Second Edition

The Science of Renewable Energy

Frank R. Spellman

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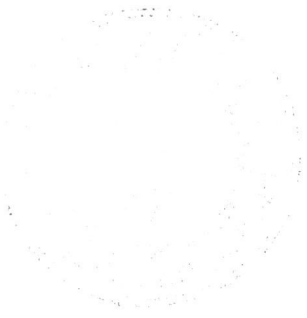


Preface

Hailed on its first publication as a masterly account for the general reader, the environmentally concerned, and the serious student, *The Science of Renewable Energy, Second Edition*, continues where the first edition left off. That is, the first edition explained that studying renewable energy through science affords us the opportunity to grasp not only the pressing need for renewable energy but also the complicated task of developing viable energy sources for the future—what I consider to be a long and challenging slog. Based on critical reviews, reader input, and current developments (remember, the dynamic science of renewable energy is ever changing and advancing), it became apparent that a follow-up second edition was required to fill in some gaps left by the first edition. For example, the basic energy section in this new edition adds important energy parameters dealing with both fossil fuel supplies and renewable resources. In a science book of any type, basic parameters cannot and should not be ignored. In the second edition they are not ignored.

With regard to future energy needs, there is no question nor doubt that we are facing an international crisis of unprecedented proportion. We are ultimately headed for a train wreck when the temporarily affordable and currently accessible petroleum products are no longer so, and economic and political turmoil results. Keep in mind that we need to find replacements for liquid hydrocarbon fuels not only because the wells are almost dry (after we frack them, of course) but also because we need to clean up the environment. We need to be able to produce reliable renewable energy that will not destroy or pollute our fragile environment.

But, here is the problem. No one questions that developing renewable, sustainable energy supplies is a good thing—a very good thing—but what is the tradeoff? Most people feel strongly or are being told in no uncertain terms that renewable energy supplies are better than the filthy, polluting, disgusting fossil fuels that are destroying our environment and negatively impacting our personal health. The problem is that these same people are not being told about the problems related to renewable energy. Indeed, renewable energy is not a pure energy source devoid of any environmental or other problems. Renewable energy comes with its own set of environmental problems.

It is generally known and widely accepted that the utilization of any energy source impacts our environment. Fossil fuels (oil, coal, natural gas) do substantially more harm than renewable energy sources by almost any measure: air and water pollution, damage to public health, loss of wildlife and their habitats, significant use of water and land, and the production of emissions exacerbating global climate changes. In contrast to fossil fuels, renewable energy—wind, solar, geothermal, hydroelectric, biomass for electricity, and hydrokinetic—offers substantial benefits for our climate, our health, and our economy:

- Little to no global warming emissions
- Improved public health and environmental quality
- Vast and inexhaustible energy supply
- Jobs and other economic benefits
- Stable energy prices
- A more reliable and resilient energy system

Again, however, it is important to understand that renewable energy sources also have environmental impacts. The exact type and intensity of environmental impacts will vary depending on the specific technology used, the geographic location, and a number of other factors:

- Air quality
- Cultural resources
- Ecological resources

- Water resources
- Land use
- Soil and geologic resources
- Paleontological resources
- Transportation
- Visual resources
- Socioeconomics
- Environmental justice
- Safety and health

The important point (and the message woven in the warp and woof of this text) is that by understanding the current and potential environmental issues associated with each renewable energy source we can take steps to effectively avoid or minimize these impacts as our use of these alternative energy sources grows.

This text takes a common-sense approach and presents practical (and sometimes poetic) examples. Because this is a science text, I have adhered to scientific principles, models, and observations; however, the readers does not need to be a scientist to understand the principles and concepts presented. I go easy on the hard math and science and present the material in a user-friendly manner. What the reader really needs is an open mind, a love for the challenge of wading through the muck, an ability to decipher problems, and the patience to answer questions relevant to each topic presented. Real-life situations are interwoven throughout the text in an engaging fashion, and the material is presented in straightforward, conversational plain English to provide the facts, knowledge, and information necessary to understand the complex issues involved and to make informed decisions.

As a companion text to *The Science of Water*, *The Science of Air*, and *The Science of Environmental Pollution*, *The Science of Renewable Energy, Second Edition*, follows the same proven format used in the other three texts. But, like its forerunners, this text is not an answer book. Instead, it is designed to stimulate thought. Although solutions to specific renewable energy questions are provided, the disadvantages and hurdles that must be overcome to make renewable energy a viable alternative to fossil fuels are highlighted. The goal is to provide a framework of principles to help develop an understanding of the complexity of substituting renewables for fossil fuels. *The Science of Renewable Energy, Second Edition*, is designed to reach a wide range of diverse readers and students. The text focuses on the various forms of renewable energy derived from natural processes that can be constantly replenished: solar energy, wind energy, ocean energy, wave energy, tidal energy, geothermal energy, biomass energy, hydropower energy, biofuels, and hydrogen fuel cells. Their design and implementation should prevent pollution of the atmosphere, of surface and groundwater, and of soil (the three environmental media). Keep in mind that all of these naturally produced processes are critical to our very survival. Because renewable energy and pollution prevention are real-world issues, it logically follows that we can address these issues by using real-world methods—that's what *The Science of Renewable Energy, Second Edition*, is all about.

