

Contents

List of Figures xiii
List of Tables.....xxvii
Preface.....xxxi
Acknowledgments.....xxxiii
Authors.....xxxv

Chapter 1 Introduction 1

1.1 Energy and Society..... 1
1.2 Types of Energy..... 2
1.3 Renewable Energy 3
1.4 Advantages/Disadvantages.....4
1.5 Economics4
1.6 Climate Change 5
1.7 Order of Magnitude Estimates 6
1.8 Growth (Exponential)..... 7
1.9 Solutions 9
References 10
Recommended Resources..... 10

Chapter 2 Energy 13

2.1 Introduction 13
2.2 Definition of Energy and Power 13
2.3 Heat..... 15
2.4 Thermodynamics..... 16
2.5 Energy Dilemma in Light of the Laws of Thermodynamics ... 16
2.5.1 Conservation..... 16
2.5.2 Efficiency..... 17
2.6 Use of Fossil Fuels..... 20
2.6.1 Petroleum..... 24
2.6.2 Natural Gas 26
2.6.3 Coal 27
2.7 Nuclear..... 28
2.8 Finite Resource..... 30
2.9 Summary 32
References 33
Recommended Resources..... 34

Chapter 3	Sun.....	39
3.1	Solar Power.....	39
3.2	Electromagnetic Spectrum	39
3.2.1	Visible.....	42
3.2.2	Blackbody Radiation	42
3.3	Energy Balance of the Earth	42
3.4	Earth–Sun Motion	44
3.4.1	Earth Motion	46
3.4.2	Sun Position.....	48
3.5	Insolation	49
3.6	Solar Resource.....	50
3.7	Greenhouse Effect	50
	References	55
	Recommended Resources.....	55
Chapter 4	Heat Transfer and Storage	59
4.1	Introduction	59
4.2	Conduction.....	59
4.3	Convection.....	64
4.4	Radiation.....	66
4.5	Thermal Mass.....	66
4.5.1	Thermal Mass Patterns.....	67
4.5.2	Specific Heat	67
4.6	Seasonal Heating or Cooling.....	69
4.7	Thermal Comfort.....	69
	References	72
	Recommended Resources.....	72
Chapter 5	Solar Heating and Cooling	75
5.1	Building	75
5.1.1	Air Quality	75
5.1.2	Air and Vapor Barriers.....	75
5.1.3	Wind and Vegetation	76
5.2	Passive	76
5.3	Windows and Glazing	77
5.3.1	Other Glazings	79
5.3.2	Solar Heating.....	79
5.3.3	Shading.....	82
5.4	Passive Heating and Cooling.....	83
5.4.1	Direct Gain.....	83
5.4.2	Indirect Gain	83
5.4.3	Cooling	86

5.5	Active Heating	87
5.5.1	Flat-Plate Collectors	89
5.5.2	Domestic Hot Water	90
5.5.3	Swimming Pools	93
5.6	Active Cooling	93
5.7	Daylighting	94
5.8	Hybrid and Other	94
5.9	Drying Agricultural Products, Lumber	94
5.10	Solar Cookers	97
5.11	Water Purification	99
	References	101
	Recommended Resources	102

Chapter 6	Photovoltaics	105
6.1	Introduction	105
6.2	Physics Basics	105
6.3	Energy Bands	107
6.4	Photovoltaic Basics	108
6.5	Performance	110
6.6	Design Considerations	113
6.6.1	Sizing	114
6.6.2	Tracking	115
6.6.3	Estimation of Energy Production	117
6.7	Installed Capacity and Production	119
6.8	Distributed Systems	122
6.9	Community Solar	124
6.10	Applications	125
6.10.1	Grid Connected	125
6.10.2	Village and Hybrid Power	127
6.10.3	Stand-Alone	129
6.11	Comments	133
	References	133
	Recommended Resources	134

Chapter 7	Concentrating Solar Power	137
7.1	Introduction	137
7.2	Power Tower	138
7.3	Line or Linear	144
7.4	Dish/Engine	150
7.5	Point Focus	152
7.6	Solar Pond	152
7.7	Comments	155
	References	156
	Recommended Resources	156

Chapter 8	Solar Systems	159
8.1	Introduction	159
8.2	Passive Systems	159
8.2.1	Location, Orientation, and Shape	160
8.2.2	Indoor Space	161
8.2.3	Windows	161
8.2.4	Direct Gain	161
8.2.5	Thermal Mass	162
8.2.6	Clerestories and Skylights	163
8.2.7	Sunroom (Solar Room) and Attached Greenhouse	163
8.2.8	Passive Cooling	163
8.2.9	Other	164
8.3	Hybrid Systems	166
8.3.1	Building	168
8.3.2	Passive Heating and Cooling	168
8.3.3	Solar Hot Air System	170
8.3.4	Solar Hot Water	170
8.3.5	Daylighting	170
8.3.6	Electrical Generation	172
8.3.7	Performance	174
8.4	Active Systems	176
8.5	Underground Homes	177
8.6	Computer Software	179
8.7	Others	180
8.7.1	Straw Bale House	180
8.7.2	Adobe and Rammed Earth	180
8.7.3	Tire Houses, Earthships	181
8.7.4	Double-Envelope House	181
8.7.5	Green Building	182
	References	182
	Recommended Resources	182
Chapter 9	Wind Energy	185
9.1	Introduction	185
9.2	Wind Resource	186
9.2.1	Wind Shear	187
9.2.2	Wind Maps	189
9.3	Wind Turbines	191
9.4	Wind Farms	195
9.5	Wind Industry	200
9.6	Small Wind Turbines	202
9.7	Distributed-Community Wind	205
9.8	Village Power	207
9.9	Wind Diesel	208

