Preface

Environmental Purpose

In 1990, after the first Sunrayce, the *Courier-Observer,* a newspaper serving the Potsdam area where I live, commented in an editorial that "…we don't expect solar cars to become the wave of the future…" This opinion may be taken as typical of many. However, there is another view. This view explains, in part, the motivation for writing this book.

The future is upon us. Each day our transportation system dumps millions of tons of pollutants into the atmosphere. This poisoning, even if it were the only environmental poisoning taking place (which it is not, of course), must be viewed as a crisis in the history of the earth. Furthermore, each day the millions of gallons of fuel consumed is subtracted from the remaining, decidedly finite, supply, some of which comes to us from overseas.

We must make a radical shift away from the combustion of carbon-based fuels as the energy source of our transportation system to a pollution-free transportation system with an energy source that can sustain that system indefinitely. This must be done quickly compared to the scale of historical time. To think otherwise is, as a teacher I know is fond of saying, to "live in la-la land."

What solutions are available that meet, or nearly meet, the criteria just set out? Only one: solar energy, in some form. Near-term examples are fuel cells using solar-generated hydrogen and air to power electric vehicles, electric vehicles driven directly or indirectly (by solar-charged batteries) by solar cell arrays, or vehicles driven directly by the combustion of solar-generated hydrogen with air. In the hydrogen-powered cases, the gas would be generated by the hydrolysis of water using the electric current produced by a fixed solar cell array, or by wind turbines driving electric generators.

None of these methods perfectly meet the criteria or is free of problems: the combustion of hydrogen with atmospheric air generates nitrous oxides; disposal of some battery types is a solid waste problem; the fabrication of solar cells creates wastes; large-scale solar power production requires large land areas. However, it is important to have a diversity of approaches under development. Otherwise we cannot hope to find the best approach, or combination of approaches. The history of this country is full of examples of technology rejected by our industrial establishment or our government without adequate examination, only to surface elsewhere. Perhaps, in the case of automobiles, opposition to progress would be less if gasoline prices were more than $ 5.00 per gallon (as in many countries as of this writing[1]), a price that better reflects the avoided cost of this fuel.

The potential for a net reduction in vehicular atmospheric pollution even using ordinary electric vehicles recharged by the utility grid is great. Of course, as long as the utility grid is supplied by energy from carbon-based fuels, use of electric vehicles will neither eliminate pollution entirely nor will it eliminate the consumption of these fuels. Bentley et al. (1992) studied these problems. And there is an additional risk: the reliability of the vehicle fleet would then depend upon the availability of the utility grid. Directly or indirectly solar-powered automobiles do not share this problem.

Driven by the urgent need to meet the environmental crisis, our transportation system is now changing, and it must continue to change at an increasing rate. Lightweight, hybrid-powered, very efficient but hydrocarbon-burning cars have entered the market, as have electric vehicles. Hamilton (1989) is an early general study of electric and hybrid vehicles. The "hypercar" concept of the Rocky Mountain Institute (Lovins et al. 1993, Moore and Lovins 1995) is a more recent example.

Educational Purpose

The remaining part of the motivation for this book is the improvement building solar cars brings to the education of the student engineers who build them. To design, build, test, and race a solar-powered car is experiential learning of the most effective sort. College graduates who have participated in such projects have helped to solve a real, complex, engineering problem. As such, they are prime prospective employees. And not just the engineers: the projects include marketing, fundraising, project planning and management, and public relations. Students from the Business School can be involved as well.

As of this writing (2013), 11 biennial American Solar Challenge races have been staged (the first five were named "Sunrayce"). During the period 1989–2012, there were 18 American Tour de Sol[2] races and several overseas solar-electric vehicle races, including the biennial World Solar Challenge[3] in Australia. Entrants in these events were teams from colleges, high schools, automobile companies, and individuals. It is notable that high school teams typically represented a substantial proportion of the American Tour de Sol entrants and that an annual international race just for high schools, the Solar Car Challenge,[4] was created in 1993.

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[1] See, for example, MyTravelCost.com, for a list of worldwide gasoline prices.

[2] The final American Tour de Sol, the eighteenth, was run in 2006.

[3] See http://www.worldsolarchallenge.org.

[4] See http://www.solarcarchallenge.org—a site rich with information.

