

Contents

<i>Contributor contact details</i>	<i>xiii</i>
<i>Woodhead Publishing Series in Energy</i>	<i>xix</i>
<i>Foreword</i>	<i>xxviii</i>
Part I Key issues and assessment of biofuels production	1
1 Introduction: an overview of biofuels and production technologies	3
R. LUQUE and J.M. CAMPELO, Universidad de Córdoba, Spain and J.H. CLARK, University of York, UK	
1.1 Introduction	3
1.2 Development of (bio)chemical conversion technologies	4
1.3 Development of biological conversion technologies	5
1.4 Development of thermochemical conversion technologies	6
1.5 Integration of biofuels into biorefineries	6
1.6 Future trends	8
1.7 Acknowledgements	11
1.8 Sources of further information	11
1.9 References	11
2 Multiple objectives policy for biofuels production: environmental, socio-economic and regulatory issues	13
C. DE LUCIA, University of York, UK and Technical University of Bari, Italy	
2.1 Introduction	13
2.2 Energy security and supply	14
2.3 Emission reductions, land use and other environmental impacts	17
2.4 Food safety and development of rural areas	19
2.5 Biofuels support policies	24

Contents

2.6	Conclusions and future trends	29
2.7	List of selected economies in Fig. 2.1 and 2.2, and Tables 2.1 and 2.2	32
2.8	References	33
3	Life cycle sustainability assessment of biofuels A. AZAPAGIC, The University of Manchester, UK and H. STICHNOTHE, Johann Heinrich von Thünen Institut – Institute of Agricultural Technology and Biosystems Engineering, Germany	37
3.1	Introduction	37
3.2	Sustainability issues along the life cycle of biofuels	39
3.3	Environmental sustainability of biofuels	40
3.4	Economic sustainability of biofuels	50
3.5	Future trends	55
3.6	Appendix: Life cycle assessment (LCA) methodology	55
3.7	Sources of further information	57
3.8	References	58
4	Vegetable-based feedstocks for biofuels production S. PINZI and M.P. DORADO, University of Córdoba, Spain	61
4.1	Introduction	61
4.2	Most frequent vegetable raw materials to produce first-generation biodiesel	62
4.3	Raw materials to produce low-cost biodiesel	69
4.4	Vegetable raw materials to produce bioethanol	71
4.5	Vegetable raw materials to produce biofuels from other technologies	82
4.6	Acknowledgements	86
4.7	References	86
Part II	Biofuels from chemical and biochemical conversion processes and technologies	95
5	Production of biodiesel via chemical catalytic conversion R. VERHÉ and C. ECHIM, Ghent University, Belgium, W. DE GREYT, Desmet Ballestra Group, Belgium and C. STEVENS, Ghent University, Belgium	97
5.1	Introduction	97
5.2	Biodiesel definition	98
5.3	Treatment of the feedstocks prior to production of the biodiesel	102
5.4	Current technologies of biodiesel production	102
5.5	Purification of biodiesel	120
5.6	Industrial production of biodiesel	122

5.7	Influence of the feedstock and technology on biodiesel properties	123
5.8	Conclusions and future trends	127
5.9	References	127
6	Biochemical catalytic production of biodiesel S. AL-ZUHAIIR, UAE University, UAE	134
6.1	Introduction	134
6.2	The enzymatic process	136
6.3	Limitations of the enzymatic approach	137
6.4	Sources of the enzyme: lipase	139
6.5	Feedstock	140
6.6	Acyl acceptors	142
6.7	Effect of temperature	144
6.8	Immobilized lipase	144
6.9	Kinetics of enzymatic production of biodiesel	149
6.10	Future trends	151
6.11	Sources of further information	154
6.12	References	155
7	Production of glycerol-free and alternative biodiesels A. MACARIO and G. GIORDANO, University of Calabria, Italy, F.M. BAUTISTA, D. LUNA, R. LUQUE and A.A. ROMERO, University of Córdoba, Spain	160
7.1	Introduction	160
7.2	Novel types of biodiesel: biofuels that incorporate glycerol into their composition	162
7.3	Advantages in the use of biofuels integrating glycerol	170
7.4	Processing of oils and fats in the current oil refining plants	171
7.5	Future trends	172
7.6	References	173
8	Biodiesel production from microbial oil A.A. KOUTINAS and S. PAPANIKOLAOU, Agricultural University of Athens, Greece	177
8.1	Introduction	177
8.2	Microorganisms and raw materials used for microbial oil production	178
8.3	The biochemistry of lipid accumulation in the oleaginous microorganisms	183
8.4	Biodiesel production from single cell oil	190
8.5	Future trends	191
8.6	References	192

