

## Subject Index

### a

- abandoned mining sites 644–646
- absorbers
  - flexible wave energy 373
  - metallic foam 473–474
  - point 374–375
- AC voltage, three-phase 726
- acceleration power 411
- ACE (area control error) 733
- acidic PEM electrolysis, *see* PEM electrolysis
- acidification, ocean 120
- active energy saving 21
- active wind 754
- ADAM report 917–918
- adaptive management 347
- adiabatic compression 662
- adiabatic lapse rate 273
- adsorption, pressure swing 696, 700–701
- advanced AWE, electrolyzers 218
- advanced batteries 579–596
- aerodynamic loads 279
- aerosol 120
  - solar-thermal reactor 468
- AGC (Automatic Generation Control) 612–613
- aging power plants 409
- air
  - ambient air vaporizer 672
  - ASHP 57, 761
  - CO<sub>2</sub> source 826–827
  - heat-transfer fluid 461–465
  - lithium–air batteries 585–587
  - pollution 146, 805–806
- airship, fuels 681
- alcohol, *see* bioethanol
- algae-based biofuels 534
- alkaline water electrolysis (AWE) 430–432, 440
  - advanced 218
  - power-to-gas 814–817
- all-electric building 881–882
- “allowable solutions” 877
- “allowed stress range” 777
- Alpha Ventus offshore wind farm 266
- alternating loads 778
- alternative powertrains and fuels 857
  - efficiency 864
- alternative process chains 838–841
- alumina tubes, coated 475
- ambient air vaporizer 672
- ammonia
  - borane 660
  - conversion efficiency 701
  - electrochemical conversion 691–706
  - fuel cells 699
  - synthesis 430
- anaerobically digested gas 824
- anchoring system 367
- ancillary services (AS) 88
- annual grid load balancing 232–236
- Anthropocene age 119–121
- aquifers, storage sites 642–644, 829
- arable land potential 490
- area control error (ACE) 733
- asbestos diaphragm 432
- ASHP (air source heat pumps) 57
  - “smart grids” 761
- Asse diapiir 647
- asset-heavy paradigm 769
- assimilation of carbon 491–492
- ASTERIX project 461, 467
- astigmatism 317
- Aswan/Egypt 430
- asynchronous DIG 250–252
- atmospheric aerosol loading 120
- atmospheric air pollution 146
- atmospheric boundary layer 273
- atmospheric electrolyzer 430–431

*Transition to Renewable Energy Systems*, 1st Edition. Edited by Detlef Stolten and Viktor Scherer.  
© 2013 Wiley-VCH Verlag GmbH & Co. KGaA. Published 2013 by Wiley-VCH Verlag GmbH & Co. KGaA.

- atmospheric receiver 319
- attenuator 376
- Automatic Generation Control (AGC) 612–613
- automotive fuel cell systems, *see* fuel cell vehicles
- autonomy 131
- availability assumptions 38–39
- aviation travel 103–105
  
- b**
- back contact, interdigitated 297–298
- back surface field (BSF) 287
- balance boundaries, ZEB 876–878
- balance-of-plant (BOP) cost 222–223
- balance-of-plant (BOP) system 186–187
- Balance Responsible Party 502–503
- balancing
  - cost 83, 88–89, 260
  - cross-border 733
  - energy demand and supply 568–570
  - large-scale 605
  - real-time 743–744, 747
  - ZEB 879–881
  - , *see* also load balancing
- balancing capacity
  - hydropower 398
  - marine energy 353
- bank erosion 612
- Barlow law 777
- barriers to transition 868
- base-load power, renewable 342
- base metals, coated 444–445
- BAT (best available technology) 98
- batteries
  - advanced 579–596
  - EV 587
  - lithium–air 585–587
  - lithium–ion 185, 198, 581–582, 591–592, 853
  - lithium–sulfur 584–585
  - Ni–MH 23–24
  - rechargeable, *see* rechargeable batteries
  - redox-flow 582–583, 592–593
  - smart charging 755–759
  - sodium–sulfur 23, 583–584, 593–594
- battery electric vehicles (BEV) 587, 853–854, 859
  - market development 860
  - utility index 867
- BAU (“business-as-usual”) reference 93
- “beam-down” concept 321, 462
- bell-jar solar reforming reactor 469
- Bernoulli equation 786
- best available technology (BAT) 98
- bidirectional charging control 760
- binary-cycle heat exchangers 341
- biobutanol 534
- biodiesel 528–529
- biodiversity loss 120
- bioenergy
  - Scotland 57–58
  - supply potential 111
- bioethanol
  - lignocellulosic 523
  - power density 199
  - production 529–530
- biofuels 510–516, 625–626
  - algae-based 534
  - conventional 525
  - cost 543–544, 544
  - distribution 525
  - economic feasibility 542–544, 546
  - environmental impact 537, 545–546
  - production 523–553, 535
  - raw materials 526–527
  - R&D 526–527
- biogas 473, 507, 512–513, 824
  - upgrading 515, 532
- biohydrogen 512–513, 533
- biological methanation 787–788
- biological nitrogen fixation 693
- biomass 485–554
  - as CO<sub>2</sub> source 824–825
  - co-combustion with fossil fuels 415–417, 507
  - conversion 510, 524, 540–541
  - energy efficiency 509
  - environmental impact 495
  - flexible power generation 499–521
  - gasification 452, 531
  - Germany 506
  - global resources 485–497
  - growth potential 494
  - mechanical–thermal treatment 531
  - rural China 906
  - supply 525
  - sustainable available potential 499
- biomass to liquid (BTL) fuels 530–531, 626
- biomethane 507, 512–513, 564
  - production 532
- biosyngas 824
- bipolar plate 583
- BIPV (building-integrated PV) 292–294
- bird fatalities 256
- Birkeland–Eyde process 694
- “black start” 60
  - hydropower 398

- blades, number of 247–248
- Blåsjø hydropower reservoir 392–393, 608
- boil-off loss 670
- boil-off rate 675
- boiler
  - condensing 790
  - fossil-fired 180
  - solar 171
- BOP (balance-of-plant) cost 222–223
- BOP (balance-of-plant) system 186–187
- boring machines, TBM 392
- Borkum West offshore wind farm 266
- boron hydrides 660
- Bosch, *see* Haber–Bosch process
- boundaries, planetary 119–120
- boundary layer, atmospheric 273
- Brazil 140
- BRICS 140
- Bridgeman process 286–287
- bridging technologies 195
- brine 649–650, 830
- briquetting 508
- British–Irish Council 63
- “brown economy” 5
- Brundtland Report 121
- BSF (back surface field) 287
- BTL (biomass to liquids) fuels 530–531, 626
- bubble formation 441
- buildings 99–103
  - all-electric 881–882
  - BIPV 292–294
  - building codes 152
  - China 891–911
  - commercial 904–906
  - energy demand 103
  - energy use 897
  - floor area per capita 897–898
  - public 904–906
  - rural residential 906
  - system boundaries 876–878
  - ZEB 875–889
- bulk power transport 723
  - market options 732
- bulk storage, near-surface 659–690
- bundled concentration 162–163, 172
- buses, FCV 186
- “business-as-usual” (BAU) reference 93
- Butler–Volmer equation 220
- c**
- c-Si technology, *see* crystalline Si wafer-based solar cells
- CAES (compressed air energy storage) 560, 567, 574–575
- CAESAR experiment 469–470
- California, SEGS 312
- California, ZEV standard 861–862, 864–866
- California Fuel Cell Partnership (CaFCP) 861–862
- calorific value 774, 784, 786
- “cannibalism” of VRE 78
- CAP (Common Agricultural Policy) 487
- capacity 558, 566
  - addition 766
  - mandating 148
  - “on-site” storage 878
- capacity factor 219
  - geothermal power 344
  - hydropower 382, 395
  - wind turbines 249
- capacity growth, offshore wind power 266
- CAPEX 419–421, 544
  - “smart grids” 748, 763–765
- capital
  - availability 261
  - cost 269–270, 803
  - financial 127–129
  - intensity 85
- caprock 829
- carbon capture and sequestration (CCS) 798
- carbon capture and storage (CCS) 18
  - as CO<sub>2</sub> source 823–824
  - offshore 55
  - Scotland 53–56
  - unnecessary with DSR 749, 764
- carbon capture/cycling (CCC) 788–789
- carbon dioxide, *see* CO<sub>2</sub>
- carbon emissions, China 893
- carbon fiber 248
- carbon formation 454
- carbon hydrogenation 622
- carbon intensity 29
- carbon nanotubes (CNT) 586
- carbon sinks, forests 491–492
- Carbon Trust 357
- carbonates
  - carbonate–LiAlO<sub>2</sub> electrolyte 697
  - PCM 467
  - sodium carbonate solution 826
- carbonization, hydro-thermal 508
- Carnot power cycle 309
- Carnot’s theorem 168
- Caro, *see* Frank–Caro process
- cars, *see* vehicles
- catalyst-coated membrane (CCM) 434, 442
- catalysts, noble metal 816
- catalytic activity, PEM electrolysis 433
- catalytic hydrogenation 820

- catalytic methanation 787
- catalytic reduction, selective 698–699
- catalytic systems, “structured” 456
- catchment (hydrological) 146, 383
- cathodic protection system (CPS) 780
- caverns
  - convergence 648
  - hydropower 391–392
  - salt 203
  - storage sites 646–652, 830–831
- cavity receiver 477
- CCGT (combined cycle gas turbine) 731
- CCS, *see* carbon capture and storage/sequestration
- CEDREN 605
- cells
  - fuel, *see* fuel cell
  - resistance 220
  - solar, *see* solar cells
  - voltage 226, 429
- cement production 929
- central conversion 835
- Central Europe, geological storage 636–639
- central production, H<sub>2</sub> 800
- central receiver system 309
- central storages 558
- ceramic electrolytes, YSZ 699
- ceramic foams 458, 469–474
- ceramic honeycombs 458, 468–469
- ceramics production 922
- cereals, world production 488
- cerium, *see* Zn–Ce redox-flow battery
- certificates
  - REC 6
  - ROC 352
- CES (constant elasticity of substitution) 33
- CGE (computable general equilibrium) 31
- charge/discharge time 559
- charging
  - EV 755–759
  - uni-/bidirectional control 760
- CHARM® (CH<sub>4</sub> airborne remote monitoring) 781–782
- chemical conversion 564–565
- chemical energy carriers 438
- chemical energy storage 327
- Chemical Engineering Plant Cost Index (CEPCI) 543
- chemical fuel production 619–621
- chemical hydrides 660
- chemical pollution 120
- chemical storage 619–628
- China 140
  - buildings energy conservation 891–911
  - carbon emissions 893
  - climate policy goals 30–31
  - CO<sub>2</sub> emissions 29–46
  - Copenhagen commitment 45
  - green energy strategies 29–46
  - China-in-Global Energy Model (CGEM) 31–35
  - CHP, *see* combined heat and power
  - chrysotile diaphragm 432
  - CIGS 288–289, 298–300
  - clean technology ranking 9
  - climate change 120
  - climate-change impacts, hydropower 387–388
  - climate policy goals
    - China 30–31
    - diverging objectives 74
  - climate protection, Developing World 145
  - cluster strategy 808
  - CNT (carbon nanotubes) 586
  - CO<sub>2</sub>
    - buildings 875
    - catalytic hydrogenation 820
    - disproportionation 454
    - methanation 204, 210–212
    - methane reforming 451
    - ocean sink 491–492
    - recovery from air 826–827
    - specific energy consumption of sources 827
    - steam co-electrolysis 438
    - synthetic methane production 788
    - tax 495–496
    - , *see also* carbon, greenhouse gases
  - co-combustion of biomass 415–417, 507
  - co-electrolysis 437–438
  - CO<sub>2</sub> emissions
    - China 29–46
    - Developing World 146–147
    - gas scenario 793
    - Germany 196–197
    - hydropower 396–397
    - marine energy 352
    - reduction 40–42
    - smart EV charging 760
  - co-evaporation process 300
  - co-generation 21, 195
  - coal
    - and biomass 416
    - China 893
    - ex- and importers 4
    - gasification 802, 834
    - pulverized 508
  - coated alumina tubes 475

