

Index

a

1000-roof program 20
 Aachen model 20, 289
 Absorption 25, 48, 64–67, 72, 75, 76,
 78–79, 112, 252, 309
 Absorption coefficient 65, 67, 75, 78, 79,
 112, 118, 121, 126, 309
 Absorption efficiency 78–79, 309
 Active density of states 54, 62
 Active power 192, 193
 Aerial tube 267
 Air mass 24, 25
 Albedo 37, 38
 Ambient temperature 148
 Amorphous silicon (a-Si) 67, 112–113,
 115, 116, 120, 123–124, 164, 243,
 309, 310
 Angle of incidence 96, 243
 Anode 209, 210, 217
 Anti-reflection coating 73, 109
 Anti-reflection layer 68, 75, 78, 97
 Area utilization factor 286, 288, 289, 315
 Avalanche breakthrough 64, 139, 259

b

Back-surface-field 77, 109
 Band diagram 57, 58, 61–62, 77
 Bandgap 52–54, 64, 65, 74, 80, 84, 91, 112,
 116–118, 122, 185, 255, 329
 Bandgap wavelength 91
 Band model 51–54
 Base 73, 76, 102, 162
 Bidirectional meter 172, 173

Biomass 8, 9, 11, 13, 234, 287, 288, 292,
 298
 Bohr's atomic model 47–49
 Bohr's postulate 47, 48
 Boost converter 169–170, 175, 180
 Brick 106, 107
 Buck converter 166–169, 205
 Buffer operation 201
 Buried contact 97–100
 Busbar 74, 97, 256
 Bypass diode 142–147, 149, 155, 258, 259,
 272, 311
 Bypassing 212

c

Cable losses 158, 270
 Cadmium-telluride (CdTe) 15, 51,
 119–121, 123, 129, 131, 132, 135,
 149, 177, 243, 311
 Cathode 209–211, 214, 218, 313
 Charge controller 197, 204–207, 232, 233,
 312
 Choke coil 167, 170, 175, 185
 CID 211, 212
 CIGS 121–123, 134, 151
 CIGSe 122
 CIS cells 121, 122, 311
 CIGSe 122
 Climate change 9–11
 Cloud enhancements 26
 Commercial enterprise 221, 227–228,
 302
 Compound interest rate 274

Compound semiconductor 49–51, 121, 150
 Compressed air energy storage (CAES) 301, 302
 Concentration gradient 60, 77
 Concentrator system 126, 128–129, 132
 Conduction band 52, 53, 58, 61, 65–67, 74, 83, 91
 Conductor 53, 58, 62, 207
 Connector 110, 156, 157
 Constant current, constant voltage (CCCV) 211
 Consumption meter 172
 Contact resistance 249, 254
 Control energy 293–294
 Control power plant 189
 Conversion efficiency 181–184
 Coordinated Universal Time (UTC) 33
 Copper indium gallium sulfide (CIGS) 121–123, 134
 Copper indium gallium selenide (CIGSe) 122
 Copper indium sulfide (CIS) cells 121–123
 Copper indium selenide (CISe) 122
 Crystalline silicon (c-Si) 65, 67, 75, 80, 94, 112, 118, 120, 123, 126, 148, 149, 243, 254, 259, 277, 309, 310, 314
 Current density 56, 57, 63, 91–93, 97, 220
 Current interrupt device (CID) 211
 Current matching 117
 Cycle operation 201
 Cycle stability 212
 Czochralski method 17, 105

d

Dangling bonds 112, 115
 Dark current 71, 77
 DC/DC converter 166, 171, 197, 204, 205
 Dead layer 76, 102, 309
 Deep discharging 212, 221, 309
 Degradation 115, 116, 118, 147, 177, 257, 262, 282
 Degree of efficiency 6, 15, 69, 71, 175, 288
 Degree of self-sufficiency 173, 223
 Demand side management (DSM) 304
 Density of states, effective 54, 62

Depth of discharge (DoD) 202, 225
 Diffuse radiation 26, 28, 35–37, 41, 129, 147, 244, 254, 308, 313
 Diffusion cell 114, 310
 Diffusion current 56, 57, 60, 63, 86, 309
 Diffusion length 63, 74–75, 99
 Diffusion voltage 60–62, 64, 309
 Diode characteristics 63–64
 Direct radiation 12, 26, 28, 35, 36, 37, 41, 244
 Direct semiconductor 65–67, 112, 120, 254
 Disconnecter 156
 Discontinuous current mode 168
 Domestic hot water heat pump 226
 Doping 14, 57–59, 61, 63, 75, 77, 98, 99, 129, 130, 309
 Drift cell 114, 310
 Drift current 55
 Drift velocity 55, 115
 Duty cycle 167, 170, 171
 Dye sensitized solar cell 125

