

Energy for Sustainability: Technology, Planning, Policy

Section I: Energy Patterns and Trends 1

Chapter 1: The Energy Imperative and Patterns of Use 3

- 1.1 Our Energy Dilemma 4
- 1.2 Historical Perspective: Energy and Civilization 5
- 1.3 Global Energy Supply and Consumption 7
- 1.4 U.S. Energy Supply and Consumption 12
- 1.5 Summary 25

Chapter 2: Energy Sources and Sustainability 29

- 2.1 Criteria for Sustainable Energy 30
- 2.2 The Geologic Limits of Fossil Fuels 32
- 2.3 The Environmental Limits of Fossil Fuels 42
- 2.4 Opportunities and Limits for Non-fossil Energy 60
- 2.5 Summary 67

Chapter 3: Energy Futures 71

- 3.1 Planning and Visioning the Future 72
- 3.2 Business-as-Usual: Energy Outlook of the U.S. Energy Information Administration and the International Energy Agency 80
- 3.3 Some Visions of U.S. Energy Future 82
- 3.4 Visions for Renewable Energy and Efficiency 96
- 3.5 Carbon Futures and Global Climate Change 104
- 3.6 The Global Population-Economy-Energy Conundrum 107
- 3.7 Summary 113

Section II: Energy Fundamentals 115

Chapter 4: Fundamentals of Energy Science 117

- 4.1 Introduction 117
- 4.2 Basics of Energy Science 118
- 4.3 Mechanical Energy 123
- 4.4 Thermal Energy 128
- 4.5 Chemical Energy 131
- 4.6 Solar Energy 140
- 4.7 Nuclear Energy 150
- 4.8 Electrical Energy 157
- 4.9 Summary 161

Chapter 5: Energy Analysis and Life-Cycle Assessment 165

- 5.1 Some Principles of Life-Cycle Thinking and Sustainability Analysis 166
- 5.2 Energy Analysis 168
- 5.3 Energy Monitoring and Energy Audits 181
- 5.4 Economic Analysis of Energy Systems 186
- 5.5 Environmental Analysis of Energy and Materials Systems 203
- 5.6 Summary 211

Section III: Buildings and Energy 213

Chapter 6: Energy Efficiency for Buildings 215

- 6.1 Residential and Commercial Buildings 216
- 6.2 Introduction to Heat Loss Calculations 218
- 6.3 Heat Loss through Windows 227
- 6.4 Heat Loss through Walls, Ceilings, and Floors 233
- 6.5 Heat Loss Due to Infiltration 238
- 6.6 The Overall Heat Loss Factor 241
- 6.7 Let's Size a Furnace 245
- 6.8 Annual Cost of Heating 246
- 6.9 Impacts of Improving Efficiency 252
- 6.10 Heating, Ventilating, and Air-Conditioning (HVAC) Systems 253
- 6.11 Software Packages for Building Energy Analysis 260
- 6.12 Summary 261

Chapter 7: Solar Energy for Buildings 263

- 7.1 The Solar Resource 263
- 7.2 Passive Solar Heating 268
- 7.3 Cooling Loads 279
- 7.4 Domestic Water Heating 292
- 7.5 Solar Collectors for Hot Water 294
- 7.6 Summary 304

Chapter 8: From Whole Building to Whole Community Energy 307

- 8.1 The Evolution toward Green Buildings and Communities 307
- 8.2 Building Energy Codes and Standards: Toward Whole Building Energy 312
- 8.3 Whole Building Energy: Electrical Appliances and Lighting in Buildings 317
- 8.4 Whole Building Life-Cycle: Embodied Energy in Buildings 335
- 8.5 Green Building Ratings: Helping the Market Advance Whole Building Life-Cycle 339
- 8.6 Zero-Energy Buildings: Toward Whole Community Energy 351
- 8.7 Summary 353

