

Index

Page numbers followed by f and t indicate figures and tables, respectively.

A

- Absorption chillers; *see also* Chillers
 - cost estimates for, 266, 266t
 - double-effect (2E), 371
 - exhaust absorption chiller, 277, 278f
 - Li-Br, 273, 277
 - schematic, 266, 267f
 - single-effect (1E), 264–265, 265f, 371
 - types, 277, 278t
 - water/LiBr, 266
- Absorption cooling systems, 97–100
- Absorption TES
 - performance improvement, 397–399, 398f
 - working pairs, 393–394, 395t
 - working principle, 385, 388–389, 388f
- Active systems, solar water heating systems, 331, 331f
- Active thermal energy storage systems, 240–243
- Actuator problems, 423
- Actuators, 192
- Adaptive fault detection, 435
- Adsorption TES
 - performance improvement, 399–400, 400f
 - for space cooling, 403–404, 405f
 - test facility, 403–404, 405f
 - working pairs, 394, 396–397
 - silica gel and water, 394
 - zeolites and water, 394, 396–397, 396f, 397f
 - working principle, 389–392, 390f, 391f, 392f
- Advanced Automated HVAC
 - Fault Detection and Diagnostics Commercialization project, 448
 - AFUE (annual fuel utilization efficiency), 113–114, 117
- Aggregated thermal demand (ATD) method, extended, 270–271
- Air conditioning energy consumption, 475–496
 - case study sites, 478, 480, 480f, 481f, 482f
 - future work, 495–496
 - methodology for case study, 483–490
 - BEM, 485–488, 487f, 487t, 488f
 - BEP, 484–485
 - SBEM, EnergyPlus™, 488–490, 489f, 490f
 - uWRF, city scale model, 483, 483f
 - overview, 475–478, 477f, 478t, 479t
 - results and discussion, 490–495
 - dark roof AC energy consumption simulation, 490, 492f
 - SBEM sensitivity analysis, 493–495, 495f
 - SBEM vs. uWRF, 493, 494f
 - TMY weather file, 490, 491f
 - total energy demand, 492, 493f
 - uWRF weather outputs data, 490, 491f
 - summer 2010 heat wave event, 481, 482
 - US National and regional studies, 478, 479t
- Air conditioning (A/C) technology, building, 349–358
 - chilled water storage/aquifers, 349–352, 350f, 351f, 352t
 - PCMs, 352, 353–354
 - ceiling board, 357, 357f, 358
 - cumulative energy saving of load levelling strategy, 355t
 - free cooling systems, 355f

- ice TES system, schematic diagram, 353f
- for solar shading, 354, 355, 356f, 357, 357t
- various thermal storage systems, 354t
- Air conditioning (A/C) technology, solid desiccant, 268–269
- Air-cooled condensers, 104–105
- Air handling units (AHU), 124–127
 - diagnostic algorithms for, 437, 440
 - diagram, 453, 454f
 - FDD methods, 438t–439t
 - fresh air ventilation rates, 126–127
- Air humidity, 484
- Air supply temperature control loop, 131
- Alarm functions, 206
- Alarm management, 421–424
 - PMM, 424, 425f
 - process/system fault definition, 422–423, 423f
- Algorithms for recovery times estimation, 219–220
- Allocation, costs and investment, 344–345
- AM10 Natural Ventilation in Non-Domestic Buildings, 154
- Analysis
 - economic and feasibility, CCHP systems, 279–283
 - cost, 282, 283t
 - detailed electricity and natural gas usage, 280, 280t
 - electric and natural gas costs, 281, 283t
 - electric output, 281, 281t
 - heat output, 281, 282t
- Anova Verzekering Co., 352
- APAR & VPACC, 446t
- Applications
 - FDD, challenges in, 450–452
 - strategy/approach related, 451–452
 - industrial and HVAC, fault detection methods, 441–449
 - business models and commercial solutions, 443
 - commercial software, 443, 444t–447t
 - hardware/software requirements, 442–443
 - implementations, review of, 443, 448–449
 - solar ventilation air preheating, 320
 - TES, 348
- Aquifers
 - chilled water storage, 349–352, 350f, 351f, 352t
 - hot water tank, 358–361, 358f, 360f
- Arizona Public Service (APS), 281
- Artificial lighting, annual use of, 214
- Artificial neural networks (ANN), 202; *see also* Intelligent control systems
 - PCA and, 435–436
- Artificial neuro-fuzzy inference system (ANFIS), 435
- ASHRAE 62.1, 150
- ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers), 113, 127, 260, 328
- ASHRAE 188: Prevention of Legionellosis Associated with Building Water Systems, 161
- ASHRAE 62.1 standard, 150
- ASHRAE Standard 52, 161
- ASHRAE Standard 55, 149
- ASHRAE Standard 62, 221, 226
- ASHRAE Std. 189.1, 10
- ASME Boiler and Pressure Vessel Code, 115
- ASME ISBES Workshop, 8–10
- AspenTech, 443
- Automated fault detection and diagnosis, in HVAC systems, *see* Fault detection and diagnosis (FDD)
- Autoscaling, defined, 430
- Azeotrope, 96

B

BACnet, 442
BACnet device, 209
Bahnfleth's solution, 35
Bayesian-Emulator approach, 86–88
BEM (building energy model), 483, 483f, 485–488, 487f, 487t, 488f
Benefits, TES, 270–271
BEopt™ (Building Energy Optimization) software, 5
BEP (building energy parameterization), 483, 483f, 484–485
Bishop, 42
BLAST, 42, 84
Boiler Efficiency Institute, 117
Boilers, 110–124
 control for, 236
 electric heat pumps, 120–121
 electric resistance heating, 119
 low-temperature radiant heating systems, 121–124
 selection, 115–116
Bottoming cycle, CCHP systems, 271
Boundary layer
 defined, 320
 temperature, 321
Building automation systems (BAS), 204
 implementation, 443
Building Description Language (BDL), 83
Building energy model (BEM), 483, 483f, 485–488, 487f, 487t, 488f
Building Energy Modeling, 4–5
Building energy parameterization (BEP), 483, 483f, 484–485
Building integrated PV (BIPV), 299
Building integration, CCHP (case studies), 271–279
Building level challenges and solutions, ESI, 337–341
 overcurrent protection, 337f, 338, 339

 sizing, 337, 338
 voltage regulation, 338f, 339
 wear-and-tear on reactive power compensation equipment, 340–341, 340f
Building load coefficient (BLC), 76, 82
Building loads, 240
Building management & control systems (BEMS), 443
Building management systems (BMS), 204
Building Optimization System program, 448
Building systems control strategies, 5–6
Building thermal mass, precooling of, 236–239
Buildings
 CCHP in, *see* Combined cooling, heating and power (CCHP) systems
 energy storage systems for, *see* Energy storage systems
 FDD application, challenges in, 450–452
 strategy/approach related, 451–452
 sorption TES system for, 385, 388–407
 working principle, 385, 388–392
 with TES integration literature summary, 375–379, 376t–378t
Buoyancy-driven natural ventilation, 143, 153–154
Business models, industrial and HVAC application, 443