e

EEG 15, 20, 191, 272, 273, 289–292
 Efficiency 2, 5, 11, 15–18, 45, 69, 71, 76, 78–80, 83, 90–99, 102, 115–128, 132, 147, 181–186, 218, 225, 234, 247, 270, 279, 287, 298, 300–303, 308–311, 315, 327
 Efficiency, European 184–185, 281, 327
 Efficiency, spectral 91–94, 310
 Efficiency, theoretical 94, 95, 118, 120, 310
 Efficiency yield 288, 289
 EFG 107, 108, 310
 Electric heating rod 327
 Electricity 5, 6, 11–14, 17, 165, 172, 188, 197, 221–223, 225–228, 231, 234, 238, 273, 278, 288, 290, 292–305, 308, 315
 Electroluminescence 3, 254, 255, 257, 314
 Electroluminescence measurement 255, 257–259
 Electron-hole pair 53, 66, 71, 74, 76, 91, 112, 115, 256, 261, 309, 310
 Electronic grade 104
 Emitter 73, 75–76, 98, 108, 109, 124, 261

- Emitter, local 100
 End-of-charge voltage 200, 202–206
 Endenergy 5
 Energy 3–9, 11, 234, 266, 269
 Energy bands 51–53
 Energy management system 222, 223, 226, 228, 230, 231, 327
 Energy payback time 14
 Equivalent circuit 73, 81, 82, 88–90, 147, 190, 310
 ERoEI 133, 134, 311
 Ethyl-vinyl-acetate (EVA) 111, 119, 130, 143, 144, 261, 262
 European efficiency 184–185, 281, 327
 Excess feed-in 173, 312
 Exit angle 96
- f**
- Façade plants 38, 39, 111, 119, 164, 285–288
 Feed-in 20, 172–173, 176, 179, 180, 191, 213, 220, 229, 231, 276, 289–292, 301, 304, 312, 314, 328
 Feed-in management 191
 Feed-in meter 15, 172
 Feed-in tariff 172, 220, 225, 273, 275–277, 281, 289–292, 314
 Feed-in variants 172–173
 Fermi 61, 62, 77
 Field current 55–56, 60, 63, 114, 309
 Fill factor 82–83, 87, 149, 262, 314
 Final yield 278–282, 314
 Flat roof plant 161–162, 269, 283, 288
 Float-zone method 105
 Fluidized bed reactor 103, 104, 134
 Flyback diode 168, 170, 185
 Forward voltage 62, 63, 258
 Foundation 17, 71, 159–161
 Fresnel equations 69, 96
 Fresnel lens 126, 128
 Full feed-in 172, 312
 Full load hours 29, 236, 237, 278, 279, 281, 298, 308, 315
- g**
- Gallium arsenide (GaAs) 18, 51, 67, 95, 124
 Gallium nitride (GaN) 185
 Gassing 200, 204
 Generator connection box 156, 157, 173
 Generator losses 278–280
 Generator reference-arrow system 80, 139, 140
 Glass-foil module 111
 Glass-glass module 111, 119, 287
 Global radiation 26, 129
 Grätzel cell 125
 Greenhouse effect 10, 307
 Grid connection point 190, 193, 229
 Grid coupling 3, 14, 20, 197, 204
 Grid impedance 175, 189, 190, 193
 Grid operator 188–194
 Grid parity 220, 292, 315
 Ground mounted plants 2, 35, 158–161
- h**
- Heat pump 11, 12, 226, 231, 288, 300, 304, 327
 High efficiency cells 80, 99, 102
 HIT cell 110, 123–124
 Hotspot 144, 146, 150
 Hourly mean values 186
 Hybrid wafer cells 123
- i**
- IBC cell 99–100
 Ideality factor 81, 86, 88, 90, 311
 Incident angle 241
 Inclination 39, 40, 237, 265, 269, 286, 289, 308, 314–317
 Indirect semiconductor 65–67, 254
 Indium tin oxide (ITO) 113, 121
 Inductance 176, 178, 181, 193, 194
 Ingot 105–107, 130
 In-roof plant 163, 164
 Insulator 53, 54, 111
 Integrated series connection 119, 149, 257
 Intercalation 208
 Intercalation material 209, 210, 212
 Intercept theorem 267
 Interdigitated back contact 100, 124
 Intrinsic carrier concentration 54, 185

