

Index

- acetal, **70–71**, 82, 164, 214, 217, 221, 254
acetaldehyde, 57, **163–4**, 218, 278
acetic acid, 19, 60, 71, 82, 138, 155, **158**, 161, 164, 180, 186, 188, 191, 202, 214, 218, 221, 246, 253, 254, 278
acetone, 58, 155, 179, **180–81**, 202
acetylated wood, **164**
acid hydrolysis, 71, 82, 162, 163, 175, 184, **187–90**
acyl group, **62–3**, 64
acrylic acid, 155, **159**
agricultural production. *See* biomass, production
agricultural residues, 7, **75**, **76–7**, 82, **94–9**, 107, 119, 125, 130, 143, 167, 187, 223, 251, 252, 256, 276, **287–9**
air pollution, 78, 143, 264, **268–9**, 273, 274, **277**
aldehydes, 54, 55, **57–9**, 65, 67, 217, 218, 219, 232, 269, 278
alfalfa, 78, 92, 104, 110, 113, 293, 301
algae. *See* biomass, oleaginous
alkali metals, 56, 71, **93**, 139, 143, 144, 148, 185, **200–201**, 208, **210–11**, **220**, 240
alkanes, **46–9**, 51, 54, 55, 57, 59, **150–51**, 181, 214, 216, 229, 232, 233, 241, 243
alkenes, 47, **49–52**, 56, 181, 216, 232
alkyl group, **46–9**, **51**, 53, 54, **56–8**, 60, 62
alkynes, 47, **49–52**, 181
amides, 47, 54, **64**, 84
amines, 47, 52, **64**, 156, 157, 275, 276
ammonia fiber explosion (AFEX), 185, **187**
amylose starches, 69, **175**
anaerobic conditions or fermentation, 130, 171, 179, 181, 182, 183, 190, 268, 282
anaerobic digestion, 9, 29, 89, 139, 144, 193, 201, 208, 214, 237, 242, 243, **245–9**, 272, 336
angiosperms, **82**
annual crops, annuals, 78, **80–82**, 265, 267, **289–95**, 296, 300
annual operating costs, 301, **310**, **313**, 314, 322, 323
annual production costs, **309**, 311
arabinose, 70, 186, 191, 192, 193
aromatic, polyaromatic compounds, **43**, 47, **52–3**, 69, 71, **150–51**, 156, 161, 197, 225, 228, 229, 230, 232, 234, 242, 243, 246, 276
aryl group, **53**, 56–8
ash, 5, 82, **90–92**, 93, **198–201**, 203, 205–6, 209, 211, 256, 274, 276, 277
autotrophic cultivation, metabolism or organisms, **89**, 103, **125–7**
aveloz, **Appendix A**
aviation fuel. *See* jet fuel
azeotropes, 188, **193**

bagasse, 76, 90, 92, 93, 94, 95, 130, 131, 162, **173–4**, 249, 256, **257–8**
baling, 113, **114–19**, 130, 291
benzene, **52–3**, 56, 150, **155–8**, 160, 193, 225, 243, 280
benzene, toluene, xylene (BTX), **155–8**, 225
big bluestem, 81, **Appendix A**
biobased materials, biobased products, **2–10**, 11, 43, 46, 54, 62, 75, 78, 112, 129, 134, **137–8**, **154–68**, 184, 212, 215, 237, 261, 262, 282, 287, 288, 299, 300, 301, **325–6**
biocatalytic synthesis, **214–5**
biochar, **207**, **273**, 336
biochemical oxygen demand, 172, 281, 282
biochemical processing/conversion, 82, **Chapter 7**
biodiesel, 84, 85, 86, 88, 94, 151, 152, **154**, **239–40**, 284, 327, 331, 334
biodiversity, **262–4**, **269–70**
bioeconomy, **2**, **4–7**, **9–10**
bioenergy, **2**, 4, 5, 6, 11, 99, 101, 127, **137**, 273
biofuels
 cellulosic/lignocellulosic, 84, 88, 212, **213–15**, 235, 253–4, 271, 280, 300
 first generation, **153–4**, **171–9**, 271, 272, 279–80
 general, **2**, **3**, **7**, **33**, **43**, **137**, **138**, **149–54**, 233, 271, 329, 330, 331, 334
 lipid-based, 84, 89, **154**, **241–5**
biogas, 29, **245–9**
biomass
 dedicated energy crops, 75, **78–9**, 90, 96, 97, 99, 266, 269, **287–9**, **Appendix A**
 definition, **2**
 herbaceous energy crops (HEC)/herbaceous crops, **79–82**, 266, **103–20**, **Appendix A**