C

C ratio, defined, 258
Cadmium telluride, 296–297
Caissons, concrete, 298
Calcium chloride, 107
California Energy Commission, 448
Carnot cycle method, 120

Carnot Refrigeration Cycle, 94–97
 Case studies; *see also* District cooling systems (DCS), fault detection system for (case study); Fault detection system for DCS (case study); Passive cooling, case studies
 air conditioning energy consumption methodology, 483–490
 sites, 478, 480, 480f, 481f, 482f
 CCHP sizing options, building integration, operation and system controls, 271–279
 fault detection system for DCS design and features, 454–455, 455f
 implementation results, 455–461, 456t, 457f, 457t, 459f, 460f
 process layout and specifications, 452–453, 453f, 454f
 fault detection system for district cooling systems, 452–464
 Cast-iron boilers, 115
 CCHP, *see* Combined cooling, heating and power (CCHP) systems
 Ceiling board, PCM, 357, 357f, 358
 Center for Research and Technology Development (CRTD), 2
 Central communications controller (CCC), 205
 Central control unit (CCU), 205
 Central inverters, 301
 Challenges
 building level, ESI, 337–341
 overcurrent protection, 337f, 338, 339
 sizing, 337, 338
 voltage regulation, 338f, 339
 wear-and-tear on reactive power compensation equipment, 340–341, 340f
 in FDD application, 450–452
 strategy/approach related, 451–452
 substation-level, ESI
 grid-level, 342–343
 network protectors in systems, 341–342
 RE on local substation, 341
 Chilled water storage/aquifers, sensible TES with, 349–352, 350f, 351f, 352t
 Chiller water loops and VAV systems, 127–133
 energy recovery systems, 132–133
 Chiller-priority control strategy, 240
 Chillers, 100; *see also* Absorption chillers
 control for, 235
 recommendations for chiller system operation in commercial buildings, 105–106
 set-point temperature, 244, 245
 Chlorofluorocarbons (CFCs), 96
 City scale model, uWRF, 483, 483f
 Classification
 fault detection methods, 424, 425–436
 commonly used methods, 427–429, 428f, 429f
 current trends, 435–436
 overview, 424, 425
 PCA, 430–434, 432f, 434f
 traditional alarm management, prismatic approach, 425–427, 426f
 sensible/latent TES systems, 348, 349f
 Climate change and sustainable buildings, 17–18
 Climate Consultant, 145–146
 ClockWorks, 444t
 Closed loop system, 192
 Coefficient of performance (COP), 98–99
 GAX with, 265
 ground-source heat pump, 369
 Li-Br 2E absorption chiller, 277
 space cooling/heating, 268
 standalone solid desiccant systems, 269
 Collectors, solar water heating
 efficiency curves, 329, 329f
 evacuated tube, 326–327, 334–335
 glazed flat plate, 326, 332t
 integrated-collector-storage collectors, 330

- parabolic-trough, 327–328
- types, 324–335, 325f
- unglazed, low temperature, 325–326, 330, 332t
- Combined cooling, heating and power (CCHP) systems, 251–284
 - absorption chillers
 - cost estimates for, 266, 266t
 - double-effect (2E), 273, 277, 278f
 - schematic, 266, 267f
 - types, 277, 278t
 - water/LiBr, 266
 - bottoming cycle, 271
 - building integration, case studies, 271–279
 - combined cycle, 271
 - conventional systems vs., 252–253, 253f
 - cooling technology, matching, 261
 - datacenter
 - electric and cooling demand for, 272–273, 273f
 - electric LDC of, 274, 274f
 - two-dimensional LDC for, 275–276, 275f, 276f
 - economic and feasibility analysis, 279–283
 - cost analysis, 282, 283t
 - detailed electricity and natural gas usage, 280, 280t
 - electric and natural gas costs, 281, 283t
 - electric output, 281, 281t
 - heat output, 281, 282t
 - future, 284
 - goal, 271
 - heat recovery, 254, 261, 262–264, 263t
 - installation, 281, 282f
 - operation, case studies, 271–279
 - overview, 252–253, 253f
 - prime movers, 260–261, 260f, 262t
 - sizing options, case studies, 271–279
 - system controls, case studies, 271–279
 - technology, state-of-the-art review, 254–260
 - basic elements, 254
 - commercial application, 256
 - general diagram, 254–255, 254f
 - key system parameters and characteristics, 259, 259t
 - large-scale CCHP systems, 258
 - micro-CCHP systems, 256–257
 - overall efficiency, 255
 - performance, evaluation, 256
 - schematic diagram, 255, 255f
 - technical potential, 256, 257f
 - tri-generation, 259
 - TES requirements/benefits, 270–271
 - thermally activated, 264–269
 - absorption and vapor-compression chillers, 265–266, 266t, 267f
 - category, 264
 - ejector heat pump cycle, 269, 270f
 - single-effect (1E) absorption cycle, 264–265, 265f
 - solid desiccant A/C technology, 268–269
 - standalone liquid desiccant A/C, 269
 - topping cycle, 271
- Combined production of heating and power (CHP), TES and, 370–375
- CCHP system
 - diagram of, 371, 372f
 - hot water heat TES systems, 373–374, 374f
 - performance, 372, 373t
 - general layout, 370, 371f
- Commercial building lighting and window designs, 16–17
- Commercial solutions, industrial and HVAC application, 443
- Communication protocol, 209–210; *see also* Supervisory controllers
- Compressor integration, absorption TES performance, 398, 398f
- Concrete caissons and footers, 298
- Conduction transfer functions (CTFs), 34, 41–43

- Constant-air volume (CAV), 225
 - Contaminants in buildings, 126
 - Control modes, 198–201
 - Control strategies
 - applications
 - about, 210–211
 - electrical systems, 211–218, 212t, 215t, 218t
 - HVAC equipment operation, 221–236, 223t
 - HVAC systems with thermal storage, 236–246
 - optimal start of HVAC systems, 218–221
 - control modes, 198–201
 - control system components, 190–198, 191t, 195t
 - intelligent control systems
 - about, 201
 - artificial neural networks, 202
 - expert controls, 202
 - fuzzy control, 202
 - overview, 189–190
 - supervisory controllers
 - communication protocol, 209–210
 - components of EMCS, 204–206
 - design considerations of EMCS, 207–209
 - functions of ECMS, 206–207
 - types of, 202–203
 - Controller bias, 199
 - Conventional systems, CCHP systems
 - vs., 252–253, 253f
 - Cool tower ventilation, 152
 - Cooling by desiccant equipment, 106–109
 - Cooling coil fouling, 457, 458, 461, 459f, 460f
 - Cooling demands
 - building heating and, 272
 - for data center, 272–273, 273f
 - Cooling load avoidance, 313–319, 317f
 - Cooling towers, 101–103
 - Cooling vapor compression systems, 94–97
 - Cooling/heating central plant
 - optimization, 234–236
 - Cost(s)
 - CCHP systems
 - analysis, 282, 283t
 - electric and natural gas, 281, 283t
 - of daylighting system, 311
 - energy, TES and, 352
 - estimates, for absorption and vapor-compression chillers, 266, 266t
 - installation of PV system, 301–302
 - Interconnection Requirement Study, 336
 - solar ventilation air preheating, 319, 320, 323t
 - solar water heating systems, 332t, 333, 334–335
 - utilities' electrical generation systems, 344–345
 - Crop drying, solar ventilation air preheating, 319
 - Crown Casino and Entertainment Complex, 448–449
 - CSIRO Energy Transformed Flagship, 449
 - Current-voltage relation, of PV cell, 295–296, 295f
 - Cycling stability, defined, 380
- D**
- DABO™, 445t, 449
 - Data centers, 17
 - in commercial sector, 256
 - cooling LDC of, 274–275, 275f
 - electric and cooling demand, 272–273, 273f
 - electric LDC of, 274, 274f
 - two-dimensional LDC for, 275–276, 275f, 276f
 - Data transmission medium (DTM), 206
 - Data-driven approach
 - defined, 427
 - review, 429, 429f
 - Daylighting, 305–313, 312f

