INDEX

Page references followed by t indicate material in tables.

Absorption, in monoethanolamine, 57
Acid hydrolysis, of biomass cellulose, 196–197
Active solar heating, 248–250
Active solar systems, large, 249–250
Adiabatic compression, 68
Adsorbents, efficacy of, 106
Adsorption substrates, microporous, 99
Adsorption systems, carbon-based, 97–99
Advanced gas-cooled reactor (ACR), 128
Agribusiness economy, biodiesel and, 242
Agricultural residues
  for biomass ethanol production, 190
  cost of, 190
Agricultural waste, for ethanol conversion, 190
Alanates, as hydrogen carriers, 89
Albedo radiation, 246
Alcohols, in petroleum diesel, 236–237
“Al Gore camp,” 3. See also Gore, Al
Aliphatic hydrocarbons, 96
Alkali metal hydroxides, 95
Alkaline fuel cell (AFC), 273
Alkaline hydrogen–oxygen fuel cell, 264, 265
Alkyl monoester biofuels, 235t
Alternate-technology vehicles, 311
Alternative energies, justifications for, xvii
Alternative energy sources, 187–188
  rational, 164
Alternative fuels, 40
  from coal, 178
  hydrogen as, 44
  technology of, xv
Alternative hydrocarbons, xxiii
Aluminum pressure vessels, 80
AM1.5D radiation, 246
Ammonia. See also Anhydrous ammonia
  as a hydrogen carrier, 101–102
  toxicity of, 102, 106
Ammonia borane, 95
Amorphous silicon (a-Si) technology, 253–254
Anaerobic fermentation procedures, 188
Anhydrous ammonia, 274. See also Ammonia for hydrogen storage, 102
Animal feed, as biomass conversion by-products, 193–194
An Inconvenient Truth, 4
Antarctic temperature, climate forcings contributing to, 4
Anthropogenic activity, CO₂ generated by, 12
Anthropogenic carbon dioxide, 30
Anthropogenic contribution, effect on global warming, 12, 13
Arrhenius, Svante, 8
ASTM D-6751 Biodiesel Specification/Standard, 231t
Atmospheric carbon dioxide, man-made contributions to, 14
Atmospheric water vapor, influence on global warming, 15–20
Automobile emissions, 26 regulating, 223
Automobile fuel cell efficiencies, 266–269
Automobiles, user expectations for, 278–279
Autothermal reforming, 56, 213
Average global temperature, 29
Bacteria, photosynthetic, 64
Battery–electric vehicles, 320–321
Battery-powered electric vehicles, 287–289
Battery technology, 321
Beam radiation, 246
Beryllium compounds, toxicity of, 94–95
Bi-Gas process, 183
“Big industry” carbon dioxide producers, 13
“Big oil,” 65
Biodiesel, 203, 223–236. See also Biodiesel fuels
advantages of, 227–233
Clean Air Act and, 232
CO₂ control obtained from, 242
cost of, 242
defined, 224–227
demand for, 233t
disadvantages of, 233–234
foreign oil dependency and, 232
positive impacts of, 243–244
production capacity of, 217
soybean conversion to, 207
sulfur content of, 229
use in diesel hybrids, 236
Biodiesel fuels. See also Biodiesel average emissions impact of, 231t
European DIN 51606 Standard for, 227–229, 230t
methanol in the production of, 217
properties summary for, 228t
Biodiesel process, commercial development of, 232
Biodiesel products antioxidants in, 235
variation in, 233
Biodiesel Standard DIN V 51606, 227–229, 230
Biofuels, oxidative stability of, 234–235
Biomass
alternative raw materials for, 194–198
availability of, 189–191
chemicals production from, 196
cost implications of using, 198–199
Biomass Canada, 195
Biomass cellulose, acid hydrolysis of, 196–197
Biomass conversion, 63, 64–65
non-corn, 195
Biomass conversion processes, commercialization of, 198
Biomass conversion products/by-products, 193–194
Biomass conversion technologies, 191–193
Biomass International, 195
Biomass pyrolysis, 6, 55
Biomass-to-liquid (BTL) fuels, 223
Biomass-to-liquid products, as diesel substitutes, 238–241
Biomass waste, 188
Bio-oils, 65
Biosphere, as part of the carbon cycle, 31, 32
Bituminous reserves, 180
Boiling-water reactors, 151
BP Solar, 260–261. See also British Petroleum (BP)
“Breakthrough” technologies, 65
British Petroleum (BP), 159. See also BP Solar
BTU value, of biodiesel, 234
Buckyballs, as hydrogen storage media, 98
Bulk storage, off-vehicle, 107–111
Buoy uranium recovery method, 151
Bush Administration hydrogen program, 324
By-product oxygen, 311

Cadmium telluride (CdTe), 256
Calcium hydride, 94
California Air Resources Board (CARB), NOx emissions target, 223
Canada. See also Biomass Canada; Ontario Power Generation; Shell Canada SCGP plant
energy future of, 176
proven natural gas reserves in, 167
Canadian crude oil, 172
Canadian Oil Sands, 167, 171
development of, 160
Canadian oil sources, xxiv
CANDU reactors, 152
Canola oil, analysis of, 225t
Capacity constraints, hydrogen storage without, 112
Carbohydrate conversion, 196
Carbon, removing from coal, 179. See also Coal entries
Carbonate mineral deposition, 9
Carbonate–silicate cycle, 9
Carbon-based adsorbents, 106
Carbon-based adsorption systems, 97–99
Carbon-based particulates, as global warming forcing agents, 26
Carbon-based sorbents, 98–99
Carbon cycle, CO2 and, 7–10
Carbon dioxide, 13–14. See also CO2 entries plant growth and, 13
Carbon dioxide contribution, exaggeration of, 19
Carbon dioxide emissions, 42 control of, 30
Carbon dioxide model of global warming, 36
Carbon dioxide sinks, 14
Carbon emissions, largest producers of, 39
Carbon fullerenes, as hydrogen storage media, 98
Carbon transfers, exchange methods accounting for, 8–10
Car technology, short-term change in, 322
Catalytic steam methane reforming (SMR) process, 55
Catalytic thermochemical reforming, 55–56
Catalyzed hydrogen adsorption/desorption, 91–92
Cell reactions, maximum equilibrium efficiencies for, 51
Cellulases, 197
genetic engineering of, 193
Cellulose, enzymatic saccharification of, 192
Cellulose conversion technologies, 196
Cellulose derivatives, as biomass conversion by-products, 194
Cellulosic biomass, 189
acid hydrolysis of, 196–197
in fuel ethanol production, 191
Cellulosic conversion methods, 191–193
Cellulosic municipal waste, conversion into ethanol, 194–195
Centralized hydrogen production model, 309–310
Centralized-production hydrogen economy, 297
Cetane numbers, 227
“Chemical hydrides,” 92–93, 95
Chemical industry, use of methanol in, 216
Chemical processes, manufacturing efficiency of, 200–201
Chemicals, from corn, 195
Chemicals production technologies, 196
Chemosynthesis, 31
Chernobyl disaster, 118
China, oil demand from, 174
Chlorofluorocarbons (CFCs), in the ozone depletion process, 22
Clathrates, 168
hydrogen capacity of, 106–107
Clean Air Act of 1990, 214
“Clean coal” gasification technology, 176
Clean coal-to-gas technologies, 185–186
“Clean diesel” engines, performance data for, 220t
“Clean diesel” fuel, 219–222
Clean diesel technology, 243
“Clean energy” technologies, 38
Climate change, 5 carbon sequestration and, 315 recent, 11–12
Climate models, IPCC, 33–34
“Closed loop” fast breeder reactor designs, 128
Club Rome, xviii
CO₂. *See also* Carbon dioxide entries

