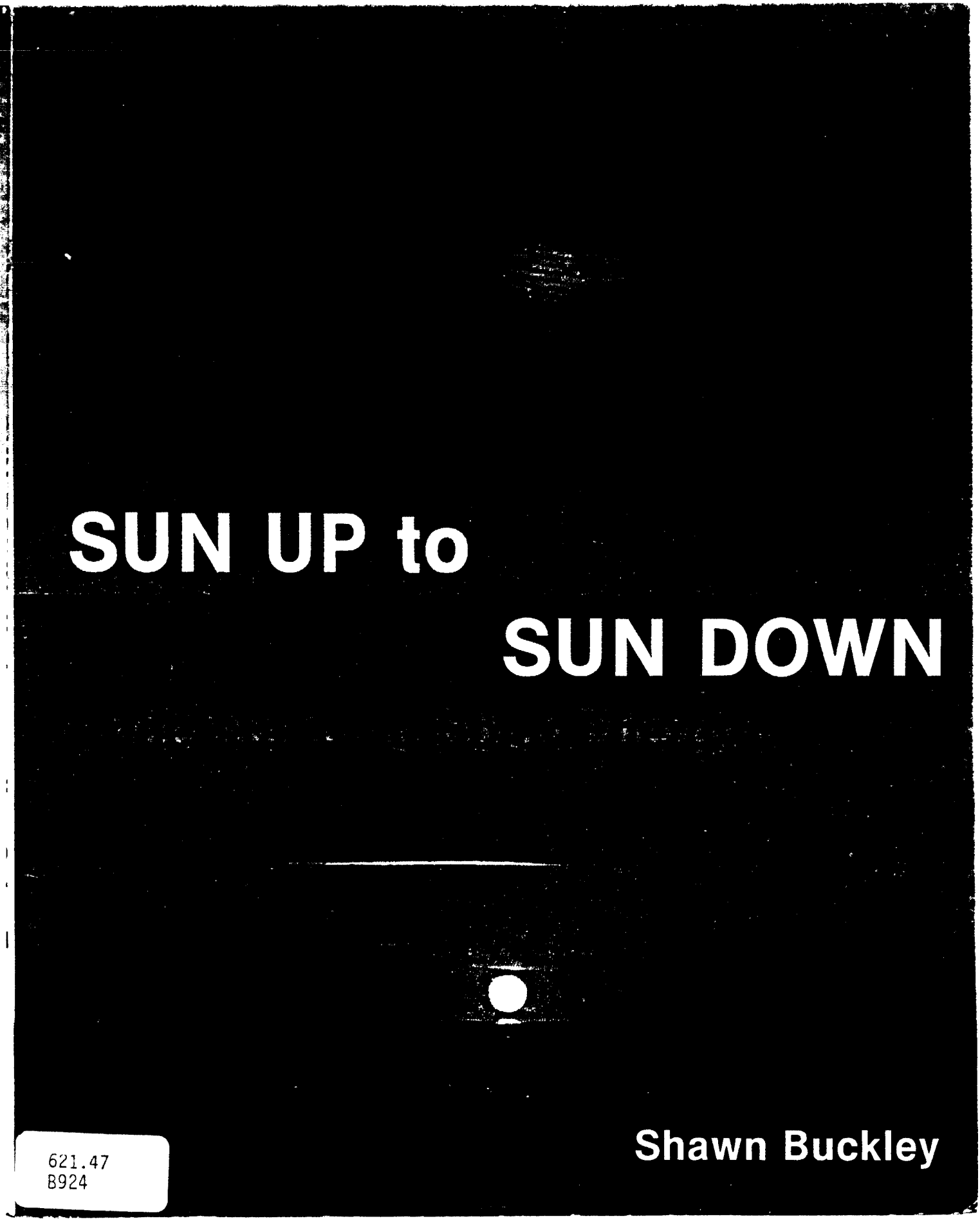
SUN UP to SUN DOWN



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An Energy Learning Systems Book

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Foreword

Our nation walks a tightrope today because of our addiction to foreign oil. The revolution in Iran and subsequent oil cutoffs demonstrated our vulnerability. Unlike the other energy crises of the 1970's, the most recent crisis won't go away. Shortages are going to get worse and the ramifications more serious. No matter how much we may wish for an energy panacea, there isn't one. The only cure is painful-withdrawal.

If you are feeling the pinch of the energy crisis now, you may be ready to help save this country from potential economic, political and environmental disaster. We live in a nation that demands an electric toothbrush and worries about nuclear waste disposal. We cannot have it both ways. Continuing on our present course invites the bureaucratic nightmare of gas rationing, a loosening of environmental protections, a serious loss of jobs, and increased environmental hazards from nuclear wastes, coal production and breeder reactors.

While there is no panacea, there are ways to wean ourselves from the oil well. Solar energy is an alternative-clean, renewable and safe. Solar offers the best means to get us through this century. It fosters energy conservation and self-reliance. Solar will create a new industry and thousands of new jobs. If we made solar and other renewable energy sources a national priority, we could meet 25 percent of our energy needs with these alternative sources by the year 2,000. Without a commitment to develop and commercialize solar, this nation's energy future is bleak.

Everybody likes solar energy. The success of "Sun Day" proved that the American people understand solar's benefits.

The problem is to transfer that positive public image into some. thing people will buy and use. Making the basic concepts more easily accessible is one answer. Fortunately, Shawn Buckley, an MIT professor, is a technician with the ability to simplify solar technology for a general audience.

You and I don't have to wait another five years to use solar. Solar can meet some of our energy needs right now. Solar hot water and heating systems can be applied immediately. With the current oil price increases, solar is becoming more cost effective.