- coated base metals 444–445
- coating technologies, large-area 288–290
- Cobb–Douglas CES 33
- coefficient of performance (COP) 571
  - smart grid heat pumps 761
- coke-oven gas 785
- cold start-up tests 189
- cold storage 561–563
- collector systems, linear Fresnel 309, 317–320, 457
- combined cycle gas turbine (CCGT) 731
- combined heat and power (CHP) 50, 58–59
  - biomass 507
  - demand-driven electricity commission 510–515
  - distributed 557
  - district heating 413–414
  - fossil power plants 413–414
  - geothermal 341
  - industrial use 923–926, 932–934
  - natural gas system 789–790
  - VRE 80, 87
  - ZEB 877, 883–885
- combustion
  - ammonia 698–699
  - biomass 824–825
  - co- 415–417, 507
  - heating systems 835
  - ICE 836–838
  - turbines 835
- commercial buildings 904–906
- commercial floor space 101
- commercialization programs, hydrogen FCV 796
- Common Agricultural Policy (CAP) 487
- compatibility, infrastructure 806
- compensator, static VAR 715
- complex metal hydrides 675
- composite design simulation 225
- composite materials 248
- compound thin-film PV 302
- comprehensive transition concept 119–136
- compressed air energy storage (CAES) 560, 567, 574–575
- compressed gaseous hydrogen storage 662–668
- compressed natural gas (CNG) 787, 792
  - as fuel 836–837
- compressibility factor 773
- compressors
  - natural gas pipelines 778–779
  - switching 754
- computable general equilibrium (CGE) 31
- concentrating photovoltaics (CPV) 302–303
- concentrating solar high-temperature heat (CSH) 110
- concentrating solar power (CSP) 95, 110, 307–338
  - environmental impact 311–312
  - large-scale plants 159–182, 461
  - methane reforming 457
- concrete, sensible heat storage 326
- condenser 173–174
- condensing boiler 790
- conduction band 285
- conductive oxides, transparent 288–289
- conductor glass film, super-ionic 585
- “connect and manage” approach 61
- connection to shore 274–276
- constant elasticity of substitution (CES) 33
- consumer behavior 131–132
- consumer-friendly cost structures 560
- contamination
  - natural gas 473
  - subsurface storage 635
- continuous recharge, geothermal power 345
- “control hydro”/“control wind” 613
- control loops, fast-reacting 410
- control manifold 672
- control of domestic appliances 750–755
- controlled load profile 751
- conventional biofuels 525
- conventional petroleum 624, 852
- conventional power plants 403–422
- conventional vehicles 579
- convergence, caverns 648
- conversion
  - biomass 510, 524, 540–541
  - chemical 564–565
  - (de)central 835
  - efficiency 296, 301
  - electrochemical 691–706
  - hydrogen 797–798
  - ortho-to-para 669–670
  - “savings” 934
  - solar 283, 460
  - technologies 712–717
- converter
  - LCC technique 716
  - multilevel 720
  - overtopping wave energy 378
  - VSC technologies 716–717, 739
- cooling energy intensity 903
- cooling system, CSP 169
- coordination of stakeholders 807
- Copenhagen commitment, China 45
- cordierite honeycomb 469
- core-shell structures 443

- corn-based bioethanol 523
  - corrosion
    - biomass co-combustion 417
    - natural gas pipelines 778, 783
  - Corruption Perceptions Index 138
  - cost
    - assumptions 38–39, 70–71
    - balancing 83, 88–89, 260
    - biofuel production 543–544, 544
    - BOP 222–223
    - capital 269–270, 803
    - CEPCI 543
    - competitiveness 40
    - consumer-friendly structures 560
    - cost of energy trajectory 357–360
    - distribution 517
    - drilling 346
    - EGC 296–297
    - electrolysis 440, 444
    - energy storage systems 559, 566, 572–575
    - EV 589
    - excess 868
    - FCV 185, 191–192, 854
    - generating technologies 329
    - geological storage 831
    - grid-related 83, 89
    - H<sub>2</sub> feed to natural gas grid 833
    - highly efficient electric drives 919
    - hydrocarbon fuel upgrading 626
    - hydrogen infrastructure 210–213
    - hydrogen production 223–224, 803
    - hydropower 394–396
    - LCOE, *see* levelized cost of energy
    - LEC 325
    - LRMC 339, 346
    - marine energy 353
    - maximum acceptable storage costs 573–574
    - natural gas 210–212
    - near-surface bulk storage 677–679
    - offshore wind power 271
    - power-to-gas 839
    - profile 78–82, 85–88
    - PV 290–291, 296, 301
    - reinforcement 756–759
    - risk-adjusted 259
    - “smart grids” 754
    - solar thermal power 328–332
    - solid-state storage 677
    - substation 735
    - supply–cost curve 394, 396
    - transition 857
    - WACC 762
    - water electrolysis 221–223
  - Cost Reduction Task Force (CRTF) 269
  - counter-rotating Wells turbines 377
  - CPS (cathodic protection system) 780
  - cracking
    - methane 476
    - natural gas 452
  - crashworthiness 188–189
  - creep tendency, salt caverns 648
  - Crescent Dunes solar tower system 323
  - crop, energy, *see* biomass
  - crop management 486
  - cross-border balancing 733
  - cross-border trading 732
  - cross-cutting technologies 914–915, 920, 926–927
  - cross-linked polyethylene (XLPE) insulation 711–712, 716
  - Crown Estate 355
  - crude oil
    - ex- and importers 4
    - subsurface storage 632
  - cryogenic liquid hydrogen storage 669–675
  - crystalline Si wafer-based solar cells 286–288, 297–298
    - R&D 301
  - CSIRO 463–464
  - cultural perspective 131–132
  - culturalists 132–134
  - curb weight 205
  - current
    - capacity 728
    - collectors 443–445
    - density 222, 225
    - parasitic 219
  - current policy assumptions 37–38
    - RE 39–40
  - current–voltage curve 220, 285
    - alkaline electrolysis 429
    - high-temperature electrolysis 437
    - PEM electrolysis 434
  - cushion gas 828
  - cycling, subsurface storage 634–635
  - Czochralski process 286–287
- d**
- daily winter sunshine 144
  - dams 385, 389
    - PSH 602–603
  - Danish concept 243
  - Darcy–Weissbach equation 773–774
  - day–night cycles 619
  - DC CAPEX 748, 763–765
  - DC grids, meshed 718
  - DC supergrid concept, European 275

- DCORE (dual-coil reformer) 463–464
- “dead” wood 415
- decarbonization, *see* CO<sub>2</sub> emissions
- decentral conversion 835
- decreasing market value, VRE 75–92
- deforestation 491–492
- degradation 743
- delivery, *see* transmission, distribution
- demand
  - and supply 486–487, 568–570, 743–744, 747
  - demand-driven electricity commission 510–515
  - demand-driven power options 95
  - FED 927
  - flexible 709, 749
  - heat 900
  - peak 741, 751
  - reduction 51–52
  - response 86
  - stoichiometric H<sub>2</sub> 622
  - storage and balancing 606–607
  - transmission grid changes 731–732
  - weighted 879
- demand-side response (DSR) 749–768
- democratic question 129
- dendritic growth 585
- depleted oil/gas fields 642
- deployment potential 109
  - bioenergy 111
  - geothermal power 343–345
  - hydropower 397–398
  - PSH 598–599
  - UK marine energy 354–356
- DES (distributed energy storage systems) 570–571
- DESERTEC concept 181, 308
  - transmission grid systems 731
- deserts, solar power plants 160
- deterministic scheduling 767
- Developing World
  - policies 147–153
  - R&D 153
  - RE 137
- development, sustainable 121
- device power up-rating 359
- dewars 671
  - spherical 683
- DG (distributed generation) 143, 405
- DHW (domestic hot water) 561, 903
- diaphragm, electrolyzers 432
- diapirs 646
- diesel fuel
  - bio- 528–529
  - HHV 693
- DIG/DFIG (doubly fed induction generator) 250–252, 272
- dimethyl ether (DME) 533
- direct ammonia fuel cells 699
- direct conversion, solar radiation 283
- direct drive wind generators 251–252
- direct feed-in, hydrogen 212
- direct-hydrogen FC systems 836
- direct land use change (dLUC) 538–539
- direct normal insolation (DNI) 329
- direct semiconductors 288
- direct steam generation
  - CSP 168, 172, 316
  - geothermal power 341
  - heat storage 179
- directly irradiated annular pressurized receiver (DIAPR) 474
- directly irradiated reactors 468–476
- directly irradiated solar receivers (DIR) 458
- discharge, relative 390
- discharge times 559, 561
  - CAES 785
  - natural gas system 785
  - PSH 785
- dish solar collectors 309, 477
- dish Stirling receiver 164
- dishwashers 752
- disproportionation, CO<sub>2</sub> 454
- disruptive innovations 360
- dissociation potential, water 220
- dissociation pressure, metal hydrides 676
- distillation residues 623
- distributed CHP 557
- distributed energy market 768–770
- distributed energy storage systems (DES) 570–571
- distributed generation (DG) 143, 405
- distributed storage, hydrogen 678
- distribution 709–844
  - cost 517
  - grid 209, 731–732
  - hydrogen 796–802
  - Scotland 60
- district heating 88
  - fossil power plants 413–415
  - , *see also* residential heating
- disturbance recognition and visualization tools 746
- diverging objectives 74
- diversification
  - energy sector 17–23
  - supply system 353
  - water heater demand 750

- DNI (direct normal insolation) 329
- dogmas on sustainability 132
- domestic appliances, control 750–755
- domestic energy supply, China 894
- domestic hot water (DHW) 561, 903
- domestic industries, Developing World 149
- double-circuit AC lines 736–739
- doubly fed induction generator (DIG/DFIG) 250–252, 272
- Douglas, Cobb–Douglas CES 33
- downregulation, wind power 615
- downstream migration 391
- downwind wind turbines 250
- drain and refill cycle, geological storage 631
- drilling
  - cost 346
  - subsurface storage 633
  - tunnel 611
- drive train concept 250–252
- drives
  - drivetrain losses 854
  - electric 853–854, 916–922
  - frequency-controlled 410
  - hydraulic systems 313
  - variable-speed 604, 919
- driving distance 579
  - FCV 184
- dry methane reforming 451
- dryers, tumble 752
- drying, thermal 930
- DSR (demand-side response) 749–768
- dual-coil reformer (DCORE) 463–464
- duality of structure 124
- ductility, salt caverns 648
- ducts, steam generation inside 175–177
- durability
  - EV 589
  - fuel cells 184, 797
  - tests 190
- dye-sensitized solar cells (DSSC) 298–299
- dynamic positioning vessels 271
- dynamic pressure 776
- e**
  - EAFs (electric arc furnaces) 928
  - ebb tides 363
  - eco-friendly vehicles 579
    - , *see also* electric vehicles, zero-emission vehicles
  - “eco villages” 907
  - ecological guard rails 145–147
  - ecological trajectories 125
  - economic feasibility 68
    - biofuel production 542–544, 546
    - energy storage systems 572
    - fossil power plants 419
    - geothermal power 346
    - hydrogen supply pathways 802–804
    - hydropower 385–386
    - near-surface bulk storage 677–679
    - wind power 258–260
  - economic growth
    - and energy transition 15
    - model assumptions 35–37
  - economic incentive schemes 343
  - “economic literacy” 128
  - economic perspective 127–129
    - “New Economics” 123
  - economic potential, renewable energies (RE) 141–143
  - economic question 129
  - economies, emerging 140
  - ECOSTAR project 331
  - ecosystems, marine 146
  - education, Developing World 152–153
  - EEG (Erneuerbare-Energien-Gesetz) 127, 500–502, 506–507
  - EEKV (energy equivalent of water) 381
  - EER (European Energy Regulators) 733
  - EESG 252
  - EEX (European Energy Exchange) 502
  - efficiency
    - alternative powertrains and fuels 864
    - ammonia conversion 701
    - biofuel production 535
    - biomass use 509
    - BOP 223
    - electricity 230
    - electrolyzers 237
    - energy, *see* energy efficiency
    - Faraday 220
    - four-pole electric motors 916
    - Haber–Bosch process 696
    - heating 901
    - hydrogen FCV 795, 797
    - hydropower 381
    - NREL chart 303
    - optical 318
    - PEM electrolyzers 440
    - PV conversion 296, 301
    - storage 559, 566, 679–681
    - theoretical total 310
    - turbines 390
    - vehicles 854–856
  - efficiency limit 284
  - efficiency path 876
  - EfW (energy from waste) 58
  - EGC (energy generation cost) 296–297