- carbon cycle and, 7–10
- combustion energies per ton of, 57t
- as a consequence of global warming, 20
- conversion into carbonic acid, 9–10
- diffusion into water, 8–9
- recent geologic history of, 6–7
- uses for, 58

CO₂ Acceptor process, 183–186

CO₂ atmospheric emissions, 291

- comparison of, 63

CO₂ concentration, seasonal cycles in, 10

CO₂ exchange system, 8

CO₂ levels

- increase in, 4
- short-term variability of, 34

CO₂ production, reduction in, 37

Coal. *See also* Carbon entries

- clean processing methods for, 182–186
- hydrogen from, 61
- underground processing of, 186–187

Coal-based methanol, 283

Coal-bed methane (CBM), 165, 169–171

Coal coke, 178–179

Coal fired power-generating facilities, 314

Coal gas, 178

Coal gasification, 184

Coal processes, alternative, 186

Coal reserves, 178–188

- U.S., 179, 180
- worldwide, 181–182t

Cold filter plugging point (CFPP), 234

Combined heat and power (CHP)

- applications, solid oxide fuel cells in, 272

Combustion CO₂, from reforming, 57–59

Combustion emissions, 13

Commonwealth of Independent States, natural uranium from, 148. *See also* Russian Federation

Complex hydrides, 85, 86, 89–91

Composite pressure vessels, 80

Compressed gases

- data on, 71t
- difficulties in storing, 79

Compressed hydrogen gas, storing and transporting, 78–80

Condensed gases, data on, 71t

Consumer electronic devices, photovoltaics in, 250

Conventional natural gas, 164–171

- recovery of, 166

Conventional oil production, 158

Conventional oil reserves, depletion of, 162

Copper indium diselenide (CIS), 256

Copper indium gallium diselenide (CIGS), 256

Corn

- chemicals from, 195
- combustion enthalpy of, 202
- thermodynamics of growing, 201–207

Corn ethanol, net energy balance of, 191

Corn production, in the United States, 207–208

Corrective actions, impact on global warming, 14

Costs, electrolysis-related, 53–54

Countercurrent hydrolysis, 197

Covalent hydrides, 85

Cropland, utilization of, 207

Cryogenic containment, 81

Cryogenic propellants, 82

Crystalline molecular compounds, for hydrogen storage, 100

Cycloalkanes, reversible dehydrogenation of, 96

“Dangling bonds,” 254

Decision-making process, assumptions underlying, 1

DECON nuclear facility decommissioning method, 138

Dedicated energy crops, 190–191

Deep sea gas production, 165

Dehydrogenation. *See also* Partial dehydrogenation

“Demand adjusted” consumption slope, 164

Department of Energy (DOE). *See also* DOE entries

- fuel storage system performance targets, 105, 107, 112–113, 114
- hydrogen storage program, 80