- Daylighting control system, 213–218, 213f, 214f, 215t, 218t; *see also* Electrical systems
 - Daylighting simulation tool, 216
 - DCS, *see* District cooling systems (DCS)
 - Dehumidification, 106–107, 125
 - solid desiccant, 268
 - Demand controlled ventilation (DCV), 225–228, 228t
 - Demand side management (DSM), 343
 - Dense urban environments, air conditioning energy consumption in, *see* Air conditioning energy consumption
 - Department of Energy (DOE), 256
 - Desiccant equipment, cooling by, 106–109
 - Designs
 - direct gain, 315–316
 - FDD, 454–455, 455f
 - Desorber, defined, 265
 - Detection, fault, *see* Fault detection and diagnosis (FDD)
 - Diagnosis, fault, *see* Fault detection and diagnosis (FDD)
 - Dichlorodi-fluoromethane, 97
 - Dimensionality reduction technique, PCA as, 433
 - Direct digital control (DDC) systems, 202, 203
 - Direct gain
 - defined, 315
 - designs, 315–316, 317f
 - Discharging method
 - double stage, 398–399, 398f
 - three phase cycle, 398f, 399
 - Discussion, air conditioning energy consumption, 490–495, 491f, 492f, 493f, 494f, 495f
 - District cooling systems (DCS), fault detection system for (case study), 452–464
 - design and features, 454–455, 455f
 - implementation results, 455–461
 - cooling coil fouling, 457, 458, 461, 459f, 460f
 - historical data set clusters
 - classification, 457, 457f
 - monitored variables, 455, 456f
 - recommendations, 461, 464
 - reduced chilled water flow, 457, 461, 462f, 463f
 - statistics thresholds, 457, 457t
 - process layout and specifications, 452–453, 453f, 454f
 - Disturbance parameter change, 422
 - DOE-2, 76, 83, 84–85, 87, 88
 - Double skin facade, 168–173; *see also* Passive cooling
 - design considerations, 170–173
 - performance, 169–170
 - principle, 168–169
 - Double stage discharging method, 398–399, 398f
 - Double-effect (2E) absorption chillers, 371; *see also* Chillers
 - exhaust absorption chiller, 277, 278f
 - Li-Br, 273, 277
 - Downflow furnace, 111–112
 - “Drain down” systems, 331
 - Duty cycling, 210
- E**
- Earth cooling, 143
 - Economic analysis, CCHP systems, 279–283; *see also* Costs
 - cost analysis, 282, 283t
 - detailed electricity and natural gas usage, 280, 280t
 - electric and natural gas costs, 281, 283t
 - electric output, 281, 281t
 - heat output, 281, 282t
 - Economizer systems, 222
 - Ecotect, 145–146
 - Efficiency curves, for solar water heating collectors, 329, 329f
 - Ejector heat pumps, 269, 270f
 - Electric devices, 202

- Electric grid, synchronization of
 - generation equipment on, 342–343
- Electric service, to building with RE
 - overcurrent protection, 337f, 338, 339
 - sizing, 337, 338
 - voltage regulation, 338f, 339
- Electrical generation systems, utilities, 343–345
- Electrical power (maximum), defined, 241–242
- Electrical systems; *see also* Control strategies
 - daylighting control system, 213–218, 213f, 214f, 215t, 218t
 - motor duty cycling controls, 211–213
- Electronic devices, 202
- Electronic thermal anemometer, 222
- Electronicto-pneumatic (E/P) transducers, 203
- EMCS, *see* Energy management and control systems (EMCS)
- Emerging Technologies (ET), 2
- Energy analysis methods, detailed, 70–76
 - heat balance method, 70–73
 - thermal network method, 73–74
 - weighting factors, 74–76
- Energy analysis methods, simplified, 60–70
 - transient thermal network analysis, 67–70
 - variable base degree days method, 60–66
- Energy cost savings, 237–238, 239f
- Energy Information Administration (EIA), 475
- Energy management and control systems (EMCS)
 - about, 189
 - communication protocol, 209–210
 - components of, 204–206
 - cost benefits of, 208
 - design considerations of, 207–209
 - functions of, 206–207
 - size categories, 204
- Energy Management System (EMS), 204
- EnergyPlus, 42, 71–72, 76, 84–85, 87, 233, 243
- EnergyPlus™, SBEM and, 319, 483, 488–490
 - energy sources interaction, 489, 489f
 - model, 489, 490f
 - parametric studies for, 495, 495f
 - SBEM vs. uWRF for Midtown, 493, 494f
 - total energy demand, 492, 493f
- Energy savings from daylighting controls, 213
- Energy storage density (ESD)
 - comparison of, 392, 393f
 - of sensible TES, 385
- Energy storage systems, for buildings, 347–408
 - overview, 347–348
 - sorption TES system for buildings, 385, 388–407
 - performance improvement, 397–407; *see also* Performance improvement
 - working pairs, 392–397; *see also* Working pairs
 - working principle, 385, 388–392
- TES systems, sensibility and latency, 348–385
 - air conditioning, 349–358
 - ceiling board, PCM, 357, 357f, 358
 - ceilings, PCM, 366, 367
 - chilled water storage/aquifers, 349–352, 350f, 351f, 352t
 - CHP and, 370–375, 371f, 372f, 373t, 374f
 - classification, 348, 349f
 - floor heating, PCM, 366, 367f
 - for heating, 358–367
 - heat pumps and, 367–370, 368f, 369f
 - hot water tank/aquifers, 358–361, 358f, 360f

integration literature summary,
 building with, 375–379,
 376t–378t
 latent TES with PCMs, 352, 353–
 354, 364–365; *see also* Phase
 change materials (PCMs)
 materials, 379–383; *see also*
 Materials, for sensible/latent
 TES
 mathematical modeling of
 storage system, 383, 384–385,
 386t–387t
 PCMs, 352–355, 357–358,
 364–367; *see also* Phase change
 materials (PCMs)
 rock and brick reservoir, 361–364,
 362f, 363f
 solar shading, PCM for, 354, 355,
 356f, 357, 357t
 wallboards, PCM, 365, 366f
 Energy system integration (ESI),
 335–345
 challenges, 336–337
 challenges and solutions, building
 level, 337–341
 overcurrent protection, 337f, 338,
 339
 sizing, 337, 338
 voltage regulation, 338f, 339
 wear-and-tear on reactive power
 compensation equipment,
 340–341, 340f
 challenges and solutions, grid-level,
 342–343
 synchronization of generation
 equipment, 342–343
 voltage stability, 342
 challenges and solutions, substation-
 level, 341–342
 network protectors in systems,
 341–342
 RE on local substation, 341
 net metering policies, 335–336
 utilities, electrical generation
 systems, 343–345