Note to the Reader

In 1976, energy policy analyst Amory B. Lovins coined the term *soft energy path* to describe an alternative future where energy efficiency and appropriate renewable energy sources steadily replace a centralized energy system based on fossil and nuclear fuels. In 2009, Joshua Green, then a writer for *Businessweek*, pointed out that Lovins further argued that the United States had arrived at an important crossroads and could take one of two paths. The first, supported by U.S. policy, promised a future of steadily increasing reliance on dirty fossil fuels and nuclear fission and had serious environmental risks. The alternative, which Lovins called the *soft path*, favored "benign" sources of renewable energy such as wind power, solar power, biofuels, geothermal energy, and wave and tidal power, along with a heightened commitment to energy conservation and energy efficiency.

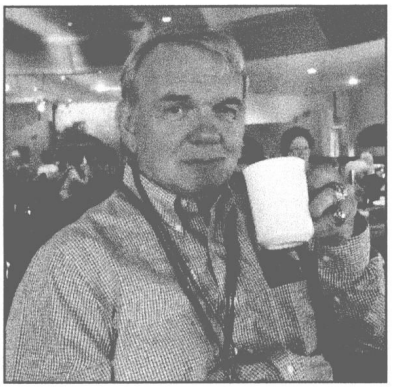
As a lifelong student, researcher, lecturer, and ardent advocate of the development and use of renewable or alternative energy sources (eventually excluding all fossil fuel use to the extent possible), I agree with Lovins in many respects, but I take issue with those who state that renewable energy sources are "benign." In my view, the definition of the term "benign" means something that is harmless, innocent, innocuous, or inoffensive. Thus, the labeling of renewable energy sources as benign implies that the use of renewable energy sources is totally safe. The truth is the use of renewable energy sources is not totally safe.

Again, I am an advocate for the use of renewable energy. Simply, I think using renewable energy sources instead of fossil fuels is a good thing. However, with any good thing there usually comes a bad thing. Nothing made by and used by humans is absolutely harmless to the environment. Nothing. Only Mother Nature, with her ultimate plan, affects nature as we know it in beneficial ways. Even when she kills millions of us with designed orchestrations that change life as we know it, we must realize that these are simply timed mechanizations, part of her long-range plan. Remember, Mother Nature's plan is the ultimate plan. Who are we to argue otherwise?

Anyway, because I do not agree with the idea that the so-called soft path is the "benign" path, I also cannot say that the impacts of renewable energy source are necessarily bad, baneful, damaging, dangerous, deleterious, detrimental, evil, or harmful to the environment. The question is: What can I say in this book and elsewhere about renewable energy? I can say that I am biased toward the use of renewable energy, that I am for Lovins' soft path and against the hard path. But, I qualify this by also stating that renewable energy sources have impacts on the environment, both good and bad, and it is these good and bad impacts that this book addresses.

So, let's cut to the chase. My broad conclusion is that renewable energy sources are not the panacea for solving our many pollution problems that they are popularly perceived to be. In reality, their adverse environmental impacts can be just as strongly negative as the impacts of nonrenewable energy sources, but we need to eventually replace nonrenewables so renewables are the option we must pursue.

Author



Frank R. Spellman, PhD, is a retired adjunct assistant professor of environmental health at Old Dominion University, Norfolk, Virginia, and the author of more than 100 books covering topics ranging from concentrated animal feeding operations (CAFOs) to all areas of environmental science and occupational health. Many of his texts are readily available online, and several have been adopted for classroom use at major universities throughout the United States, Canada, Europe, and Russia; two have been translated into Spanish for South American markets. Dr. Spellman has been cited in more than 850 publications. He serves as a professional expert witness for three law groups and as an incident/accident investigator for the U.S. Department of Justice and a northern Virginia law firm. In addition, he consults on homeland security vulnerability assessments for critical infrastructures, including water/wastewater facilities, and conducts pre-Occupational Safety and Health Administration and Environmental Protection Agency audits throughout the country. Dr. Spellman receives frequent requests to co-author with well-recognized experts in several scientific fields; for example, he is a contributing author to the prestigious text *The Engineering Handbook*, 2nd ed. Dr. Spellman lectures on wastewater treatment, water treatment, and homeland security, as well as on safety topics, throughout the country and teaches water/wastewater operator short courses at Virginia Tech in Blacksburg. In 2011, he traced and documented the ancient water distribution system at Machu Picchu, Peru, and surveyed several drinking water resources in Amazonia, Ecuador. He has also studied and surveyed two separate potable water supplies in the Galapagos Islands, in addition to studying Darwin's finches while there. Dr. Spellman earned a BA in public administration, a BS in business management, an MBA, and both an MS and a PhD in environmental engineering.

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