“Destructive distillation,” 46

DeWeese, Tom, 39

Diesel automobiles, nonturbocharged, 221–222
Diesel-engine hybrids, 295
Diesel engines
  emissions from, 222–223
  future of, 219–221
  in freight-carrying trucks, 222
  in the United States, 221
Diesel fuels
  advantages of, 243
  “clean,” 219
  future of, 221
  substitutes for, 219–222
Diesel hybrid vehicles, biodiesel in, 236
Diesel market, 219
Diesel-powered vehicles, high efficiency, 311
Diesel substitutes, gas-to-liquid or biomass-to-liquid products as, 238–241
Diffuse solar gain, 246
Direct conversion hydrogen generation, 64
Direct-injection gasoline engines, 323
Direct-methanol fuel cells (DMFCs), 212, 216, 269–271
  applications of, 270
Direct solar energy, 248–250
Direct solar installations, subsidies for, 250
Discovered oil reserves, 158
Discretionary uranium inventory, 147
Distributed hydrogen manufacturing
  “network,” 308
Distributed hydrogen production, 292
Distributed manufacturing, 75–76, 297
“Distributed reformer” model, 311
Distributed reforming, 77
Distribution, of hydrogen, 67–75
Distribution alternatives, for hydrogen, 75–77
Distribution infrastructure issues, hydrogen-related, 289–290
DOE criteria, hydrogen storage and, 103–104. See also Department of Energy (DOE)
DOE objectives, for LDV transportation, 280t
DOE targets, current status of, 281–284
Domestic gas supplies, developing, 176
Domestic oil producers, 172
Drake oil well, 157
Dupont Nafion membrane, 266
Dye-sensitized solar cells (DSSC), 257–258
preparing, 258
Earth, gradual warming of, 4
Earth cycles, variability of, 3
Earth’s climate, longer history of, 6–7
“Easy” oil, 172
E-diesel, unofficial standard for, 237t
Education, importance of, xvi
“Effective compression,” 84
Efficiency, in energy conversion, 2
“Efficiency chain,” 275–276
Electrical supply, dependence on nuclear energy, 117–118
Electricity generation, nuclear share in, 120
Electric vehicles, battery-powered, 287–289
Electrolysis
  distributed manufacturing of hydrogen by, 75
  economics of, 53–54
  efficiency of, 52
  emissions from, 53
  energy consumption and electrolyzer efficiency in, 50–53
  in hydrogen production, 44–45, 48–54
Electrolytic hydrogen, cost of, 59–60
Electrolytic hydrogen generator, 307–308
Electrolytic oxygen, 49–50
Electrolyzers
  capital costs of, 53
  efficiency of, 50
Electron hole migration, 252
Emissions
  diesel engine, 222–223
  effect of biodiesel on, 231
  electrolysis, 53
  GTL and BTL fuels and, 242–243
  particulate, 222–223
  sulfur, 24, 25
Endothermic hydrogen reaction, 88
Energy, frequently asked questions concerning, 285–324
Energy choices, rational, 3
Energy consumption, xv
prolificate, 38
Energy conversion, 62–63
Energy costs, rising, xvii–xxiv
Energy crops, 190
  dedicated, 190–191
“Energy economics,” hydrogen, 72
Energy efficiency policies, 175
Energy footprint, sustainable, xvi
Energy industry
hydrogen acceptance by, 316–317
role of, xv–xvi
Energy Information Administration (EIA), 159
Energy “opportunity costs,” 202, 203
Energy options, rational assessment of, 1
Energy policy, xiii
approaches to, 36
Energy requirements, for hydrogen compression, 68–69
Energy reserves, xix–xxi
Energy sources, xiv
alternative, 187–188
depletion of, xviii
Energy supply disruption, xiv
Energy supply problems, in Ontario, Canada, 152
Energy sustainability, transformation to, xiv
Energy technology
complexity of, xvii–xviii
irrational approach to, 1
Enthalpy, 50, 51t
ENTOMB nuclear facility decommissioning technique, 139
Environmental impact, of the Shell Coal Gasification Process, 185
Environmental status
extreme views regarding, xiii
truth about, xvii
Enzymatic hydrolysis, 197
Enzymatic saccharification, of cellulose, 192
Enzymatic saccharification/fermentation, 192–193
Enzyme hydrolysis technology, 192
Estimated Additional Resources I (EAR-I), 146
Estimated Additional Resources II (EAR-II), 146
Estimated Ultimately Recoverable (EUR) global oil reserves, 174
Ethanol, 283–284
annual corn crop for producing, 208
comparison with other fuels, 209–210
as a diesel fuel component, 236
federal subsidies for, 208
future prospects for, 208–209
manufacture of, 209
net energy balance for, 200
net energy use in producing, 204–205
pathways for producing from biomass, 203
production costs of, 199
production efficiencies of, 206–207, 210
production efficiency calculation for, 201
production of, 196
as a replacement for gasoline, 206–207
thermodynamics of processing corn into, 202–207
Ethanol conversion, 190
Ethanol market, growth in, 198–199
Ethylene glycol alkyl ethers, 238
Europe, biodiesel use in, 224
European clean diesel technology, 243
European diesel fuel, 221, 222
Evacuated tube thermal collectors, 248–249
Exhaust gas recirculation (EGR), 223, 241
Exothermic hydrogen reaction, 88
Extreme environmental remedies, justifications for, xvii
Factual decision making, framework for, 1–2
Factual truth, widespread disregard for, xiii
FAME fuels, tallow-based, 234. See also Fatty acid methyl esters (FAMEs)
Farmland, utilization of, 207
Fast-breeder reactors (FBRs), 127–131, 154
Fast reactors
gas-cooled, 128, 129
lead-cooled, 128–129, 130
sodium-cooled, 129–131
Fatty acid methyl ester fuel components, property data for, 225t
Fatty acid methyl esters (FAMEs), 226t, 227, 231. See also FAME fuels
Fatty acids, chemical structure and properties of, 226t
Federal subsidies, for ethanol, 208
Fertilizer, net energy balance for, 200
Filament-wound storage vessels, 79
Fischer-Tropsch technology, 239
Fission transmutation process, 141
Flash point, of biodiesel products, 229–230
Flat plate thermal collectors, 248
Flow resistance, 72
Foreign energy supplies, U.S. dependence on, 62
Forestry waste, 190
Formed thermal collectors, 248
INDEX

