and storage for everything? This book first explores the three main reasons: to eliminate air pollution, global warming, and energy insecurity. Air pollution kills about 7 million people and injures hundreds of millions more each year worldwide. It is the second-leading cause of death. The impacts of global warming are accelerating as greenhouse gases and dark pollution particles in our atmosphere continue to increase. Such impacts include melting of glaciers and sea ice, rising sea levels, more droughts and floods, more intense hurricanes and wildfires, more air pollution and

heat-related deaths and illnesses, agricultural shifts and famine, climate migration, species extinction, coral reef damage, and more. Lastly, fossil fuels are limited resources. As they run out, economic, social, and political instability will ensue. These three problems require an immediate and drastic solution.

Do we need *miracle technologies*? No. Then what is the solution? It is to transition the world's current combustion-based energy to 100 percent clean, renewable **wind, water, and solar (WWS)** and storage for all energy purposes and to eliminate non-energy emissions. The main idea behind the solution comes from the fact that air pollution health and climate problems arise from the same cause: combustion of fossil fuels, bioenergy fuels, and open biomass. **Fossil fuels** include coal, oil, natural gas, and all their derivatives, such as gasoline, diesel, kerosene, jet fuel, and liquefied natural gas. **Bioenergy fuels** include liquid biofuels, such as ethanol, biodiesel, and bio jet fuel, for transportation, and solid biomass, such as wood, wood pellets, dung, and vegetation, for electricity and heat. **Open biomass** includes forests, woodland, grassland, savannah, agricultural crops, and agricultural residues. Burning any of these leads to pollution that affects both health and climate.

To solve the problems, it is necessary to move away from combustion by electrifying and providing direct heat without combustion. For the electricity and heat to remain clean and available for millennia to come while not creating other risks, they need to originate from clean, renewable, and sustainable sources, namely WWS.

WWS includes energy from **wind** (onshore and offshore wind electricity), **water** (hydroelectricity, tidal and ocean current electricity, wave electricity, geothermal electricity, and geothermal heat), and **sunlight** (solar photovoltaic (PV) electricity, concentrated solar power (CSP) electricity and heat, and direct solar heat). WWS electricity and heat need to power all current energy sectors, which include the electricity, transportation, building heating and cooling, industrial, agriculture/forestry/fishing, and military sectors. Although human-designed energy systems cause about 90 to 95 percent of **anthropogenic** (human-produced) air pollution and 75 percent of anthropogenic greenhouse gas emissions, this book also discusses methods of eliminating non-energy anthropogenic emissions that damage air quality and warm the planet.

Many solutions to date that have focused on the climate problem have included some technologies that are less helpful than WWS

technologies. This book describes such technologies, which raise costs to consumers and society, increase emissions relative to WWS sources, create substantial risks that WWS sources do not have, and/or delay the solution to pollution and global warming because of the long time they take to come online. Given our limited time and funding available to solve the pollution, climate, and energy security problems we face, it is essential to focus on known, effective solutions that can be implemented rapidly. Money spent on less-useful options will permit more health, climate, and energy insecurity damage to occur.

In fact, to solve the three problems posed here, we have 95 percent of the technologies that we need already commercially available. We also know how to build the rest, which include primarily long-distance aircraft and ships, powered by hydrogen fuel cells, and some industrial technologies. As such, we do not need *miracle technologies* to solve these problems. We need the collective willpower of people around the world to solve them.

Why 100 percent clean, renewable energy and storage for everything? Why not 50 percent, 80 percent, or 99 percent? First, the health plus climate damage of every bit of pollution that we allow to remain in the air is so enormous that it is important both morally and economically to eliminate 100 percent of emissions. Second, 99 percent is not an ambitious goal to shoot for. Did Magellan aspire to circumnavigate 99 percent of his way around the Earth? Did the Apollo 11 crew aspire to reach 99 percent of its way to the moon? No. One hundred percent is the goal because that is the best society can do and will result in the cleanest air and most stable climate possible for future generations. Societies often strive for the best and safest.

How fast do we need to transition? In order to avoid more than 1.5 degrees Celsius global warming compared with temperatures between 1850 and 1900, we need to eliminate at least 80 percent of all emissions by 2030 and 100 percent no later than 2050, but ideally by 2035. In order to avoid tens of millions more air pollution deaths, we need to eliminate all emissions even faster.

Can we reach the goal of 100 percent WWS across all energy sectors and eliminate non-energy emissions at that speed? This book examines this question, including the data and scientific studies that say we can. It concludes that a transition among all energy and non-energy sectors worldwide is economically possible with technology that is almost all existing. The main obstacles are social and political.

This book is for lay-readers concerned about the massive air pollution, climate, and energy security problems the world faces. To summarize, it discusses why no *miracle technologies* are needed to solve these problems in the short period we have left to do so. The solution is to use existing and known technologies to harness, store, and transmit energy in the wind, the water, and the sun, and to ensure reliable electricity and heat supplies worldwide. The book also discusses what technologies are not helpful or needed but are being pursued vigorously. “Transition highlights” throughout the text offer examples of changes to renewable energy somewhere in the world. Finally, the book gives information about what individuals, communities, and nations can do to solve the problems, as well as the cost, health, climate, and land benefits of the solution.