
Contents

Preface	VII
Acknowledgments	IX
Part I	
Introduction to Primary Energy – Nonrenewable Sources	1
1 Introduction to World Energy	3
1.1 Concepts in Energy and Definitions	3
1.1.1 Significance of Energy Resources	4
1.1.2 Broad Definition of Energy	5
1.2 A Universal View of Energy	6
1.3 Energy Systems	7
1.3.1 Laws of Energy and Energy Efficiency	7
1.3.2 Equilibrium and Environmental Systems	8
1.3.3 Energy Flow in Environmental Systems	8
1.4 Future of Energy Industry	9
1.4.1 Introduction	9
1.4.2 Energy in 1990 to 2000 – Overview	11
1.4.3 World Primary Energy Production Trends Leading To 21 st Century	11
1.4.4 Major Energy Producers and Consumers	13
1.4.5 Regional Energy Production and Consumption	13
1.4.6 Petroleum	15
1.4.7 Natural Gas	15
1.4.8 Coal	16
1.4.9 Hydroelectric Power	16
1.4.10 Nuclear Electric Power	17
1.4.11 Geothermal, Solar, Wind, and Wood and Waste Electric Power	17
1.4.12. Carbon Dioxide Emission from the Consumption and Flaring of Fossil Fuels	17
1.5 Fast Track Energy Markets	19
1.6 Economic and Demographic Variables	20
1.6.1 Energy Use, Efficiency, and Population Growth	20
1.6.2 Global Population Growth	21

1.6.3	Population Growth and Industry	21
1.6.4	Consumption Processes	22
1.6.5	Exponential Growth/Consumption of Resources	23
1.6.6	Commodity Doubling Time	23
1.6.7	Commodity Expiration Time	24
1.6.8	Globalization-A Global View of Energy Use	24
1.7	Some Mineral Economic Considerations	25
1.7.1	Definition of Resources and Reserves	25
1.7.2	Computation of Mineral and Mineral-Fuel Reserves	26
1.7.3	Estimation of Potential Resources	26
1.7.4	Geological Example of Exploration Evaluation	26
1.7.5	Assessment Methodologies For Nonfuel Minerals	27
1.8	Resource, Exploration, Conservation, and Environmental Management Issues	27
1.8.1	Role of Geology	27
1.8.2	International Exploration Activity	31
1.8.3	U.S. Environmental Concerns and Regulations	31
1.8.4	Summary	33
2	Historical Perspective of Energy	35
2.1	Historical Perspective	35
2.1.1	View of Energy in the Universe	35
2.1.2	Early Energy Development In Europe and North America	35
2.2	Historical Developments of World Oil Industry	38
2.3	World Energy Demand	43
2.4	Long-Term Projections	44
2.5	World Energy Supplies	45
2.6	World Oil Demand	47
2.7	Alternative Fuels for Transportation	48
2.8	International Oil Complex	48
2.8.1	Essential Role of Oil	48
2.8.2	Evolution of International Oil Industry	49
2.8.3	International Oil Consumption	51
2.8.4	International Oil Supply	54
2.8.5	Technological Advancements	56
2.8.6	Government Intervention	56
2.8.7	Expanded Opportunities	57
2.9	Summary	60
3	World Primary Energy Overview	61
3.1	Perspective on Energy Resources	61
3.1.1	Overview of Energy Production and Consumption	61
3.2	World Petroleum and Natural Gas Resources	65
3.2.1	Historical Developments in Petroleum and Natural Gas Markets	65
3.2.2	Composition	66
3.2.3	Occurrence	67