- biomass (*Continued*)
 oleaginous crops, 79, **84–9**, 103, **125–9**, **Chapter 9**, **Appendix A**
 production, **Chapter 5**
 properties, **Chapter 4**
 short rotation wood crops (SRWC)/woody crops, **79**, **82–3**, **90**, **120–25**, 265, 266, 273, 274, 291, 293, 296, 301, **Appendix A**
 sugar and starch crops, 75, **78–9**, 80, 81, **89–90**, **95**
 waste material/wastes, 7, 29, **75–8**, 83, 90, 92, 93, 99, 138, 193, 199, 200, 214, 245, 249, 268, 274, 289, 326
- bio-oil, 195, **207**, **216–19**, **221–35**, 242, 243, 244–5, 314, **319–24**
- biopolymers
 natural. *See* natural fibers
 synthetic, 3, 135, 138, **164–6**
- biopower, **137**, **140–49**
- biorenewable resources
 general, **2–10**, 137–8, 143, 149, 154, 156, 157, 158, 159–66, 172, 179, 182, 212, 261, 273, 274, 276, 277, 278, 280, 282, 287, 289, 299, 300, 301, 306, 309, 314, 315, 317, 319, 327, 328, 329, 330, 331, 333, 336, 337, 338
 production, **Chapter 5**
 properties, **Chapter 4**
- biosphere, **2**, 143, 261
- biotechnology, 103, **131–5**, **261–4**
- black liquor, **255–7**, 282
- black locust, 83, 92, 120, 121, 274, **350**, **Appendix A**
- blighted stands, **76–7**
- boiler, boiler fuel, 8, 9, 78, 83, 93, **140**, 173, 174, 184, 189, 193, **198–202**, 256, 258, 259, **275–8**, 282, 303, **304–7**, 312
- Brayton cycle, 140, 142, **143–4**, 150
- Bt corn, **263**
- BTX. *See* benzene, toluene, xylene
- butadiene, **157**
- butane, **45–8**, 151, 155, 156, 159, 160
- butanediol, 156, 161, **180**
- butanol, 54, 151, 152, **154**, 155–6, **160**, 161, **180–81**, 182, 214, 221
- canola, **Appendix A**
- capacity factor, 200, 310, **311**, 312, 313, 323
- cap-and-trade, **336–9**
- capital cost, 116, 140, 143, 207, 241, 296, **301–9**, 314, **316–7**, 321, 322, 325, 326
- carbohydrate chemistry, 59, **65–70**
- carbon dioxide, 1, 5, 12, 13, 14, 15, 27, 28, 29, 30, 62, 88, 89, 90, 125, 126, 135, 139, 148, 172, 176, 179, 180, 182, 191, 193, 195, 196, 201, 211, 226, 241, 245–9, 257, 265, **270–73**, 277, 278, 280, 284
- carbon monoxide, 5, 27, 39, 53, 148, 153, 158, 196, 201, **211–5**, 227, 268, **283**
- carbon price, **335–7**, 338
- carbon sequestration, 123, **272–3**
- carbon-carbon bonds, 44, 46, 48, 49, 51, 61, 138, 227, 231, 232, 241
- carbon-hydrogen bonds, 44, 138, 231
- carbonylation, 159, 161, 225, 231
- carbonyl group/carbonyl compounds, **57–60**, 61, 66, 67, 158, 163, 210, 234
- carboxyl group, **60–63**
- carboxylic acids, 47, 52, 55, 59, **60–64**, 71, 158, 159, 179, 180, 185, 216–19, 222, 232, 237, 255
- Carnot efficiency, 141, 145
- cash flow analysis, 293, **296–300**
- cassava, **Appendix A**
- catalyst, catalysis, 20, 52, 55, 63, 131, 147, 148, 157, 159, 162, 171, 186, 195, 204, **209–15**, **224–6**, 227–8, **230–35**, 239, **240–42**, 243, 244, 275, 320, 322, 323
- catalytic pyrolysis. *See* fast pyrolysis
- cellobiohydrolase I and II, 189
- cellobiose, 68, 70, 190, 192
- cellulose
 biochemical processing. *See* lignocellulose, biochemical processing
 chemistry, **67–70**
 feedstock. *See* biomass, dedicated energy crop
 thermochemical processing. *See* lignocellulose, thermochemical processing
 cellulose derivatives, 160, 163, 251, 254
- char, 20–25, **196–7**, 200, **202–3**, **205–7**, 209–10, **215–19**, **221**, **223**, **224**, **244**, **273**, **284**, **311**, **314**, **320**, **322**
- charcoal, 205, 207
- chemical equilibrium, **37–41**, 204, 210
- chemical nomenclature, **44–6**
- chemical oxygen demand (COD), 281
- chemicals, commodity, 1, 3, 9, 75, 79, **138**, **154–66**, 179, 212, 229, 243
- Chinese tallow, 83, 96, 120, **Appendix A**
- chlorofluorocarbons (CFCs), 5, 261, 270
- Clean Air Act, 283
- climate change, 1, 5, **270**, 284, 335
- clonal propagation, **121–2**
- Clostridium*, 158, 159, 160, **180–82**, 191, 214
- cofiring, **200–201**
- coke, 5, 206, 209, 225, 226, **231**, 234, 243
- coking, 231
- coliform bacteria, 245
- combined cycle, **144–5**, **149**
- combustion, 3, 5, 9, 15, **16–17**, 28, 29, 30, 93, **137–49**, **151–4**, **195–201**, 202–3, 205–7, 209, 211, 217, 240, 243, 256, 268, 272, **274–80**, 282, **283–4**, 321
- composition, **Appendix A**
- condensation reaction, **44**, 59, 63, 64, 185, 235
- conservation tillage, **107–8**, 265