Fossil fuels, net energy balance for, 199–200
France
  MOX reprocessing in, 126
  nuclear power generation in, 120
Free energy, 50, 51t
“Fuel assembly,” 134
Fuel cell autos, onboard reforming of
gasoline for, 306
Fuel cell efficiencies
  in-vehicle, 295
  real-world, 276–278
Fuel cells, 42
  ammonia, 101–102
  comparison of, 267–268t
  direct-methanol, 216
  early, 263
  fuels for, 265, 274
  hydrogen, 274–276
  intrinsically available work from, 50
  operating temperatures of, 265–266
  place in power generation, 296
  principles of, 264
  for stationary and mobile use, 263–284
  types of, 264–274
  variety of fuels for, 264
Fuel cell technology, further advances in, 290
Fuel cell vehicles (FCVs), 321–322
  efficiency of, 104
  on-the-road efficiencies of, 277–278
  operational, 298–304t
  performance targets for, 279
Fuel cycle, in generation IV reactors, 123–124
Fuel gases
  from coal, 178, 183–186
  comparison of, 282t
Fuels
  alternative, 40
  combinations of, 283
  comparison of, 282t
  energy densities of, 217t
  pipelined, 70t
Fuel storage requirements, onboard, 279–284
Fuel-tax increase, xxii
Fuel-to-electric power efficiencies, 266,
  271–272, 274
Fuel transition, complexity of, xix
Fusion energy/power, 153, 313–314
Future, energy options for, xxiv
Gas
  high pressure above-ground storage of,
    111
  orphaned, 170–171
  “tight,” 170
  “unconventional,” 168–169
Gas consumption, xx–xxiii
Gas-cooled fast reactors (GFRs), 128, 129
Gas discoveries, xx
Gasholders, 111
Gas hydrates, hydrogen-containing,
  106–107
Gasoline
  benefits of, 105
  from natural gas, 239
  phase-out process for, 43
  U.S. wholesale price of, 60
Gasoline-fueled vehicles, tank capacities
  of, 103
Gasoline–hydrogen cars, 319–320
Gasoline–methanol blends, 214
Gasoline use, in the United States, 60,
  207–208
Gas permeation barrier, 79
Gas reserves, xx–xxi
  estimating, 158
Gas supplies, domestic, 176
Gas-to-liquid (GTL) products, 171
  as diesel substitutes, 238–241
Generation I reactors, 122
Generation II reactors, 122
Generation III reactors, 123
Generation-IV International Forum (GIF),
  123, 124, 128
Generation IV reactors, 123–125
Georgetown U fuel cell program, 274
Global gas reserves, 164–165
Global net primary productivity (NPP), 30–32
Global oil reserves, 163
Global radiation, 246, 247
Global temperature, anthropogenic
  contributions to, 4
Global warming (GW), xiv, 3–40
  as a cause versus a result, 5
  commonly held myths about, 30
  controlling, 37–38
  as a cyclic event, 17
  dealing with, 36–37
Global warming (continued)
methane release and, 168
as a normal, natural event, 36, 37–38
positive effects of, 38
primary causes of, 36
proposed remedies for, 30
protection from the effects of, 37
sources and mechanisms of, 11–12
opposing camps concerning, 3
Global warming forcing agents, 15–30
insolation and irradiance, 26–30
methane, 20–21
nitrous oxide, 21–22
ozone, 22–24
particulates, 26
pollutants, 24–25
sulfur, 24
water vapor, 15–20
Global warming gases, 36
Global warming models, disagreement on, 36
Global weather, modeling the complexity of, 36
“Gloom-and-doom-sayers,” xvii
Glycerol by-product, from biodiesel, 232–233
Gore, Al, 4. See also “Al Gore camp”
Graphite, hydrogen adsorption by, 97–98
Graphitic nanotubes, hydrogen absorption by, 98–99
Gravimetric energy density, 111–112
Greenhouse effect, 8, 10
Greenhouse gas emissions, hydrogen and, 42
Greenhouse gases, 10
absorption wavelengths of, 18t
heat trapping efficiency of, 19t
increases in, 4
non-CO₂, 25
cnuclear fuel production, 118
overlap of absorption bands of, 17t, 18
Grid-connected solar energy, 259
Gross Heating Value (GHV), 69
H₂ adsorption, by metals, 86–87. See also Hydrogen entries
Hansen, James, global warming predictions by, 35
“Heat islands,” 29. See also Therm- entries
Heavy-duty vehicles (HDVs)
hydrogen storage for, 107, 112
storage technologies for, 78
Heavy metals, filtering from water, 150
“Heterojunction” electric fields, 255
High BTU waste, 188
High efficiency diesel-powered vehicles, 311
Higher Heating Value (HHV), 69, 70, 71t
High level nuclear wastes, 134
storage locations for, 137
Highly enriched uranium (HEU), 143
from Russian nuclear weapons, 147
High pressure electrolysis cells, 52
High pressure hydrogen gas, 71, 105, 106
High temperature gas-cooled reactors (HTGRs), 122, 128
Hindenburg airship fire, 293
Hot potassium carbonate (HPC) process, 57–58
Hot water systems
active, 249
passive, 248
H-PEDOT polymer, 79
Hubbert curve, 158, 161–162
Hubbert oil peak, 175
Hybrid power systems, solid oxide fuel cells in, 272
Hybrid vehicles, 319–320, 321–322
performance targets for, 279
Hydrane process, 184
Hydrate research and development (R&D), 168, 169
Hydride-forming reaction, 89
Hydride powder, 90–91
Hydrides, maximum possible hydrogen content of, 90t. See also Nonmetallic “hydrides”
Hydride slurries, 93–95
Hydride systems, recharging, 91–92
Hydrocarbon fuels replacing, xv
in solid oxide fuel cells, 272
Hydrocarbon reforming, 65
Hydrocarbon resources, xxii
Hydrocarbons alternative, xxiii
hydrogen from, 54–61
via partial dehydrogenation, 96
Hydrochlorofluorocarbons (HCFCs), in the ozone depletion process, 22–23
Hydrofluorocarbons (HFCs), 25
Hydrogen. See also H₂ adsorption; Liquid hydrogen
as an alternative fuel, 44
biomass conversion to, 64–65
for a car fleet, 310–311
centrally produced, 296–297
competition with gasoline, 308–309
as a competitive threat, 316
compressing, 68, 294
compressing for automotive storage tanks, 307–308
current “PR” about, 323
dangers associated with, 292–293
density of, 67–68
distributed manufacturing of, 75–76
energy-equivalent amount of, 104
fossil-fuel energy and, 286
frequently asked questions concerning, 285–324
as a high-quality form of energy, 286
historic uses, of–44
from hydrocarbons, 54–61
inefficiency of, 293–296
issues related to, 116
lightness of, 286–287
low pressure storage for, 111
manufacture by electrolysis, 294
manufacture from an energy source, 276
National Research Council report on, 53
nuclear energy as a source of, 118
onboard manufacture of, 77
oxygen consumption and, 318
pipelining, 70–73
point-of-use production of, 76
promise of, 42
pumping power requirement for, 72–73
pure, 42, 309
road tanker transportation of, 73–74
safety considerations related to, 66–67, 105,114–116
sources of energy for conversion into, 312
storage in metals and metal hydrides, 84–86
as a supplementary fuel, 305
theoretical energy recoverable from, 58–59
transportation and distribution alternatives for, 75–77
transporting and distributing, 60, 67–75
as a universal fuel supply, 41
Hydrogen adsorption/desorption process, 88–89
catalyzed, 91–92
“chemical hydrides” in, 92–93
Hydrogen adsorption potential, 97–98
Hydrogenation reaction, 88, 254
Hydrogen carriers, 93, 101–103
Hydrogen combustion, CO₂ emissions from, 58
Hydrogen explosions, 116, 293
Hydrogen-filling stations, 75
Hydrogen fires, 293
Hydrogen flame, 115–116
Hydrogen flow rate, 72
Hydrogen fuel cells, 274–276
“benchtop efficiency” of, 88
efficiency of, 276, 287
reducing the cost of, 305
Hydrogen-fueled vehicles. See also Hydrogen vehicles
DOE criteria for, 103
storage system in, 104
ventilation of, 114
Hydrogen Fuel Initiative, 41
Hydrogen industry, development from scratch, 291–292
Hydrogen leakage, 71–72, 73, 79
losses from, 74–75
Hydrogen leak/flame detection, 115
Hydrogen manufacture. See also Hydrogen production entries
costs of, 53–54
natural gas and, 62
water consumption and, 317
Hydrogen manufacturing industry, safety record of, 115
Hydrogen–metal (H–M) systems, evolution of, 86
Hydrogen pipelines, 297–305
Hydrogen production. See also Hydrogen manufacture; Hydrogen production methods
carbon release from, 59
costs of, 59–61
distributed versus centralized, 311
efficiency losses associated with, 278 from natural gas, 61, 62
summary of, 65–66
uses for, 46–47
Hydrogen production methods, 44–54 alternative, 62–65
electrolysis, 44–45, 48–54
water splitting, 45–46, 47–48
Hydrogen reformers
reliability of, 76
safety of, 76–77
Hydrogen research, 316
Hydrogen storage, 77–91, 285–286. See also Hydrogen storage methods; Hydrogen transportation/storage
approaches to, 78–91
assessment of, 112–114
without capacity constraints, 112
in cars, 306–307
costs of, 113
DOE criteria and, 103–104
“nanoapproach” to, 100
“new materials” for, 114
Hydrogen storage media, effective, 106
Hydrogen storage methods, novel, 99–101
Hydrogen storage systems, heating and cooling requirements of, 90
Hydrogen storage tanks, 80
Hydrogen transition, 322–323
.crash program for, 323
Hydrogen transportation/storage, hydride slurries for, 93–95
Hydrogen user industry, accidents in, 115
Hydrogen vehicles, major challenges related to, 305. See also Hydrogen-fueled vehicles
Hydrolysis
of cellulose, 192
countercurrent, 197
enzymatic, 197
Hygas process, 183
Hythane mixtures, 297–305
Impacts, permanent versus transient, 2
Imported energy, dependence on, 42–43
Inconvenient Truth, An, 4
India, oil demand from, 174
Industrial activities, carbon dioxide from, 14 “Inferred” oil reserves, 158
Inorganic cycle, carbon transfer via, 10
Insolation, as a global warming forcing agent, 26–30. See also Solar insolation
Intergovernmental panel on climate change (IPCC), 32–34. See also IPCC reports
Iogen bioethanol plant, 192
Ionic hydrides, 85
IPCC reports, 11–12, 32–34. See also Intergovernmental panel on climate change (IPCC)
conclusions of, 34–35
Irradiance, as a global warming forcing agent, 26–30
Isothermal compression, 68, 69
ITER project, 153
Japan power-demonstration reactor, decommissioning of, 140
Jet-A fuel, 283
JP-8 jet fuel, 283
“Junk facts,” xiii
Junk science, xviii
Kellogg Transport Reactor, 186
“Knowledge gap,” xviii
Kyocera Corporation, 260
Kyoto Protocol, xviii
alternative views on, 39
failures of, 38–39
revision of, 39
Kyoto Treaty, 3, 36, 72
claims made by proponents of, 7
ineffectiveness of, 37
Land-based gas production, 165
LDV applications, hydrogen storage for, 108–110. See also Light duty vehicles (LDVs)
LDV transportation
  DOE objectives for, 280t
  realistic objectives for, 281t
Lead-cooled fast reactors (LFRs), 128–129, 130
Lean-burn direct-injection (LBDI) gasoline engine, 295
Less-developed countries, CO₂ emissions in, 38–39
Light duty military vehicles, liquid hydrogen storage for, 83–84
Light duty vehicles (LDVs). See also LDV entries; Light duty military vehicles
  storage implications for, 104–112
Light metal hydrides, 106
Light-water reactors (LWRs), 122, 123, 151
  mixed oxide fuel in, 125–126
Lignin/lignin derivatives, as biomass conversion by-products, 194
Limits to Growth, The (Club Rome), xviii
Linde cryogenic tank, 82
Liquefied hydrogen dormancy period, 82
Liquefied natural gas (LNG), xxii
  comparison to methanol, 215–216
  importation of, 62, 167
Liquid ammonia, storage of hydrogen as, 102
Liquid hydrocarbon fuel supply, 209
  containers for, 81
  manufacture of, 83
  realistic standards for, 281
  safe handling of, 82–83
  shipping, 81
  storage of, 83–84
  as vehicle fuel, 307
Lithium batteries, 320
Lithium ion batteries, 288
Lithospheric carbon, 8
Little Ice Age, 27, 28
  temperature changes around, 12
Localized data, extrapolating to a complex system, 5
Long term energy needs, xiv
Lovins, Amory, 316, 321, 322
Low-carbon energy supply, 297
Low level wastes (LLW), 135
  storage fees for, 140
Low level waste volumes, 136t
Low molecular weight hydrocarbons, 283
Lurgi process, 182–183
Magnesium alanates, 92
Magnesium hydride, 94
Magnesium hydroxide, 94
“Magnox” reactors, 128
Manufacturing efficiency, of a chemical process, 200–201
Mass extinction, historical perspective on, 7
Maunder minima, 28
Maximum equilibrium efficiencies, for cell reactions, 51
Medieval Warming Period, 27, 28, 38
“MegaMethanol” technology, 213
Metal hydrides, 85
  background on, 86–89
  complex, 89–91
  hydrogen release by, 88
  hydrogen storage in, 84–86, 101
  as storage media, 92
  types of, 85–86
Metal hydride storage system, 104
Metallic hydride slurries, 94
Metallurgical coke, 179
Metals, hydrogen storage in, 84–86
Methane
  coal-bed, 169–171
  as a global warming forcing agent, 20–21
  sources of, 21
  syngas from, 213, 214
Methane hydrate deposits, gas production from, 165
Methane hydrates, 168
  exploiting, 169
Methane release rates, 21
Methanol, 211–218
  applications of, 215, 216–218
  emissions and, 218
  as an energy carrier, 215–216, 217
  as a fuel, 216–217
  as a hydrogen carrier, 103
  in internal combustion engines, 215
  lifecycle cost of, 306
  as a motor fuel, 214
  production of, 212, 213
  as a transportation fuel, 211
  world market for, 215
“Methanol crossover” problem, 270–271
Methanol fuel cell, 270
Methanol–gasoline blends, 214
Methanol manufacturing, 67, 216–218 overseas, 213
Methanol reformers, 56, 310
Methyl ester biodiesel fuels, property data for, 226
Methyl tallowate, 229
Methyl tertbutyl ether (MTBE), 214, 237, 306
Microballoons, for hydrogen storage, 100
Middle distillate liquid (MDL) products, 239
Mixed oxide (MOX) fuel, 125–126
production and processing of, 126–127
uranium–plutonium, 147–148
Molten carbonate fuel cell (MCFC), 273–274
Molten metal technologies, 128
Monoethanolamine (MEA), absorption in, 57
Monolithic cell, 258
Montreal Protocol, 23
Multijunction cell technology, 63
Multijunction PV cells, 257
Municipal solid waste (MSW), 190
Municipal waste
as an alternative energy source, 188
cellulosic, 194–195

