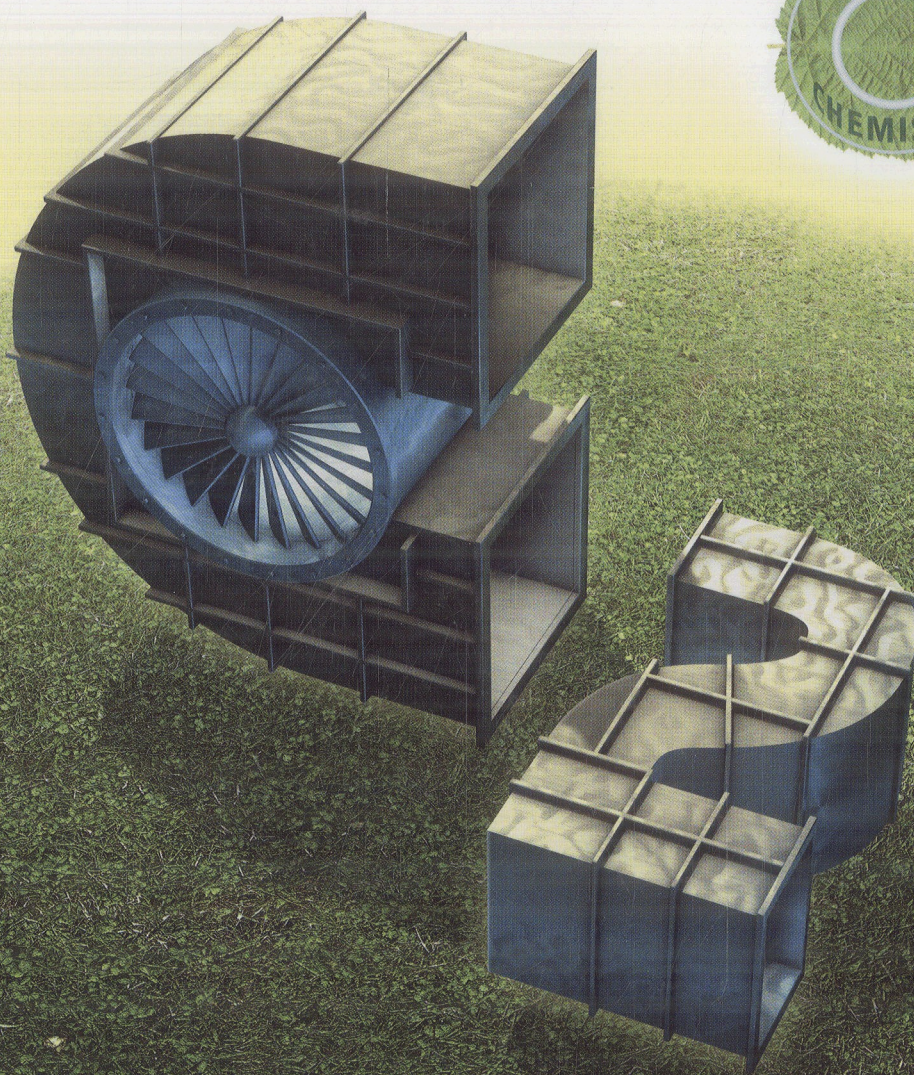
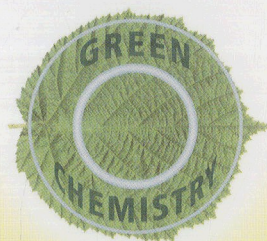