- EGPS (Electricity Generation Policy Statement) 47–48
- EGS (enhanced geothermal system) 339
- electrodes, batteries 581
- electric arc furnaces (EAFs) 928
- electric drives 916–922
  - technologies 853–854
- electric motors 208
  - four-pole 916
- electric power
  - capacity distribution 229
  - chemical fuel production 619–621
  - CO<sub>2</sub> emission source 196
  - consumption reduction 920
  - cost assumptions 70–71
  - cross-cutting technologies demand 915
  - demand-driven commission 510–515
  - Europe 404
  - gaseous biofuels 512–515
  - generation in UK 48
  - Germany 200–202, 501
  - heat–electricity interface 87
  - hydrogen production 799
  - industrial use 920
  - Japan 15
  - LEC 325
  - liquid biofuels 511–512
  - low-carbon systems 743–744
  - market design 73
  - massive PV integration 303
  - methane production 565
  - necessary investments 70
  - present system structure 742
  - renewable 31, 501
  - Scotland 47–65
  - solar radiation 160
  - solid biofuels 510–511
  - Spain 217, 228–229
  - storage 59–60, 86, 217
  - sub-sea electricity grid 61
  - tri-generation system 801
  - wholesale and retail market 769
- electric vehicles (EV) 106, 579–596
  - BEVs 587, 853–854, 859–860, 867
  - charging 755–759
  - cost 589
  - fuel cell, *see* fuel cell vehicles
  - “on-site” storage capacity 878
  - rechargeable batteries 587
  - “smart grids” 755–760
- electricity
  - efficiency 230
  - peaks 570
  - storage 559–561
  - trade 730
- Electricity Generation Policy Statement (EGPS) 47–48
- Electricity Market Reform (EMR) 352
- Electricity Market Reform Expert Group (EMREG) 354–355
- Electricity Networks Steering Group (ENSG) 60
- electrification 112
  - rate 107
- electrocatalysts 235
  - alkaline electrolysis 441–442
  - hydrogen evolution reaction 442–443
  - oxygen evolution reaction 443
- electrochemical conversion, ammonia 691–706
- electrochemical synthesis 697–698
- electrodes, MEA 817
- electrolysis 200, 203, 207, 425–450, 797, 799
  - AWE 430–432, 440–442
  - cost 221–223, 440, 444
  - HTE 436–438, 818–819
  - hydrogen pipeline system 834
  - large-scale hydrogen technologies 218–226
  - PEM 433–436, 442, 817–818
  - physico-chemical foundations 426–430
  - power-to-gas 814–820
  - production simulation 224–226
  - R&D 438
  - specific energy consumption 428
- electrolytes
  - batteries 581
  - carbonate–LiAlO<sub>2</sub> 697
  - ion-conducting solid 583
  - KOH 815
  - pH 433
  - YSZ ceramic 699
- electrolyzers
  - efficiency 237
  - energy yield 222
  - grid stabilization 226–236, 439
  - partial load 432
  - performance 219–221, 224
  - pressurized 227, 441
  - RE integration 819–820
- electromobility 851–873
  - Model Regions 861–862
- EM (enriched methane) 467
- embrittlement, hydrogen 674
- EMEC (European Marine Energy Centre) 361
- emerging economies, BRICS 140
- emissions
  - CO<sub>2</sub>, *see* CO<sub>2</sub> emissions
  - industrial sector 934–935

- near-zero 800–801
- NO<sub>x</sub> 495, 698
- Trading Scheme 496
- transport sector 851–852
- WTW 805–806
- employment opportunities
  - marine energy 354
  - RE 142
- EMR (Electricity Market Reform) 352
- EMREG (Electricity Market Reform Expert Group) 354–355
- encased receiver tubes 176
- end energy carriers, Germany 621
- end-member mixing analysis (EMMA) 77, 81–82
- end-use technologies 834–838
- endogenous growth theory 123
- ENE FARMs 24
- EnerCalC 883
- Energiewende, *see* energy transition
- energy
  - active energy saving 21
  - buildings 875
  - capacity addition 766
  - chemical 327, 438
  - Chinese buildings 891–911
  - co-generation 21, 195
  - cost of energy trajectory 357–360
  - crops, *see* biomass
  - demand and supply 568–570
  - distributed market 768–770
  - energy–economic system 39
  - FED 927
  - formation energy of liquid water 426
  - GEA report 851
  - green, *see* green energy ...
  - hydrogen, *see* hydrogen ...
  - industrial savings potentials 913–936
  - LCOE, *see* levelized cost of energy
  - marine 351–379
  - on-site generation 881
  - payback ratio 400
  - primary energy credits 885
  - renewable, *see* renewable energies
  - reserves 141
  - risk-adjusted cost 259
  - storage, *see* storage
  - sustainable global energy system 93–117
  - tidal 360–370
  - TPES 244
  - use in transport 854
  - wave 371–378
  - World Energy Outlook 824, 891, 913
  - ZEB, *see* zero energy buildings
- energy analysis, buildings 876–877
- energy-band diagram 285
- energy carriers
  - ammonia 692–698
  - hydrogen, *see* hydrogen
  - , *see also* fuels
- energy consumption 4
  - Scotland 52
- energy demand
  - buildings 103
  - global 108
  - industries 100
  - modeling 94
  - reduction 51–52
  - sector definitions 96
  - transport 107
- energy density
  - chemical fuels 620
  - cryogenic storage 669
  - EV 589
  - gravimetric 208
  - metal hydrides 676
- energy efficiency 112
  - biomass 509
  - Scotland 51
- Energy Efficiency Action Plan 58
- Energy Efficiency Directive 413
- energy equivalent of water (EEKV) 381
- energy from waste (EfW) 58
- energy generation cost (EGC) 296–297
- “energy highway” 776
- energy infrastructure
  - new model 143
  - North Sea 51
- energy-intensive industries 71
- energy intensity 856
  - buildings 102, 897
  - Chinese buildings 899–900
  - cooling 903
  - rural China 907
  - transport 105–106
- energy-intensive materials, substitution 932
- energy model
  - CGEM 31–35
  - ISLES 61–64
- energy payback ratio (EPR) 399–400
- energy payback time 283
- Energy Performance of Buildings Directive (EPBD) 875–880
- energy recovery 698–700
- Energy Roadmap 2050 913
- energy saving, buildings 99
- energy sector
  - diversification 17–23

- transition 14
  - energy services, *see* power system services
  - energy storage systems (ESS), *see* storage
  - energy supply
    - global 112
    - primary 621
    - Sweden 492
  - energy transition
    - comprehensive concept 119–136
    - German industry 67–74
    - Japan 14
    - supranational level 73
    - , *see also* transition
  - energy yield, electrolyzers 222
  - “Engineering, Procurement and Construction” (EPC) contractor 328
  - engines
    - gas 835
    - internal combustion 836–838
    - losses 854
    - Stirling 170, 310
    - , *see also* vehicles, transport
  - enhanced geothermal system (EGS) 339
  - enriched methane (EM) 467
  - ENSG (Electricity Networks Steering Group) 60
  - entropy 173
  - ENTSO-E 729–730, 735
  - environmental impact
    - biofuel production 537, 545–546
    - biomass 495
    - CSP 311–312
    - geothermal power 346–350
    - hydrogen supply pathways 802, 805–806
    - hydropower 387–388, 399
    - PSH 602–604, 611–612
    - “smart grids” 768
    - wind power 255–257
  - “environmental literacy” 122
  - EPR (energy payback ratio) 399–400
  - equilibrium price 80
  - Erneuerbare-Energien-Gesetz (EEG) 127, 500–502, 506–507
  - erosion, bank 612
  - esters, hydrotreated 529
  - ethanol
    - power density 199
    - , *see also* bioethanol
  - eucalyptus 490
  - EURELECTRIC 419
  - EURO3 norm 698
  - Europe
    - district heating 414
    - geological storage 636–639
    - hydropower potential 386
    - industrial energy savings potentials 913–936
    - natural gas infrastructure 791
    - PSH capacity 599
    - transmission grid 408, 729
  - European Association of Refrigeration, Heating and Ventilation (REHVA) 875
  - European DC supergrid concept 275
  - European Energy Exchange (EEX) 502
  - European Energy Regulators (EER) 733
  - European Integrated Hydrogen Project 663
  - European Marine Energy Centre (EMEC) 361
  - European Network of TSOs (ENTSO) 733
  - European Union
    - Common Agricultural Policy 487
    - electricity market 730
    - Energy Roadmap 2050 913
    - Parliament Test Drive Program 193–194
    - 20/20/20 targets 403
  - European Water Framework Directive 389
  - EV, *see* electric vehicles
  - excess cost 868
  - excess electricity 203
  - expected repair delay time 277
  - exploration, subsurface storage 633
  - externalities concept 856–857
  - Eyde, *see* Birkeland–Eyde process
- f**
- FACTS (flexible AC transmission systems) 714–715, 745
  - Faraday efficiency 220
  - Faraday, Michael 725
  - fast-reacting control loops 410
  - fast response, PEM electrolysis 818
  - fatty acid methyl ester (FAME) 528
  - fatty acids, hydrotreated 529
  - FCCJ (Fuel Cell Commercialization Conference of Japan) 860
  - FCV, *see* fuel cell vehicles
  - FDNPP (Fukushima Dai-Ichi nuclear power plant) 13–14, 16, 67
  - feed-in tariffs (FIT)
    - Developing World 148
    - EEG 506
    - Japan 21–22
    - South Korea 6
    - wind power 257
  - feedstock conversion, biomass 510
  - fermentation 530
    - biomass 824
  - fertilizer production 430
  - filling nozzle, IR 191

- filling stations
  - hydrogen 210
  - , *see also* refueling
- final energy consumption, Scotland 52
- final energy demand (FED) 927
- financial capital 127–129
- “financial crisis” 229
- financial implementation procedure 181
- financial incentives 151–152
- financial security, Developing World 149
- financial support, RE 407
- fins 474–475
- fire tests 188–189
- Fischer-Tropsch process 438, 451
  - biofuel production 530–531
- fish-friendly power plants 391
- Five-Year Plan 30, 35
- “flashed” steam 341
- flat mirrors 163
- flat panel display (FPD) 299
- “flexibility effect” 81
- flexibilization capability 505
- flexible AC transmission systems (FACTS) 714–715, 745
- flexible blade design 248
- flexible demand 709, 749
- flexible EV charging 758
- flexible hydropower 612–615
- flexible power generation
  - biomass 499–521
  - fossil power plants 408–410
- flexible solar cells 294–295
- flexible transmission 709
- flexible wave energy absorbers 373
- float, spar and 375
- floating point absorber 374
- floating turbines 370
- floating wind turbines 279–280
- flood protection 387
- flood tides 363
- floor area 897–898
- floor space, commercial/residential 101
- flow 381
  - two-phase 175
- flow-based market coupling 86
- flow variability 383–384
- fluctuating RE, *see* variable RE
- fluctuations
  - RE generation 199–200
  - reservoir water level 609–611
- fluids
  - geothermal 343
  - heat-transfer, *see* heat-transfer fluids
  - working 165–168
- foams, ceramic 458, 469–474
- focal point 320
- food production, global 487–490
- forecast errors 75, 85
- forests
  - carbon sinks 491–492
  - energy supply 492
  - , *see also* wood
- formation energy, liquid water 426
- fossil-fired boiler 180
- fossil fuels
  - China 29, 44, 893
  - natural gas, *see* natural gas
  - petro-mobility 851–873
  - storage medium 567
- fossil power plants 403–422
  - economic feasibility 419
- foundations, offshore wind power 267, 271, 276
- four-pole electric motors 916
- FPD (flat panel display) 299
- Frank-Caro process 694
- FreedomCAR 659
- frequency-controlled drives 410
- frequency regulation 600, 604
  - , *see also* balancing
- freshwater use, global 120
- Fresnel mirrors 163–164
  - linear 309, 317–320, 457
- friction coefficient, integral 775
- Fuel Cell Commercialization Conference of Japan (FCCJ) 860
- fuel cell vehicles (FCV)
  - cost 185, 191–192, 854
  - efficiency 795, 797
  - European deployment activities 192–194
  - Germany 205, 207–208
  - HMC 183–194
  - Japan 22–23, 25
  - Mercedes-Benz B-Class 208
- fuel cells
  - CaFCP 861–862
  - direct ammonia 699
  - direct-hydrogen systems 836–838
  - HTE 437
  - Japan 24–25
  - low-temperature 218
  - natural gas system 790
  - passenger car powertrains 836
  - PEMFC 183, 586, 700–701
  - SOFC 923
  - stack durability 184
- fuel gas, refinery waste 455
- Fuel Partnership 659