“Nanoapproach,” to hydrogen storage, 100
Nanostructured graphite, 97
Nanotube hydrogen absorption, 98–99
National Research Council reports, 53, 80
Natural gas, 175–177. See also
Conventional natural gas; Liquefied natural gas (LNG); Orphaned natural gas; Proven natural gas reserves;
Synthetic natural gas (SNG)
from coal beds, 170
conventional, 164–171
conversion into hydrogen, 294–295
as a hydrogen source, 61, 62, 312–313
hydrogen manufacture and, 62
running cars on, 66–67, 319
thermal and catalytic reforming from, 54–55
transportation of, 70
world reserves of, 61–62
Natural gas-fueled vehicles, 66–67, 319
Natural gas leakage losses, 75
Natural gas prices, 164
Natural gas reserves, 61–67
by country, 166t
depictions of, 165
depletion of, 315–316
Natural gas spot prices, 59
Natural gas supplies, xxii, 66
Natural oils, conversion into biodiesel, 227
n-doped semiconductor, 251, 254
Neat alcohol fuels, 214
Net energy balances, 191, 199–201
Net primary productivity (NPP), 30–32
satellite data on, 31–32
Niederaichbach reactor, decommissioning of, 139
Nitrogen, anthropogenic additions of, 21
Nitrogen levels, in biodiesel, 229
Nitrogen oxide (NOx) emissions, 222, 223, 241
Nitrous oxide, as a global warming forcing agent, 21–22
Non-CO2 greenhouse gases, 25
Non-corn biomass conversion, large-scale, high-value end products from, 195
Non-gasoline fuels, replacing, 43
Nonmetal hydrides/hydrogen carriers, 95–96
Nonmetallic “hydrides,” 106
North America, hydrogen industry in, 290
North American conventional oil reserves, depletion of, 162
Nuclear energy. See also Nuclear power entries
influence of, 117–122
safety record of, 117
supplies of, xx
Nuclear facilities, maintenance and disposal in, 137
Nuclear facility decommissioning, 137–140
examples of, 139–140
factors influencing, 138
techniques for, 138–139
Nuclear fuel, disposing of, 141
Nuclear power, xiv. See also Nuclear energy future of, 153
renewed interest in, 118–119
Nuclear Power 2010, 123
Nuclear power industry, 154
Nuclear power plants, worldwide, 120–121
Nuclear power stations, decommissioning costs for, 140
Nuclear reactor designs, evolution of, 122–125
Nuclear reactors, 118
  legislative acts related to, 123
  production capacity factor for, 152
Nuclear waste(s)
  disposal of, 134–142
  safe repository for, 136
Nuclear waste transmutation, 140–142
  beneficial impacts of, 141–142