 allocating costs and investment,
 344–345
 ramp-rates and spinning reserve,
 343–344
 EQUEST, 83
 Error transfer function, 197
 ESI, *see* Energy system integration
 (ESI)
 Ethernet local area networks, 209
 Evacuated tube collectors, 326–327,
 334–335
 Evaporative cooling, direct/indirect,
 158–162; *see also* Passive cooling
 design considerations, 160–162
 performance, 159–160
 principle, 158–159
 Evaporative cooling systems, 143
 Expert controls, 202; *see also*
 Intelligent control systems
 Exponentially Weighted Moving
 Average (EWMA) control charts,
 440, 441

F

Facility loads, 190
 Fanger comfort model, 232, 233, 234
 Fatty acid, as PCM, 353
 Fault detection and diagnosis (FDD),
 automated, 421–464
 alarm management, 421–424
 PMM, 424, 425f
 process/system fault definition,
 422–423, 423f
 application, challenges in, 450–452
 strategy/approach related, 451–452
 classification, 424, 425–436
 current trends, 435–436
 most commonly used methods,
 427–429, 428f, 429f
 overview, 424, 425
 PCA, 430–434, 432f, 434f
 traditional alarm management,
 prismatic approach, 425–427, 426f
 for DCS, case study
 design and features, 454–455, 455f

- implementation results, 455–461, 456t, 457f, 457t, 459f, 460f
 - process layout and specifications, 452–453, 453f, 454f
 - for district cooling systems, case study, 452–464
 - industrial and HVAC applications, 441–449
 - business models and commercial solutions, 443
 - commercial software, 443, 444t–447t
 - hardware/software requirements, 442–443
 - implementations, review of, 443, 448–449
 - recent advances, 436–441, 438t–439t
 - design and features, 454–455, 455f
 - implementation results, 455–461
 - cooling coil fouling, 457, 458, 461, 459f, 460f
 - historical data set clusters
 - classification, 457, 457f
 - monitored variables, 455, 456t
 - recommendations, 461, 464
 - reduced chilled water flow, 457, 461, 462f, 463f
 - statistics thresholds, 457, 457t
 - process layout and specifications, 452–453, 453f, 454f
 - Fault detection system for district cooling systems (case study), 452–464
 - FDD, *see* Fault detection and diagnosis (FDD)
 - FDD CX, 447t
 - Feasibility analysis, CCHP systems, 279–283
 - cost analysis, 282, 283t
 - detailed electricity and natural gas usage, 280, 280t
 - electric and natural gas costs, 281, 283t
 - electric output, 281, 281t
 - heat output, 281, 282t
 - Features, FDD, 454–455, 455f
 - Feedback control system, 192
 - Feed-forward networks, 244
 - Field interface devices (FID), 205, 206
 - Fins, defined, 308
 - Fire marshals, 298
 - Fire-tube boilers, 115
 - First Solar, 297
 - Flat-plate collectors, glazed, 326, 332t
 - Floor heating, PCM, 366, 367f
 - Footers, concrete, 298
 - Fouling, cooling coil, 457, 458, 461, 459f, 460f
 - Fourier’s law of heat conduction, 28
 - Fuel cells, chemical reaction in, 254–255
 - Fuel oil, 112
 - Furnaces, 110–124
 - electric heat pumps, 120–121
 - electric resistance heating, 119
 - low-temperature radiant heating systems, 121–124
 - Fusion heat, of PCMs, 379, 380f
 - Fuzzy control, 202; *see also* Intelligent control systems
- G**
- Gas-to-liquid heat exchangers, 264
 - Gaussian Process (GP) emulator, 87–88
 - Gauss-Jordan Matrix Solver, 41
 - Generator–Absorber heat eXchange (GAX), 265
 - Glazed flat plate collectors, 326, 332t
 - Grid-connected PV system, 300–301, 300f, 305, 305f
 - Grid-level challenges and solutions, 342–343
 - synchronization of generation equipment, 342–343
 - voltage stability, 342
 - Ground-coupled heat transfer, 229f
- H**
- Hardware requirement, industrial and HVAC application, 442–443
 - Harry Thomason’s technique, 361, 362f

- Heat exchanger materials, 134
 - Heat flux modulation techniques, 229
 - Heat generation and transfer
 - equipment, 109–124
 - furnaces and boilers, 110–124
 - introduction, 109–110
 - Heat pumps, TES and, 367–370, 368f, 369f
 - Heat rates, 115
 - Heat recovery, CCHP systems, 254, 261, 262–264, 263t
 - Heat recovery steam generator (HRSG), 258
 - Heat recovery unit (HRU), 255
 - Heat rejection equipment, 101–105
 - Heat transfer concepts, 24–30
 - transient heat transfer from building envelope, 26–30
 - Heat transfer enhancement methods, 383, 384f
 - Heat wave event (summer 2010), 481, 482
 - Heating Degree Days (HDD), 316
 - Heating energy
 - savings, 234
 - use, 231
 - Heating, TES for, 358–367
 - hot water tank/aquifers, 358–361, 358f, 360f
 - PCMs
 - ceilings, 366, 367
 - floor heating, 366, 367f
 - latent TES with, 364–365, 364f, 365f
 - wallboards, 365, 366f
 - rock and brick reservoir, 361–364, 362f, 363f
 - Heating, ventilation and air conditioning (HVAC) systems,
 - automated FDD in, *see* Fault detection and diagnosis (FDD)
 - Helmholtz equation, 35–36
 - Hierarchical kernel learning method, 440
 - High efficiency system integration, 127–133
 - chiller water loops and VAV systems, 127–133
 - High temperature conditions (HTC), 297
 - Hittle, 42
 - Horizontal furnaces, 112
 - Hot water heat TES systems, 373–374, 374f
 - Hot water tank/aquifers, sensible TES with, 358–361, 358f, 360f
 - Hotelling T^2 statistics, 431–432, 432f, 433, 434, 454
 - Houghton Hall Office Building in Luton, UK, 179–180
 - Humidification, 162
 - HVAC equipment operation
 - cooling/heating central plant optimization, 234–236
 - demand controlled ventilation (DCV), 225–228, 228t
 - outdoor air intake controls, 221–225, 223t–224t
 - radiant slab heating systems, 228–234, 234t
 - HVAC mechanical systems, 133–135
 - heat exchanger materials, 134
 - supervisory control systems, 133–134
 - surface enhancing heat transfer, 134–135
 - HVAC system
 - control systems used in, 202
 - optimal start of, 218–221
 - sensors used for, 191t
 - with thermal storage
 - neural network controls of, 243–246
 - passive/active thermal energy storage systems, 240–243
 - precooling of building thermal mass, 236–239
 - Hybrid ventilation, 153–154
 - Hydraulic systems, 203
- I**
- IBM TRIRIGA Energy Optimization, 446t
 - Ice storage system, 242