Edited by Hans-Joachim Leimkühler

 WILEY-VCH

Managing CO₂ Emissions in the Chemical Industry



Contents

Preface XIX

List of Contributors XXI

Trends in Energy and CO₂ Reduction in the Chemical Process Industry 1

Hans-Joachim Leimkühler

- 1 Climate Change 1
- 2 Overview of the Chemical Process Industry 4
- 3 Energy Consumption, CO₂ Emissions and Energy Efficiency 6
 - 3.1 Energy Consumption and CO₂ Emissions in General 6
 - 3.2 Energy Consumption and CO₂ Emissions in the Chemical Industry 11
 - 3.3 Energy Prices 13
 - 3.4 Energy Efficiency in the Chemical Industry 14
- 4 Political Framework and Trends 16
- 5 Kyoto Process and National Programs 17
 - 5.1 Kyoto Protocol 17
 - 5.2 Flexible Mechanisms 17
 - 5.3 Post-Kyoto Negotiations 19
 - 5.3.1 Mitigation Policy 19
 - 5.3.2 Adaptation 20
 - 5.3.3 Financing 20
 - 5.3.4 Technology 20
 - 5.4 National Programs 21
 - 5.4.1 United States of America 21
 - 5.4.2 Japan 22
 - 5.4.3 European Union 22
 - 5.4.4 China 23
 - 5.4.5 India 23
- 6 Company Initiatives 23
 - 6.1 Novartis 24
 - 6.2 Roche 24

6.3	Dow	26
6.4	DuPont	27
6.5	Bayer	28
	Acknowledgment	28
	References	28

Part One Administrative and Cultural Aspects 31

1	Analysis Methods for CO₂ Balances	33
	<i>Martin Wolf, Birgit Himmelreich, and Jörn Korte</i>	
1.1	CO ₂ Balances and Carbon Footprints	33
1.1.1	Measuring Impact on Global Warming	33
1.1.2	A Simple CO ₂ Balance	34
1.1.3	Carbon Footprints—A Few Examples	35
1.1.4	Company Carbon Balances	36
1.1.5	CO ₂ Balances Related to Emission Certificates	38
1.1.6	The CO ₂ Abatement Curve	38
1.2	Product Carbon Footprints (PCF)	40
1.2.1	PCF Methodology	41
1.2.1.1	Goal and Scope	41
1.2.1.2	Data Retrieval and Data Sources	42
1.2.1.3	Calculation Tools	42
1.2.2	PCF from Cradle-to-Gate	42
1.2.2.1	Energy Supply	44
1.2.2.2	Raw Materials	46
1.2.2.3	Logistics and Supply Chain	47
1.2.2.4	Manufacturing and Product Allocation	48
1.2.3	Cradle-to-Grave Carbon Footprints	51
1.3	Remarks and Summary	54
	References	54
2	Managing the Regulatory Environment	57
	<i>Nathan Steeghs</i>	
2.1	Introduction	57
2.2	Overview of Climate Policy	59
2.2.1	Economics of Climate Change	59
2.2.2	Policy Measures to Mitigate Greenhouse Gas Emissions	59
2.2.2.1	Cap-and-Trade	59
2.2.2.2	Command-and-Control	61
2.2.2.3	Hybridization of Taxation and Trading	62
2.3	Carbon Compliance for the Chemical Process Industry	63
2.3.1	Carbon Pricing and Industry Exposure	63
2.3.2	Applying Carbon Pricing to the Chemical Production Chain	64
2.3.2.1	Electricity Generation and Supply	66
2.3.2.2	Feedstock Extraction, Transportation, and Preparation	67

2.3.2.3	Basic Chemical Preparation	68
2.3.2.4	Subsector Chemical Preparation	70
2.3.3	Opportunities within a Compliance Market	71
2.4	Carbon Offsetting in the Chemical Industry	71
2.4.1	Concept of Offsetting	71
2.4.2	Flexible Mechanisms of the Kyoto Protocol	72
2.4.2.1	Developing a CDM Project	73
2.4.2.2	Developing a JI Project	80
2.4.3	International Offsetting in a Post-2012 Context	81
2.4.3.1	Scaling up the CDM via Benchmarking	81
2.4.3.2	Sectoral Crediting Mechanisms (SCM)	82
2.5	Positioning Industry for a Global Framework on Climate Change	82
2.5.1	Defining Sectors within a Regulated Environment	83
2.5.2	Allocating for the Chemical Industry	84
2.5.3	Key Messages Moving Forward	85
	References	86