Oceans
  acidity of, 13
  influence of CO₂ on, 37
  primary production in, 31
Off-board hydrogen storage, 107–111
Offshore methane hydrates, exploiting, 169
Oil
  future supply, demand, and pricing for, 172–175
  growing demand for, 171
  “unconventional,” 167–168
  worldwide availability of, 175
*Oil & Gas Journal*, 159
Oil commodity traders, impact on oil prices, 172
Oil consumption, xxi–xxiii
Oil discoveries, xx
Oilfields, early, 157–158
Oil prices
  OPEC control over, 174
  responsibility for setting, 171–172
  rising, 162–163
  worldwide volatility in, 164
Oil production
  peaks in, xviii
  U.S., xv
Oil recovery technologies, enhanced, 160
Oil reserves, xx–xxi, 158–164
  estimating, 158, 159
  forecast of, 163–164
  recoverable, xxiii
  untapped, 162
  viable, 159
Oil sand reserves, 171. *See also* Canadian Oil Sands
Oil sands bitumen, xxiii
Oil shortage, status of, 171
Oil traders, 164
Onboard compressed gas storage, 84
Onboard fuel storage requirements, 279–284
  system, 104
Onboard hydrogen storage, 78
Onboard reforming, 77
Ontario Power Generation, difficulties facing, 152
“Open-fuel cycle” reactors, 142
Organic solar cells (OSC), 258–259
Organization of Petroleum Exporting Countries (OPEC)
  control over oil prices, 172, 174
  oil production by, 173t
Orinoco Belt bituminous crudes, 167–168
Orinoco Oil Belt, xxiii–xxiv, 175
  development of, 160
Orphaned gas, 170–171, 176
Orphaned natural gas, 239
Oxygenated additives, 242
  effect on emissions, 241
  in petroleum diesel, 237–238
Oxygenated diesel fuel substitutes, 238t
Oxygenated fuels, 243
Oxygen by-products, of electrolytic hydrogen production, 49–50
Oxygen disposal, 75
Ozone, as a global warming forcing agent, 22–24
Ozone cycle, 23
Ozone depletion process, 22–23
“Ozone Hole,” 24
Ozone layer, hydrogen harm to, 318
Ozone reports, polar region, 5
Palladium, 86
PAMPAS polymer, 79
Parallel-hybrid gasoline/electric drive train technology, 277
Partial dehydrogenation, hydrocarbons via, 96
Partial oxidation/ceramic membrane reactors, 56
Partial oxidation (POx) processes, 56–57.
  *See also* POx (partial oxidation) gas
Particulates, as global warming forcing agents, 26
Passenger-carrying vehicles, hydrogen storage for, 112
Passive solar heating, 248–250
p-doped semiconductor, 251–252, 254
*Peak Oil Report* (Hirsch), xviii
PEM cell power densities, 266. See also Proton exchange membrane (PEM) fuel cells
PEMFC fuel, 269. See also Polymer electrolyte membrane/proton exchange membrane fuel cell (PEMFC)
PennWell Corporation, 159
Perfluorocarbons (PFCs), 25
Personal transportation, user expectations for, 278–279
Personal vehicles
  DOE objectives for, 103
  hydrogen for, 66–67
Petroconsultants, 159
Petroleum-derived energy sources, pervasive use of, 4
Petroleum diesel fuel
  alcohols in, 236–237
  oxygenated additives in, 237–238
  as a solution for fuel shortages, 241
Petroleum products, transport of, 73–74
Phosphoric acid fuel cell (PAFC), 273
Photobiological technology, 64
Photoelectric effect, 251
Photoelectrochemical (PEC) light harvesting systems, 63
Photoelectrolysis, 63
Photosynthesis, 31
Photovoltaic (PV) cells, 245. See also PV entries
  efficiencies of, 254t
  multijunction, 257
  polycrystalline silicon, 255
Photovoltaic systems
  international applications for, 250–251
  solar, 250–251
Phytoplankton, 32
“p-I-n” structure, 254
Pipelines
  infrastructure of, 70
  leakage losses from, 73
Plant growth rate studies, 13
Plutonium-239, 124, 125
“Plutonium economy,” 154
p/n junction, 252
Polar regions, ozone reports in, 5
Political agendas, in IPCC reports, 32–33
Pollutants, as global warming forcing agents, 24–25
Polycrystalline silicon devices, 255
Polycrystalline thin films, 255
materials for, 255–257
Polymer electrolyte membrane/proton exchange membrane fuel cell (PEMFC), 266–269
Polyoxyethers, 237
Possible oil reserves, xix, xx, 158
Power producers, difficulties facing, 152
POx (partial oxidation) gas, 55. See also Partial oxidation (POx) processes
Preparation technologies, biomass conversion, 191
Pressure-composition-temperature (PCT) curves, 88
Pressure vessel, gravimetric energy density of, 111–112
Pressurized-water reactors, 151
Primary producers, 31
Primary production, 30–31
Probable oil reserves, xix, xx, 158
Producer uranium inventory, 147
Product liability, in the transportation industry, 289
Product streams, removing carbon dioxide from, 57
Pronuclear argument, 121
Proton exchange membrane (PEM) fuel cells, 49, 86, 264. See also PEM cell power densities
  regenerative, 269
Proven coal reserves, 178
Proven natural gas reserves, 166
  in Canada, 167
Proven oil reserves, xix, xx, 158
  for oil-producing countries, 160t
Pure hydrogen, 42
cost of, 309
PV cells, operation of, 251–255. See also Photovoltaic entries
PV manufacturers, major, 260–261
PV materials, breakthrough advances from, 253–255
PV semiconductor, 251
PV solar energy prices, 259–260
Pyrolysis
  biomass, 55, 65
  coal, 179
R-22 refrigerants, 23
Radioactive waste disposal, 134–142
Radioactive waste materials, levels of, 134
RAR uranium reserves, 148. See also
  Reasonably Assured Resources (RAR)
Reactor fuel, 124–125
  recycling of, 125
Reactor Pressure Vessel (RPV), disposal of, 139
Reactors, number by age, 138
Reactor technology, safe and sustainable, 151–152
Real-world fuel cell efficiencies, 276–278
Reasonably Assured Resources (RAR), 146.
  See also RAR uranium reserves
Recoverable oil, estimates of, 174–175
Recycled hydroxide, hydride regeneration from, 94
Red Book, 149
Reformer furnace fuels, 55
Reformers
  maintenance of, 66
  reliability of, 76
Reforming
  autothermal, 56
  combustion CO₂ from, 57–59
  distributed manufacturing of hydrogen by, 76
  hydrocarbon, 65
  reactions, 48
  thermal and catalytic, 54–55
  thermochemical, 56–57
Remedial actions, current direction of, 36–37
Re-radiation trapping, 18
Reserves, xix–xxi
“Reserves growth,” 159
Resources, “recoverability” of, xix
Reversible cell reaction, 50–51
Reynolds number, 72
Russian Federation, as a uranium market supplier, 143, 144. See also
  Commonwealth of Independent States
Saccharification/fermentation, enzymatic, 192–193. See also Simultaneous
  saccharification and fermentation (SSF)
Safety issues, hydrogen-related, 114–116
SAFSTOR nuclear facility
  decommissioning strategy, 138–139
Sasol Slurry Phase Distillate Process, 186
Scalability, 2
Scattered radiation, 246
Scrubbing technology, for CO₂ removal, 58
Seawater, uranium from, 150–151
Selexol Process, 58
Semibitumen oil, xxiii
Shale oil deposits, U.S., 167
Shale oils, xxiii
Sharp Corporation, 260
Shell Canada SCGP plant, 185
Shell Coal Gasification Process (SCGP), 185
Shell Solar, 261
Shippingport reactor, decommissioning of, 139
Sieverts’ Law, 88
Silicon-based solar cells, 250
Silicon PV cells, 251
Simple hydrides, 85, 86
Simultaneous saccharification and fermentation (SSF), 192–193, 197
Single-crystalline silicon cells, 254–255
Small to medium sized reactors (SMRs), 119
Sodium alanate, 90, 91
Sodium borate, 94
Sodium borohydride, regeneration of, 93
Sodium-cooled fast reactors (SFRs), 129–131
Solar cells
  dye-sensitized, 257–258
  organic, 258–259
Solar electric system, utility-tied, 259
Solar energy, 245–250
  direct, 248–250
  future outlook for, 261–262
  grid-connected, 259
  power generation via, 52–53
Solar farms, 261
Solar heating, passive and active, 248–250
Solar influences, as global warming forcing agents, 26–30
Solar insolation, 247. See also Insolation
Solar magnetic cycles, 27, 28
Solar photovoltaic market installations, worldwide, 261
Solar photovoltaic power, 312
Solar photovoltaic systems, 250–251
Solar radiation, 245–250
standard measure of, 245
Solar thermal collectors, types of, 248
Solid oxide fuel cells (SOFCs), 271–272
advantages of, 272
hybrid power systems incorporating, 272
Source-to-use analysis, 275t
Source-to-use energy efficiencies, 277t
realistic, 296t
South African Sasol process, 186
Soybean esters, properties of, 229t
Soybean oil
analysis of, 225t
nitrogen, sulfur, and phosphorus contents of, 229
Space programs, hydrogen cooling/storing techniques for, 81
Spent fuel, recycling of, 96
Staebler–Wronski effect, 254
Stationary fuel cells, 269
Steam-assisted gravity drainage (SAGD) technology, 167
Steam explosion technology, 192
Steam-hydrocarbon reforming, 48
Steam-hydrocarbon reformer furnace, 54–55
Steam methane reforming (SMR) process, 55, 213
modified, 55
Steam reforming process, 54
Storage media, metal hydrides as, 92
Storage technologies, most promising, 105
Stranded gas, 170–171, 176. See also Orphaned entries
Subnanostructured metal grids, for hydrogen storage, 100–101
Subsidies, for ethanol, 208
Sugars, as biomass conversion products, 193. See also Saccharification/fermentation
Sulfur, as a global warming forcing agent, 24
Sulfur hexafluoride, 25