This activity implies a strong interest in solar-electric and electric vehicle racing at colleges and also at secondary and post-secondary schools. However, solar car design, construction, and racing, demand technical knowledge that may not be readily available to private individuals, secondary school students, and in an integrated form, to college students.

Books have been written at the professional level on the aerodynamics of vehicles, on suspension design, on solar cells, and on composite materials—on every component used in a solar car. The book aims to provide a primer on those subjects as they apply to the design of solar-electric cars. The book emphasizes the integration and application of fundamental knowledge and skills to the process of creating a low-energy-consumption vehicle.

Background Assumed

The readers of this book are likely to be of diverse technical backgrounds. Therefore, emphasis has been placed on physical explanations. Mathematical relationships have, when possible, been accompanied or replaced by graphs. However, I have assumed a high-school-level knowledge of algebra, trigonometry (elementary calculus will be helpful, but is not vital), physics (statics, dynamics, thermodynamics), and electrical circuits. Knowledge of basic fabrication techniques and terminology also has been presumed.

Use of this Book

I have defined "courses" to include both conventional design courses and project-based learning communities (PBLC). The former tend to produce only paper designs[5] and center around the familiar classroom environment: lecturing, homework, etc. They generally last a semester and include students of one grade level. The latter run more or less continuously, are likely to include students of various grade levels and educational specialties, and are very fruitful when built around a large, multidisciplinary project such as a solar car.

The features of *A Solar Car Primer* already discussed make it useful for both conventional design courses and PBLCs. The book contains a discussion of the relevant physics, which is keyed to the project to motivate the discussion and a detailed example based on an actual solar car. The book is modular, so advanced students can skip the basic theory and apply the example directly to their project. Beginners can do the reverse. The test, energy management, and fund raising and public relations chapters should be especially useful to PBLCs.

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[5] Although there is a trend toward more product realization: multi-semester sequences in which prototypes are designed, built, and tested.

Acknowledgments

In Chaps. 9, 10, and 11, I have drawn upon some of the designs made, and some of the manufacturing methods used, by Clarkson University's 1995 and 1999 Sunrayce teams. I would like to thank those teams and to acknowledge certain members of those teams whose work contributed, directly or indirectly, to this book. These are: Vivek Sarin, Leslie Ann Hummel, Mathieu Gratton, Renay Bouchard Gratton, Jules Leduc, Dan Retajczyk, Tim St. Hilaire, Nate Ryder, Craig Evans, Scott Leonard, Rob Preuss, Matt Duquette, Lou Fasulo, Allison Green, Brian Lisiecki, and Dan Lyskawa.

The cost information in Chap. 14 is based in large part on information submitted by many of the US teams which have participated since 2010 in the American Solar Challenge and the Formula Sun Grand Prix.[6] Most of these teams were in the midst of designing, building, or testing new solar racing cars. So I am especially grateful that the following team members took the time to submit cost information: Wilkins White, Oregon State University; Logan Wells, University of Kentucky; Amy Sunderlin, Southern Illinois University Edwardsville; Min Ju Lee, University of California Berkeley; and Eric Hausman, University of Michigan.

Most of the photographs of solar cars were taken by Brian Lisiecki, Mike Griffin, Director of News Services at Clarkson University, and Jules Leduc. The photographs in Chap. 12 were taken by Mike Griffin and the staff of the Advanced Aerodynamic Laboratory in Ottawa, Canada. Photographs not otherwise credited were taken by the author.

Many thanks to Chuck Goodwin, Glen Botto, Kelly Eston-Thacher, Nancy Boyer-Rechlin, Drs. Dana Barry, Norbert Ackerman, Jim Carroll, and Ken Visser for reading drafts, or portions, of this book and for their helpful comments there on. Any errors remaining are my own.

I acknowledge with gratitude Dr. Russ Read, who was a co-advisor for Clarkson's 1990 and 1993 Solar Car Teams, Dr. Tom Ortmeyer, who was a co-advisor for the 1990 team, and Dr. Larry Compeau, who was a co-advisor for the 1995 and 1997 teams, Mr. Mike Griffin, and Ms. Karen St.Hilaire, who were staunch supporters of the project from its inception.

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[6] See Chapter 16.

Springer

http://www.springer.com/978-3-319-17493-8

A Solar Car Primer
A Guide to the Design and Construction of Solar-Powered Racing Vehicles
Thacher, E.F.
2015, XXV, 466 p. 195 illus., 36 illus. in color., Hardcover
ISBN: 978-3-319-17493-8