



Preface

The story told here is fascinating, unusual, and challenging. Like many good novels, it is necessarily extensive, both in its breadth of historical sweep and in its depth of detail. We must therefore ask the reader's patience as we seek to develop, piece by interlinked piece, some big ideas that have important consequences for the world's largest industry—providing electricity.

This discussion of a complex and wide-ranging field is presented in the way we feel will best serve diverse readers, ranging from interested laypeople and citizen activists to technical specialists and market participants. Those with a background in the essential concepts of the relevant disciplines are invited to skip familiar introductory material. Those lacking it may be glad of the introduction provided to help with basic terminology and navigation in fields perhaps unfamiliar to them. And those expert in these fields we ask to forgive the occasional simplifications made to increase clarity for nonexperts.

To simplify navigation and to avoid breaking up the narrative flow, certain details appear in color-coded boxes and sidebars: yellow for tutorials, gray for definitions, pale yellow for examples, and white for summaries. Technical notes appear in small italics. The 207 distributed benefits are numbered consecutively throughout Part Two, highlighted in green, and summarized on the front and rear endpapers. A detailed Table of Contents serves in place of an Index. Information about the authors and publishers is at the end of the book. Parenthetical reference numbers appear in blue throughout the text. These numbers correspond to an alphabetical Reference List at the end of the book.

The book is organized in three main parts:

- **Part One** introduces the history of the extraordinary transition now underway from very large to mainly small power plants, reviews the origins and course of our research, clarifies semantic issues, describes the existing U.S. electricity system and the main kinds of distributed resources, and concludes with brief discussions of some important background issues.
- **Part Two** introduces and launches a systematic and detailed survey of scale effects (how size affects value) and the corresponding 207 distributed benefits, explaining technical and economic concepts as needed. Although many distributed benefits could be classified in a variety of ways, we use some license to describe them under three main headings: system planning, construction and operation, and other sources of value. The system planning benefits, though they have important engineering content, are expressed mainly from the perspective of financial economics to make the narrative more coherent. In contrast, the construction and operating benefits use mainly the concepts and language of electrical engineering, as do most of the "other sources of value" (except such externalities as avoiding social and environmental costs).
- All the fine-grained analysis in Parts One and Two must ultimately be applied in a real business and policy context. Those seeking to harvest distributed benefits must understand market evolution, and those making the rules within which markets function

must understand distributed benefits. **Part Three** therefore describes public-policy initiatives that could help distributed benefits to realize their value in the marketplace; explores threats and opportunities for the private sector; and recommends attention and action by citizens.

We offer these findings with the humility of discovering, after diligent effort but with resources inadequate to the size of the task, that we have only mapped, not fully delved into, a very rich lode of ideas. But we have persevered in the hope of encouraging a far wider, deeper, more public, and more widely applied base of understanding of this perennial yet badly neglected question of what's the right size for the job. And although for specificity we have focused here on electric power systems, analogous scale issues clearly apply throughout many other technical and economic systems; indeed, Rocky Mountain Institute has already begun to apply them fruitfully to water and wastewater systems.

As with any survey of a vast and tangled web of ideas, we have drawn freely—though, we hope, with due and grateful attribution—on the work of hundreds of other researchers and practitioners. Our many intellectual debts will be evident from the hundreds of references cited throughout the text and consolidated at the end. But we want here to express special appreciation to those who have particularly lightened our task by providing obscure information, patiently correcting our errors, or kindly reviewing drafts and offering helpful suggestions for improvement. Though any remaining errors and omissions are solely our responsibility, any value of this book springs from the courtesy and insight of these and scores of other valued colleagues:

Nancy Mohn (ABB and Alstom Power), Bernard Chabot (ADEME), Daniel Shugar (Advanced Photovoltaic Systems and PowerLight), Michael Margolick (ARA Consulting Group), Bob Shaw (Arete Ventures), Peter Fox-Penner (Brattle Group), Pat McAuliffe, Sanford Miller, Commissioner Arthur H. Rosenfeld, John Wilson, and Eric Wong (California Energy Commission), Chris Robertson (Chris Robertson & Associates), Joe Iannucci (Distributed Utility Associates), Joe Galdo, Dick Holt, and Philip Overholt (DOE), Greg Kats (DOE and Capital E Group), Greg Motter (Dow Chemical), Roger Pupp (Econix), Vijay Vaitheeswaran (*The Economist*), Michael McGrath and Chuck Linderman (Edison Electric Institute), Nancy Bacon (Energy Conversion Devices), Elliot E. Mainzer (Enron), Howard Learner (Environmental Law and Policy Center), Michael Shelby and Jim Turner (EPA), Clark W. Gellings and Vito Longo (EPRI), Gary Cler, Bill Howe, Nicholas Lenssen, and Michael Shepard (E SOURCE), Caes Daey Ouwens (Government of Haarlem), Elizabeth Teisberg (Harvard Business School), D. Gordon Howell (Howell-Mayhew Engineering), Scott Gates (Idaho Power), Doug Koplou (Industrial Economics), Shimon Awerbuch (International Energy Agency), S. Chauham (Joe Wheeler Electric), Charlie Komanoff (Komanoff Energy Associates), Jon Koomey (Lawrence Berkeley National Laboratory), Tom Stanton (Michigan PUC), David Schoengold (MSB Associates), Ralph Cavanagh (Natural Resources Defense Council), Jim Welch (The Nature Conservancy), Mike Curley (NERC), Jeff Petter (Northern Power Systems), Lynn Coles, Dick DeBlasio, and Yih-huei Wan (NREL), Roland Schoettle (Optimal Technologies), Richard Ottinger (Pace Law School), H. J. Wenger and