3.3	Global View	71
3.3.1	Reserves	71
3.3.2	Production and Consumption	72
3.4	Position of United States in Petroleum and Natural Gas Markets	79
3.5	Future Trends	80
4	World Coal Resources	83
4.1	Coal Resources	83
4.1.1	World Trends	83
4.1.2	History	83
4.2	Composition	87
4.3	Occurrence	88
4.4	Global View	89
4.4.1	Reserves and Resources	89
4.4.2	Production and Consumption	89
4.5	Position of the United States	90
4.6	Future Trends	95
4.6.1	Past Projections	95
4.6.2	Environmental Considerations	95
4.6.3	Future Markets	95
4.7	Transportation of Coal	96
4.8	Clean Coal Technologies	98
4.8.1	Clean Combustion Cycles	98
4.8.1.1	Gasification Combined Cycle	98
4.9	Summary	99
5	Nuclear Energy	101
5.1	Introduction to Nuclear Energy	101
5.1.1	Historical Perspective	101
5.1.2	Theoretical Basis	102
5.1.3	Nuclear Reactions	102
5.1.3.1	Nuclear Fission	102
5.1.3.2	Nuclear Fusion	103
5.2	Nuclear Reactors	103
5.2.1	Nuclear Reactor Technology	104
5.2.1.1	Nuclear Reactor Design	104
5.2.1.2	Nuclear Fuel	107
5.2.2	Spent Fuel Reprocessing	108
5.3	Global View	109
5.3.1	Nuclear Energy Capacity	109
5.3.1.1	Dominant Countries	109
5.3.1.2	Brief History	109
5.3.2	Production And Consumption of Nuclear Energy	112
5.3.2.1	International Markets	112
5.4	Uraniums Production and Exploitation	113
5.4.1	Early Developments	113

5.4.2	Geological Exploitation	113
5.4.3	Price Structure (U ₃ O ₈)	114
5.4.4	Reserves and Resources	116
5.4.5	Production and Consumption	118
5.5	Position of the United States	121
5.5.1	Nuclear Energy Capacity and Electricity Generation	121
5.5.2	Uranium Resources	121
5.5.3	Cost Comparison – 1973 to 1981	122
5.6	Environmental Concerns	124
5.6.1	Radon Gas Hazard	124
5.6.2	Factors Affecting Future Trends	124
5.6.2.1	Three Mile Island 1979 to 1986	124
5.6.2.2	Rationale For Use	125
5.6.2.3	Cost Overruns and Failures	126
5.6.3	Summary	127
6	Hydroelectric Power	129
6.1	Resources	129
6.2	Types of Powerplants	132
6.3	Total World Potential	133
6.3.1	Capacity	133
6.3.2	Environmental Drivers	133
6.4	Total World Production	134
6.5	Commercialization	137
6.6	Summary	137
7	Meeting Future Demands for Energy Resources	139
7.1	World Demand	139
7.2	Policy Approaches	139
7.3	Conservations Measures	141
7.4	Advanced Vehicles	143
7.4.1	Use of Alternative Fuels For Automobiles	143
7.4.2	Gasohol Production	143
7.5	Methane in Coal Beds	144
7.6	Municipal Waste Fuels	146
7.7	Advanced Recovery and Discovery Methods	147
7.7.1	Oil and Natural Gas	147
7.7.1.1	New Discoveries Through Advanced Technologies	147
7.7.1.2	Enhanced Recovery Technologies	148
7.7.2	Coal	151
7.7.2.1	Coal Reserves	151
7.7.2.2	Underground Coal Gasification	152
7.8	Nuclear Energy	153
7.9	Summary	153

Part II**Renewable Energy Sources and Alternative Energy Technologies 155**

8	Geothermal Energy	157
8.1	Basics of Geothermal Energy	157
8.2	Geothermal Heat Extraction	157
8.3	Resources and Production	158
8.3.1	Hydrothermal Systems	158
8.3.2	Geopressured Systems	160
8.3.3	Hot Dry Rocks	160
8.3.4	Magma	160
8.4	History of Production	161
8.5	Geothermal Resources	161
8.6	United States Position	161
8.6.1	USA Estimates	161
8.6.2	Geysers Field	162
8.6.3	Other Research and Development	162
8.7	Uses of Geothermal Energy	163
8.7.1	Generation of Electricity	163
8.7.2	Space Heating	163
8.7.3	Miscellaneous Industrial Uses	163
8.8	Developmental Problems	163
9	Solar Energy	167
9.1	Solar Energy Demand	167
9.2	Major Drawbacks	167
9.3	Utilization of Solar Energy	168
9.3.1	Direct Thermal	168
9.3.2	Solar Electric	169
9.3.3	Fuels From Biomass	170
9.4	Direct Thermal Applications	170
9.4.1	Passive Solar Heating	170
9.4.2	Active Solar Heating	170
9.5	Thermal Electric Conversion	171
9.6	Photovoltaic Conversion Through Solar Cells	173
9.7	Summary	174
10	Wind Energy	175
10.1	Wind	175
10.1.1	Wind Energy Conversion	175
10.1.2	Windmills	175
10.2	Demonstration Projects	177
10.3	Wind Turbine Generators	177
10.4	Summary	178