9.10	Others	212
9.11	Performance.....	213
9.12	Comments.....	216
	References	216
	Recommended Resources.....	217
Chapter 10	Bioenergy	221
10.1	Introduction	221
10.2	Climate Change	222
	10.2.1 Climate Change-Anthropocene.....	223
	10.2.2 Intergovernmental Panel on Climate Change	224
10.3	Biomass Production.....	224
10.4	Conversion.....	229
10.5	Heat and Power.....	232
	10.5.1 Municipal Solid Waste	233
	10.5.2 Landfill Gas.....	234
	10.5.3 Biogas.....	235
10.6	Biofuels.....	237
	10.6.1 Ethanol	238
	10.6.2 Biodiesel.....	241
	10.6.3 Biogas Digesters	242
	10.6.4 Microalgae.....	243
10.7	Comments.....	246
	References	247
	Recommended Resources.....	248
Chapter 11	Geothermal Energy	253
11.1	Introduction	253
11.2	Resource	254
11.3	Types of Geothermal Resources.....	256
11.4	Direct Use	262
	11.4.1 Springs, Space Heating, and Others.....	263
	11.4.2 District Heating	263
	11.4.3 Case Studies	265
11.5	Geothermal Heat Pumps	265
11.6	Electricity	268
	11.6.1 Dry Steam	270
	11.6.2 Flash	271
	11.6.3 Binary Plants	273
	11.6.4 Combined Heat and Power.....	274
	11.6.5 Other Systems	274
11.7	Comments.....	275
	References	275
	Recommended Resources.....	276

Chapter 12	Water	279
12.1	Introduction	279
12.2	World Resource	281
12.3	Hydroelectric	281
12.3.1	Large (≥ 30 MW)	281
12.3.2	Small Hydro (100 kW to 30 MW, 10 MW in Europe)	287
12.3.3	Microhydro (≤ 100 kW)	288
12.4	Turbines	290
12.4.1	Impulse Turbines	291
12.4.2	Reaction Turbines	292
12.5	Water Flow	293
12.6	Tides	296
12.7	Ocean	299
12.7.1	Currents	299
12.7.2	Waves	301
12.7.3	Ocean Thermal Energy Conversion	306
12.7.4	Salinity Gradient	308
12.8	Others	308
	References	309
	Recommended Resources	311
Chapter 13	Storage	313
13.1	Introduction	313
13.2	Pumped Hydro	318
13.2.1	Case Study	319
13.3	Compressed Air	320
13.4	Flywheels	321
13.5	Batteries	322
13.5.1	Lead Acid	322
13.5.2	Lithium Ion	324
13.5.3	Sodium Sulfur	325
13.5.4	Flow Batteries	325
13.5.4.1	Case Study	326
13.5.5	Other Types of Batteries	327
13.6	Other Storage Systems	327
13.6.1	Magnetic Systems	327
13.6.2	Capacitors	328
13.6.3	Phase Change Materials	328
13.7	Hydrogen	329
	References	330
	Recommended Resources	330

Chapter 14 Institutional Issues..... 333

14.1 Introduction 333

14.2 The United States 333

14.2.1 Avoided Cost 334

14.2.2 Utility Concerns 335

14.3 Regulations 337

14.4 Environmental Issues 337

14.5 Politics 340

14.6 Incentives..... 341

14.6.1 The United States 342

14.6.1.1 Federal Support 343

14.6.1.2 State Support..... 344

14.6.1.3 Green Power 345

14.6.1.4 Net Metering..... 345

14.6.2 Other Countries 347

14.6.2.1 Wind 347

14.6.2.2 Photovoltaic Energy,
Solar Hot Water 349

14.7 Externalities (Social Costs/Benefits) 350

14.8 Transmission..... 352

References 353

Recommended Resources..... 354

Chapter 15 Economics 357

15.1 Introduction 357

15.2 Factors Affecting Economics 358

15.3 Economic Analyses 360

15.3.1 Simple Payback 360

15.3.2 Cost of Energy..... 362

15.4 Life-Cycle Costs..... 364

15.5 Present Worth and Levelized Costs..... 366

15.6 Externalities..... 367

15.7 Project Development..... 367

15.7.1 Landowner Considerations..... 371

15.8 Cost (Value) of Energy and Different Sources 372

15.8.1 Passive Solar..... 375

15.8.2 Active Solar Heat 375

15.8.3 Photovoltaics 375

15.8.4 Concentrating Solar Power..... 376

15.8.5 Wind 377

15.8.6 Bioenergy 379

15.8.7 Geothermal Systems 379

15.8.8	Water	380
15.8.9	Village Power	381
15.8.10	Wind Diesel	382
15.9	Summary	383
15.10	Future Trends	386
	References	387
	Recommended Resources.....	387
Chapter 16	Observations	391
16.1	Solid-State Electronics	395
16.2	Internet	395
16.3	Geographic Information Systems.....	396
16.4	Satellites	396
16.5	Examples	397
16.5.1	Interactive Maps	397
16.5.2	Interactive Database	398
16.5.3	Tools	398
16.5.4	Others	399
16.6	Predictions.....	399
16.7	Science.....	400
16.8	Authors' Predictions.....	401
16.9	On the Downside	402
	References	403
	Recommended Resources.....	404
Appendix.....		407
Index.....		413