Tom Hoff (Pacific Energy Group and Clean Power Research), Paul Gipe (Paul Gipe & Associates), John Carruthers, Bob Lambert, Bob Stewart, and David Turner (PG&E), John Fox (PG&E, Ontario Hydro, Perseus LLC, and RMI Board), Carl Weinberg (PG&E and Weinberg Associates), Landis Kannberg (PNL), Demetrio Borja (Polydyne), Gary Wayne and Tom Dinwoodie (PowerLight), John Mungenast (*Power Quality*), Tom Casten (Private Power LLC), Brian Farmer (PVUSA), Doug Pratt and John Schaeffer (Real Goods), Kevin Best, Dan Cashdan, and Paul Slye (RealEnergy—they generously contributed the first draft of the real-estate discussion in Section 3.4.6), Peter A. Bradford and David Moskovitz (Regulatory Assistance Project), Michael Vickerman (Renew Wisconsin), Jerrold Oppenheim (Renewable Technology Analysis), Paul Chernick, Adam Auster, and Rachel Brailove (Resource Insight), Chris Lotspeich (RMI and Second Hill Group), Brett Williams (RMI and University of California at Davis), Michael Edesess (RMI Board), Bent Sørensen (Roskilde University), Walter C. Patterson (Royal Institute of International Affairs), Don Wood (SDG&E), Jim Harding (Seattle City Light), Eric Daniels (Siemens Solar), Donald Osborn and Ed Smeloff (SMUD), Steven J. Strong (Solar Design Associates), Karl E. Knapp and William F. Sharpe (Stanford University), Georg Furger (Sustainable Asset Management), Christopher Freitas (Trace Engineering), Michael Tennis (Union of Concerned Scientists), Daniel Kammen (University of California at Berkeley), Ewald Fuchs (University of Colorado), John Michael Byrne (University of Delaware), Mike Russo (University of Oregon), Richard F. Hirsh (University of Vermont), Jim Hewlett (USEIA), Michael Mulcahy (Utility Free), Jason Edworthy (Vision Quest Wind Electric, Inc.), Andy Ford (Washington State University), Michael Totten (World Resources Institute and Conservation International), Chris Flavin (Worldwatch Institute), Dick Baugh, Janet Ginsburg, Paul Maycock, Neal McIlveen, Kelso Starrs, and Jeff Williams. A major debt is also owed to the numerous peer reviewers of several drafts from 1997 onward. Most importantly, the senior coauthors built on a great deal of hard work by three dedicated research assistants—Dr. André Lehmann, 1995–97; Ken Wicker, 2000–01; and Daniel Yoon, 1993–94. We are deeply in their debt.

This book was produced through the extraordinary effort and meticulous professionalism of graphic designer Ben Emerson and editor Beatrice Aranow. They were ably supported by numerous production assistants (listed in the colophon of this book) and by RMI's information-systems wizard Marty Hagen. All were led by RMI's Communications Director Norm Clasen, Executive Director Marty Pickett, and co-CEO (until June 2002) L. Hunter Lovins. I am grateful to them all for their faith, hope, and clarity.

Rocky Mountain Institute, as an independent nonprofit applied research center, is also grateful to the sponsors of this research and publication. The roots of this research go back more than two decades: scale issues were the subject of a chapter in *Soft Energy Paths* (1977) and an appendix in *Brittle Power* (1981/82). An RMI project to update and assemble a systematic survey of distributed benefits was launched in 1993 with partial funding from The Pew Charitable Trusts, which patiently awaited its long gestation. The research then made sporadic progress through the 1990s, sustained by the Institute's general-support donors, notably The William and Flora Hewlett Foundation and The Surdna Foundation, as well as by numerous private donors. Parts One and Two were drafted and peer-reviewed in 1997,

but got stuck in the production queue behind *Natural Capitalism* (1999). In 2000–01, new grants from The Energy Foundation for editorial completion and the Shell Foundation for production and dissemination permitted RMI to resume and complete the project. Special thanks to The Energy Foundation’s Hal Harvey and Eric Heitz and to Shell’s Kurt Hoffman for their vision and persistence. RMI senior energy consultants Karl R. Rábago and Tom Feiler drafted portions of Part Three around the turn of 2001–02, when we also incorporated new insights from RMI energy team leader Dr. Joel N. Swisher PE’s 2002 monograph *Cleaner Energy, Greener Profits: Fuel Cells as Cost-Effective Distributed Energy Resources*, funded chiefly by the W. Alton Jones Foundation. E. Kyle Datta generously contributed most of Part Three in the spring of 2002. With the help of all our generous and tolerant donors, editing and layout were finally completed in summer 2002 for August publication. Without the loyal support of all these friends, none of this work would have been possible. As primary author and final editor, I am responsible for all the deficiencies that doubtless remain.

Finally, a request to the reader: we need and solicit your help to improve this work. Please send your criticisms, comments, suggestions, references, contacts, examples, and any additional concepts or evidence on distributed benefits to sipcomments@rmi.org. Only by enlisting the distributed knowledge of the many emerging expert practitioners in this new field can we hope to advance the state of the art as quickly as its importance deserves. Corrections, updates, and related papers will be posted periodically in the Library/Energy section of www.rmi.org.

—ABL

Old Snowmass, Colorado
15 July 2002