11	Advanced Alternative Energy Sources	179
11.1	Introduction to Ocean Thermal Energy Generation	179
11.1.1	Introduction	179
11.1.2	Ocean Thermal Energy Generation (OTEC)	179
11.2	Biomass Fuels	180
11.3	Ocean Energy	183
11.3.1	Tidal Power	183
11.3.2	Commercial Operations	184
11.4	Wave Power	185
11.5	Controlled Nuclear Fusion Energy	185
11.6	Fuel Cells	188
11.6.1	Applications	188
11.6.2	Technologies	188
11.6.3	Advantages	189
11.6.4	Uses	189
11.7	Magnetohydrodynamic (MHD) Conversion	190
11.7.1	Basic Principle	190
11.7.2	Systems	190
11.8	Hydrogen Fuel	190
11.8.1	Applications	191
11.8.2	Advantages	191
11.8.3	Drawbacks	191
11.9	Summary	192
12	Nonrenewable Alternative Energy Resources and Technologies	193
12.1	Estimates of Energy Resources	193
12.2	Oil Shales	194
12.2.1	Kerogen Oil	194
12.2.2	Resources and Production	194
12.2.3	World Reserves	195
12.2.4	Recovery Technology	196
12.2.5	United States Position	196
12.2.6	History of Development	197
12.2.7	Development Factors	198
12.2.8	Development Problems	199
12.3	Tar Sands	201
12.3.1	Composition	201
12.3.2	Resources and Production	201
12.3.3	Technology	202
12.3.4	United States Position	203
12.3.5	Developmental Problems	203
12.4	Synthetic Fuels (Liquids and Gases) from Coal	204
12.4.1	History	204
12.4.2	Technology	204
12.4.3	United States Position	206
12.5	Summary	206

13	Environmental Issues and Concerns in Energy	207
13.1	Environmental Issues	207
13.1.1	Nuclear Energy Issues	207
13.1.2	Malfunctioning of Nuclear Reactors	208
13.1.3	Risks From Low-Level Radiation From Nuclear Reactors	211
13.2	Nuclear Waste Disposal	214
13.2.1	Low Level Waste	214
13.2.2	High Level Waste	214
13.2.3	Spent Fuel and Isotopes	217
13.2.4	Reprocessing Spent Fuel	218
13.2.5	Waste Disposal	218
13.2.6	Nuclear Waste Policy Act	219
13.3	Political Considerations	220
13.4	Non-Proliferation Efforts	220
13.5	Nuclear Fuel and Technology	221
13.6	Terrorist Activity	222
13.7	Breeder Reactor Technology Research	222
13.8	Conservations of Uranium	222
13.9	Research Programs	223
13.10	U.S. Nuclear Research	223
13.11	Summary	224
14	History of World Energy Program Policies	225
14.1	USA National Energy Policies	225
14.1.1	Oil Import Quotas	226
14.1.2	The OPEC Oil Embargo	227
14.1.3	Project Independence	227
14.2	U.S. National Energy Act (1978)	229
14.3	Windfall Profits Tax Act and Energy Security Act (1980)	231
14.4	Other Energy Program Policies	233
14.4.1	The Reagan Energy Policy	233
14.4.2	Other Pursuits	233
14.5	Synthetic Fuels Corporation	234
14.6	Stratetic Petroleum Reserve	235
14.7	Summary	236
Part III		
United States – Energy Forecasts and Modeling		239
15	Energy Modeling Approach and Assumptions	241
15.1	The USA Energy Modeling Approach	241
15.1.1	Types of Models for Forecasting	241
15.1.2	Economic Growth Rate Effects	243
15.1.3	Labor Force Effects	243