3 Implementation of Energy Awareness in Plants 89

Markus Röwenstrunk and Susanne Mütze-Niewöhner

3.1	Energy Awareness and Environmental Sustainability	90
3.2	How to Raise Awareness and Change Behavior?	91
3.2.1	Rational-Economic Theory	92
3.2.2	Attitude Theory	92
3.2.3	Behavioral Theory	93
3.2.4	Goal-Setting Theory	93
3.2.5	Theories About Feedback	94
3.2.6	Combination of Methods	95
3.3	Individual and Organizational Change Processes	96
3.3.1	Planning, Organizing, and Preparing the Program	97
3.3.1.1	Prearrangements and Pre-analyses	97
3.3.1.2	Energy Audit	100
3.3.1.3	Methods, Measures and Goals	101
3.3.1.4	Team and Resources (Budget)	102
3.3.1.5	Plan and Timeframe (Schedule)	104
3.3.2	Implementation	105
3.3.2.1	Information Materials and Events	105
3.3.2.2	Participative Workshops and Specific Techniques	106
3.3.2.3	Goal-Setting Talks	109
3.3.2.4	Feedback Instruments and Talks	111
3.3.2.5	Energy Conservation Training	113
3.3.2.6	Energy Saving Award Programs	114
3.3.3	Evaluation and Report	115
3.3.3.1	Monitoring and Controlling (Process Evaluation)	115
3.3.3.2	Evaluation of Results	116
3.3.3.3	Reporting of Results and Lessons Learned	116

3.4	Sustain the Effort	117
	References	118

Part Two Energy Efficient Design and Production 121

4	Systematic Procedure for Energy and CO₂ Reduction Projects	123
	<i>Hans-Joachim Leimkühler</i>	
4.1	Overview	123
4.2	Definition of Scope and Task	124
4.3	Analysis	126
4.3.1	Carbon Footprint	126
4.3.2	Energy Distribution per Utility	127
4.3.3	Main Energy Consumers	130
4.3.4	Operational Parameters	132
4.3.5	Process Model	132
4.3.6	Energy Baseline and Milestone 1	132
4.4	Idea Generation	133
4.4.1	Fields of Energy Savings	133
4.4.2	Brainstorming Sessions	133
4.4.3	Equipment Check	135
4.4.4	Operational Improvements and Process Control	136
4.4.5	Process Improvements	137
4.4.6	Heat Integration and Heat Recovery	138
4.4.7	Raw Materials	138
4.4.8	Buildings and Facilities	139
4.4.9	Energy and Utility Systems	140
4.4.10	Milestone 2	141
4.5	Idea Evaluation	142
4.5.1	Technical Feasibility	142
4.5.2	Profitability	143
4.5.3	Savings Portfolio	144
4.6	Sustainable Implementation	147
4.6.1	Implementation Plan	147
4.6.2	Monitoring and Controlling	149
4.6.3	Reporting and Target Setting	150
4.6.4	Energy Loss Cascade	152
4.6.5	Energy Management System and Benchmarking	153
4.6.6	Energy Awareness in Plants	154
4.6.7	Repeated Checks	155
4.7	Case Study: The Bayer Climate Check	155
4.7.1	Situation before the Bayer Climate Check	155
4.7.2	Goal and Concept of the Bayer Climate Program	156
4.7.3	Realization and Results	156
	References	158

5	Sustainable Chemical Process Design	159
	<i>Rafiqul Gani, Henrique A. Matos and Ana Isabel Cerqueira de Sousa Gouveia Carvalho</i>	
5.1	Introduction	159
5.2	Definition of Concepts	159
5.2.1	Process Retrofit	159
5.2.2	Sustainability	160
5.2.3	Safety	160
5.3	Methodology for Sustainable Process Design	161
5.3.1	Methodology—Continuous Mode	161
5.3.1.1	Step 1: Data Collection	161
5.3.1.2	Step 2: Flowsheet Decomposition	161
5.3.1.3	Step 3: Calculation of Indicators	163
5.3.1.4	Step 4: Indicator Sensitivity Analysis Algorithm	167
5.3.1.5	Step 5: Sensitivity Analysis of Operational Parameters	167
5.3.1.6	Step 6: Generation of New Sustainable Design Alternatives	168
5.3.2	Methodology—Batch Mode	169
5.3.2.1	Step 1: Data Collection	169
5.3.2.2	Step 1A: Transform Equipment Flowsheet into an Operational Flow Diagram	169
5.3.2.3	Step 2: Flow Diagram Decomposition	170
5.3.2.4	Step 3: Calculation of Indicators	170
5.3.2.5	Step 4: Indicator Sensitivity Analysis Algorithm	172
5.3.2.6	Step 5: Sensitivity Analysis of Operational Parameters	172
5.3.2.7	Step 6: Generation of New Sustainable Design Alternatives	172
5.4	<i>SustainPro</i> Software	173
5.4.1	Introduction	173
5.4.2	<i>SustainPro</i> Architecture	173
5.4.3	Supporting Tools	173
5.5	Case Studies	174
5.5.1	Continuous Processes: Biodiesel Production	174
5.5.1.1	Step 1: Collect the Steady-state Data	174
5.5.1.2	Step 2: Flowsheet Decomposition	175
5.5.1.3	Step 3: Calculate the Indicators, the Sustainability and the Safety Metrics	175
5.5.1.4	Step 4: Indicator Sensitivity Analysis (ISA) Algorithm	177
5.5.1.5	Step 5: Process Sensitivity Analysis	177
5.5.1.6	Step 6: Generation of New Design Alternatives	177
5.5.2	Batch Processes: Insulin Case Study	179
5.5.2.1	Step 1: Collect the Steady-state Data	180
5.5.2.2	Step 1A: Transform Equipment Flowsheet in an Operational Flowsheet	180
5.5.2.3	Step 2: Flowsheet Decomposition	180
5.5.2.4	Step 3: Calculate the Indicators, the Sustainability and the Safety Metrics	180