- Identification, fault, 424, 425f
 - IES-VE, 313
 - Implementations, industrial and HVAC, 443, 448–449
 - Indoor air quality (IAQ), 207, 221, 225
 - Industrial and HVAC applications, fault detection methods, 441–449
 - business models and commercial solutions, 443
 - commercial software, 443, 444t–447t
 - hardware/software requirements, 442–443
 - implementations, review of, 443, 448–449
 - Industrial heat pumps, 121
 - Institute of Electrical and Electronics Engineers (IEEE), Standard 1547, 340–341, 345
 - Integral gain constant, 200
 - derivative control, 200
 - Integrated building automation system (IBAS), 189, 204
 - Integrated-collector-storage collectors, 330
 - Integrated/Sustainable Building Equipment and Systems (ISBES) Initiative, 2
 - Integration
 - literature summary, TES, 375–379, 376t–378t
 - solar energy systems, *see* Solar energy systems
 - Intelligent control systems; *see also* Control strategies
 - about, 201
 - artificial neural networks, 202
 - expert controls, 202
 - fuzzy control, 202
 - Interconnection Requirement Study, 336
 - International Electrotechnical Commission (IEC) standard, 297
 - International Energy Agency (IEA), 347
 - Inverters, dual mode, 301
 - Investment, utilities' electrical generation systems, 344–345
 - I-v curve, of PV cell, 295–296, 295f
- J**
- Journal of Solar Energy Engineering, 2
- K**
- Kathabar, 107–108
 - K-means clustering algorithm, 457, 457f
- L**
- LabView, 442
 - Laplace transform, 193–194
 - Latency, TES, 348–385
 - air conditioning, building, 349–358
 - chilled water storage/aquifers, 349–352, 350f, 351f, 352t
 - PCM ceiling board, 357, 357f, 358
 - PCM for solar shading, 354, 355, 356f, 357, 357t
 - PCMs, 352, 353–354, 353f, 354t, 355f, 355t
 - CHP and, 370–375
 - CCHP system, diagram of, 371, 372f
 - general layout, 370, 371f
 - hot water heat TES systems, 373–374, 374f
 - performance of CCHP plant, 372, 373t
 - classification, 348, 349f
 - for heating, 358–367
 - hot water tank/aquifers, 358–361, 358f, 360f
 - PCM ceilings, 366, 367
 - PCM floor heating, 366, 367f
 - with PCMs, 364–365, 364f, 365f
 - PCM wallboards, 365, 366f
 - rock and brick reservoir, 361–364, 362f, 363f

- heat pumps and, 367–370, 368f, 369f
 - materials, 379–383
 - heat transfer enhancement methods, 383, 384f
 - main features, 382, 382t
 - PCM for TES systems, comparison, 383, 383t
 - PCMs, classification of, 379, 379f
 - PCMs, melting temperature and fusion heat, 379, 380f
 - sensible storage concepts, 380–381, 381t
 - mathematical modeling of storage system, 383, 384–385, 386t–387t
 - TES integration literature summary, building with, 375–379, 376t–378t
 - Lawrence Berkeley National Laboratory (LBNL), 83
 - Lighting energy use savings, 216
 - Lightshelves, defined, 309
 - Limitations, for FDD, 450–451
 - Liquefied propane gas (LPG), 112
 - Liquid desiccant air conditioners (LDACs), 269
 - Lithium chloride, 107
 - Load anticipation, 190
 - Load duration curve (LDC) for data centers
 - cooling, 274–275, 275f
 - electric, 274, 274f
 - two-dimensional, 275–276, 275f, 276f
 - sizing and evaluating building electric power, 273f, 274, 274f
 - Load tracking, 190
 - Local substation, RE on, 341
 - Losses, thermal, 328
 - Low irradiance conditions (LIC), 297
 - Low temperature conditions (LTC), 297
- M**
- Materials
 - for sensible/latent TES, PCMs, 379–383
 - classification of, 379, 379f
 - comparison, 383, 383t
 - heat transfer enhancement methods, 383, 384f
 - main features, 382, 382t
 - melting temperature and fusion heat, 379, 380f
 - sensible storage concepts, 380–381, 381t
 - in solar water heating systems, 329, 330
 - Mathematical modeling, of storage system, 383, 384–385, 386t–387t
 - Mean air temperature (MAT), 229, 232
 - Mean radiant temperature (MRT), 229
 - Measurement and verification (M&V) of energy savings, 78
 - Mechanical cooling equipment, 100
 - Mechanical draft towers, 103
 - Melting temperature, of PCMs, 379, 380f
 - Methodology for case study, air conditioning energy consumption, 483–490
 - BEM, 485–488, 487f, 487t, 488f
 - BEP, 484–485
 - SBEM, EnergyPlus™, 488–490, 489f, 490f
 - uWRF, city scale model, 483, 483f
 - Micro-inverters, 301
 - Mitalas, 42
 - Modeling
 - building air conditioning energy consumption, *see* Air conditioning energy consumption
 - mathematical, of storage system, 383, 384–385, 386t–387t
 - Modules, defined, 294
 - Montreal Protocol, 96
 - Motor duty cycling controls, 211–213; *see also* Electrical systems
 - Multi-level switching controls, 309
 - Multiple boilers, control for, 235
 - Multiple chillers control, 235; *see also* Chillers

Multiplexer (MUX), 206
Multi-scale PCA (MPCA), 435

N

National Electrical Manufacturers Association (NEMA), 211
National Weather Service (NWS), 481
Natural gas, 258
Natural ventilation, 147–154; *see also*
 Passive cooling
 design considerations, 150–154
 performance, 148–150
 principle, 147–148
Net metering
 defined, 335
 policies, 336
 PV for, 336
Neural network controls, 243–246
Neurons, 202
Night cooling, 143
Night cooling with thermal mass,
 154–157; *see also* Passive cooling
 design considerations, 155–157
 performance, 154–155
 principle, 154
NN-based optimal controller, 244,
 245, 245f
Nominal operating cell temperature
 (NOCT), 297, 304
NREL Chemical Storage Facility,
 323–324, 324f
NYCMetNet, 482, 482f

O

Offline model training, 454
One-zone controls of carbon-di-oxide,
 228
Online FDD, 454
Open loop systems, 192
OpenStudio, 313
Operating differential, 198
Operation, CCHP (case studies),
 271–279
Operative temperature (OT), 229

Optimal daylighting controller, 216
Outdoor air flow, 227
Outdoor air intake controls, 221–225,
 223t–224t
Overcurrent protection, on electrical
 service, 337f, 338, 339
Overhangs
 defined, 308
 window, 315