Intrinsic shading 142, 153, 265, 266, 268
 Inverter 14, 20, 45, 132, 145, 156, 165,
 172–190, 193, 195, 219, 223, 231,
 232, 234, 270, 277, 281, 287, 312
 Inverter efficiency 181–186
 Investment costs 12, 273
 Irradiance 23, 24, 26, 36, 37, 65, 67, 78, 82,
 91, 94, 127, 147, 148, 165, 184, 241,
 246, 248, 285, 308
 Isolation unit 177, 178, 183, 211

k

Kilowatt-hour 225–226, 292, 313, 314

l

Layered cell 18, 111, 207
 Lead acid battery 199–201, 208
 Lead battery 199, 200, 203, 210–212, 214,
 225
 Learning curve theory 290
 Learning rate 290, 291
 Light absorption 2, 64, 65, 72, 76, 78, 114,
 252, 309
 Light concentration 126–128
 Light trapping 98, 99, 101, 102, 116, 119
 Line-commutated inverter 175
 Lithium ion battery 206–208, 210, 211,
 223, 226, 232, 313
 Load reference-arrow system 72, 146, 152
 Local emitter 100
 Local solar time (LST) 32–34
 Low-voltage grid 193
 Low voltage guideline 189, 194

m

Mains transformer 177–178, 183
 Mains voltage 175, 178
 Maxeon cell 100
 Maximum power point 82, 142
 Medium-voltage grid 191
 MET 33
 Metallurgical silicon 103, 104
 Methanation 303
 Micro-crystalline 118, 119
 Micromorph 118, 119
 Minute reserve 294

Mismatching 153, 155, 173, 180, 181, 245,
 312
 Mobility 55, 56, 115, 298, 302
 Module inverter 174
 Monitoring 3, 157, 175, 176, 206, 211, 219,
 243, 265, 277, 278, 280, 315
 Monocrystalline 84, 96, 105, 106, 109, 135
 MOSFET 167, 175, 176, 179, 195, 205, 206
 MPP tracker 171, 175, 180, 206
 Multicrystalline 106–108, 132, 133, 159,
 164

n

NaS 213–216
 NOCT 148, 311
 Number of cycles 201, 202, 212, 216, 225,
 226

o

Object yield 39
 Oblique incidence 97
 Off-grid system 2, 313
 Open circuit voltage 77, 82–86, 95, 101,
 117, 123, 127, 140, 143, 147, 187,
 193, 203, 214, 218, 311
 Operating costs 273–275
 Operating point 82, 144–146, 152, 165,
 166, 171, 172, 247
 Overhead lines 267
 Oxyhydrogen gas 200

p

Parallel connection 139, 141, 150
 Partial shading 139, 141, 142, 155, 180
 Part-load 158, 183–186, 234
 Passivated emitter and rear cell (PERC cell)
 101–102, 135
 Passivation 101, 102, 108, 112, 123, 124
 Payback period 14
 Peak power measurement 248, 313, 328
 Peak-shaving 229, 230, 313
 Performance Ratio 279–282, 284, 315
 Photocurrent 71, 77–78
 Photodiode 71, 244
 Photovoltaic 1–3, 8, 11–21, 23, 28, 32, 33,
 38, 41, 103, 129, 130, 132, 153, 158,

- 165, 175, 181, 189, 191, 232, 235,
241, 248, 265, 270, 272
- Pin cell 113–119
- Pitched roof plant 283
- Plant monitoring 244, 277, 315
- Plant visualization 277
- Plasma enhanced chemical vapor
deposition (PECVD) 113, 118
- p-n junction 2, 14, 17, 47, 59–64, 71–73,
77, 86, 94, 95, 98, 108, 109, 114, 122,
139, 254, 261, 309
- Point contact cell 99, 100, 110, 128
- Polycrystalline 105, 106, 121, 122, 129,
159, 164
- Polysilicon 103–106, 131, 132
- Potential compensation rail 194
- Potential induced degradation (PID) 177,
259–264, 314
- Potential step 61, 77, 98
- Power factor 194
- Power generation potential 3
- Power to gas 232, 303
- Primary control 294, 302
- Primary energy 5–8, 12, 45, 132, 133, 285,
307
- Primary energy demand 132, 133
- Primary energy factor 132
- Primary winding 183
- Public grid 14, 15, 132, 169, 172, 173, 176,
235, 270, 279
- Pyranometer 241–244, 313
- q**
- Quantum efficiency 79, 80, 102, 117
- r**
- Rayleigh scattering 25
- Reactive power 192
- Reactive power provision 191–194
- Recombination 74–77, 98, 99, 102, 112,
114, 115, 124 Recycling, 129, 130,
135
- Redox reaction 199
- Reference yield 278–280
- Reflection factor 67–69, 96, 98
- Refractive index 67
- Renewable energy law (EEG) 15, 191, 273,
289
- Residual current protective device (RDC)
175
- Resistive load 165–166, 191, 192
- Return calculation 273–277
- Return on equity 273, 276
- Reverse voltage 62, 71, 139, 185
- Ribbon silicon 107–108
- Roof hook 163
- s**
- Sabatier process 303
- Sahara miracle 2, 43, 45, 285
- Saturation current 83, 88, 95
- Savings bank equation 275
- Screen printing 109, 110, 256, 257
- Secondary control 294
- Secondary energy 5
- Self-commutated inverter 175
- Self-consumption 2, 15, 172, 173, 197,
220–229, 276, 302
- Self-consumption rate 173, 197, 222, 223,
227, 229, 275, 276
- Self-discharge rate 224
- Self-shading 268–269
- Self-sufficiency 173, 223
- Semiconductor 2, 14, 47–70, 75, 86, 91,
97, 98, 104, 112, 119–121, 123–125
- Semiconductor, direct 66, 67, 120
- Semiconductor, indirect 66, 67, 254
- Sensitivity, spectral 79–80, 102, 244, 255
- Series connection 119, 141–144
- Series connection, integrated 119–120,
149, 257
- Series resistance 86, 87, 89, 109, 128, 149,
247, 249
- Shading analysis 266, 267
- Shadow losses 97
- Shockley equation 63, 64, 73, 86
- Short circuit current 81–82, 84, 88, 97,
101, 117, 127, 140, 141, 153, 256
- Shunt resistance 86, 87, 89, 147, 247, 261
- Shut down 191
- Siemens reactor 104, 134
- Silicon 14, 17, 18, 49–51, 54, 65, 93, 96,
99–101