- consolidated bioprocessing, 171, **193**
 consumer price index, **305–6**
 conventional tillage, **106–7**, 293
 conversion, 3, 8, 9, 10, 11, **17**, **19–24**, 32, 33, 34, 35, 39, 52, 69, 77, 78, 91, 93, 95, 100, 137, 141, 144, 146, 157, 171, 173, 179, 182, 183, 184, 186, 190, 191, 193, 201, 204, 206, 207, 212, 214, 215, 217, 226, 239, 240, 249, 271, 284
 corn, 6, 7, 34, 35, 75, 76, 77, 79, 80, 81, 84, 86, 88, 90, 91, 92, 94, 95, 96, 99, 104, 108, **110–13**, 119, 125, 129, 130, 133, 134, 155, 161, 162, 167, 172, 174, 175, **176–9**, 182, 185, 186, 187, 188, 193, 210, 257, 263, 265, 266, 271, 272, 276, 278, **279–80**, 282, 284, 289, **291–5**, 300, 332, 333, **Appendix A**
 corn stover, **76**, 90, 92, 95, **119**, 130, 167, 185, 187, 188, 210, 276, 280, 301
 cost estimating, 287, 289, 296, **319–26**
 cracking of hydrocarbons/tar, 140, 157, 206, 209, 210, **230–31**, 232, **234–5**, **320**
 cultivating/cultivation, 77, 87, 100, 103, **106–8**, 111, **125–7**, 175, 262, 264, 266, 268, 270, 288, 289, 291, 292, **Appendix A**
 cyclic compounds, **43**, 50, **52–3**, 58, 59, 60, **67–8**, 161, 197, 228, 245
 cycloalkanes, **48**, 150, 232

 decarbonylation, **53**, 161, **225**, 231
 decarboxylation, 182, 191, **225**, 228, 231, 241, 244
 dedicated energy crop. *See* biomass, dedicated energy crop
 deforestation, 261, **271–2**
 degree of polymerization (DP), **70**, 82
 dehydration, 22, **44**, 55, 56, 69, 157, 161, 213, 221, 235
 dehydrogenation, 191
 deoxygenation, **219**, 224, 225, 226, 228, 229, 230, 231, 232, 233, 234, 241, 243, 320
 depithing, 252, **257–9**
 dextrans, **176**, 186, 190, 219
 diene, **50**, 155, 156, **157**, 161, **238**
 diesel cycle, **141**, 150
 diesel fuel, 84, 94, 147, **150–52**, 154, 183, 218, 240, 241, 274, 284, 301, 315, 319, 320, **325**, 329
 dimethyl ether (DME), 46, 212, **213**
 dioxins, 197, **276**, 281–2
 direct combustion, 9, 140, **195–201**, 202
 direct costs, 301, **302**, 309–10, **311–14**
 direct liquefaction, 216, 226, **227–8**
 direct-fired furnaces, 129, **139–40**, 195, 199, 303
 direct microbial conversion (DMC). *See* consolidated bioprocessing
 disaccharides, **65**, 68, 69, 172, **173**, 175, 190
 discounted cash flow rate of return (DCFRROR), **296–300**, **314–16**
 discount rate, **295**, 298–300, 314, 324