5.5.2.5	Step 4: Indicator Sensitivity Analysis (ISA) Algorithm	183
5.5.2.6	Step 5: Process Sensitivity Analysis	183
5.5.2.7	Step 6: Generation of New Design Alternatives	184
5.6	Conclusions	186
	References	186

6 Heat Integration and Pinch Analysis 189

Zoran Milosevic and Alan Eastwood

6.1	Introduction	189
6.2	Heat Integration Basics	190
6.2.1	Why Heat-Integrate for Optimum Heat Recovery?	190
6.2.2	Inter-Unit Heat Integration	191
6.2.3	Benefits of Heat Integration	192
6.2.4	Pinch Analysis	192
6.2.4.1	Energy Targeting	193
6.2.4.2	Process Modifications	193
6.2.4.3	Process Synthesis	193
6.2.4.4	Utilities Optimization	193
6.2.4.5	Total Site Optimization	193
6.3	Introduction to Pinch Technology	193
6.3.1	The Concept of Quality of Energy	193
6.3.2	Energy Targeting	195
6.3.3	Composite Curves	197
6.3.4	Setting the Energy Targets	198
6.3.5	Setting the Area Targets	199
6.3.6	Capital/Energy Trade-off	200
6.4	Minimizing the Cost of Utilities	201
6.4.1	Utility Costing	201
6.4.2	Targeting for Multiple Utilities: The Grand Composite Curve	203
6.4.3	Total Site Integration	206
6.4.4	Steam and Power System and Efficient Power Generation	207
6.4.5	Options for Low Grade Heat Use	208
6.5	Process Synthesis	209
6.5.1	The Pinch Rules	209
6.5.2	Network Design	211
6.5.3	Network and Process Design Interaction	212
6.5.3.1	Process Modifications	212
6.5.3.2	The Plus/Minus Principle	213
6.5.3.3	Integration Rules for Various Process Equipment	214
6.6	Revamping Heat Exchanger Networks	214
6.6.1	Area Efficiency Method	214
6.6.2	Modern Retrofit Techniques	216
6.6.3	The Network Pinch	217
6.7	Other Applications of Pinch Technology	218
6.7.1	Area Integration	218