P

PACRAT, 447t
Palais des congrès de Montréal, 449
Panoptix Continuous Diagnostic
 Advisor, 444t
Parabolic-trough collectors, 327–328
Paraffin
 organic heat storage materials, 382
 wax, as PCM, 353
Parallel duty cycling, 212
Parameter change
 disturbance, 422
 process, 422
Passive cooling, 142–143
 case studies, 179–184
 direct/indirect evaporative cooling,
 158–162
 double skin facade, 168–173
 natural ventilation, 147–154
 night cooling with thermal mass,
 154–157
 overview, 143–145
 phase change material, 173–179
 prescreening feasibility, 145–147
 Sunspace, 165–168
 Trombe Wall, 162–165
Passive design strategies, 6, 8
Passive solar heating, 143–144,
 313–319
 computer tools for, 319
 direct gain, 315–316, 317f
 equations for, 318
 sunspace, 316, 317f
 Trombe Wall, 316, 317f
 window overhang, 315

Passive systems, solar water heating systems, 330
 Passive thermal energy storage systems, 240–243
 Pattern matching method, 440
 PCMs, *see* Phase change materials (PCMs)
 Penetration limits, defined, 336
 Performance, of CCHP plant, 372, 373t
 Performance improvement, sorption TES system, 397–407
 absorption, 397–399, 398f
 adsorption, 399–400, 400f
 prototypes and systems, 400–407
 adsorption TES test facility, 403–404, 405f
 closed H₂O/CaCl₂, 400, 403, 403f
 H₂O/silica gel, 403, 404f
 H₂O/13X zeolite, 405, 406f
 recent achievements, 400, 401t–402t
 solar sorption pilot plant, 406, 406f
 Phase change materials (PCMs), 173–179; *see also* Passive cooling
 ceiling board, 357, 357f, 358
 ceilings, 366, 367
 classification of, 379, 379f
 design considerations, 177–179
 floor heating, 366, 367f
 latent heat of, 315
 latent TES with, 352, 353–354, 364–365
 cross-sectional view of heat storage tank, 364f
 cumulative energy saving, 355t
 free cooling systems, 355f
 paraffin wax, 365f
 schematic diagram, 353f
 thermal storage systems, comparison, 354t
 melting temperature and fusion heat, 379, 380f
 performance, 174–177
 principle, 173–174
 for solar shading, 354, 355, 356f, 357, 357t
 Stefan problem for, 383, 384
 TES units, 374
 wallboards, 365, 366f
 Photo-sensor system, 216, 217f
 Photovoltaics (PVs), 292–305
 BIPV, 299
 cadmium telluride, 296–297
 cells, equivalent circuit diagram, 294, 295f
 effect, 292
 grid-connected, 300–301, 300f, 305, 305f
 IEC standard, 297
 initial, operation and maintenance costs, 303t
 i-v curve, 295–296, 295f
 roof racks, 298
 short-circuit operating current, 294
 solar insolation, map of, 292, 293f
 solar resource, map of, 292–294, 293f
 wear-and-tear on reactive power compensation equipment, 340–341, 340f
 Pierce two-node model, 233, 234
 Piles, 298
 Pitot-tube array station, 222
 Plenum, defined, 322
 Plenum pressure control, 225
 Pneumatic devices, 202
 Policies, net metering, 336
 Polycarbonate, 365
 Polymer electrolyte membrane fuel cells (PEFC/PEMFC), 258
 Polynomial transfer function, 48
 Porosity, defined, 320
 Power combustion furnaces, 112
 Power generation unit (PGU), 254, 255
 Power-to-heat ratio, defined, 370
 Pre-cooling control strategy, 237–238, 237f
 Pre-cooling energy savings, 239t
 Precooling of building thermal mass, 236–239

Predicted mean vote (PMV), 232
 Predicted mean vote modified by
 effective temperature (PMVET), 233
 Predictive control strategy, 243
 Preheating, ventilation air, *see* Solar
 ventilation air preheating
 Primary land use tax lot output
 (PLUTO), 486, 487f
 Prime movers, for CCHP systems,
 254, 260–261, 260f, 262t
 Principal component analysis (PCA)
 ANN and, 435
 fault detection method, 430–434,
 432f, 434f
 FDD design and feature, 454–455,
 455f
 MPCA, 435
 operational flow diagram, 434, 434f
 Prismatic approach, traditional alarm
 management, 425–427, 426f
 Prismatic regions, defined, 426
 Process monitoring method (PMM),
 424, 425f
 Process parameter change, 422
 Proportional control system, 199–200
 Proportional gain constant, 199
 Proportional-plus-integral control (PI
 control), 200
 Proportional-plus-integral-plus
 derivative (PID) control, 200, 201f,
 226, 228
 Propylene glycol, 331, 332
 Protectors, in network systems,
 341–342
 Protocol implementation conformance
 statement (PICS), 210
 Prototypes, sorption TES system,
 400–407
 adsorption TES test facility, 403–
 404, 405f
 closed H₂O/CaCl₂, 400, 403, 403f
 H₂O/silica gel, 403, 404f
 H₂O/13X zeolite, 405, 406f
 recent achievements, 400, 401t–402t
 solar sorption pilot plant, 406, 406f

PRRMSE indicators, 88
 Public Interest Energy Research
 (PIER), 448
 Public Utilities Commission (PUC),
 336
 PVs, *see* Photovoltaics (PVs)

Q

Qualitative model-based methods,
 FDD, 428–429, 428f
 Quantitative model-based methods,
 FDD, 427–429, 429f

R

Racks, roof, 298
 Radial Basis Function (RBF) neural
 network, 441
 Radiant gains, 328
 Radiant slab heating systems, 228–
 234, 234t
 Radiant systems, 121–124
 Ramp-rates, 343–344
 RC thermal network technique,
 67–69
 Reactive power compensation
 equipment, 340–341, 340f
 Recent trends, in FDD methods,
 436–441, 438t–439t
 Reciprocating engines, 258, 261
 Recovery time, 219
 Reduced chilled water flow, 457, 461,
 462f, 463f
 Regeneration process, 98, 268
 Regression analysis, 219
 Renewable energy (RE) systems
 advantages, 291
 electric service to building with
 overcurrent protection, 337f, 338, 339
 sizing, 337, 338
 voltage regulation, 338f, 339
 on local substation, 341
 Requirements
 hardware/software, industrial and
 HVAC application, 442–443
 TES, 270–271

- Resources, solar, 292–294, 293f
- Results, air conditioning energy
 - consumption, 490–495, 491f, 492f, 493f, 494f, 495f
- RETScreen, 279
- Reynolds averaged form, defined, 484
- RMI Headquarters Building: Amory Lovins Uber Solar Home in Colorado, US, 180, 182–184
- Rock and brick reservoir, 361–364, 362f, 363f
- Roof racks, 298
- Rotor angle stability, defined, 342