Silicon carbide (SiC) 185
 Silicon, metallurgical 103, 104
 Simulation software 29, 188, 239
 Single-diode model 86
 Slew-rate 168, 169
 Smart grid 231, 304
 Smart meter 304
 Sodium sulfur battery 213–216
 Soiling 39, 265, 287
 Solar cell 2, 14, 71, 73–77, 81, 91, 93, 96–99, 108, 109
 Solar cell symbol 81
 Solar constant 23
 Solar energy meter 173
 Solar grade 104, 134
 Solar module 14, 18, 20, 35, 36, 85, 110–112, 139, 140, 142–144, 205, 206
 Solid-state body 17, 52, 65
 Space charge region 60, 62, 64, 71, 114, 115
 Specific yield 16, 278–279
 Spectral efficiency 91–95
 Spectral sensitivity 79–80, 102, 242, 244
 Stacking faults 261
 Staebler–Wronski effect 115–116
 Stand-alone inverter 232
 Stand-alone plant 201, 235–239
 Standard equivalent circuit 86, 88, 147
 Standard test conditions (STC) 15, 26, 109, 248, 278
 State of charge (SoC) 210, 212, 238
 Step-down converter 166
 Step-up converter 169, 185
 String 14, 107, 150–152, 173, 187, 188, 194, 195, 248
 String diode 150, 155
 String fuse 150, 152, 156
 String inverter 173, 174
 String line 156, 195
 String protection
 String ribbon 107
 Substrate 113, 121
 Substrate cell 117
 Sun azimuth 33
 Sun declination 32–34
 Sun height 25

Sun height angle 25
 Sun path diagram 34, 266
 Sun path indicator 266, 267
 Sun position tracking 25, 245
 Superstrate 117, 121, 177
 Superstrate cell 114, 121, 177
 System efficiency 45, 287
 System losses 278, 279

t

Tandem cell 116, 117
 Tedlar foil 111
 Temperature behavior 147–149
 Temperature coefficient 84, 85, 120, 139, 148, 149
 Temperature dependency 120, 123, 243
 Texturing 96
 Texturization 96–98, 101
 Theoretical efficiency 94–96, 118, 120, 310
 Thermal runaway 210, 214
 Thermal voltage 63, 64
 Thermalization losses 91
 Thermography 3, 249–254, 259–260, 313–314, 328
 Thin film cell 112, 113, 120–123
 Thin film module 120, 123, 134, 149–150, 177, 257, 259
 Three-component model 35–38
 Threshold voltage 64, 143, 145
 Tile 162, 163
 Tilt angle 236, 245
 Tons of coal equivalent (Tce) 7
 Tons of oil equivalent (Toe) 6
 Tracking 41, 159, 171
 Transformer 175–179, 183, 186
 Transmission losses 91, 94, 98, 115
 Transparent conducting oxide (TCO) 113, 115, 123
 Trichlorosilane 103, 104, 129
 Triple cell 117, 118
 Two-diode, equivalent circuit 90
 Two-diode model 86–87, 124

v

Valence band 52, 53, 61, 66, 67, 74
 Vanadium redox flow (VRF) 217, 219

VisiKid 280

Visualization 280–281

W

Wafer 103, 107–109, 124, 129, 130

Wafer cells, hybrid 123–125

Watt, peak 291

Weak light behavior 147, 247, 270

Work 3, 4

Y

Yield, specific 16, 274, 284, 288