

# ENERGY RESOURCES

The Quest for Sustainable Energy



PAUL KRUGER

## ALTERNATIVE ENERGY RESOURCES:

### The Quest for Sustainable Energy

Paul Kruger Stanford University



John Wiley & Sons, Inc.

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Published by John Wiley & Sons, Inc., Hoboken, New Jersey Published simultaneously in Canada

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#### Library of Congress Cataloging-in-Publication Data:

Kruger, Paul, 1925-

Alternative energy resources: the quest for sustainable energy/Paul Kruger.

p. cm.

Includes index.

ISBN-13:978-0471-77208-8 (cloth)

ISBN-10:0-471-77208-9 (cloth)

1. Renewable energy sources. 2. Energy policy. I. Title.

TJ808.K78 2006 621.042—dc22

2005021362

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

#### ALTERNATIVE ENERGY RESOURCES:

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### **FOREWORD**

Dr. Alan C. Lloyd
Secretary
California Environmental Protection Agency
Sacramento, CA

The last few years have rekindled our interest in energy supplies, centered on various perceptions of availability and sustainability of resources, impending global demand, and the dynamics of U.S. policy in the Middle East due to fear of risks that loom behind new specters of horror, terrorism, and natural disasters. The perceived causes of these adversities are unrelated and hardly close to any semblance of agreement.

Our fears are overshadowed by hope, of the promise of what is achievable with available new technologies such as fuel cells and renewable sources of energy. Such a foundation of hope makes this book by Professor Kruger useful and timely, and important for students to keep on their active bookshelves.

The book is written around a central theme, the never-ending human quest for abundant energy, starting with the three axioms of that quest. The author surveys the status of current and developing energy sources. The text focuses on the three major large-scale energy resources for the exponentially growing demand for electric power and concludes with a section on hydrogen, the current fuel alternative for transportation and electric supply fuel cells. The three chapters devoted to the potential of hydrogen highlight the level of need for this alternative energy source as a fuel, the time period for impact on a scale such that societal benefits are realized, and the available primary energy resources that the author thinks could supply the required energy. The modeling in this area illustrates the consequences of delay in beginning a transition period. The depth of numerical data in the book provides sufficient information so that one can assess what should be an appropriate transition goal.

In this book Professor Kruger updates, in a text format, the alternatives for energy sources. He covers both available and impending

resources, representing updated technical and economic information. He also discusses in the various sections environmental benefits and the implications for health. These benefits may be more quantifiable as the costs of chosen directions have become more explicit during the last several decades.

This book is also a useful reference for policy makers who are engaged in developing directions, and in representing information that may already be known. Thus it will be a useful reality check to ground hopes of visionary advocates. Such grounding is required not merely to avoid chasing wrong directions, but also to reduce the costs of not taking or delaying the appropriate steps to reach the end goal.

Dr. Kruger, an emeritus professor at Stanford University, has evaluated, written, and taught this subject for over four decades. His work on energy and the environment influenced and helped our work in the South Coast Air Quality Management District through the 1990s, when we were battling local smog and ozone emissions in the Los Angeles area and looking at the advancement of the cleanest possible fuel technologies.

In that context, Dr. Kruger's work at the time and energy impact of changing into new technologies is pertinent. Most economic evaluations tend to be static, comparing numbers to numbers at a point in time and one case to another. The relevant point in advancing policy and technology is the dynamics of the macro-level, impact of a new technology, the way in which the energy needs will change at a macrolevel and what the delay and cost of not starting now can be. It is one thing to talk about hundreds or even thousands of alternative fuel cars such as fuel-cell hybrids, but they are only significant in a region, or a country, like ours, where millions of vehicles are in use. Since we do not want to make policies for small-scale applications, the dynamic modeling done by Dr. Kruger for hydrogen fuels on national and worldwide scales is worth noting. You may arrive at different conclusions from those of Dr. Kruger regarding energy needs, but he leads you to consider the models and to think about other more substantiated conclusions.

We, in my organization, are doing that. I hope you do too.

ALAN C. LLOYD

#### **PREFACE**

Undergraduate students, whose education occurs in a narrow age distribution centered on 20 years, generally will experience a professional career with many changes until they retire within a somewhat broader age distribution centered on 70 years. During this 50-year period, one prominent change will be a shift in the continuous human quest for abundant energy, including a major change in transportation from internal-combustion engines that burn petroleum-derived fuels (with an increasing rate of resource depletion and continuing emission of air pollutants) to engines that employ newer technology (such as fuel cells) and new transportation fuels (such as hydrogen, with assured abundance for large-scale production and with negligible emission of air pollution). A worldwide change to hydrogen fuel will allow a logical transition to a dual energy carrier system in which utilization of electricity can be focused on stationary power applications (e.g., residential, industrial, and commercial sites) and hydrogen fuel for transportation applications. With large-scale infrastructure, these two energy carriers can be interchanged readily as needed: electricity converted to hydrogen by electrolysis and hydrogen converted electricity by oxidation in fuel cells.

This book resulted from course notes that were assembled to introduce to freshmen and sophomore undergraduate students and mature adults in continuing education courses the potential for understanding, and possibly getting involved in, the development of hydrogen as a large-scale energy fuel at an early stage in the estimated 50 years required for the technology to be used globally. The text develops a broad picture of this transition in three parts: (1) an analysis of the background of the human quest for abundant energy, (2) the growth in awareness of a world with finite fossil fuel resources and a finite capacity to absorb large-scale waste products that pollute a fragile environment, and (3) the potential improvement that can result from the transition to hydrogen fuel from fossil fuels in transportation.

The text is aimed at undergraduates (and mature adults) in the hope of giving those 20-year-old students an early appreciation of the op-

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portunity to achieve a sustainable world energy supply with acceptable environmental impacts both globally and locally. A wide range of professional talent will be needed to develop the technical and social infrastructure for abundant energy with a minimal regulatory need to curtail freedom of choice.

PAUL KRUGER

Stanford, CA, 2004

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