6.7.2	Water Pinch	219
6.7.3	Hydrogen Pinch	220
	References	221
	Further Reading	221
7	Energy Efficient Unit Operations and Processes	223
	<i>Andreas Jupke</i>	
7.1	Introduction	223
7.2	Good Housekeeping	224
7.3	Centrifugal Pumps and Blowers	226
7.3.1	Centrifugal Pumps	226
7.3.2	Blowers	229
7.4	Distillation	229
7.4.1	Basic Principles	230
7.4.2	Operation and Control	231
7.4.2.1	Purity of the Product	231
7.4.2.2	Operating Pressure	231
7.4.2.3	Sub-Cooling of the Reflux Flow	232
7.4.2.4	Location of Feed Point	232
7.4.2.5	Fouling or Damage of Internals	232
7.4.2.6	Process Control	232
7.4.3	Improved Design for Single Columns	234
7.4.3.1	Column Internals	234
7.4.3.2	Feed Preheating	235
7.4.3.3	Vapor Recompression	236
7.4.3.4	Intermediate Reboiler or Condenser	238
7.4.3.5	Heat-Integrated Distillation Column (HIDiC)	240
7.4.4	Improved Design for Multi Columns	241
7.4.4.1	Dividing Wall Column	241
7.4.4.2	Indirect Coupling of Columns	243
7.4.4.3	Design of Distillation Processes	245
7.4.5	Reactive Distillation	246
7.5	Evaporation	246
7.5.1	Feed Preheating	247
7.5.2	Multistage Evaporation	247
7.5.3	Vapor Recompression	249
7.6	Drying	250
7.6.1	Operational Improvements for Convective Dryers	251
7.6.2	Heat Recovery from Convective Dryers	252
7.6.3	Additional Measures for Improving the Energy Efficiency of Dryers	253
7.7	Crystallization	253
7.7.1	Melt Crystallization by Cooling	254
7.7.2	Evaporative Crystallization from Solutions	255
7.7.3	Freeze Crystallization	256

7.7.4	Additional Measures for Improving the Energy Efficiency of Crystallization	256
7.8	Membrane Separation	256
7.8.1	Basic Principles	257
7.8.2	Applications of Membrane Separation to Increase Energy Efficiency	257
7.8.2.1	Separation of Organic Vapors	257
7.8.2.2	Pervaporation	258
7.9	Reaction and Entire Processes	258
7.9.1	Recovery of Reaction Heat	259
7.9.2	Heat Integration	260
7.9.3	Increased Conversion and Selectivity	261
7.9.4	Solvent Selection	262
7.9.5	Optimized Process Conditions	262
7.9.6	Microstructured Equipment	264
7.10	Total Site Network	265
7.11	Advanced Process Control and Performance Monitoring	265
	References	268

8 Energy Efficient Equipment 271

Roger Grundy

8.1	Introduction	271
8.2	Rotating Equipment	271
8.2.1	Compressors	271
8.2.1.1	Reciprocating Compressors	271
8.2.1.2	Centrifugal Compressors	272
8.2.1.3	Axial Compressors	274
8.2.1.4	General Considerations	275
8.2.2	Pumps	275
8.2.2.1	Centrifugal Pumps	275
8.2.2.2	Reciprocating Pumps	278
8.2.2.3	Other Types of Pump	278
8.2.3	Fans	278
8.2.3.1	Centrifugal Fans	278
8.2.3.2	Axial Fans	281
8.2.4	Power Recovery Equipment	281
8.2.4.1	Turbo-Expanders	281
8.2.4.2	Liquid Turbines	282
8.2.5	Steam Turbines	283
8.2.5.1	Factors Affecting Performance	283
8.2.5.2	Single Stage Turbines	283
8.2.5.3	Multistage Turbines	284
8.2.6	Gas Turbines	285
8.2.6.1	Frame Engines	286
8.2.6.2	Aero-Derivative Engines	286