- fuels
  - airship 681
  - alternative 857
  - ammonia 692
  - BTL 530–531, 626
  - chemical production 619–621
  - CNG 836–837
  - for transport 523–524
  - fossil, *see* fossil fuels
  - gaseous biofuels 512–515
  - hydrocarbon 619–628
  - liquid biofuels 511–512, 625–626
  - natural gas, *see* natural gas
  - solid biofuels 510–511
  - substitution of oil-based 206
  - synfuel 624
  - wood 493
  - , *see also* transport
- Fukushima Dai-Ichi nuclear power plant (FDNPP) 13–14, 16, 67
- full-scale infrastructure 804
- fully sustainable global energy system 93–117
- furnaces, electric arc 928
- g**
- G CAPEX 748, 763–765
- “game changers” 195–196
  - PV 303
- gas and steam turbines 511
- gas engines 835
- gas fields, storage sites 640–642, 829
- gas heat pump 790
- gas hourly space velocity (GHSV) 822
- gas insulated lines (GILs) 711–712
- gas losses 635–636
- gas power plants, flexibilization capability 505
- gas turbine combined cycle (GTCC) plant 18
- GasCam 782
- gaseous biofuels 512–516
- gaseous hydrocarbon fuels 620
- gaseous hydrogen storage, compressed 662–668
- gases
  - anaerobically digested 824
  - CO<sub>2</sub>, *see* CO<sub>2</sub>
  - coke-oven 785
  - cushion 828
  - greenhouse, *see* greenhouse gases
  - holders 664–665, 681–682
  - hot gas cleaning 531
  - hydrogen, *see* hydrogen
  - LFG 473, 512–513, 824
  - natural, *see* natural gas
  - pipelines 831–834
  - production 425–482
  - real gas behavior 662, 773
  - renewable 425
  - storage 514–515, 828–831
  - syngas, *see* syngas
  - town gas 651, 666
  - working 828
- gasification 452
  - biomass 531, 824–825
  - coal 802, 834
  - distillation residues 623
- gasoline
  - power density 199
  - , *see also* fuels
- GDP (gross domestic product)
  - BRICS 140
  - China 29, 36–37, 896
  - Developing World 138
  - South Korea 5
  - sustainable global energy system 97
- GEA (Global Energy Assessment) report 851
- gearbox
  - marine energy systems 361–363
  - wind generators 250, 272
- gearless-generator arrangement, gearbox 364
- generation
  - distributed 143, 405
  - fluctuations 199–200
  - “generation valleys” 784
  - hot water 922–926
  - mandating 148
- generator
  - DIG/DFIG 250–252, 272
  - radial flux 251
- geographic equity 149
- geographical factors 806
- geological storage 629–657, 828–831
  - near-surface 638
- geothermal power 339–350
  - continuous recharge 345
  - economic feasibility 346
  - environmental impact 346–350
  - fluids 343
  - seismic risk 347
  - supply potential 110
- German Advisory Council on Global Change (WBGU) 121, 123
  - guard rails concept 144–145
- German building energy code 880
- GermanHy study 206
- Germany
  - CO<sub>2</sub> emissions 196–197
  - end energy carriers 621
  - geological storage 636–639

- hydrogen pipelines 208–209
- natural gas 780, 832
- offshore wind power 267
- overlay grid 719
- primary energy supply 621
- RE 500–507
- resource mix 517
- seismic activity 636
- supply pattern 405
- TSOs 502–503
- GHG, *see* greenhouse gases
- GHSV (gas hourly space velocity) 822
- Giddens, Anthony 124
- GIGACELL Ni–MH batteries 24
- GILs (gas insulated lines) 711–712
- glass-based modules 293
- glass fiber enforcement 248
- glass production 922
- Global Energy Assessment (GEA) report 851
- global energy demand 108
- global energy supply 112
- global energy system, fully sustainable 93–117
- global food production 487–490
- global freshwater use 120
- global guard rails 145–147
- global hydropower potential 143
- global resources, biomass 485–497
- Global Trade Analysis Project (GTAP) 33
- global value research 131
- Global warming potential (GWP) 197
- global weather model, Reanalysis 606
- global ..., *see also* World ...
- Goulas hydropower plant 613–615
- government-driven strategies, South Korea 5–7
- gradient load 406, 408–410
- gradient pressure 774
- grain, world production 488
- graphene 586
- graphite 444
- gravimetric energy density 208
- gravity base foundations 276, 362
- “Great Transformation” 121
- Green Energy Revolution (Japan) 19
- green energy strategies
  - China 29–46
  - diverging objectives 74
  - Japan 13–27, 18–22
  - nuclear power technology 17
  - South Korea 3–11
- green growth 133
- green lifestyle, China 905
- green technologies, revenue potential 69
- Green Technology Center Korea (GTC-K) 10
- greenhouse gases (GHG)
  - biofuel production 536–540
  - biomass conversion 540–541
  - emission reduction 195
  - emissions in CSP plants 312
  - GWP 197
  - hydropower 396–397, 399–400
  - industrial sector 934–935
  - South Korea 5
  - transport emissions 851–852
  - well-to-wheels emissions 805–806
  - , *see also* CO<sub>2</sub>
- grid
  - AGC 612–613
  - cost 83, 89
  - distribution 731–732
  - electrical/thermal 569
  - European 275, 729
  - extension 73
  - hydrogen 209
  - infrastructure 246
  - IRENE-40 735, 747
  - load balancing 217–240
  - meshed DC 718
  - micro- 732
  - natural gas 832
  - North Sea 63–64
  - offshore 359
  - overlay 709, 719
  - stabilization 439
  - power management 226
  - services 600
  - “smart”, *see* “smart grids”
  - stabilization 436
  - sub-sea electricity 61
  - “super” 709
  - sustainable global energy system 112–113
  - technologies 69
  - transmission components 709–721
  - UCTE/ENTSO-E 729–730
  - vertical grid load 204
  - ZEB connection 877
- gross domestic product (GDP)
  - BRICS 140
  - China 29, 36–37, 896
  - Developing World 138
  - South Korea 5
  - sustainable global energy system 97
- gross power generation, Germany 517
- ground source heat pumps (GSHP) 57
  - “smart grids” 761
- GROWIAN wind turbine 180

- growth potential
  - biomass 494, 515
  - food production 490
  - hydropower 385–388
- GTAP (Global Trade Analysis Project) 33
- GTCC (gas turbine combined cycle) plant 18
- guard rails concept, global 145–147
- guide vanes 600
- GWP (global warming potential) 197
- h**
  - Haber–Bosch process 694–696, 700–701
    - efficiency 696
  - Halle mining site 644
  - hard coal 416
  - head 381
  - headrace 389
  - health impact 145
  - heat
    - binary-cycle exchangers 341
    - capture 165
    - demand 900
    - diversified water heater demand 750
    - heat–electricity interface 87
    - utilization 517
    - waste 557
    - waste heat utilization 58, 177
  - “heat grazing”, rotational 348
  - heat of vaporization 669–670
  - heat pumps (HP) 57, 101
    - gas 790
    - “smart grids” 761–762
  - heat recovery steam generator (HRSG) 316
  - heat storage 561–563
    - and utilization 517
    - CSP 178
    - media 165–168
    - , *see also* thermal storage
  - heat-transfer fluids (HTF) 307, 314–315
    - air 461–465
    - molten salts, *see* molten salts
    - sensible heat storage 326
    - sodium vapor 466
    - solar thermal methane reforming 461–465
    - solar tower systems 321
    - solid particles 467–468
  - heat-transfer sections 177
  - heated reactors 461–468
  - heating
    - Chinese buildings 899
    - combustion systems 835
    - district 88, 413–415
    - efficiency 901
    - Northern China 900–902
    - overheating 900–901
    - reheating 173, 177
    - REHVA 875
    - residential 203, 801
    - SHP 924–926
    - solar thermal collectors 884–885
    - solar water heater 142, 151–152
  - heating value, hydrogen 222
  - heavy petroleum 624
  - HEFA (hydrotreated esters and fatty acids) 529
  - heliostats 163, 320, 457
    - fields 464
  - helium, liquid 671
  - HER (hydrogen evolution reaction) 442–443
  - hetero-junction cells 297
  - high calorific value gas (H gas) 774–775
  - high-enthalpy systems 349
  - high-flow season 388
  - high-performance solar modules 297–298
  - high-pressure tubes 663
  - high-temperature superconducting (HTS)
    - cables 711–712
  - high-temperature superconducting (HTS)
    - motors 917
  - high-temperature water electrolysis (HTE)
    - 436–438, 818–819
  - high voltage AC (HVAC) cables 271
  - high-voltage DC (HVDC) 727
    - and AC lines 736–739
    - cables 274–275
    - converters 715
    - interconnectors 64
  - higher heating value (HHV) 692–693
    - hydrogen 429–430
  - highest regulated water level (HRWL) 607–609
  - highly energy-intensive materials,
    - substitution 932
  - hind casting 274
  - Hinshelwood, *see* Langmuir–Hinshelwood
    - mechanism
  - HMC fuel cell vehicles 183–194
  - Hohen Neuendorf school 884
  - Holen PSH plant 609–611
  - holistic approach 228
  - Honda FCV 22–23
  - honeycombs, ceramic 458, 468–469
  - horizontal-axis turbine 361–363, 365, 367–370
  - horizontal tanks 672
  - HOT ELLY 436, 818
  - hot gas cleaning 531
  - hot sedimentary aquifer (HSA) 339
  - hot tapping 778

- hot water
    - domestic 561, 903
    - generation 922–926
    - long-term storage 571–572
  - hourly grid load balancing 230–232
  - house-use ESS 592
  - HP (heat pumps) 57, 101
    - gas 790
    - “smart grids” 761–762
  - HRSG (heat recovery steam generator) 316
  - HRWL (highest regulated water level) 607–609
  - HTE (high-temperature water electrolysis) 436–438, 818–819
  - HTF, *see* heat-transfer fluids
  - HTS (high-temperature superconducting)
    - cables 711–712
  - HTS (high-temperature superconducting)
    - motors 917
  - hub height 247
  - human-powered travel 103
  - HVAC (high voltage AC) cables 271
  - HVDC, *see* high-voltage DC
  - hybrid cars, plug-in 106, 587, 731, 859
  - hybrid operation, CSP 172
  - hybrid power plants, geothermal power 341
  - hybrid tower concepts, wind power 253
  - hydraulic drive system 313
  - hydraulic yawing system 367–369
  - hydro-thermal carbonization (HTC) 508
  - hydrocarbons
    - fuels 619–628
    - light 798
    - solar conversion 460
    - sugars to 533
  - hydroelectric turbines 371
  - hydrofoil, oscillating 366
  - hydrogen
    - and ammonia 691, 699–700
    - as enabler for RE 195–216
    - bio- 512–513
    - chemical storage 619–628
    - compressed gaseous storage 662–668
    - compressors 662–663
    - concentration in gases 786
    - conversion 797–798, 835
    - cost 223–224
    - cryogenic liquid storage 669–675
    - delivery 796–802
    - direct-hydrogen FC systems 836
    - distributed storage 678
    - electrolysis production, *see* electrolysis
    - energy carrier 438, 630
    - FCV efficiency 795, 797
    - feed to natural gas grid 833
    - fuel upgrading 622
    - gas holders 665–666
    - grid load balancing 217–240
    - heating value 222, 429–430
    - Japan 22–23
    - leakage 188
    - liquid 208, 630
    - “merchant” 807
    - near-surface bulk storage 659–690
    - near-zero emission production 800–801
    - ortho-/para- 669–670
    - petroleum refining 623–624
    - pipeline system 208–209, 833–834
    - power density 198–199
    - power-to-gas 425
    - production 796–802
    - public acceptance 25
    - RPH 838–841
    - solubility in water 644
    - storage 208–209, 564, 679
    - storage medium 426
    - strategic approach 200
    - supply 211, 805–806
    - synfuel 624
    - synthetic methane production 788
    - tank embrittlement 674
    - transition from natural gas 629–657
    - vehicles 796–797
  - hydrogen evolution reaction (HER) 442–443
  - hydrogen infrastructure 192, 795–811
    - cost estimates 210–213
  - hydrogen refueling 190–191, 801
    - design considerations 806–807
    - filling stations 210
  - hydrogenation 622
    - catalytic 820
  - hydrological cycle 382
  - hydropower 381–401
    - cost 394–396
    - economic feasibility 385–386
    - efficiency 381
    - environmental impact 387–388, 399
    - flexible 612–615
    - global potential 143
    - pumped storage, *see* pumped storage hydropower
    - supply potential 109
  - hydrotreated esters and fatty acids (HEFA) 529
  - hydrotreated vegetable oils (HVO) 529
- i**
- I CAPEX 748, 763–765