 distillation, 4, 82, 140, 161, 173, 176, 184, 188, **193**, 230, 232, 241, 279, 284
 distillers' dried grains and solubles (DDGS), **176**, 278, 280
 drop-in fuels, **84**, 280
 drying processes, biomass, 9, **114**, 117, 127, **128–30**, 137, 139, 178, 196, 198, 200, **202–3**, 207, 238, 244, 278
 dry milling, 175, **176–7**, 179, 280

 eastern gamagrass, 81
 economies of scale, 7, 141, 242, **302–5**, 321, 332, 335
 ecosystem, 76, 77, 263, 264, 265, 266, 267, 270, 271,
Appendix A
 elimination reaction, **43–4**, 55, **230–32**
 emissions, pollutant, 1, 5, 141, 143, 154, 174, 182, 200, 211, 231, 234, 235, 243, 267, **268–9**, **270–73**, **276–8**, 280, **282–4**, **333–9**
 endoglucanase I and II, 190
 endothermic, **28**, **35–6**, 201, 203
 energy balance, 11, **25–36**, 174
 energy cane, 80
 Energy Policy Act, **328**
 energy return on energy invested (EROEI), **33–5**
 energy security, 328
 ensiling, 118, **130–31**
 enthalpy, **25–32**, 33, 34, 37, 38, 41, 92, 93, 146, 202, 210
 entropy, 32, **37–8**, 41, 146
 environmental impact, 96, 111, 127, 253, **Chapter 11**
 environmental quality, **4–5**
 enzymatic hydrolysis, 71, 171, 175, 184, 185, 186, 187, **189–90**, 192–3, 229, **325**
 enzymes, 132, 135, 171, 173, 175, 176, 178, 179, 183, **184–90**, 192, 280
 equilibrium constant, **38**, 59
 equipment costs, **302–9**, 311, 321–2
 equivalence ratio, **16–17**
 erosion, soil, 106, 107, 121, 264, **265–6**, 267, 270, 280
 ethanol
 from cellulose. *See* biofuels, cellulose/lignocellulosic
 miscellaneous, 3, 4, 7, 18–19, 27, 30, 34–6, 46, 55, 75, 138, 147, 151, 155, 157, 161, 180, 271–2
 properties, 5, 56, 84, 94, 152, **153–4**, **282–4**
 from sugar and starch. *See* biofuels, first generation
 ether, 45, 46, 47, 53, 54, **56–7**, 65, 69, 152, 163, **212–3**, 283, 328
 ethylene, polyethylene, **49**, 51, 54, 55, 64, 130, 131, 133, 155, 156, **157**, 159, 162, **164–6**, 182, 218
 eucalyptus, 83, 120, 121, 122, **Appendix A**
 eutrophication, **267**
 exothermic, **28**, **35–6**, 138, 203, 211, 212, 213