15.1.4	Manufacturing Growth Effects	243
15.2	Energy Intensive Industries	244
15.2.1	Major Industry Effects	244
15.3	Key Assumptions in Forecast Modeling	244
15.3.1	Uncertainty in Modeling	244
15.3.2	Variability in Forecasting	244
15.3.3	Variability in Expected Economic Growth	244
15.4	World Oil Prices	245
15.4.1	OPEC and Eurasian Interactions	245
15.4.2	OPEC Production Levels Effects	245
15.4.3	OPEC Oil Production Factor	245
15.4.4	OPEC Capacity Expansion Factor	246
15.4.5	Non-OPEC Production Effects	246
15.4.6	Economic Growth Assumptions	246
15.4.7	Other Assumptions and Factors	247
15.5	Cases	248
15.5.1	Integrated Forecasts	248
15.5.2	Available Data Adjustments	248
15.5.3	Carbon Emissions Coefficient Effects	248
15.6	Other Types of Forecasts	249
15.6.1	Mid-Term Modeling Assumptions	249
15.6.2	Short-Term Modeling Assumptions	249
15.6.3	Modeling Differences	249
15.7	Summary	250
16	U.S. Energy Forecasts and Modeling	251
16.1	U.S. Forecasts Models	251
16.1.1	Forecasts Basis	251
16.1.2	Outlooks and Issues Reviewed in 1995 Models	251
16.2	Energy Prices to 2010 and 2020	252
16.2.1	Primary Fuels	252
16.2.2	Technological and Productivity Effects	252
16.3	World Fuel Prices and Assessment Effects	253
16.3.1	World Oil	253
16.3.2	Natural Gas	253
16.3.3	Coal	254
16.3.4	Electricity	254
16.3.5	USA Crude Oil	254
16.3.6	Growth in Natural Gas	254
16.3.7	Renewable Energy	254
16.3.8	Nuclear Power	255
16.4	Consumption of Fuels	255
16.4.1	Oil and Gas	255
16.4.2	Natural Gas	255
16.4.3	Coal	255
16.4.4	Nuclear Power	255

16.4.5	Electricity Fuel Consumption	256
16.5	Renewable Energy	256
16.6	Energy Intensity and Use	257
16.6.1	Declines	257
16.6.2	Energy Per Dollar of GDP	257
16.6.3	Energy Regulations	257
16.7	Carbon Emissions	257
16.7.1	Carbon Factors and Methodology	257
16.7.2	Carbon Emission Coefficients	258
16.7.3	Climate Change Action Plan Effects	258
16.8	Summary	258
17	USA Energy Demand and World Markets	259
17.1	Energy Demand by End Use	259
17.1.1	Primary Energy Consumption	259
17.1.2	Transportation Sector	259
17.1.3	Residential and Industrial Sectors	259
17.2	Growth in End Use by Fuel	260
17.3	Energy Consumption	260
17.3.1	Household Energy Expenditure	261
17.3.2	Fossil Fuel Consumption	261
17.3.3	Energy End Uses	261
17.3.4	Carbon Emissions By Sector	261
17.4	Primary and End-Use Energy Consumption	262
17.4.1	Choices of End-Use Customers	262
17.4.2	Fossil Fuel Substitutions	262
17.4.3	Consumption Differences	262
17.4.4	Residential and Commercial Sectors, 2010	263
17.4.5	Carbon Emissions	263
17.5	Alternative Energy Efficiency Cases	263
17.6	Climate Change Action Program	264
17.7	Residential Demand	265
17.8	Commercial Demand	267
17.9	Industrial Fuel Shares	269
17.10	Energy Intensive Manufacturing	270
17.11	Industrial Demand	270
17.12	Transportation Demand	271
17.13	Energy Demand by End Use	274
17.14	Energy Demand-Challenges for the Future	276
17.15	Comparative Forecasts	276
17.16	Summary	278
18	USA Electricity Demand and Markets	279
18.1	Utility and Non-Utility Generators	279
18.2	Competition	280
18.3	Electricity Demand	281