- IAEA (International Atomic Energy Agency) 26
- IBC (interdigitated back contact) 297–298
- ICCT (International Council on Clean Transportation) 862
- ice formation, wind turbines 256
- ICE (internal combustion engines), passenger car powertrains 836–838
- ICT 515, 729
  - “smart grids” 744–746, 749
- ideal gas law 775
- idle losses 854
- IEA (International Energy Agency) 95
  - geothermal power Roadmap 339, 343–344
  - Technology Roadmap 494
  - Wind Task 258
  - World Energy Outlook 824, 891, 913
- IGA (International Geothermal Association) 339, 343–344
- IHA (International Hydropower Association) 398–399
- incentives, financial 151–152, 343
- incident angle correction 318
- incident solar radiation per year (ISR) 296
- inclination of roof 292
- India 140
- indirect land use change (iLUC) 538–539
- indirectly heated reactors 461–468
- indirectly irradiated solar receivers 458
- indoor temperature control 905
- induction generator, doubly fed 250–252, 272
- industrial GDP 896
- industrial reformers 455
- industrial round wood 493
- industries
  - as CO<sub>2</sub> source 825–826
  - domestic 149
  - energy-intense 71
  - energy savings potentials 913–936
  - energy transition 67–74
  - intensity 98
  - non-energy-intensive sector 914
  - renewable energy 9
  - secondary 895
  - sustainable global energy system 97–99
- industry standards 152
- inertia of the system 412
- information management 746
- infrastructure
  - compatibility 806
  - full-scale 804
  - grid 246
  - hydrogen 192, 210–213, 795–811
  - natural gas 791
  - new model 143
  - North Sea 51
  - public acceptance 417
  - scaled-up 804
  - societal transition 125–127
- Infrastructure Roadmap for Energy Networks in Europe (IRENE-40) 735, 747
- inlet temperature, CSP 168–169
- innovations, disruptive 360
- in/out storage 571
- inspection tools, pipelines 781
- institutional change 133
- institutional perspective 129–131
- institutionalists 132–134
- insulated gate transistors/thyristors 716
- insulating duct 175–176
- insulation 900
  - hydrogen storage tanks 674
  - XLPE 711–712, 716
  - , *see also* zero-energy buildings
- integral friction coefficient 775
- integrated solar combined cycle (ISCCS) plants 315
- intensity
  - capital 85
  - carbon 29
  - energy 102, 105–106, 856, 899–900, 903, 907
- inter-machine spacing 274
- interconnector cross-border 733
- interdigitated back contact (IBC) 297–298
- interlinkages, structural 124–125
- intermittent RE, *see* variable RE
- internal combustion engines (ICE), passenger car powertrains 836–838
- internal currents 219
- International Atomic Energy Agency (IAEA) 26
- International Council on Clean Transportation (ICCT) 862
- International Energy Agency (IEA) 95
  - geothermal power Roadmap 339, 343–344
  - Technology Roadmap 494
  - Wind Task 258
  - World Energy Outlook 824, 891, 913
- International Geothermal Association (IGA) 339, 343–344
- International Hydropower Association (IHA) 398–399
- International Solar Energy Society (IRENA) 153
- internationalization 129
- interstitial sites 675

- intra-day markets, liquid 89
  - inward investment, marine energy 354
  - ion-conducting solid electrolytes 583
  - IPCC emission reduction targets 893
  - IPCC SRREN report
    - geothermal power 339
    - offshore wind power 267, 278
  - IR filling nozzle 191
  - iridium catalysts 442–443
  - Irish–Scottish Links on Energy Study (ISLES) 61–64
  - Irish Sea 62
  - iron production 922
    - , *see also* steel ...
  - irreversibilities, thermodynamic 557
  - irrigation 387
  - ISCCS (integrated solar combined cycle) plants 315
  - ISES White Paper 137
  - isothermal compression 662
  - ISR (incident solar radiation per year) 296
  - Ivanpah solar tower system 322–323
- j**
- jacket foundations 267, 276
  - Japan
    - green energy strategies 13–27
    - nuclear power technology 17
    - offshore wind power 268
  - jobs from RE, *see* employment opportunities
  - Joule–Thomson expansion 670
  - Juklavatn reservoir 607–608
- k**
- K, *see* potassium
  - karst 642
  - Kennedy Space Center (KSC) 630
  - kiln technology 929
  - Kölbel–Schulze methodology 543
  - Korea, South, *see* South Korea
- l**
- L gas (low calorific value gas) 774
  - lamps, LED 906
  - land
    - arable 490
    - footprint 343
    - use 146, 525
  - land use change (LUC) 120, 538–539
  - landfill gas (LFG) 473, 512–513, 824
  - Langmuir–Hinshelwood mechanism 698
  - large-area coating technologies 288–290
  - large-scale CSP plants 159–182, 461
  - large-scale hydrogen technologies 217–240
  - large-scale methanation plants 839
  - large-scale storage and balancing 605
  - latent heat storage 326–327, 562
  - LAVE-Trans (Light-duty Alternative Vehicle Energy Transitions) model 862–869
  - laws and equations
    - Barlow law 777
    - Bernoulli equation 786
    - Butler–Volmer equation 220
    - Darcy–Weissbach equation 773–774
    - ideal gas law 775
    - Le Chatelier principle 820
    - net social value 858
    - second law of thermodynamics 426
    - Tafel equation 220
  - LCC (line-commutated converter) technique 716
  - leakage, hydrogen 188
  - leakage effects 43
  - LED lamps 906
  - lenses, optical 317
  - Leontief CES 33
  - Leuna plant, Haber–Bosch process 695
  - level fluctuations, reservoir water 609–611
  - levelized cost of energy (LCOE) 245, 357–360
    - fossil power plants 420–421
    - hydropower 394–395
  - levelized electricity cost (LEC) 325
  - LFG (landfill gas) 473, 512–513, 824
  - LHV (lower heating value) 661
  - LIDAR, load prediction 254–255, 274
  - life-supporting systems, natural 147
  - lifecycle assessment (LCA)
    - biofuel production 537–538
    - hydropower 395, 399
  - lifestyle, green 905
  - light-duty vehicles 863
    - LAVE-Trans model 862–869
  - light hydrocarbons 798
  - lignite power plants 507
  - lignocellulosic bioethanol 523, 539
  - line-commutated converter (LCC) technique 716
  - line loading 736–739
  - linear concentration 162–163
  - linear Fresnel mirrors 309, 317–320, 457
  - liquefaction
    - hydrogen 208
    - plants 670–671
  - liquid biofuels 511–512, 516, 625–626
  - liquid-dominated systems 349
  - liquid helium 671
  - liquid hydrocarbon fuels 620
  - liquid hydrogen (LH<sub>2</sub>) 630

- cryogenic storage 669–675
  - liquid intra-day markets 89
  - liquid materials, sensible heat storage 326
  - liquid water, formation energy of 426
  - liquids, organic 660
  - lithium–air batteries 585–587
  - lithium–ion batteries 185, 581–582, 853
    - energy storage systems 591–592
    - power density 198
  - lithium–sulfur batteries 584–585
  - lithium super-ionic conductor glass film 585
  - living standards, China 902
  - load
    - aerodynamic 279
    - alternating 778
    - following 408–410
    - leveling 591
    - local network peak 757
    - prediction 254–255, 274
    - (un)controlled profile 751
  - load balancing
    - grid 217–240
    - hydropower 398
    - ZEB 879
  - load factor 742
  - loading, line 736–739
  - local overexploitation 119
  - local storage, liquid hydrogen 671–672
  - locational specificity 84
  - long-distance trucks 106
  - long-run marginal cost (LRMC) 339, 346
  - long-term hot water storage 571–572
  - long-term stability, subsurface storage 635
  - losses 715
    - biodiversity 120
    - boil-off 670
    - drivetrain 854
    - engine 854
    - gas 635–636
    - idle 854
    - loss-aversion behavior 869
    - ohmic 445, 725, 728
    - parasitic 854
    - power-to-wheel 854
    - thermal 319, 325
    - wake 255
  - low calorific value gas (L gas) 774
  - low-carbon development 30
  - low-carbon systems 743–744
  - low-flow season 389
  - low-head projects 391
  - low-interest loans 151
  - low-temperature fuel cells 218
  - lower heating value (LHV) 661
    - hydrogen 430
  - lowest regulated water level (LRWL) 607–609
  - LRMC (long-run marginal cost) 339, 346
  - lubrication, sea-water 369
  - LUC (land use change) 120, 538–539
- m**
- magnetic flux line (MFL) 781
  - magnets
    - PM generator 250–252, 272–273, 365
    - rare earth 273
  - maintenance, offshore wind power 276–277
  - management, adaptive 347
  - mandating capacity/generation 148
  - manual reserve 411
  - marginal net present social value 858
  - marine ecosystems 146
  - marine energy 351–379
    - cost 353
  - Marine Energy Array Demonstrator (MEAD) 355
  - Marine Energy Technology Roadmap 357
  - Marine Renewables Commercialization Fund (MRCF) 355
  - market design 73
  - market options, bulk power transport 732
  - market reform, EMR 352
  - markets
    - constraints 406–407
    - distributed 768–770
    - flow-based coupling 86
    - liquid intra-day 89
  - markup 38
  - massive integration, PV electricity 303
  - maximum acceptable storage costs 573–574
  - Measure–Correlate–Predict (MCP) 274
  - mechanical–thermal treatment, biomass 531
  - membranes
    - CCM 434, 442
    - electrolyzers 221
    - membrane electrode assembly (MEA) 817
    - Nafion 697, 700, 817
    - proton-conducting 427
  - “merchant” hydrogen 807
  - merit order 79, 406
  - meshed DC grids 718
  - metal hydrides
    - hydrogen storage 675–676
    - Ni–MH batteries 23–24
  - metal liner 664
  - metal surfaces, heat capture 165
  - metallic foam absorbers 473–474
  - meteoric water 646
  - meteorological models 88

- meteorology, offshore 274
  - methanation 787–788
    - CO<sub>2</sub> 204, 210
    - large-scale plants 839
    - power-to-gas 820
  - methane
    - and ammonia 691, 702
    - catalytic CO<sub>2</sub> hydrogenation 820
    - CHARM® 781–782
    - cracking 476
    - feedstocks 453
    - physical properties 775
    - power-to-gas 425
    - RPM 823, 838–841
    - synthetic 788
  - methane reforming
    - dry 451
    - scale-up 476–477
    - solar thermal 451–482
    - steam 451, 453
  - methanol 533
    - and ammonia 691, 702
  - MFL (magnetic flux line) 781
  - micro-CHPs 790, 792
  - micro-grids 732
  - microeconomic development 145
  - migration, fish 391
  - mild steel 777
  - mineral oil
    - sensible heat storage 326
    - subsurface storage 632
  - minerals, water-soaked 642
  - mining sites, abandoned 644–646
  - Ministry of International Trade and Industry (MITI) 15
  - mirror shape 163–164
  - mixing, vertical 603, 611
  - mobility
    - electro-/petro- 851–873
    - zero-emission 183, 217, 587
    - , *see also* vehicles, transport
  - modeling
    - CGEM 31–39
    - German wind power potential 205–207
    - hydrogen electrolysis 224–226
    - improved meteorological 88
    - ISLES 61–64
    - mobility transition 862–870
    - Reanalysis global weather model 606
    - sustainable global energy system 94–95
  - modules, glass-based 293
  - Molasse Basin 640
  - molten salts 166–167
    - as heat-transfer fluid 466–467
    - nitrate 315–317
  - monocrystalline wafers 286
  - monolithic ceramic structures 458
  - monopile foundations 276
  - monorail train 24
  - motorized transport 851
  - MRCF (Marine Renewables Commercialization Fund) 355
  - multicatalyst systems 441
  - multilayer insulation 674
  - multilevel converter 720
  - multiple-junction solar cell 284
  - multiple rotors, marine energy 359
  - multitube receiver 319
  - “must-run” RE 406
- n**
- N-1/N-2 769
  - Na super-ionic conductor (NASICON) 587
  - Na, *see also* sodium
  - nacelle 361–362, 368
  - Nafion membrane 697, 700, 817
  - nanodesigned catalysts 443
  - nanostuctured carbon materials 586
  - NASA spherical storage tank 673
  - national RE 144
  - National Renewable Energy Action Plan (nREAP) 502
  - National Renewable Energy Laboratory (NREL) 184, 540, 817
  - natural gas
    - CNG 787, 792, 836–837
    - contaminated 473
    - cost 210–212
    - cracking 452
    - (de)central conversion 835
    - ex- and importers 4
    - German industry 780
    - grid 832
    - hydrogen feed-in 212, 833
    - hydrogen production 802
    - infrastructure 791
    - pipeline systems 668, 773–794, 831–833
    - power plants 200
    - R&D 784–790
    - storage 631–633
    - substitute 624–625
    - subsurface storage 632
    - synthetic 511, 532, 823
    - transition to hydrogen 629–657
  - natural life-supporting systems 147
  - near-surface bulk storage
    - cost 677–679
    - economic feasibility 677–679