- externality, **335**
 extractives, 72, **73**, 255
- fast pyrolysis, 144, 163, 207, **215–26**, 229, 235, 301, 311, 315, **319–24**
- fats. *See* triglycerides
- fatty acids, **61**, **64**, 72, 89, **154**, 180, 214, **237–8**, **239–41**, 243–5, 256
- feed-in tariff (FIT), **334–5**
- feedstock
 cellulosic/lignocellulosic. *See* biomass, dedicated energy crop
 oleaginous. *See* biomass, oleaginous
- fermentation
 ethanol, 3, 4, **19**, 36, **153**, 155, **171–9**, **191–3**, 254, **325**
 other products, 4, 130, **154**, **158**, 159, **160**, 162, **171–3**, **179–83**, **214–15**, **245–9**, 254
- fertilizer, fertility, 6, **109–10**, **122**, 212, 213, 243, 249, 254, **265–6**, **267–8**, 270, 271, 278, 279, 284, 289, 291, 292, 293, 294, 295, 299, 314, 329
- fescue, Tall, 81
- fibers
 natural, **138**, **166–8**
 synthetic. *See* synthetic biopolymers
- first law of thermodynamics, **35**
- Fischer–Tropsch (F–T) synthesis, 212, **214**, 315, 325
- fixed costs, 289, 291, 310, **313**, 323
- forage crops, 112, **113–20**, 291
- forestry residues, 98, 199
- formic acid, **159**
- fructose, **65–6**, 67, 69, 173, **175**, **178**, 182
- fuel cells, 3, 35, 38, 142, **145–9**, 208, 209, 211
- fungi, 89, 111, 122, 190, 191
- furfural and other furans, 20, **53**, **69**, 159–60, **161**, 186, 188, 191, 197, 217, 218, 219, 221, 228, 254, 276, 281, 282
- galactose, **66**, **70–71**, 173
- gasification, **16–17**, 31, 39, 78, 139, 143, 147, 149, 152, 158, 181, 195, **201–15**, 216, 273–7, 315, **325**
- gasoline, 5, 33, 34, 35, **46**, 84, 94, **149–53**, 154, 157, 158, 160, 174, 182, 183, 212, 213, 214, 225, 227, **232–5**, 240, 241, 244, 245, 254, 271, 273, 282, **283–4**, 301, 315, 319–20, **325**, 328, 330, 333
- gas turbine, 141, 142, **143–5**, 149, 150, **208**, 211, 218
- Gibbs function, **37–41**, 146
- global warming. *See* greenhouse gases
- gluconic acid, **162**, 179–80
- glucopyranose, **67–9**, 219
- glucose, 18–25, 36, **65–71**, 135, 162, 163, 164, 173, **175–6**, 178, 180, 182, 188, 189–93, 218, 219–20, 228, 246, 252
- gluten, **175**, 177–9
- glycerol, **54**, 63, 154, 181, 237, **239–41**, 244, 245
- grains. *See* biomass, starch crops
- grasses. *See* biomass, herbaceous energy crops
- greenhouse gas emissions/greenhouse effect, 5, 174, 182, 211, 234, 235, 264, 268, 269, 270–73, **277–80**
- gymnosperms, **82**, 133
- hardwoods. *See* angiosperms
- harvesting, 33, 77, **78**, **81**, **89**, 103, **111–20**, 121, **123–5**, **127–9**, 199, 245, 287–9, 300
- haylage, haymaking, 2, 61, 81, **113–19**, **129–31**, 291
- heat and power production, 2, 3, 8, 9, 33, 75, **137–49**, 195, **198–201**, 202
- heating values, 8, 9, 30, 89, **92–3**, 97, 98, 99, **100**, 144, **152**, 153, 154, 195, 200, **207**, 217, 228, 256, 325, **Appendix A**
- heat rate, **33**, 201
- hemiacetal, **59–60**, **67–8**
- hemicellulose, **69–71**, **82**, **89–91**, 161, 162, **183–93**, 196, 215, 216, 217, **219–21**, **228–9**, 251, **253–5**, 257
- hemiketal, **59–60**, **67–69**
- herbaceous crops/herbaceous energy crops (HEC). *See* biomass, herbaceous energy crops
- herbicides, 56, 107, 108, 111, 134, 158, 160, 262, 263, **266–8**, 290, 294
- heteroatoms, **43**, 231
- heterocyclic, **43**, **53**, 161, 245
- heterotrophic cultivation, metabolism, or organisms, **89**
- hexose, 65, 66, 67, 70, 71, 163, 172, 173, 184, **187–93**, 253, 254
- high fructose corn syrup (HFCS), **178**
- hydrocarbons, **44–53**
- hydrogenation, **52**, 161, 162, 163, 203, 232
- hydrolysis. *See* acid hydrolysis or enzymatic hydrolysis
- hydroprocessing, **84**, **228**, **230**, 233, **234–5**, 284, 315, **319–24**, **325–6**
- hydropyrolysis. *See* fast pyrolysis
- hydrothermal processing, **226**, **228–9**, 237, 242, **244–5**
- hydrotreating and hydrocracking, 230, **232**, **234**, **235**, 239, **241–2**, **243**, **319–24**
- hydroxyacetaldehyde. *See* acetaldehyde
- hydroxyl group, 44, **45–6**, 52, **54–6**, 59, 60, 62, 63, 66–8, 70–72, 164
- impacts
 local, regional, global or environmental, 4–5, 98, 127, **261–84**
- indirect costs, 301, 307, **308**
- indirect-fired furnaces, **140**, 195
- indirect land use change (ILUC), **271–2**, 284
- indirect liquefaction, **226–7**
- inflation index factors, **305–6**