18.4	New Capacity Additions	282
18.5	New Technologies	282
18.6	Electricity Fuel Share Flexibility	282
18.7	Options	283
18.8	Dominant Fuel	283
18.9	Gas-Fired Generation	284
18.10	Sulfur Dioxide Emissions	284
18.11	Licensing Period	285
18.12	Reactor Lifetime Assumptions	285
18.13	Electricity – Renewable Energy	286
18.14	Electricity Prices	289
18.15	Electricity – Challenges for the Future	290
18.16	Electricity – Comparative Forecasts	291
18.17	Summary	293
19	USA Oil and Natural Gas Consumption Forecasts	295
19.1	Natural Gas Consumption	295
19.2	Wellhead Prices	295
19.3	Gas Prices	296
19.4	Oil and Gas Production	296
19.5	Gas Reserve Additions	297
19.6	Oil and Gas Production Trends	297
19.7	Oil Production	297
19.8	Conventional Oil and Gas Production	298
19.9	Technology Gains	298
19.10	Natural Gas Markets	298
19.11	Gas Transmission and Distribution	299
19.12	Natural Gas Policy Issues	299
19.13	USA Oil Markets	302
19.14	International Oil Markets	304
19.15	Oil and Gas: Challenges for Future	306
19.16	Oil and Gas: Comparative Forecasts	307
19.17	Summary	308
20	Coal Market Forecasts and Analysis	309
20.1	Coal Consumption	309
20.2	Coal Demand	310
20.3	Electricity Generation	310
20.4	Coal Demand Trend	311
20.5	USA Coal Exports	311
20.6	Coal Reserves	312
20.7	Electricity Coal Demand	312
20.8	Coal: Environmental Issues	313
20.9	Coal: Challenges for the Future	314
20.10	Coal: Comparative Forecasts	316
20.11	Summary	317

Part IV

World Regional Energy Overview	319
21 Regional Overview – North America and Latin America	321
21.1 Introduction	321
21.2 Regional Position in World Mineral Economy	323
21.3 Regional Production Trends	323
21.4 Trade Liberalization Developments	326
21.5 Privatization and Investment Interests	327
21.6 Summary	328
22 The Middle East	329
22.1 Regional Overview	329
22.2 Bahrain	332
22.3 Cyprus	334
22.4 Iran	335
22.5 Iraq	339
22.6 Israel	341
22.7 Jordan	342
22.8 Kuwait	344
22.9 Lebanon	348
22.10 Oman	349
22.11 Qatar	352
22.12 Sauda Arabia	355
22.13 Syria	362
22.14 Turkey	364
22.15 United Arab Emirates	369
22.16 The Republic of Yemen	371
23 Antarctica and Canada	375
23.1 Antarctica	375
23.1.1 Introduction	375
23.1.2 International Policies and Programs	376
23.1.3 Mineral Potential	377
23.1.4 Infrastructure	377
23.1.5 Outlook	378
23.2 Canada	378
23.2.1 Economy	378
23.2.2 Environmental Concerns	379
23.2.3 Government Policies and Programs	380
23.2.4 Environmental Regulations	380
23.2.5 Production	381
23.2.6 Trade	382
23.2.7 Structure of the Mineral Industry	382
23.2.8 Commodity Review and Hydroelectric Potential	383

23.2.9	Mineral Fuels	384
23.2.10	Other Non-Petroleum Reserves	386
23.2.11	Infrastructure	387
23.2.12	Outlook	388
23.2.13	Summary	389
24	Latin America	391
24.1	Argentina	391
24.2	Belize	401
24.3	Bolivia	402
24.4	Brazil	409
24.5	Chile	417
24.6	Columbia	426
24.7	Costa Rica	429
24.8	Cuba	431
24.9	Dominican Republic	433
24.10	Ecuador	434
24.11	El Salvador	440
24.12	French Guiana	442
24.13	Guatemala	442
24.14	Guyana	444
24.15	Honduras	445
24.16	Jamaica	446
24.17	Mexico	447
24.18	Nicaragua	458
24.19	Other Islands of The Carribean	459
24.20	Panama	464
24.21	Paraguay	466
24.22	Peru	467
24.23	Suriname	471
24.24	Trinidad and Tobago	472
24.25	Uruguay	474
24.26	Venezuela	476
25	Europe and Central Eurasia	481
25.1	Regional Overview	481
25.2	Albania and Armenia	492
25.3	Austria	496
25.4	Azerbaijan	497
25.5	Belarus	498
25.6	Belgium and Luxembourg	501
25.7	Bosnia and Herzegovina	502
25.8	Bulgaria	503
25.9	Croatia	505
25.10	The Czech Republic	506
25.11	Denmark	511