8.2.7	Electric Motors	287
8.2.8	Air Coolers	288
8.2.8.1	Air Cooler Fin Types	290
8.3	Fixed Equipment	290
8.3.1	Fired Heaters	290
8.3.1.1	Configuration and Design	291
8.3.1.2	Fuel System	291
8.3.1.3	Burner Design	292
8.3.1.4	Instrumentation and Control	292
8.3.2	Flares and Flare Systems	292
8.3.3	Piping	293
8.3.3.1	Capital Cost versus Running Cost	293
8.3.3.2	Design for Low Line Loss	294
8.3.4	Insulation	295
8.3.4.1	Economic Insulation Thickness	295
8.3.4.2	Mis-Use of Insulation	295
8.3.4.3	Insulation Types	296
8.3.4.4	Sealing	296
8.3.5	Tank Farms	296
8.3.5.1	Tank Gas Blanketing	297
8.3.5.2	Tank Heating	297
8.3.6	Steam Systems	297
8.3.6.1	Header Pressure and Temperature Control	297
8.3.6.2	Boilers	298
8.3.6.3	De-Aerators	298
8.3.6.4	Steam Traps and Condensate Recovery	298
8.3.7	Cooling Water Systems	299
8.3.7.1	Cooling Towers	299
8.3.7.2	Cooling Tower Fans	301
8.3.7.3	Circulation Pumps	301
8.3.7.4	Tower Packing	303
8.3.7.5	System Tuning	303
9	Energy Efficient Refineries	305
	<i>Carlos Augusto Arentz Pereira</i>	
9.1	Historical Evolution from Energy Conservation to Energy Efficiency in Refineries	305
9.1.1	Global Scenarios and Impact on the Oil Business	306
9.2	Good Practices for Energy Conservation Programs	308
9.2.1	Energy and Material Balances	309
9.2.1.1	Measurements and Basic Units	310
9.2.1.2	Calculi and Approximation	311
9.2.1.3	Analysis and Basis	312
9.2.1.4	Standards, Averages and Deviations	314
9.2.1.5	Usual Figures	315

9.2.2	Process Units	315
9.2.2.1	Transformation Units	316
9.2.2.2	Separation Units	319
9.2.2.3	Storage and Transport	322
9.3	Awareness and Motivational Work	325
9.3.1	Communication	325
9.3.1.1	Target Clients	325
9.3.1.2	Language	326
9.3.1.3	Media	326
9.3.2	Education	327
9.3.2.1	Speeches	327
9.3.2.2	Courses	328
9.4	Saving Energy by Operation and Maintenance	329
9.4.1	Scheduling and Maintenance	330
9.4.2	Pre-Maintenance Work	330
9.4.3	Conditioning and Testing	331
9.4.4	Best Practices in Operation	332
9.4.4.1	Combustion	332
9.4.4.2	Heat Transfer	334
9.4.4.3	Cooling	335
9.4.4.4	Fluid Movement	335
9.4.4.5	Energy Distribution	336
9.5	Upgrading and New Projects for Better Energy Performance	338
9.6	Organizational Issues on Energy	339
9.6.1	Initial Work	339
9.6.2	Committees	340
9.6.3	Task Forces	341
9.6.4	Leadership	342
9.6.5	Accountability	343
9.6.6	Corporate Goals	344
9.6.7	Evolutionary Organization	346
9.7	Future and Environmental Concerns	347
9.8	Approach and Literature	348
	Further Reading	348
10	Energy Efficient Utility Generation and Distribution	351
	<i>Carlos Augusto Arentz Pereira</i>	
10.1	Characteristics	351
10.1.1	Use of Utilities	351
10.1.2	Quality	352
10.1.3	Energy Exchange	353
10.1.4	Investment and Operational Costs	354
10.1.5	Energy Efficiency	354
10.2	Common Utilities	355
10.2.1	Steam	355

10.2.2	Electrical Power	356
10.2.3	Water	356
10.2.3.1	Industrial Water	357
10.2.3.2	Cooling Water	357
10.2.3.3	Boiler Water	358
10.2.3.4	Condensate	360
10.2.4	Air	361
10.2.4.1	Cooling	362
10.2.4.2	Instrument Air	362
10.2.4.3	Service Air	363
10.3	Generating Systems	363
10.3.1	Power Cycles	363
10.3.2	Main Pieces of Equipment	369
10.3.2.1	Boilers	369
10.3.2.2	Gas Turbines	371
10.3.2.3	Steam Turbines	372
10.3.3	Ancillary Systems	373
10.4	Utility Units	374
10.4.1	Steam Generation	374
10.4.2	Power Generation	375
10.4.3	Water Treatment	376
10.4.4	Cooling Units	376
10.4.5	Ancillary Systems	377
10.5	Distributing Systems	378
10.5.1	Pipes	378
10.5.1.1	Steam	378
10.5.1.2	Condensate	380
10.5.1.3	Water	381
10.5.1.4	Air	381
10.5.2	Wiring	381
10.5.2.1	Phase	382
10.5.2.2	Frequency	382
10.5.2.3	Power Factor	382
10.5.2.4	Voltage and Current	383
10.6	Design Aspects	383
10.6.1	Availability	384
10.6.2	Technology	384
10.6.3	Integration with Process	384
10.7	Operational and Maintenance Aspects	385
10.7.1	Stability	385
10.7.2	Safety	385
10.7.3	Reliability	386
10.7.4	Efficiency	386
10.8	Approach and Literatur	387
	Further Reading	387