Sun
impact on earth temperature, 28
influences on climate change, 29
SunFuel (SunDiesel), 240
“Supercharged” metals, 87
Supercritical-water-cooled reactor (SCWR), 131–132
Superphenix reactor, decommissioning of, 140
Sustainability, xvi, 2
Sustainable mobility, 318–319
“Swing” fuel, 194
Synthane process, 184
Synthesis gas (syngas), 45, 46, 47, 56. See also Synthetic natural gas (SNG)
biomass-based, 283
from coal, 182–183, 215
conversion to methanol, 103, 212
fossil sources of, 214–215
from methane, 213, 214
Synthesized liquid fuels, value of, 240–241
Synthetic diesel fuels, 239
Synthetic fuels
from biomass, 242
carbon as a source of, 179
Synthetic natural gas (SNG), 176. See also Synthesis gas (syngas)
from coal, 183
Tallow-based methyl ester biodiesel, 233–234
“Thermal Depolymerization” process, 188
“Thermal mass” materials, 248
Thermal technologies, for biomass conversion to hydrogen, 64–65
Thermochemical processes, improving, 56
Thermochemical reforming, 65
catalytic, 55–56
scaling issues related to, 56–57
Thermodynamic faituality, 1
Thermodynamic processes, efficiencies of, 51. See also “Heat islands”
Thin-film cells, 255
Third-world countries, clean energy technology in, 40
Three Gorges Dam, 45
Three Mile Island, 118
“Tight gas,” xxiii, 170, 176
Titanium hydride, 86
“Town gas,” 179
Transmutation, 141
Transport, of hydrogen, 67–75
Transportation, hydrogen storage for, 78
Transportation activities, carbon dioxide from, 14
Transportation alternatives, for hydrogen, 75–77
Transportation costs, hydrogen, 74
Transportation fuel
    biodiesel as, 224
    price of, xxi
Transportation industry, hydrogen safety in, 114
Transuranics (TRUs), removal of, 141
Transuranic waste materials, 134–135
Tree species, as raw materials for biomass, 194
Tropospheric ozone, 22
Turbocharged diesel engines, 220
Turbulent flow, 72