- Germany 638
- hydrogen 659–690
- near-zero emission, hydrogen production 800–801
- near zero-energy concept 102
- nearly/net-zero energy buildings 875–889
- Nesjen reservoir 607–608
- net mass capacity 681–682
- net present value (NPV) 858
- net social value (NSV) 858
- networks
  - asset utilization 743
  - ENSG 60
  - externalities 857
  - peak load 757
  - transmission 723–739
- “New Economics” 123
- new materials development, EV 589
- New Zealand, geothermal power 340
- next generation turbines, offshore 278–280
- Ni–MH batteries 23
  - GIGACELL 24
- nickel
  - catalysts 454
  - electrodes 441
  - Raney 226
- night-time operation, solar power 161–162, 178
- nitrate salts 317
  - sensible heat storage 326–327
- nitrogen
  - cycle 120
  - emissions 495, 698
  - fixation 693
  - nitrogen-doped carbon materials 587
  - nitrogen–hydrogen compounds 691
- “no-coal villages” 907
- “No Policy” 35
- noble metal catalysts 816
- noise, wind turbines 256
- nominal operation cell temperature (NOCT) 291
- non-cyclic changes 619
- non-dispatchable RE, *see* variable RE
- non-energy-intensive industry sector 914
- non-fossil sources of primary energy 29
- non-residential buildings 886
- non-structured reactors 476
- NorNed cable 732
- North German Basin 640
- North Sea
  - energy infrastructure 51
  - grid 63–64
  - offshore wind power 267–268, 607
- Northern ISLES 63
- Norway
  - geological storage 646
  - hydropower 605
  - PSH 601
- “Norwegian arc process” 694
- NOW study 440
- nozzle, IR filling 191
- NPV (net present value) 858
- nREAP (National Renewable Energy Action Plan) 502
- NREL (National Renewable Energy Laboratory) 184, 540, 817
  - chart of cell efficiencies 303
- NSV (net social value) 858
- nuclear accidents 243
  - , *see also* Fukushima
- nuclear power
  - China 893
  - Fukushima 13–14, 16, 67
  - Japan 17, 19
  - plant flexibilization capability 505
  - Scotland 56–57
- number of blades 247–248
- o**
- Obama, Barack 269
- ocean
  - acidification 120
  - energy, *see* marine energy
  - sink 491–492
- OER (oxygen evolution reaction) 443
- off-board storage, regenerable 659
- off-grid applications 819
- offshore grid, marine energy 359
- offshore meteorology 274
- offshore resources, RE 53–54
- offshore wind power 203, 265–281
  - capacity growth 266
  - cost 271
  - CRTF 269
  - next generation turbines 278–280
  - synergy with marine energy 360
- ohmic losses 445, 725, 728
- oil crisis, second 431
- oil fields, storage sites 640–642, 829
- oils
  - crude 4, 632
  - hydrotreated vegetable 529
  - mineral 326
  - palm 540
  - substitution of oil-based fuels 206
  - vegetable 624
- on-board storage 659

- on-site generation 881
- on-site H<sub>2</sub> production 800, 803
- on-site storage capacity 878
- one-way storage 571
- onshore hydroelectric turbines 371
- onshore wind power 203, 243–263
- open-center turbines 365
- “open-loop” systems 452
- operating pressure 667
  - gas holders 682
- operating temperature, solar tower systems 325
- operational strategies
  - hybrid 172, 324
  - night-time operation 161–162, 178
  - PSH 601–602
  - turbines 390
- OPEX 419–421, 544
- “smart grids” 748, 763–765
- optical efficiency 318
- optical lenses 317
- optical path 318
- optical quality, parabolic trough 314
- optimization
  - charging 756
  - electric drives 919–922
- organic liquids 660
- organic photovoltaics (OPV) 298–299
- organic Rankine cycles (ORC) 508
- ortho-to-para conversion, hydrogen 669–670
- oscillating hydrofoil 366
- oscillating water column 377
- oscillating wave surge converter 371–372
- overexploitation, local 119
- overhead lines 710
- overheating 900–901
- overlay grid 709
  - Germany 719
- overload, efficiency impact 440
- overpotentials 226, 429
- overtopping wave energy converter 378
- ownership
  - building floor space 897
  - equity 149
- oxygen evolution reaction (OER) 443
- ozone depletion, stratospheric 120
  
- p**
- packing, fuel cell stacks 184–185, 187
- palm oil 540
- paper, recycled 929–930
- paper industry 929–930
- para-hydrogen 669–670
- parabolic dish 309
- parabolic trough 164, 309, 312–317, 457
- parasitic currents 219
- parasitic losses 854
- partial load, electrolyzers 432, 435
- passenger car powertrains 836–838
- passive house concept 883
- passive wind 754
- PCM, *see* phase change material
- peak demand 741
  - “smart grids” 751
- peak electricity 230, 234
- peak load, local network 757
- peak shaving 591
- Pearl Street system 724
- pelletization 508
- pellets 416
- PEM (polymer electrolyte membrane)
  - electrolysis 433–436, 442
  - electrolyzers 439–440
  - power-to-gas 817–818
- PEMFC (polymer electrolyte membrane FC) 183
  - ammonia conversion 700–701
  - and Li–air batteries 586
- penetration rate 81
- performance
  - AWE 816
  - COP 571, 761
  - CSP technologies 311
  - electrolyzers 219–221, 224
  - rechargeable batteries 590
  - residential PV systems 292
  - seasonal 881
  - testing 188–191
- perlite vacuum insulation 674
- permanent magnet (PM) generator 250–252, 272–273
  - tidal energy 365
- permeability, rock structures 829
- petro-mobility 851–873
- petroleum
  - refining 623–624
  - (un)conventional 852
- PFPB (point feeder pre-baked) electrodes 928
- pH, electrolytes 433
- phase change material (PCM) 165–167, 178
  - carbonates 467
  - energy storage systems 562–563
- phase separator 174
- Phasor Measurement Unit (PMU) 729
- PHES (pumped hydro energy storage), *see* pumped storage hydropower
- PHEV, *see* plug-in hybrids
- phosphorus cycle 120

- photovoltaics (PV) 110, 883–887
  - building-integrated 292–294
  - concentrating 302–303
  - cost 290–291, 296, 301
  - organic 298–299
  - power density 198
  - R&D 300–301
  - semi-transparent modules 294
  - technological design 290–300
  - terawatt scale technology 283–306
  - thin-film 288–290, 294–295, 298–300, 302–303
  - ZEB 877
- pipe storage facilities 668
- pipeline systems
  - hydrogen 833–834
  - inspection tools 781
  - natural gas 773–794, 831–833
  - R&D 784–790
- pistons, reciprocating 662
- pitch system 254
- planetary boundaries 119–120
- planning permits 152
- plant capacity, biofuel production 534–535
- plates, bipolar 583
- platinum catalysts 442–443
- plug-in hybrids 106, 587, 731, 859
- plus energy buildings 875–889
- PM (synchronous permanent magnet)
  - generator 250–252, 272–273
  - tidal energy 365
- point absorber 374–375
- point concentration 162–163
- point feeder pre-baked (PFPB), electrodes 928
- policy
  - CAP 487
  - climate policy goals 30–31, 74
  - current policy assumptions 37–38
  - EGPS 47–48
  - green energy strategies, *see* green energy strategies
  - “No Policy” 35
  - polycentric approach 130
  - South Africa 154
  - TEN-E 747
- political participation 129
- “polluter pays principle” (PPP) 495
- pollution
  - air 146, 805–806
  - chemical 120
  - “poly-Si” 287
- polycrystalline wafers 286
- polyethylene, XLPE insulation 711–712, 716
- polymer electrolyte membrane FC (PEMFC) 183
  - ammonia conversion 700–701
  - and Li-air batteries 586
- polymer electrolyte membrane (PEM)
  - electrolysis 433–436, 442
  - electrolyzers 439–440
  - power-to-gas 817–818
- polysulfide dissolution 584
- population growth 97
  - China 897
- “porcupine” concept 474–475
- pore-space storage sites 639–640, 829–830
- porous materials, heat capture 165
- potassium hydroxide (KOH) 815
- potassium nitrate 315–317
- potential feed 833
- “Potential Fernüberwachung” 783
- poverty alleviation 142–143
- power
  - bulk transport 723, 732
  - density 197–199
  - electric, *see* electric power
  - export 614
  - geothermal, *see* geothermal power
  - grids, *see* grid
  - hydro-, *see* hydropower
  - losses 715
  - management 226
  - nuclear, *see* nuclear power
  - reserve balancing 260
  - smoothing 24
  - solar, *see* solar power
  - thermal, *see* thermal power
  - transformers 714
  - up-rating 359
  - wind, *see* wind power
- power plants
  - flexibility potential 409, 505
  - fossil 403–422
- power rating 247
  - energy storage systems 561
  - offshore 272
- power system services
  - CSP 155
  - fossil power plants 410–413
  - hydropower 398
- power-to-gas 425, 571–572, 813–848
- power-to-wheel losses 854
- power tower, *see* solar tower systems
- power transmission extensions, Germany 719
- power/capacity ratio 325
- powertrains
  - alternative 857

- passenger car 836–838
- “predict and provide” philosophy 744
- present value annuity factor (PVANF) 572–573
- pressure cycles 778
- pressure gradient 774
- pressure level, subsurface storage 634
- pressure swing adsorption (PSA) 696, 700–701
- pressure vessels, hydrogen 663–668
- pressurized electrolyzers 227, 441
- price pressure 44
- primary energy
  - China 895
  - credits 885
  - electric power generation 201
  - Germany 621
  - nonfossil sources 29
  - sectoral demand 914
- primary reserve/control 411
- PRIMES baseline 917–918, 932
- problem shifting 126
- process chain alternatives 838–841
- Production Tax Credit (PTC) 151, 244, 257
- profile
  - cost 78–82, 85–88
  - (un)controlled load 751
- project planning 51
- “proof of value” point 358
- propane 692
- proton conductors
  - membrane 427
  - solid-state 697
- PTC, *see* Production Tax Credit
- public acceptance 68
  - green energy 25
  - infrastructure projects 417
- public buildings 904–906
- pulp 492, 929–930
- pulverized coal 417, 508
- pump, wave-powered 371
- pumped storage hydropower (PSH) 389, 559, 567, 574–575, 597–618
  - deployment 398, 598–599
  - environmental impact 602–604, 611–612
  - existing reservoirs 602–603
  - R&D 604
- PV, *see* photovoltaics
- PVcomB 289–290
- pyrolysis 454
  - fast 511–512

**q**

Qinhuangdao, Shimen Village 908

quality, natural gas 786

quantification, VRE market value 77–83

quickly responding capacity 85

quotas 148

- wind power 257

**r**

radial flux generator 251

radial systems 724

radiation, solar, *see* solar radiation

radioactivity 17

rainforest destruction 415

ramping down 330

Raney nickel 226

Rankine cycle 172–174

ranking, clean technology 9

rapeseed 540

rapid system response 436

rare earth magnets 273

R&D, *see* research and development

reactive reserves 412

reactors
 

- bell-jar solar reforming 469
- biological methanation 788
- directly irradiated 468–476
- indirectly heated 461–468
- non-structured 476
- solar receiver/reactor concepts 456–460
- solar-thermal aerosol 468
- three-phase 821

real gas behavior 662, 773

real-time demand–supply balancing 743–744

real-world experiments 131

Reanalysis global weather model 606

rebound effect 126

receivers
 

- cavity 477
- development 314
- dish Stirling 164
- (in)directly irradiated 458
- solar receiver/reactor concepts 456–460
- tubes 165, 175
- vacuum/atmospheric 319
- volumetric 477

reception point 256

rechargeable batteries 23, 581–587
 

- applications 580
- EV 587
- performance 590
- R&D 581–587
- “smart grids” 755–759