Part Three Future Developments 389

11 Carbon Capture and Storage 391

Frank Schwendig

- 11.1 Background 391
- 11.2 General Description of the Technology with its Components 393
- 11.3 Carbon Capture 394
 - 11.3.1 Post-Combustion CO₂ Scrubbing 395
 - 11.3.1.1 The Basic Idea of Carbon Capture 395
 - 11.3.1.2 Technological Implementation 396
 - 11.3.1.3 Importance for the Chemical Industry 399
 - 11.3.2 Oxyfuel 399
 - 11.3.2.1 The Basic Idea of Carbon Capture 399
 - 11.3.2.2 Technological Implementation 400
 - 11.3.2.3 Importance for Chemical Industry 402
 - 11.3.3 ICGG with Carbon Capture 402
 - 11.3.3.1 The Basic Idea of Carbon Capture 402
 - 11.3.3.2 Technological Implementation 403
 - 11.3.3.3 Importance for the Chemical Industry 405
 - 11.3.4 Technologies to Reduce Energy Consumption for Carbon Capture 406
- 11.4 CO₂ Transport 407
 - 11.4.1 Pipeline 408
 - 11.4.2 Ship 409
 - 11.4.3 Railway and Truck 410
- 11.5 CO₂ storage 410
 - 11.5.1 Underground Storage of CO₂ 410
 - 11.5.2 Carbonation 412
- 11.6 Efficiency and Economy Parameters of CCS 413
 - 11.6.1 Efficiency Parameters of CCS 413
 - 11.6.2 Assessing the Economic Efficiency of CCS 415
- 11.7 Upshot 416
 - Further Reading 417

12 CO₂-Neutral Production—Fact or Fiction? 419

Stefan Nordhoff, Thomas Tacke, Benjamin Brehmer, Yvonne Schiemann, Thomas Böhland, and Christos Lecou

- 12.1 Introduction 419
- 12.2 Renewable Feedstocks 420
 - 12.2.1 Overview 420
 - 12.2.2 Volumes, Trading and Pricing 421
 - 12.2.2.1 Renewable Feedstock Trends 421
 - 12.2.2.2 Sugar 422
 - 12.2.2.3 Starch 423
 - 12.2.2.4 Oils, Fats 424
 - 12.2.2.5 Biomass and Residues 425

12.2.3	Competitiveness	426
12.2.3.1	Competition between Fossil and Renewable Feedstocks	426
12.2.3.2	Yields and Efficiency of Chemical Processing	427
12.3	Industrial Biotechnological Processes	429
12.3.1	Market, Field of Application, and Currently Available Products	429
12.3.2	Existing and Future Opportunities of Industrial Biotechnology	430
12.3.2.1	General Developments	430
12.3.2.2	Amino Acids	430
12.3.2.3	Bioethanol and Bioethylene	431
12.3.2.4	Building Blocks	432
12.3.2.5	Bioacrylic Acid	432
12.3.2.6	Oils for Chemicals	433
12.3.2.7	Biocatalysis for the Production of Emollient Esters	434
12.4	Expansion to Multiproduct Biorefineries	435
12.4.1	CO ₂ Saving Limitations of Single Product-based Systems	435
12.4.2	Entire Biomass Use	436
12.4.2.1	Chemical Breakdown	436
12.4.2.2	Pure Syngas	437
12.4.2.3	Partial Syngas and Partial Biochar	437
12.4.2.4	Chemical Structure Retention	437
12.4.2.5	Proteins for Functionalized Chemicals	438
12.4.3	Technical Gaps and Future Development Considerations	439
12.5	Determination of CO ₂ Emissions in Processes of Chemical Industry	439
12.5.1	Data Generation	439
12.5.2	The Diversity in the Interpretation of Data	440
12.6	The Three-Pillar Interpretation of Sustainability	442
12.6.1	Common Practice and Future Needs	442
12.6.2	Fuel vs. Food and other Misbalances	443
12.7	Outlook	444
	References	445