- installation costs, 309, **321**
 integrated gasification/combined cycle (IGCC),
 144–5, 149
 internal rate of return (IRR), **298, 315–16**
 invasive species, **76–7**
 isoprene, **50, 156–7, 183, 238**
- jatropha, **84, 85–6, 87, 91, 95, 96, 237**
 Jerusalem artichoke, 90, 95, 104, 172, 175, **Appendix A**
 jet fuel, 84, 85, 143, **150–52, 183, 325–6**
 jojoba, **Appendix A**
- kelp, 77, 79, 249, **Appendix A**
 kenaf, **Appendix A**
 kerosene, 147, **151**
 ketal, **60, 65, 68**
 ketones, 47, 54, 55, **57–60, 65–7, 156, 179, 182, 217–19**
 kraft process pulping, 71, 185, 252–4, **254–7, 280, 281–2**
- lactic acid/polylactic acid, **61, 159, 160, 161–2, 166, 180, 182**
 levoglucosan, **69, 163, 218–20**
 levulinic acid, **61, 163**
 lifecycle assessment, 271–2, 280, **282–4, 336**
 lignin, **70–72, 79, 82, 89, 90, 165, 183–93, 196, 215–19, 222–3, 225–6, 228–34, 243, 244, 245–6, 251–6, 280, 282**
 lignocellulose
 biochemical processing. *See* biofuels,
 cellulosic/lignocellulosic
 feedstock. *See* biomass, dedicated energy crop
 thermochemical processing. *See* biofuels,
 cellulosic/lignocellulosic
- machinery costs/expenses, **291–2, 294–5**
 mandate, **283, 328–9, 331–5**
 manitol, **163**
 mannose, 70–71, 173, 253
 manure, 76, 92, **96–7, 99–100, 138, 237, 244, 245, 268, 272**
 marker genes, **132, 134, 262–3**
 Marshall and Swift (M&S) equipment index, **305**
 mechanical pulping, **252**
 mesquite, 77, 83, 120, **Appendix A**
 methanogenesis, 181, **214, 245–6, 248**
 methanol, 4, 27, 68, 82, 94, 151, **152, 154, 155, 158, 160, 181, 202, 208, 212–4, 218, 239–40, 325**
 methyl ester, **154, 239–40**
 microalgae (or algae)
 cultivation and recovery, **103, 125–9**
 feedstock, 78, 79, 84, **87–9, 90, 91, 95, 97, Appendix A**
 processing, 237, **238–9, 242–5**
- minimum selling price (MSP), **299, 314–15**
 miscanthus, **80, 301, Appendix A**
 monoculture and biodiversity, **269–70**
 monosaccharides, **65–71, 175, 178, 179, 187, 190, 217, 218, 221, 244, 245**
 municipal solid waste (MSW), **76, 77, 92, 98, 138, 199, 245, 249, 273, 274**
- naphtha, 157, 158, 232, 233, 320
 naphthalene, 53, 155
 naphthenes, **150, 232**
 Napier grass, 80, 110, 249
 national security, **4–6**
 net present value (NPV), 296, 297, 299, **316–17**
 nitrates, 109, 110, **267–9**
 nitric oxide, **268–9, 274**
 nitrogen fixation, **121**
 nitrous oxide, **268–70, 274, 277**
 no-till, **99, 106, 108, 292**
- oak, 82, 92, 93
 ocean cultivation (microalgae), **126–7**
 octane, 47, **151–4, 157, 182, 213, 225, 232, 233, 233, 244**
 oil palm (or palm oil), **84–5, 87, 91, 96, 180, 271**
 oils. *See* triglycerides
 oleaginous crops. *See* biomass, oleaginous crop
 oligosaccharides, **65, 68, 176, 179, 187–8, 218, 219, 245**
 Otto cycle, **141, 150**
 ozone depletion, **5, 261**
- paraffin, **46, 150, 151, 232**
 particulate/particulate matter, 5, 143, 144, 149, 200, 201, 206, 207, **208–11, 268, 277, 282, 284, 335**
 pentane/pentene, **44, 47, 48, 49, 151, 157, 233**
 pentose, **67, 70–71, 161, 162, 172, 184, 186, 188–9, 191–3, 253–4**
 perennial crops, **80–82, 104, 200, 265–8, 270, 273, 291, 293, 295–300**
 pest control, 95, 104, **110–11, 122**
 petroleum refining
 combining, **230, 233**
 cracking, **230–31**
 reforming, **230, 232–3**
 reshaping, **230, 233**
 treating, **230, 231–2**
- phenol, phenolic compounds, 47, **52–4, 56, 71–3, 135, 155, 157, 160, 167, 186, 216–19, 222–3, 225–6, 228, 231–4, 243, 254**
 phenoxy group, 57, 62–3
 phosphorous, 84, 109, **265, 267**
 photosynthetic pathway, **Appendix A**
 polyhydroxybutyrate/polyhydroxyvalerate, **164**
 polymer, 3, 49, 56, 60, 62, 64, **69–72, 138, 157, 158, 159, 163, 164–166, 167, 175, 192, 219**