- S**
- Salt hydrates, 382
- Saturation enthalpy, 108–109
- SBEM, *see* Single building energy model (SBEM)
- SCIwatch®, 445t
- Screws, 298
- Secondary systems, 124–127
 - fresh air ventilation rates, 126–127
- Sensibility, TES, 348–385
 - air conditioning, building, 349–358
 - chilled water storage/aquifers, 349–352, 350f, 351f, 352t
 - PCM ceiling board, 357, 357f, 358
 - PCM for solar shading, 354, 355, 356f, 357, 357t
 - PCMs, 352, 353–354, 353f, 354t, 355f, 355t
 - CHP and, 370–375
 - CCHP system, diagram of, 371, 372f
 - general layout, 370, 371f
 - hot water heat TES systems, 373–374, 374f
 - performance of CCHP plant, 372, 373t
 - TES integration literature summary, building with, 375–379, 376t–378t
 - classification, 348, 349f
 - ESD of, 385
 - for heating, 358–367
 - hot water tank/aquifers, 358–361, 358f, 360f
 - PCM ceilings, 366, 367
 - PCM floor heating, 366, 367f
 - PCM wallboards, 365, 366f
 - rock and brick reservoir, 361–364, 362f, 363f
 - heat pumps and, 367–370, 368f, 369f
 - materials, 379–383
 - heat transfer enhancement methods, 383, 384f
 - main features, 382, 382t
 - PCM for TES systems, comparison, 383, 383t
 - PCMs, classification of, 379, 379f
 - PCMs, melting temperature and fusion heat, 379, 380f
 - sensible storage concepts, 380–381, 381t
 - mathematical modeling of storage system, 383, 384–385, 386t–387t
- Sensors, 191
- Shaft energy, 254
- Shockley, William, 294, 295
- Short-circuit operating current, of PV module, 294
- Sick Building Syndrome (SBS), 140, 149–150
- Silica gel, water and, 394, 403, 404f
- Single building energy model (SBEM)
 - AC compressor work in, 488
 - energy consumption for, 493
 - Energy Plus, 489
 - energy sources interaction, 489f
 - ensemble of, 475–476
 - sensitivity analysis, 493, 495f
 - solutions to uWRF, 487
 - thermal zones, 489
 - by TMY weather file, 475, 490, 494
 - using US Department of Energy, 483
 - uWRF vs., 493, 494f
- Single chiller control, 235
- Single-effect (1E) absorption chillers, 264–265, 265f, 371

- Sizing
 - of electrical service to building, 337, 338
 - options, CCHP (case studies), 271–279
- SkySpark, 444t, 448
- Software requirement, industrial and HVAC application, 442–443
- Sol-air temperature, 71–72
- Solar energy systems, integration of, 291–345
 - cooling load avoidance, 313–319, 317f
 - daylighting, 305–313, 312f
 - ESI, 335–345
 - allocating costs and investment, 344–345
 - building level challenges and solutions, 337–341; *see also* Building level challenges and solutions
 - challenges, 336–337
 - grid-level challenges and solutions, 342–343
 - net metering policies, 335–336
 - ramp-rates and spinning reserve, 343–344
 - substation-level challenges and solutions, 341–342
 - utilities, electrical generation systems, 343–345
 - overview, 291–292
 - passive solar heating, 313–319
 - computer tools for, 319
 - direct gain, 315–316, 317f
 - equations for, 318
 - sunspace, 316, 317f
 - Trombe Wall, 316, 317f
 - window overhang, 315
 - photovoltaics, 292–305
 - BIPV, 299
 - cadmium telluride, 296–297
 - cells, equivalent circuit diagram, 294, 295f
 - effect, 292
 - grid-connected, 300–301, 300f, 305, 305f
 - IEC standard, 297
 - initial, operation and maintenance costs, 303t
 - i-v curve, 295–296, 295f
 - roof racks, 298
 - short-circuit operating current, 294
 - solar insolation, map of, 292, 293f
 - solar resource, map of, 292–294, 293f
 - ventilation air preheating, 319–324
 - applications, 320
 - components, 321, 322f
 - costs, 319, 320, 323t
 - maintenance requirements, 319
 - NREL Chemical Storage Facility, 323–324, 324f
 - potential energy delivery, map of, 319, 320f
 - transpired solar collector and bypass damper, 323, 324f
 - water heating systems, 324–335
 - active systems, 331, 331f
 - collectors, types, 324–335, 325f
 - costs, 332t, 333, 334–335
 - efficiency curves, 329, 329f
 - evacuated tubes, 326–327, 334–335, 334f
 - glazed flat plate collectors, 326, 332t
 - integrated-collector-storage collectors, 330
 - materials and components, 329, 330
 - parabolic-trough collectors, 327–328
 - passive systems, 330
 - SRCC, 328–329
 - unglazed collector, low temperature, 325–326, 330, 332t
- Solar heat gain coefficient (SHGC), 308, 314
- Solar insolation, map of, 292, 293f
- Solar Rating & Certification Corporation (SRCC), 328–329

Solar resource, map of, 292–294, 293f

Solar shading, PCMs for, 354, 355, 356f, 357, 357t

Solar ventilation air preheating, 319–324

- applications, 320
- components, 321, 322f
- cost, 319, 320
- initial cost, operation and maintenance cost, 323t
- maintenance requirements, 319

NREL Chemical Storage Facility, 323–324, 324f

potential energy delivery, map of, 319, 320f

transpired solar collector and bypass damper, 323, 324f

Solar water heating (SWH) systems, PCM-charged, 364–365, 364f, 365f

Solid desiccant A/C technology, 268–269

Solid oxide fuel cells (SOFC), 258

Solutions

- building level challenges and, ESI, 337–341
- overcurrent protection, 337f, 338, 339
- sizing, 337, 338
- voltage regulation, 338f, 339
- wear-and-tear on reactive power compensation equipment, 340–341, 340f

substation-level challenges, ESI

- grid-level, 342–343
- network protectors in systems, 341–342
- RE on local substation, 341

Sorption TES system for buildings, 385, 388–407

performance improvement, 397–407

- absorption, 397–399, 398f
- adsorption, 399–400, 400f
- prototypes and systems, 400–407, 401t–402t, 403f, 404f, 405f, 406f
- working pairs, 392–397
- absorption, 393–394, 395t
- adsorption, 394, 396–397, 396f, 397f
- ESD, comparison of, 392, 393f
- working principle, 385, 388–392
- absorption, 385, 388–389, 388f
- adsorption, 389–392, 390f, 391f, 392f

Southwest Gas Corporation (SWG), 281

Spherical geometry, models for, 385, 386t–387t

Spinning reserve, 343–344

Squared prediction error, defined, 434

Stack ventilation, 151, 152

Staggered duty cycling, 212

Standalone solid desiccant A/C technology, 268–269

Standard, IEC, 297

Standard test conditions (STC), 297

Steel boilers, 115

Stefan-Boltzmann equation, 123

Stefan problem, for PCMs, 383, 384

Stephenson, 42

Storage-priority control strategy, 240

Strategy/approach related challenges, FDD application, 451–452

String inverters, 301

Substation-level challenges and solutions, ESI

- network protectors in systems, 341–342
- RE on local substation, 341

Summer 2010 heat wave event, 481, 482

Sun Shot program, 134

SunPower, 297

Sunspace, 165–168; *see also* Passive cooling

- design considerations, 167–168
- passive solar heating strategy, 316, 317f
- performance, 166–167
- principle, 165–166
- temperature of, 316