reciprocating pistons 662

recovery
 

- CO<sub>2</sub> 826–827



- energy 698–700
- rectification 227
- recycling 98, 932
- paper 929–930
- redox-flow batteries 582–583
- energy storage systems 592–593
- reduction, selective catalytic 698–699
- refill, *see* drain and refill cycle
- refinery waste fuel gas 455
- refining, petroleum 623–624
- reflector materials 313
- reforming
  - bell-jar solar reforming reactor 469
  - DCORE 463–464
  - industrial reformers
  - methane, *see* methane reforming
  - SCORE 463–464
  - steam 623
  - thermodynamics 453–454
- refueling, hydrogen 190–191, 210, 801, 806–807
- regenerable off-board storage 659
- regional factors 806
- regulation, heating 900–901
- reheating 173, 177
- REHVA (European Association of Refrigeration, Heating and Ventilation) 875
- reinforcement cost 756–759
- relative discharge 390
- reliability, EV 589
- remote monitoring, CHARM® 781–782
- Renewable Energies Act, *see* EEG
- renewable energies (RE)
  - base-load 342
  - China 30–31
  - comprehensive transition concept 119–136
  - consumption 3
  - cost competitiveness 40
  - cost reduction 42–43
  - current policy assumptions 39–40
  - demand prediction 7
  - deployment potentials 109
  - Europe 404
  - financial support 407
  - generation fluctuation 199–200
  - generation targets 37–38
  - Germany 500–507
  - hydrogen, *see* hydrogen ...
  - in the Developing World 137
  - integration with electrolyzers 819–820
  - Japan 18–22
  - load following 409
  - methane production 565
  - national 144
  - offshore resources 53–54
  - photovoltaics, *see* photovoltaics
  - poverty alleviation 142–143
  - power density 197–199
  - public acceptance 25
  - rapid diffusion 21
  - residual power 421–422
  - Scottish routemap 52–53
  - South Korean industries 9
  - technical and economic potential 141–143
  - transport sector 105
  - variable, *see* variable RE
  - wind power, *see* wind power
- renewable energy certificates (REC) 6
- renewable gases 425
- “renewable methane”, *see* biomethane
- Renewable Obligation Certificates (ROC) 352
- Renewable Portfolio Standard (RPS) 5, 246
- renewable power hydrogen (RPH) 838–841
- renewable power methane (RPM) 823, 838–841
- renovated buildings 886
- repair delay time, expected 277
- Republic of Korea, *see* South Korea
- “Reregulation Support Centre” 9
- research and development (R&D)
  - biofuels 526–527
  - Developing World 153
  - natural gas pipeline systems 784–790
  - PSH 604
  - PV 300–301
  - rechargeable batteries 581–587
  - solar thermal methane reforming 460–476
  - strategies 7–9
  - water electrolysis 438
- reserve balancing power 260
- reserves
  - geothermal 344–345
  - primary/secondary reserve/control 411
  - strategic 631
- reservoirs 383, 387
  - water level fluctuations 609–611
- residential floor space per capita 99
- residential grid-connected PV system 290–292
- residential heating 203
  - tri-generation system 801
  - , *see also* district heating
- residential PV systems, cost 290–291
- residual demand curve 79
- residual generation capacity 81
- residual load 80
- residual power 421–422
- resin-impregnated continuous filament 664

- resource mix, Germany 517
- retail electricity market 769
- revenue, hydrogen 211
- reversible cells, solid oxide 437
- reversible pump turbines (RPT) 597–600
- risk-adjusted cost 259
- risk management 145
- rivers
  - flow variation 384
  - protection 146
- Rjukan PSH plant 609–611
- robustness of technology, solar power 161, 169–170
- ROC (Renewable Obligation Certificates) 352
- rock caverns, hydropower 391–392
- rock salt 647
- rock structures, permeability 829
- rocks, near-surface 638
- roll-to-roll processes 295
- roof inclination 292
- roof installation 290–292
- “rotational heat grazing” concept 348
- rotors
  - materials 248
  - multiple 359
- round wood, industrial 493
- RPH (renewable power hydrogen) 838–841
- RPM (renewable power methane) 823, 838–841
- RPS (Renewable Portfolio Standard) 5, 246
- RPT (reversible pump turbines) 597–600
- run-of-river hydropower 388
- runoff 385
- rural residential buildings 906
- Russia 140
- Russian natural gas 775
  
- s**
- S CAPEX 748, 763–765
- SA (smart appliances) 752–753
- Saccharomyces cerevisiae* 529
- safety
  - EV 589
  - safety factor 777
  - subsurface storage 635
- salt caverns 203
  - storage sites 646–652, 830–831
- salts
  - molten, *see* molten salts
  - nitrate 317, 326–327
- sandstone 640
- saving
  - active energy 21
  - conversion “savings” 934
  - energy in buildings 99, 891–911
  - industrial energy savings potentials 913–936
- scale-up
  - infrastructure 804
  - PEM electrolysis 436, 442
  - solar methane reforming 476–477
  - solar thermal power 331
- scheduling, stochastic/deterministic 767
- Scholz, Roland 122
- school buildings, ZEB 884
- Schulze, *see* Kölbel–Schulze methodology
- SCORE (single-coil reformer) 463–464
- Scotland
  - electric power 47–65
  - marine energy 351
  - SEA 50
- Scotrenewables Tidal Turbine (SRTT) 370
- sea crossings 733
- SEA (Strategic Environmental Assessment) 50
- sea-water lubrication 369
- sealing, subsurface storage 633, 650
- seasonal buffers 629
- seasonal performance 881
- seasonal turbines 601
- second law of thermodynamics 426
- second oil crisis 431
- secondary batteries, *see* rechargeable batteries
- secondary industries, China 895
- “sector leakage” 42
- sectoral primary energy demand 914
- security
  - financial 149
  - supply 68, 352–353, 412–413
- SEGS 312
- seismic risk
  - geothermal power 347
  - Germany 636
- selective catalytic reduction (SCR) 698–699
- self-consumption 879
- SEMI International Roadmap for Photovoltaics 298–299
- semi-transparent solar modules 294
- semiconductors
  - compound 302
  - direct 288
- sensible heat storage 326, 561–562
- sensitivity analysis 869
- separate heat production (SHP) 924–926
- separate turbines 599
- separators 581
  - plates 443–445

- sequestration, carbon 798
- “shadow price” 865
- Shimen Village 908
- shock waves 778
- shore connection 274–276
- “short-circuit effect” 412
- short-term regulation 601
- short-term supply curve 79
- shut-down and sealing, subsurface storage 633, 650
- Si hetero-junction cells 297
- Si wafer-based solar cells, crystalline 286–288, 297–298, 301
- SiC foams 473
- significant wave heights 276
- simple metal hydrides 675
- simulated wind power production 607
- simulation, composite design 225
- single-circuit AC lines 736–739
- single-coil reformer (SCORE) 463–464
- single-junction solar cell 284
- single-tube receiver 319
- site assessment, wind power 273–274
- smart appliances (SA) 752–753
- smart charging, EV 755–759
- “smart grids” 571, 709, 741–771
  - cost 754
  - energy storage 762–768
  - environmental impact 768
  - EV integration 755–760
  - ICT 744–746, 749
  - ZEB 882
- smart refrigeration (SR) 753–754
- smart wet appliances 752–753
- SmartSim® 784
- SMR (steam methane reforming) 451, 453
- SNG (substitute natural gas) 624–625
- SNG (synthetic natural gas) 511–513, 823
  - thermochemically produced 532
- social question 129
- societal transition 123–132
- societal willingness 858
- socio-economic balance 304
- socio-economic guard rails 145
- socio-economic structure, China 895
- socio-technical system 124
- sodium carbonate solution 826
- sodium nitrate 315–317
- sodium reflux heat pipe solar receiver/reformer 465–466
- sodium–sulfur (NaS) batteries 23, 583–584, 593–594
- sodium vapor, as heat-transfer fluid 466
- solar boiler 171, 176
- solar cells
  - crystalline Si wafer-based 286–288, 297–298, 301
  - dye-sensitized 298–299
  - efficiency limit 284
  - fabrication 284–290
  - flexible 294–295
  - hetero-junction 297
  - semi-transparent modules 294
- solar conversion, hydrocarbons 460
- Solar Decathlon Europe 2010 882
- solar dish collectors 477
- solar fields 164–165
- solar-hybrid operation 324
- solar-hydrogen stations 22–23
- solar power
  - CES production structure 34
  - China 31
  - CSH 110
  - CSP, *see* concentrating solar power
  - IRENA 153
  - night-time operation 161–162, 178
  - Spain 229
  - supply potential 110
  - , *see also* variable RE
- solar radiation
  - concentration 162–163
  - direct conversion 283
  - electric power 160
  - incident 296
- solar receivers
  - receiver/reactor concepts 456–460, 465–466
  - volumetric/tubular 458
- solar thermal methane reforming 451–482
  - R&D 460–476
- solar thermal power 307–338
  - aerosol reactor 468
  - capacity 139
  - collectors 884–885
  - cost 328–332
- solar tower systems 320–324
  - Solar Tower Jülich (STJ) 459
  - updraft 170
- solar water heaters (SWH) 142, 151–152
- SOLASYS reactor 471–472
- solid biofuels 510–511, 516
- solid electrolytes 583
- solid oxide electrolyte 427, 437
- solid oxide FC (SOFC) 923
- solid particles
  - as heat-transfer “fluid” 467–468
  - non-structured reactors 476
- solid-state proton conductor 697

- solid-state storage 677
  - sensible heat 326
- SOLREF reactor 472–473
- solubility, hydrogen in water 644
- SOLUGAS 323
- solution mining 649
- sound power level 256
  - wind turbines 247
- sources, CO<sub>2</sub> emissions 196
- South Africa 140
  - policies 154
- South Korea
  - geological storage 646
  - green energy strategies 3–11
  - offshore wind power 268
- Southern ISLES 63
- soybean 540
- space flight 673
- Spain
  - electric power 217, 228–229
  - solar tower systems 322–323
  - wind power 229
- spar and float 375
- specific energy consumption 428
  - CO<sub>2</sub> sources 827
- spherical dewar 683
- spherical pressure vessels 665–666
  - cost data 678
- spherical solar boiler segment 176
- spherical storage tank, NASA 673
- Spindletop hydrogen storage site 652–653
- spinning reserves 330
- “split benefits” 768
- sporadic buffers 629
- SR (smart refrigeration) 753–754
- SRTT (Scotrenewables Tidal Turbine) 370
- stability, subsurface storage 635
- stabilization
  - grid 436, 439
  - wind power 592
- stack durability 184
- stakeholder coordination 807
- stall-regulated wind turbines 243
- Standard Test Conditions (STC), solar cells 285
- start–stop operation 614
- static VAR compensator (SVC) 715
- stationary end use 835–836
- stationary storage, hydrogen 679
- steady drain rate 633
- steam
  - CO<sub>2</sub> co-electrolysis 437–438
  - electrolysis 428
  - power plants 505
  - supercritical 323
- steam generation 922–926
  - direct, *see* direct steam generation
  - heat recovery 316
  - inside ducts 175–177
- steam reforming 623
  - methane 451, 453
- steel
  - mild 777
  - production 922
  - tubular tower 253
- Stirling engines 170, 310
- Stirling receiver, dish 164
- STJ (Solar Tower Jülich) thermal power plant 459
- stochastic scheduling 767
- stoichiometric H<sub>2</sub> demand 622
- stone
  - sensible heat storage 326
  - , *see also* geological storage
- storage 555–706
  - capacity temperature dependency 563
  - CCS, *see* carbon capture and storage
  - central 558
  - chemical 564–565, 619–628
  - compressed gaseous 662–668
  - cost 559, 566, 572–575
  - cryogenic liquid hydrogen 669–675
  - density 198–199
  - distributed 678
  - economic feasibility 572
  - efficiency 559, 566, 679–681
  - electric power 59–60, 86, 217, 559–561
  - electrochemical ammonia conversion 691–706
  - energy 557–577
  - gases 514–515, 828–831
  - geological 629–657
  - heat, *see* heat storage
  - hydrogen 208–209, 426, 564, 679
  - in/out 571
  - Japan 22, 24
  - large-scale 605
  - local 671–672
  - maximum acceptable storage costs 573–574
  - natural gas 631–633, 784–785
  - near-surface bulk 659–690
  - net mass capacity 681–682
  - on-/off-board 659
  - “on-site” capacity 878
  - one-way 571
  - period 559, 566
  - pipe storage facilities 668