ULSD diesel fuel, 239–240. See also Ultra low sulfur diesel (ULSD)
    “Ultimately recoverable” oil, 174
    Ultimately recoverable reserves, xix, xx
Ultra low sulfur diesel (ULSD), 221, 223. See also ULSD diesel fuel
    “Unconventional” gas, 168–169
    “Unconventional” oil, xxiii, 167–168
    world reserves of, 175
Underground coal gasification (UCG), 186–187
Underground hydrogen storage, 101
    “Undiscovered recoverable” gas reserves, 166–167
United Nations Framework Classification (UNFC) for Energy and Mineral Resources, 158
United States. See also Department of Energy (DOE); Federal subsidies;
    National Research Council reports;
    U.S. entries
    availability of coal in, 180
    biodiesel standards in, 229
    corn production in, 207–208
    demand for biodiesel in, 233t
    dependence on natural gas, 309
    exploration activities in, xxii
    growing dependence on imported gas, 176
    hydrocarbon resources in, xxiii
    natural gas supply in, 166, 167
    nuclear energy in, 121
    oil and gas consumption in, xx
    oil prices in, 174
    oil production by, xv
    tight gas reserve data for, 170
    transportation fuel use in, 43
    wholesale gasoline prices in, 60
UP1 Reprocessing Plant, decommissioning of, 140
Uranium
    captive production of, 148
    from the Commonwealth of Independent States, 148
    inventories of, 147
    mined and processed, 148
    prices of, 126
    production and supply forecast for, 145
    reprocessed, 147–148
    from seawater, 150–151
    sources of, 143
    supply concerns related to, 142–151
    supply projections for, 146–149
    Uranium-235, 124
    Uranium-238, 124
    Uranium industry, supply issues in, 149
    Uranium ore reserves, xx. See also Uranium reserves
    by grade, 147t
    Uranium ore yield, estimating, 148–149
    Uranium–plutonium mixed oxide fuel, 147–148
    Uranium reserves, 143–146. See also
    Uranium ore reserves
    estimated quantities of, 146
    types of, 145–146
    U.S. oil production peak, 161
    U.S. road diesel fuel, 221
    Utility-tied solar electric system, 259
    Utility uranium inventory, 147
    Value-added biomass conversion products, 193
    van’t Hoff equation, 89
    Vanadium, 106
Vanadium hydride, 86
Vegetable oil-based biodiesel, alternatives to, 236
Vegetable oils
in biodiesel manufacture, 227
 carbon chain distribution of, 234t
as fuels, 225
 modified, 232
Vehicles. See also Alternate-technology vehicles; Battery–electric vehicles;
 Battery-powered electric vehicles;
 Diesel hybrid vehicles; Diesel-powered vehicles; Electric vehicles; Fuel cell vehicles (FCVs); Gasoline-fueled vehicles; Heavy-duty vehicles (HDVs);
 High efficiency diesel-powered vehicles; Hybrid vehicles; Hydrogen-fueled vehicles; Hydrogen vehicles;
 Light duty military vehicles; Light duty vehicles (LDVs); Natural gas-fueled vehicles; Passenger-carrying vehicles;
 Personal vehicles
 fuel cell, 298–304t
 natural gas-fueled, 66–67
 user expectations for, 278–279
Velikhov, Yevgeny, 154
Venezuela, hydrocarbon reserves in, xxiii
Very high-temperature reactors (VHTRs), 122, 133–134
Volcanic emissions, 26

Warming phases, repetitive, 12
Water, electrolysis of, 48–49
Water gas, 47, 179
Water-gas shift reaction, 213
Water-splitting, 45–46, 47–48
 reforming using, 54
Water splitting systems,
 photoelectrochemical, 64
Water vapor
 atmospheric, 14
 as a global warming forcing agent, 15–20, 27–28
 ocean heating from, 27–28
Water vapor levels, increasing, 16
“Well-to-wheels” analyses, of petroleum fuel use, 295
“Well-to-wheels” energy efficiencies, 277t, 288
 realistic, 296t
Wind energy power generation, 52–53, 312
World nuclear energy capacity, 148
Worldwide hydrogen industry, 291

Yankee Rowe nuclear power plant,
decommissioning of, 139
Yttria-stabilized zirconia electrolytes, 271
Yucca Mountain project, 135–136, 140
Zeolites, hydrogen storage capacity of, 99
Zero Boil Off (ZBO) technology, 82
Zero Emissions Coal Alliance Corporation (ZECA), 183
 CO2 acceptor technology of, 184
Zero-emissions coal technologies, 185
Ziegler-Natta hydrogenation catalysts, 92