Section IV: Sustainable Electricity 357

Chapter 9: Centralized Electric Power Systems 359

- 9.1 Introduction 359
- 9.2 Electromagnetism: The Technology behind Electric Power 359
- 9.3 Creating the Modern Electric Utility: Edison, Westinghouse, and Insull 361
- 9.4 Electric Power Infrastructure: Generation 364
- 9.5 Economics of Centralized Power Plants 376
- 9.6 Electric Power Infrastructure: Transmission and Distribution 382
- 9.7 Evolving Regulation of Electric Power 386
- 9.8 Summary 392

Chapter 10: Distributed Energy Resources 393

- 10.1 Distributed Generation (DG) 393
- 10.2 Demand-Side Management (DSM) 396
- 10.3 Electricity Storage 397
- 10.4 The View from the Customer's Side of the Meter 402
- 10.5 Heat Engines and the Carnot Efficiency Limit 410
- 10.6 Combined-Heat-and-Power (CHP) Systems 413
- 10.7 Microturbines 416

- 10.8 Reciprocating Engines 418
- 10.9 Fuel Cells 419
- 10.10 Stirling Engines 424
- 10.11 Summary 426

Chapter 11: Photovoltaic Systems 429

- 11.1 Introduction to Photovoltaics 429
- 11.2 Basic Semiconductor Physics 431
- 11.3 Photovoltaic Efficiency 435
- 11.4 Photovoltaic Fabrication 440
- 11.5 From Laboratory Cells to Commercial Modules 443
- 11.6 Grid-Connected Photovoltaic Systems 443
- 11.7 Economics of Photovoltaics 450
- 11.8 Stand-Alone Photovoltaic Systems 455
- 11.9 Summary 460

Chapter 12: Large-Scale Renewables: Wind and Solar 461

- 12.1 Renewable Electric Power Systems 461
- 12.2 Historical Development of Wind Power 461
- 12.3 The Wind Resource 463
- 12.4 Wind Turbine Technology 466
- 12.5 Energy from the Wind 470
- 12.6 Economics of Wind Power 477
- 12.7 Environmental Impacts of Wind 479
- 12.8 Concentrating Solar Power (CSP) Technologies 482
- 12.9 Summary 487

Section V: Sustainable Transportation and Land Use 489

Chapter 13: Transportation Energy and Efficient Vehicles 491

- 13.1 Energy Use in Transportation 494
- 13.2 Highway Passenger Vehicle Technologies, Efficiency, and Emissions 503
- 13.3 Emerging Vehicle Technologies 519
- 13.4 Well-to-Wheel Studies of Vehicle Technologies 530
- 13.5 Summary 537

Chapter 14: Biofuels, Biomass, and Other Alternative Fuels 539

- 14.1 Introduction to Alternative Transportation Fuels 540
- 14.2 Prospects and Potential for Biomass Fuels 543
- 14.3 Fuel Ethanol 550
- 14.4 Biodiesel 568
- 14.5 Other Biomass Energy and Emerging Biotechnologies 574
- 14.6 Natural Gas and Hydrogen as Transportation Fuels 578
- 14.7 Summary 581

Chapter 15: Whole Community Energy and Land Use 583

- 15.1 Community Transportation 584
- 15.2 Land Use, Transportation, and Energy 591
- 15.3 Land Use Design and Smart Growth Management 595
- 15.4 Land Use and Whole Community Energy 606
- 15.5 Planning for Whole Community Energy 618
- 15.6 U.S.A. 2040: Land Use and Energy for the Next 100 Million Americans 621
- 15.7 Summary 625

Section VI: Energy Policy and Planning 627

Chapter 16: Market Transformation to Sustainable Energy 629

- 16.1 Some Fundamentals of Market Transformation 630
- 16.2 The Techno-Economic Solutions 633
- 16.3 The Policy Solutions 642
- 16.4 The Social Solutions 654
- 16.5 Summary 660

Chapter 17: Energy Policy 661

- 17.1 International Perspectives on Energy Policy 661
- 17.2 U.S. Federal Energy Policy 679
- 17.3 Summary and Prospects for U.S. Federal Energy Policy 699

Chapter 18: U.S. State and Community Energy Policy and Planning 703

- 18.1 State Energy Policy 704
- 18.2 Community Energy Planning and Policy 728
- 18.3 Summary 757