What I like about Sun Up to *Sun Down* "Understanding Solar Energy" is that it doesn't waste the reader's time trying to sell solar energy. It simply explains how solar technologies for hot water and heating work. The section on "solar economics', realistically explains its costs. The author uses descriptive analogies so the reader gets information without becoming bored or overwhelmed.

This book can move the reader from wondering about solar to becoming a solar consumer. I hope it moves thousands of Americans to make that choice. When I look at my two young daughters, I see energy as the greatest threat to their having healthful, productive lives. Our generation's failure to address this issue will hurt them far more than you or me. Those who read this book, advocate solar power, and install solar in their homes will be at the vanguard of an energy revolution. A revolution away from fossil fuels to renewable energy sources will make the United States more energy conscious and self-sufficient. The solar age will help give our children a comfortable and safe lifestyle.

Senator Paul E. Tsongas

Preface

I have written this book in an attempt to teach solar energy by analogy. Use of analogy in teaching technology is as nearly as old as technology itself. For example, when early electrical engineers sought to explain current flow in wires, they likened it to the flow of water through pipes. Many more people understood water flow in pipes; their knowledge could be extended to electricity by showing the analogy between water flow and electric current flow.

Even today, analogy makes learning easier. In my engineering courses at M.I.T., I teach that the behavior of systems are similar: not just fluid and thermal (i.e., heat) systems, but mechanical and electrical systems as well. When you learn how one "media" (as they are called) works, you can extend your knowledge to the other media very easily. All the media (fluid, thermal, electrical and mechanical) behave the same if the proper analogies are made. The analogy tool is used as a way to condense information. Instead of separately learning about each media, one is learned in detail and the knowledge is extended to the others. Often, on the first day of class I bring in a hot pad, a bicycle wheel, a cup of water, and an electrical circuit. Few students believe that these four "systems"-one from each media-behave the same way. Yet, by the end of the class I have shown how they are all closely related by analogy.

Analogy has been successfully used by others. Prof. Jay Forrester, of "Limits to Growth" fame, uses fluid analogies to convey his method of understanding social behavior. In a course I taught with Jay and several others at M.I.T., we showed how such diverse subjects as nuclear reactor behavior, the scrap

metal market, the growth and decline of civilizations, and the national economy all have an analogous methodology. One of my contributions was, not surprisingly, the behavior of a solar heating system. Richard Feynman, Cal Tech's famous physicist, uses analogies quite successfully in his series of physics books. For example, electrostatic field theory is learned by analogy to stretched rubber membranes.

Knowing that thermal phenomena are difficult concepts to master, I felt learning by analogy could help transfer knowledge. I was left with a dilemma: which media should I use for the analogy. Had I been writing for electrical engineers I might have chosen an electrical media for analogy. Heat loss from a collector becomes an electrical resistor; heat storage becomes an electrical capacitor. In fact, my colleague, Richard Thornton of M.I.T.'s Electrical Engineering Department, teaches an excellent course on solar energy using just this analogy. But I felt that lay people are most familiar with fluid analogies and water flow is very easy to visualize. I find that imagining water squirting from a leaky rainbarrel forms an easier image than electrons leaking across capacitor plates.

A major problem with the analogy approach is that neither analogy may be familiar. To a person who doesn't understand either heat flow or fluid flow, the analogy approach may confuse more than it enlightens. I empathize with these people because there is no sugar coating for the pill. My approach is but one way to make the pill slide down easier. Learning is a difficult process and any aid to understanding is helpful. Of the lay people who initially found the fluid analogy confusing, most of those who stuck with it soon became comfortable with it. They claim now to understand *both* analogies quite well-the fluid and the thermal.

By using a fluid analogy to describe solar heating, I have been able to avoid mathematics. This may not be to everyone's liking; some readers are no doubt more comfortable with mathematical symbols and equations than they are with my somewhat contrived fluid analogies (the leaky pipe being the most notorious example). However, my experience has been that most lay people are not comfortable with mathematical language, Including graphs and equations. That's not to say there are not difficult concepts presented in the book. Concepts such as stagnation temperature and collector efficiency are difficult to understand whether math or analogies are used. I've tried to avoid as much as possible the very technical aspects of solar engineering. I've slid past a great many details in hope of elucidating the major points. For example, I'm sure my portrayal of

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radiation heat flow caused many winces by my colleagues. Nevertheless, I feel the book is fairly complete since most aspects, including some rather technical material, are well covered.

Although I have been rather glib in presenting fluid analogies to thermal phenomena without resorting to mathematics, there is a very analytically precise methodology behind my presentation. Each concept is backed by rigorous mathematic analogies which have been taught to M.I.T. students for twenty years. I cannot take credit for developing the methodology although I am proud to have worked with those who did. Simply by adding appropriate equations for concepts I have discussed in prose, this book could become a college engineering text.

Cambridge, Mass.
April 1979

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Robert Entwistle: Bob, more than any other person, was responsible forthis book being written. As it evolved from first a text and then into a more general book, it was Bob who was always prodding me to finish those last few chapters. His company, Energy Learning Systems, is co-publishing the book with McGraw-Hill. His production specialists have transformed my clumsy wording and crude figures into a polished tome.

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Patricia Dinneen: Last, but far from least, Patty gave me encouragement when I was'down, advice when I came to stumbling blocks, and most important, provided a supportive environment.

The concept of consistent analogies between thermal fluid, electrical, and mechanical mediums has been pioneered by my colleagues, notably Hank Paynter, Art Murphy, Lowen Schearerand Herb Richardson. I am indebted to them for laying out the fundamental structure which I used in this book.