- polysaccharides, **65–71**, 79, 165, 167, 176, **179**, **183–9**, 214, 221–2, 245, 255, 256, 281
- poplar, hybrid, 9, 78, 82, **83**, 92, 93, 95, 120–21, 122, 189, 216, 218, 295, **Appendix A**
- potassium, 51, **93**, **109–10**, **139**, 181, **200**, **210**, **219**, **265**, 267
- pretreatment of lignocellulose, **184–9**, 325
- process heat, process heaters, **137**, **138–40**
- production costs, **295–6**, 311, 321, 326, 332, 336
- production of biorenewable resources, **Chapter 5**
- products from biorenewable resources, **Chapter 6**
- promoter sequence, **132**, **263**
- propionic acid, **159**, 180, 181
- proximate analysis, 89, **90**, **92**, 203, **Appendix A**
- pulping process, 4, 70, 71, 98, 167, 185, 187, 238, **251–7**, **280–82**
- pyranose, **67–70**, **219–21**
- pyrolysis. *See* fast pyrolysis
- pyrolysis liquid. *See* bio-oil
- Rankine cycle, 140, **142–3**, 195, 199
- rape seed, **Appendix A**
- rearrangement reactions, **44**, 230, **233**
- reduced tillage, 99, **106–7**
- reed canarygrass, 81, 113
- Reid Vapor Pressure (RVP), **283**
- Renewable Fuel Standard (RFS1), **328**, **331–4**
- Renewable Identification Number (RIN), **331–3**
- Renewable Portfolio Standard (RPS), **334**
- residue factors, **95–6**
- return on investment (ROI), 33, 313
- Revised Renewable Fuel Standard (RFS2), **331–4**
- rubber tree, 4, **238**
- rural development, 4, 7
- saccharification, **175–8**, **192**
- salicornia, 84, **86–7**, 95, 96, 125
- saponification, **63**, **239**, 256
- second law of thermodynamics, **35**, **38**
- seeding and planting, 107, **108–9**, **121–2**
- selectable marker genes, **132–4**, **262**
- selectivity, **19–24**, 175, 214, 226
- sensitivity analysis, 287, **317–18**
- short rotation woody crops (SRWC). *See* biomass, short rotation woody crops
- silage. *See* ensiling
- silver maple, 83, 121
- simultaneous saccharification and fermentation, **192–3**
- site preparation, **104–8**, **121–2**
- smog, 5, 143, **269**, 274, 276, 335
- soap, **63**, 86, **239–40**, 255–6
- soda process pulping, 71, 254, 256
- softwoods. *See* gymnosperms
- soil classification, **105**
- soil erosion. *See* erosion, soil
- soil fertility. *See* fertilizer/fertility
- solid fuel, 9, **93–4**, 139, **196–201**, **206–7**, 225, 277
- solid waste, 5, **76–7**, 199, 245, 273, 274, 280
- solvent liquefaction. *See* solvolysis
- solvolysis, 195, **226–9**, 234, **244–5**
- sorbitol, **162**, 163, 180
- sorghum, 79, 80, 90, 92, 95, 96, 113, 172, 173, 289, **Appendix A**
- soybeans, 79, **84**, 85, 86, 87, 91, **95–6**, 99, 104, 108, 125, 129, 133, 237, **242**, 265–6, **271**, 293, 300, 326, **Appendix A**
- stack wagons, **115–18**
- starch
 - biochemical processing. *See* biofuels, first generation chemistry, **65**, **69**
 - crops. *See* biomass, sugar and starch crops
- starch plastics, **164**
- stationary power, **141–2**, 217, 249, 274
- steam explosion pretreatment of lignocellulose, **185–7**
- Stirling cycle, 140, **141**
- stoichiometric reaction, **16–20**, 22, 30, **38–40**, 153, 203, 275
- storage (of biomass), 81, 103, 113, 116, 118–19, **129–31**
- structural formulas and chemical nomenclature, 44–6
- subsidy, **329–35**, 338
- substitution reactions, **44**, 230, **232**
- succinic acid, **62**, **159–60**, 180, **182–3**
- Sudangrass, 80, 92, 113
- sugar
 - biochemical processing. *See* biofuels, first generation chemistry, **65–71**
 - crops. *See* biomass, sugar and starch crops
- sugar beets, 78–9, 110, 172, 173, 289, **Appendix A**
- sugarcane, 104, **119–20**, 125, 131, 289
- sulfate process pulping, **252–3**, **255–7**
- sulfite process pulping, **252–4**
- sulfur, 5, 43, 53, 64–5, 89, 90, 139, 143, 177, 186, 200–201, **208–10**, 212, 214, 231, 232, 247, 256, 273, 274, 275, 276, 280, 282
- sunflower, **Appendix A**
- supply curve, **288–9**
- switchgrass, 9, 30–31, 78, **81**, 92, 93, 95, 104, 271, 295, 301, **Appendix A**
- sycamore, 83, 110, 120, 121
- syngas, 153, 156, 158, 164, 181, **201**, **208–15**, 232
- synthetic biopolymers, **164–6**
- tar, 139, 144, 148, 149, 204, **205–11**, 277
- tariff, **328**, **333**, **334–5**
- tax, 179, 291, 293, **296–9**, 308, 310, 313, 322, 323, 324, 325, **328–33**, **337–9**
- tax credit, 293, **328–9**, **330–31**, 333
- taxonomic name, **Appendix A**
- techno-economic analysis, **Chapter 12**
- terpene, **50**, **183**, 237, **238**, 256, **269**