Contents

9	Biochemical production of bioethanol M. ARSHADI, Swedish University of Agricultural Sciences, Sweden and H. GRUNDBERG, Processum Biorefinery Initiative AB, Sweden	199
9.1	Introduction	199
9.2	Properties	200
9.3	Feedstocks	201
9.4	Processing technology	208
9.5	Pilot plant for ethanol production from lignocellulosic feedstock	217
9.6	Environmental aspects of ethanol as a biofuel	217
9.7	Future trends	218
9.8	References	219
10	Biochemical production of biobutanol M. KÖPKE and P. DÜRRE, Universität Ulm, Germany	221
10.1	Introduction	221
10.2	Principles, materials and feedstocks	222
10.3	Process technologies and techniques	230
10.4	Modeling and optimization	235
10.5	Advantages and limitations	240
10.6	Future trends	241
10.7	Sources of further information and advice	242
10.8	Acknowledgments	242
10.9	References	242
11	Biochemical production of other bioalcohols: biomethanol, biopropanol, bioglycerol, and bioethylene glycol S.D. MINTEER, St Louis University, USA	258
11.1	Introduction	258
11.2	Biomethanol	259
11.3	Biopropanol	260
11.4	Bioglycerol	261
11.5	Bio-ethylene glycol	261
11.6	Other possible bioalcohols	262
11.7	Advantages and limitations	263
11.8	Conclusions and future trends	263
11.9	Sources of further information and advice	264
11.10	References	264

12	Production of biogas via anaerobic digestion K. STAMATELATOU, G. ANTONOPOULOU and G. LYBERATOS, University of Patras, Greece	266
12.1	Introduction: the anaerobic digestion process	266
12.2	Factors affecting the anaerobic digestion process	268
12.3	Advantages and limitations	272
12.4	Process integration for biogas production	274
12.5	Process modelling	281
12.6	Process monitoring and control	284
12.7	Biogas utilisation	289
12.8	Existing biogas installations	290
12.9	Conclusions and future trends	294
12.10	Sources of further information and advice	295
12.11	References	296
13	Biological and fermentative production of hydrogen G. ANTONOPOULOU, I. NTAIKOU, K. STAMATELATOU and G. LYBERATOS, University of Patras, Greece	305
13.1	Hydrogen	305
13.2	Biological hydrogen production methods	306
13.3	Fermentative hydrogen production	318
13.4	Hydrogen economy	333
13.5	Advantages and limitations	335
13.6	Future trends	336
13.7	Sources of further information and advice	336
13.8	References	337
Part III	Biofuels from thermal and thermo-chemical conversion processes and technologies	347
14	Production of bio-oils via catalytic pyrolysis M.A. MORRIS, University College Cork, Ireland	349
14.1	Introduction	349
14.2	Pyrolysis: a brief background	350
14.3	Pyrolysis economics	356
14.4	Catalytic pyrolysis: catalysis	357
14.5	Catalytic pyrolysis for improved pyrolysis-oil generation	361
14.6	Reactors for catalytic pyrolysis	363
14.7	Catalysts used in catalytic pyrolysis	368
14.8	Conclusions and future trends	376
14.9	Acknowledgements	378
14.10	References	378