25.12	Greenland	512
25.13	Estonia	513
25.14	Finland	516
25.15	France	517
25.16	Georgia	520
25.17	Germany	521
25.18	Greece	525
25.19	Hungary	527
25.20	Iceland	529
25.21	Ireland	529
25.22	Italy	530
25.23	Kazakhstan	533
25.24	Kyrgyzstan	537
25.25	Latvia	539
25.26	Lithuania	540
25.27	Macedonia	541
25.28	Malta	542
25.29	Moldova	542
25.30	Netherlands	543
25.31	Norway	545
25.32	Poland	547
25.33	Portugal	550
25.34	Romania	552
25.35	Russia	555
25.36	Serbia and Montenegro	567
25.37	Slovakia	570
25.38	Slovenia	572
25.39	Spain	573
25.40	Sweden	577
25.41	Switzerland	579
25.42	Tajikistan	579
25.43	Turkmenistan	581
25.44	Ukraine	583
25.45	United Kingdom	585
25.46	Uzbekistan	590
26	Africa	593
26.1	Regional Overview	593
26.2	Algeria	601
26.3	Angola	606
26.4	Botswana	608
26.5	Cameroon	611
26.6	The Central African Republic	613
26.7	Chad	614
26.8	Congo (Brazzaville)	615
26.9	Cote d'Ivoire	618

26.10	Egypt	620
26.11	Gabon	624
26.12	Ghana	627
26.13	Guinea	631
26.14	The Islands of Comores, Mauritius, Reunion, and Seychelles . . .	633
26.15	Kenya	635
26.16	Libya	637
26.17	Madagascar	640
26.18	Malawi	643
26.19	Mali	644
26.20	Mauritania	645
26.21	Morocco and Western Sahara	646
26.22	Mozambique	650
26.23	Namibia	653
26.24	Nigeria	659
26.25	Senegal	664
26.26	The Gambia	665
26.27	Guinea-Bissau	666
26.28	Sierra Leone	666
26.29	South Africa	667
26.30	Tanzania	675
26.31	Togo	677
26.32	Tunisia	678
26.33	Democratic Republic of the Congo (Formerly Zaire)	680
26.34	Zambia	684
26.35	Zimbabwe	688
26.36	Burundi	689
26.37	Equatorial Guinea	691
26.38	Lesotho	691
26.39	Rwanda	692
26.40	Sao Tome e Principe	694
26.41	Swaziland	694
26.42	Djibouti	696
26.43	Eritrea	696
26.44	Ethiopia	697
26.45	Somalia	700
26.46	Sudan	702
26.47	Uganda	704
26.48	Benin	705
26.49	Burkina Faso	706
26.50	Cape Verde	707
26.51	Liberia	707
26.52	Niger	707

27	Asia and Pacific	709
27.1	Regional Overview and Australia	709
27.2	Afghanistan	723
27.3	Bangladesh	725
27.4	Bhutan	726
27.5	Brunei	727
27.6	Burma	729
27.7	Cambodia	731
27.8	China	732
27.9	Fiji	739
27.10	India	740
27.11	Indonesia	744
27.12	Japan	749
27.13	North Korea	756
27.14	The Republic of Korea	757
27.15	Laos	760
27.16	Malaysia	761
27.17	Mongolia	764
27.18	Nepal	765
27.19	New Caledonia	766
27.20	New Zealand	766
27.21	Pakistan	768
27.22	Papua New Guinea	771
27.23	Philippines	773
27.24	Sri Lanka	775
27.25	Taiwan	776
27.26	Thailand	779
27.27	Vietnam	782
27.28	Summary	785
	References	787
	Appendix I. Conversion Table of Energy Units	801
	Author Index	803
	Subject Index	805