- Supervisory control and data acquisition (SCADA), 442
 - Supervisory control systems, 133–134
 - Supervisory controllers; *see also*
 - Control strategies
 - communication protocol, 209–210
 - components of EMCS, 204–206
 - design considerations of EMCS, 207–209
 - functions of ECMS, 206–207
 - Support vector data description (SVDD) algorithm, 440
 - Support vector regression (SVR) models, 440
 - Surface enhancing heat transfer, 134–135
 - Switching controls, 309
 - System(s)
 - controls, CCHP (case studies), 271–279
 - sorption TES, 400–407
 - adsorption TES test facility, 403–404, 405f
 - closed H₂O/CaCl₂, 400, 403, 403f
 - H₂O/silica gel, 403, 404f
 - H₂O/13X zeolite, 405, 406f
 - recent achievements, 400, 401t–402t
 - solar sorption pilot plant, 406, 406f
- T**
- Temperature-modulation control, 229
 - Temperatures
 - solar water heating system, 331–332
 - unglazed collector, 330, 332t
 - Tennessee Eastman process, 435
 - TES, *see* Thermal energy storage (TES)
 - Thermal comfort, 232, 233
 - Thermal energy storage (TES)
 - applications, 348
 - defined, 348
 - requirements/benefits, 270–271
 - sensibility and latency, 348–385
 - air conditioning, 349–358
 - ceiling board, PCM, 357, 357f, 358
 - ceilings, PCM, 366, 367
 - chilled water storage/aquifers, 349–352, 350f, 351f, 352t
 - CHP and, 370–375, 371f, 372f, 373t, 374f
 - classification, 348, 349f
 - floor heating, PCM, 366, 367f
 - for heating, 358–367
 - heat pumps and, 367–370, 368f, 369f
 - hot water tank/aquifers, 358–361, 358f, 360f
 - integration literature summary, building with, 375–379, 376t–378t
 - latent TES with PCMs, 352, 353–354, 364–365; *see also* Phase change materials (PCMs)
 - materials, 379–383; *see also* Materials, for sensible/latent TES
 - mathematical modeling of storage system, 383, 384–385, 386t–387t
 - PCMs, 352–355, 357–358, 364–367; *see also* Phase change materials (PCMs)
 - rock and brick reservoir, 361–364, 362f, 363f
 - solar shading, PCM for, 354, 355, 356f, 357, 357t
 - wallboards, PCM, 365, 366f
 - sorption TES system for buildings, 385, 388–407
 - performance improvement, 397–407
 - working pairs, 392–397
 - working principle, 385, 388–392
 - Thermal energy storage (TES) systems
 - active and passive systems, 240–243
 - neural network controls of, 243–246
 - Thermal losses, 328
 - Thermally activated cooling systems, 264–269
 - absorption and vapor-compression chillers, 265–266, 266t, 267f
 - category, 264
 - ejector heat pump cycle, 269, 270f
 - single-effect (1E) absorption cycle, 264–265, 265f

- solid desiccant A/C technology, 268–269
 - standalone liquid desiccant A/C, 269
 - Thermal mass, 154, 157
 - Thermal sensation vote (TSV), 233
 - Thermocline, 358
 - Three phase cycle discharging method, 398f, 399
 - Topping cycle, CCHP systems, 271
 - Traditional alarm management, prismatic approach, 425–427, 426f
 - Trane Intelligent Services, 445t
 - Transfer function, 194, 197f
 - Transient building envelope energy analysis, 30–59
 - conduction transfer function (CTF) methods, 41–44
 - finite difference methods, 31–34
 - frequency-domain regression (FDR) method, 45–53
 - interzone temperature profile estimation (ITPE) techniques, 34–41
 - response factors, 53–59
 - Transient System Simulation Program (TRNSYS) modeling, 364
 - Triethylene glycol, 107
 - Trigeneration, defined, 252
 - TRNSYS, 42, 76, 85
 - Trombe Wall, 162–165, 316, 317f; *see also* Passive cooling
 - design considerations, 164–165
 - performance, 163–164
 - principle, 162–163
 - Turbulent kinetic energy, 485
 - Two-position control system, 198–199
 - Two-zone controls of carbon-di-oxide, 228
 - Typical Meteorological Year (TMY), 319, 483, 490, 491f, 492
- U**
- Unglazed collector, low temperature, 325–326, 330, 332t
 - Upflow furnace, 111
 - Urban heat island (UHI) effect, 476–477, 477f, 478t
 - Urbanized weather forecasting model (uWRF)
 - building parameters for locations, 486–487, 487t
 - city scale model, 483, 483f
 - PLUTO and, 486
 - SBEM *vs.*, 493, 494f
 - TMY and, 492
 - weather outputs, 490, 491f
 - Utilities, electrical generation systems, 343–345
 - allocating costs and investment, 344–345
 - ramp-rates and spinning reserve, 343–344
 - UWRF, *see* Urbanized weather forecasting model (uWRF)
- V**
- Vapor-compression chillers, 266, 266t
 - Variable air volume (VAV), 221, 225
 - Variable air volume (VAV) systems and chiller water loops, 127–133
 - energy recovery systems, 132–133
 - Variable air volume (VAV) terminal boxes, 453
 - Ventilation, 125
 - Ventilation air, preheating, *see* Solar ventilation air preheating
 - Visible light transmittance (VLT), 308
 - VisualDOE, 83
 - Voltage regulation, on electric service to building with RE, 338f, 339
 - Voltage stability, of electric grid, 342
- W**
- Wallboards, PCM, 365, 366f
 - Water heating systems, solar, 324–335
 - active systems, 331, 331f
 - collectors, types, 324–335, 325f
 - evacuated tube, 326–327
 - glazed flat plate collectors, 326, 332t

- integrated-collector-storage collectors, 330
 - parabolic-trough collectors, 327–328
 - unglazed collector, low temperature, 325–326, 330, 332t
 - costs, 332t, 333, 334–335
 - efficiency curves, 329, 329f
 - evacuated tube, 334–335, 334f
 - materials and components, 329, 330
 - passive systems, 330
 - SRCC, 328–329
 - Water tank, hot water, 358–361, 358f, 360f
 - Water/ammonia ($\text{NH}_3/\text{H}_2\text{O}$), 98
 - Water/LiBr absorption chillers, 266
 - Water/lithium-bromide ($\text{H}_2\text{O}/\text{LiBr}$), 98
 - Water-tube boilers, 115
 - Wear-and-tear on reactive power compensation equipment, 340–341, 340f
 - Web-bulb depression efficiency (WBDE), 159–160
 - Whole-building energy models, 76–89
 - forward modeling methods, 81–86
 - inverse modeling methods, 77–81
 - meta-modeling approach, 86–89
 - Wind-driven natural ventilation, 143, 150–151
 - Working pairs, sorption TES system, 392–397
 - absorption, 393–394, 395t
 - adsorption, 394, 396–397, 396f, 397f
 - silica gel and water, 394
 - zeolites and water, 394, 396–397, 396f, 397f
 - ESD, comparison of, 392, 393f
 - Working principle, of sorption TES system, 385, 388–392
 - absorption, 385, 388–389, 388f
 - adsorption, 389–392, 390f, 391f, 392f
 - World urban database and access portal tools (WUDAPT), 486
 - Wright, Frank Lloyd, 307
- Z**
- Zeolites, water and, 394, 396–397, 396f, 397f, 405, 406f
 - Zero-input response, 43
 - Zion National Park Visitor Center, 152