Contents

15	Production of biofuels via catalytic cracking J.A. MELERO, A. GARCÍA and M. CLAVERO, Rey Juan Carlos University, Spain	390
15.1	Introduction	390
15.2	Catalytic cracking of highly oxygenated biomass-derived feedstocks	393
15.3	Catalytic cracking of triglyceride-based feedstocks	397
15.4	Co-processing of triglycerides and petrol feedstocks mixtures in fluid catalytic cracking refinery units	404
15.5	Future trends	414
15.6	References	415
16	Production of bio-syngas and biohydrogen via gasification A. DUTTA, University of Guelph, Canada and B. ACHARYA, Dalhousie University, Canada	420
16.1	Introduction	420
16.2	Mechanism of gasification	425
16.3	Factors affecting performance of gasification	427
16.4	Types of gasifier	429
16.5	Modeling of the gasifier	442
16.6	Designing of gasifier	450
16.7	Conclusions	456
16.8	Sources of further information and advice	456
16.9	References	457
17	Production of bioalcohols via gasification J.M.N. VAN KASTEREN, Eindhoven University of Technology, The Netherlands	460
17.1	Introduction	460
17.2	Gasification routes for alcohol production	462
17.3	Conceptual design of a bio waste ethanol plant	466
17.4	Conclusions and future trends	475
17.5	Acknowledgements	476
17.6	Notes	476
17.7	References	476
18	Production of biofuels via hydrothermal conversion S.R.A. KERSTEN and D. KNEŽEVIĆ, University of Twente, The Netherlands and R.H. VENDERBOSCH, BTG Biomass Technology Group B.V., The Netherlands	478
18.1	Introduction	478
18.2	Chemistry, product characteristics and product distribution	479
18.3	Process layout	484

18.4	Process development and demonstration activities	485
18.5	Current research	488
18.6	Conclusions and future trends	488
18.7	References	489
19	Production of biofuels via Fischer-Tropsch synthesis: biomass-to-liquids	493
	A. LAPPAS and E. HERACLEOUS, CPERI – Chemical Process Engineering Research Institute, Greece	
19.1	Introduction	493
19.2	Biomass-to-liquids-Fischer-Tropsch process technologies and techniques	496
19.3	Biomass gasification to syngas	497
19.4	Synthesis of biofuels via Fischer-Tropsch	501
19.5	Upgrading of biomass-to-liquids-Fischer-Tropsch products	509
19.6	Biomass-to-liquids-Fischer-Tropsch final fuel products	517
19.7	Commercial status of the biomass-to-liquids-Fischer- Tropsch processes	521
19.8	Future trends	522
19.9	References	524
20	Production of biofuels via biomass reforming	530
	G. VAN ROSSUM and S.R.A. KERSTEN, University of Twente, The Netherlands	
20.1	Introduction	530
20.2	Related technologies	533
20.3	Chemical thermodynamics	535
20.4	Feedstocks and processes	537
20.5	Description of the ongoing research and status of proposed and tested technologies for biomass reforming	541
20.6	Conclusions	550
20.7	References	551
Part IV	Integrated production and application of biofuels: biorefineries, by-product valorisation and engine utilisation	557
21	Biofuel-driven biorefineries for the co-production of transportation fuels and added-value products	559
	R. VAN REE, J. SANDERS, R. BAKKER and R. BLAAUW, Wageningen University and Research Centre (WUR), The Netherlands and R. ZWART and B. VAN DER DRIFT, Energy Research Center of The Netherlands (ECN), The Netherlands	
21.1	Introduction	559

Contents

21.2	Biofuel-driven biorefineries: conventional biofuels	564
21.3	Biofuel-driven biorefineries: advanced biofuels	565
21.4	Optimising biomass value chains	574
21.5	Current status and future trends	576
21.6	Sources of further information	577
21.7	References	578
22	Valorization of by-products for the production of biofuels C. ECHIM, R. VERHÉ and C. STEVENS, Ghent University, Belgium and W. DE GREYT, Desmet Ballestra Group, Belgium	581
22.1	Composition of deodorizer distillate	581
22.2	Applications and estimates of deodorizer distillates	582
22.3	Production of biodiesel/biofuel from deodorizer distillates	584
22.4	Recovery of sterols, tocopherols and squalene from deodorizer distillate	590
22.5	Future trends	606
22.6	Acknowledgements	606
22.7	References	606
23	Utilisation of biofuels in diesel engines T. LE ANH, School of Transportation Engineering, Hanoi University of Science and Technology, Vietnam, I.K. REKSOWARDOJO, Institut Teknologi Bandung, Indonesia and K. WATTANAVICHIEAN, Chulalongkorn University, Thailand	611
23.1	Introduction	611
23.2	Utilisation of vegetable pure plant oil and crude oil in diesel engines	612
23.3	Utilisation of biodiesel based palm oil, jatropha oil, coconut oil and kapok nut oil in diesel engines	632
23.4	Utilisation of biodiesel B5 based cat-fish fat in diesel engines	634
23.5	The concept of using biofuel in engines (prime movers)	642
23.6	Conclusions	643
23.7	References	644
	<i>Index</i>	647