- textiles, 158, 159, 162, 163, 165, 166, 168
thermochemical processing/conversion, **Chapter 8**
thermodynamic efficiency, **32–3**, 141, 145, 146, 147, 149, 201, 207
thermodynamics, **Chapter 2**
thermoplastics, 157, 163, 164
tillage, tillage zones, 99, **104, 106–8**
Timothy grass, 81
toluene, 155, 156, **158**, 225, 243
total direct and indirect costs (TDIC), **308**, 309
total purchased equipment cost (TPEC), **302, 306–10, 321–2**
transesterification, **239–40**, 284
transgenic crops
 environmental implications, **261–4**
 technology, 103, **131–5**, 164
triglycerides, **63–4**, 84, 85, 154, **237–8, 239–41**, 245

ultimate analysis, 89, **90–92, Appendix A**
uncertainty analysis, 287, **318–19**
unit cost, manufacturing, **289, 293, 295, 300, 301–4**, 311
upgrading, 183, 216, 219, 221, 224, 225, 227, **229–35**, 237, **240–42**, 243

value-added chemicals, 7, 242
variable costs, 289, **291**, 310, 311, 323

volatile matter, volatile solids, **90, 92**, 202, 203, 217, **247–8**
volatile organic compounds, 154, 196, 269, 282
Volumetric Ethanol Excise Tax Credit (VEETC), **328, 330–32**

waste materials, as biorenewable resource. *See* biomass, waste materials
wastewater treatment, 76, 127, 172, 210, 277, 308, 312
water hyacinth, 249, **Appendix A**
water pollution, 264, **266–8**, 274, 277, 280, 283, 328
wet milling, 175–6, **177–9, 278–80**
willow, **Appendix A**
woody crops. *See* biomass, short rotation woody crops

xylan, **70–71, 82**, 186, **221**, 253
xylene, 155, 156, **158**, 225, 243
xylitol, **162**
xylose, **70–71**, 159, **162, 186, 191–3, 221**, 253, 254

yeast, 36, 89, 162, **173–80, 183, 191, 192, 193**, 238, 254

yield
 crop, 6, 7, 75, 80, **83–8, 95–6**
 chemical products, **17–25**

zero till. *See* no-till