- power-to-gas 813
- pumped hydropower, *see* pumped storage hydropower
- “smart grids” 762–768
- solid-state 677
- stationary 679
- subsurface 633–636
- wind power 412
- storage media
  - fossil fuels 567
  - heat 165–168
  - hydrogen 426
  - power density 197–199
- strain–stress diagram 777
- Strangford Lough project 363
- Strategic Environmental Assessment (SEA) 50
- Strategic Research Agenda for Solar Energy Technology (SRA) 300–301
- strategic reserves 631
- stratification, thermal 603
- stratospheric ozone depletion 120
- straw 415–416
- structural interlinkages 124–125
- structuration theory 123
- structured catalytic systems 456
- structured reactors 468–474
- structures, monolithic ceramic 458
- sub-sea electricity grid 61
- sub-transmission system 724
- sub-zero conditions tests 189
- “substantial change” 134
- substation cost 735
- substitute natural gas (SNG) 624–625
- substitution, highly energy-intensive materials 932
- suction cation foundations 276
- sugarcane 490
- sugars to hydrocarbons 533
- sulfur
  - lithium–sulfur batteries 584–585
  - sodium–sulfur (NaS) batteries 23, 583–584, 593–594
- Sun Belt 311
- sun position sensor 313
- sunshine, daily winter 144
- “super grids” 709
- super-ionic conductor glass film 585
- superconductors, HTS 711–712, 917
- supercritical steam cycles 323
- supergrid concept, European DC 275
- superheating 173, 177, 316
- supply
  - and demand 486–487, 568–570
  - China 894
  - diversification 353
  - hydrogen 211
  - potential 108
  - primary 621
  - real-time demand–supply balancing 743–744, 747
  - supply–cost curve 394, 396
  - supply-driven power options 95
  - weather dependence 405
  - weighted 879
- supply security 68
  - fossil power plants 412–413
  - marine energy 352–353
- supranational level 73
- sustainability
  - biomass co-combustion 415
  - dogmas on 132
  - energy transitions 858–859
  - geothermal power 346–350
  - hydrogen supply pathways 805–806
  - hydropower 398–400
  - transitions 130
- sustainable available potential, biomass 499
- sustainable development 121
- sustainable global energy system 93–117
- sustainable land use 146
- SUVs, FCV 186
- Sweden
  - energy supply 492
  - wheat production 488–489
- SWH (solar water heaters) 142, 151–152
- switchgears/substations 712–714
- synchronous PM generator 250–252, 272–273
- synfuel production 624
- synthesis gas (syngas) 451, 798
- synthetic BTL fuels 530–531
- synthetic methane 788
- synthetic natural gas (SNG) 511–513, 823
  - thermochemically produced 532
- system analysis
  - biofuel production 534–544
  - hydropower 398
  - natural gas pipelines 791–793
  - wind and flexible hydropower 612–615
- system balance 536
- system base price 76
- system boundaries, ZEB 876–878
- system inertia 412
- system integration
  - demand-side response 749–768
  - low-carbon electricity systems 743–744
  - transmission technologies 717–719

- system optimization 517
  - electric drives 919–922
- t**
- T CAPEX 748, 763–765
- Tafel equation 220
- tanks
  - hydrogen embrittlement 674
  - liquid hydrogen storage 671–675
  - metal hydride 676
  - “table versus tank” issue 790
  - temperature 682
- tapping, hot 778
- taxes
  - carbon dioxide 495–496
  - PTC, *see* Production Tax Credit
  - relief 151
- TBM (tunnel boring machines) 392
- TCI (total capital investments) 542
- TCO (transparent conductive oxides) 288–289
- TCS (thermochemical thermal energy storage) 562
- techno-economists 132–134
- technology
  - cross-cutting 914–915, 920, 926–927
  - robustness 161, 169–170
- Technology Innovation Needs Assessment (TINA) 357
- technology readiness level (TRL) 533
- Teesside gas storage site 652–653, 830
- temperature
  - and storage capacity 563
  - indoor control 905
  - inlet 168–169
  - NOCT 291
  - smart variation 754
  - subsurface storage sites 636
  - tanks 682
  - temperature-entropy diagram 173
- TEN-E (Trans-European Energy Network Policy) 747
- TEPCO (Tokyo Electric Power Co., Inc.) 13–14
- terawatt scale technology 283–306
- tertiary reserve 411
- Tesla, Nikolai 725
- Texas, geological situation 653
- The Geysers geothermal power plant 341
- theoretical total efficiency, CSP 310
- thermal drying 930
- thermal grid 569
- thermal losses, solar tower systems 319, 325
- thermal methane reforming, solar
  - thermal power
    - Japan 18
    - Scotland 53
    - solar 307–338
    - VRE 80
  - thermal recovery time 348
  - thermal storage 324–328, 561–563
    - commercial systems 327
    - CSP 178
    - , *see also* heat storage
  - thermal stratification 603
  - thermochemical synthesis 790
    - hydrogen 797–798
  - thermochemical thermal energy storage (TCS) 562
  - thermochemically produced SNG 532
- thermodynamics
  - ammonia 692
  - compressed gaseous storage 662–668
  - cryogenic liquid storage 669–670
  - irreversibilities 557
  - reforming 453–454
  - second law of 426
- thermoneutral voltage 431
- thin-film PV 288–290, 298–300
  - compound semiconductor-based 302
  - flexible solar cells 294–295
  - R&D 302–303
- Thomson, *see* Joule–Thomson expansion
- three-phase AC voltage 726
- three-phase reactor 821
- tidal energy 360–370
  - cost trajectory 356
- timber 492
- time horizons, “smart grids” 746
- tip speed 247
- “tipping points” 119
- Tokyo Electric Power Co., Inc. (TEPCO) 13–14
- top-down analysis 572–575
- top-down institutional change 134
- total capital investments (TCI) 542
- total primary energy supply (TPES) 244
- tower concepts, wind power 253–255
- town gas 651
  - spherical pressure vessels 666
- TradeWind project 605–606
- trading, cross-border 732
- traffic volume 103
- trajectories, ecological 125
- Trans-European Energy Network Policy (TEN-E) 747
- transformation paradigms 132–134
- “transformative literacy” 122–123

- transformers, power 714
  - transient characteristics, ZEB 881–882
  - transition
    - barriers to 868
    - cost 857
    - hydrogen 807–808
    - in the Developing World 138–140
    - natural to hydrogen gas 629–657
    - petro-mobility to electro-mobility 856–857
    - societal 123–132
    - sustainability 858–859
    - , *see also* energy transition
  - transmission
    - development stages 724–727
    - European grid 408, 729
    - flexible 709
    - grid components 709–721
    - hydrogen 209, 796–802
    - networks 723–739
    - offshore wind power 271
    - Scotland 60
    - system tasks 727–728
    - technologies system integration 717–719
  - transmission system operator (TSO) 89, 410–413
    - cross-border balancing 733
    - Germany 502–503
  - Transparency International 138
  - transparent conductive oxides (TCO) 288–289
  - transport 103–107
    - bulk power 723, 732
    - energy use 854
    - fuels 523–524
    - GHG emissions 851–852
    - hydrogen fuels 212, 660
    - motorized, *see* vehicles
    - pipeline capacity 776
    - , *see also* fuels
  - Treuchtlingen mining site 644
  - tri-generation system 801
  - tripod-style foundations 267, 276
  - TRL (technology readiness level) 533
  - Tropsch, *see* Fischer-Tropsch process
  - trough, parabolic 164, 309, 312–317, 457
  - trucks, long-distance 106
  - tubular solar receivers 458
  - tubular steel tower, wind power 253
  - tumble dryers 752
  - tunnel boring machines (TBM) 392
  - tunnel drilling 611
  - tunneling hydropower plants 391–393
  - turbidity 603
  - turbines
    - CCGT 731
    - combustion 835
    - counter-rotating Wells 377
    - efficiency 390
    - floating 370
    - gas and steam 511
    - hydropower 390
    - offshore wind power 271
    - onshore hydroelectric 371
    - operational regime 390
    - RPT 597–600
    - “seasonal” 601
    - separate 599
    - tidal energy 361–378
    - wind, *see* wind turbines
  - two-axis tracking 308
  - two-phase flow 175
- u**
- UCTE/ENTSO-E grid 729–730, 735
  - Ulla-Førre hydropower complex 392–393
  - ultra-supercritical (USC) plant 18
  - unbundling 502
  - uncontrolled load profile 751
  - unconventional petroleum 852
  - underground hydropower plants 391–393
  - underground lines 711–712
  - underground storage, *see* geological storage
  - undeveloped hydropower 385
  - unidirectional charging control 760
  - United Kingdom (UK)
    - electric power generation 48
    - marine energy 351–379
    - offshore wind power 267–268
    - smart EV charging 758–759
    - smart grid heat pumps 761
    - smart storage 762–763
    - Zero Carbon Home approach 877
  - up-rating, device power 359
  - updraft towers 170
  - upgrading
    - biogas 515, 532
    - fuel 622
  - upper energy bound 892
  - upstream migration 391
  - upwind wind turbines 250
  - uranium resources 17
  - urbanization rate, China 897, 904
  - Urdorf pipe storage facility 668
  - urea 698–699
  - USA
    - hydrogen transition scenario 807–808
    - , *see also* California, Texas
  - USC (ultra-supercritical) plant 18
  - utility index 866–867

- utilization, network asset 743
- “utilization effect” 81
- utilization factor 217, 229–230
- v**
- vacuum receiver 175, 319
- valence band 285
- value research, global 131
- van der Waals radius 640
- vanes, guide 600
- vaporization heat 669–670
- vaporizer, ambient air 672
- VAR compensator 715
- variability
  - hydrological 383–384
  - reservoir water level 609–611
- variable RE (VRE)
  - and biomass energy 500
  - decreasing market value 75–83
  - integration options 84–89, 819
  - marine energy 354
  - “smart grids” 743–744
- variable-speed drive (VSD) 604, 919
- vegetable oils 624
  - hydrotreated 529
- vehicle travel 103
- vehicles
  - CNG-fueled 837
  - electric, *see* electric vehicles
  - fuel, *see* fuels
  - hydrogen 796–797
  - light-duty 863
  - plug-in hybrids 106, 587, 731, 859
  - ZEV standard 861–862, 864–866
- vertical grid load 204
- vertical mixing 603, 611
- vertical tanks 672
- VGB 419
- videoconferencing 103
- Vindeby offshore wind farm 265–266
- visualization tools 746
- Volmer, *see* Butler–Volmer equation
- voltage
  - levels 741
  - regulation 412, 600,
  - three-phase AC 726
- voltage-source converter (VSC) technologies 716–717, 739
- volume production effects, solar thermal power 331
- volumetric receiver 458, 477
- w**
- wafers, mono-/polycrystalline 286
- Wairakei geothermal power plant 341
- wake losses 255
- washing machines 752
- wasp 274
- waste
  - recycling 932
  - wood 493
- waste heat 58, 177, 557
- water
  - CSP cooling 311
  - dissociation potential 220
  - diversified heater demand 750
  - EEKV 381
  - electrolysis, *see* electrolysis
  - formation energy of liquid 426
  - global freshwater use 120
  - hot water generation 561, 903, 922–926
  - level fluctuations 609–611
  - meteoric 646
  - oscillating water column device 377
  - solar water heaters 142, 151–152
  - solubility of hydrogen in 644
  - supply 387
  - water-soaked minerals 642
- water cycle 382
- water-gas shift reaction (WGS) 438, 452–454, 819
- water power, *see* hydropower
- water source heat pumps (WSHP) 57
- watt-peak (unit) 283
- wave energy 371–378
  - cost trajectory 356
  - flexible absorbers 373
  - overtopping converter 378
- wave heights 276
- wave surge converter 371–372
- WBGU (German Advisory Council on Global Change) 121, 123
  - guard rails concept 144–145
- weather dependence, supply pattern 405
- weather model, global 606
- weighted average cost of capital (WACC) 762
- weighting systems, ZEB 878–879
- Weissbach, *see* Darcy–Weissbach equation
- Weizmann Institute of Science (WIS) 459, 462
- well-to-tank (WTT) analysis 840–841
- well-to-wheels (WTW) emissions 805–806
- Wells turbines 377
- wet appliances, smart 752–753
- wheat prices 487
- wheels, power-to-wheel losses 854
- white asbestos diaphragm 432



- wholesale electricity market 769
  - wide-area measurement 746
  - wind power
    - capital availability 261
    - CES production structure 34
    - China 31
    - decreasing market value 76
    - design of turbines 87
    - downregulation 615
    - economic feasibility 258–260
    - environmental impact 255–257
    - fluctuations 199
    - Germany 200–205
    - GROWIAN 180
    - linking with hydropower 612–615
    - offshore, *see* offshore wind power
    - onshore 203, 243–263
    - simulated production 607
    - site assessment 273–274
    - Spain 229
    - stabilization 592
    - storage 412
    - supply potential 109
    - wind capacity 139
    - wind farm control 255
    - wind farm design 274–276
    - , *see also* variable RE
  - wind speed 247
    - offshore 265
  - wind turbines 246–255
    - capacity factor 249
    - floating 279–280
    - offshore sites 271–273
    - stall-regulated 243
  - wind value factors 82
  - WindFloat 280
  - “winter peak” 517
  - winter sunshine, daily 144
  - Wobbe index 773, 786–787
  - Wolfurt school 884
  - wood
    - as bioenergy 491–493
    - “dead” 415
    - paper industry 929–930
  - working fluids 165–168
  - working gas 828
    - volume 633, 640
  - working point, solar cells 285
  - working principles, photovoltaics 284–290
  - World, Developing, *see* Developing World
  - World Energy Outlook 824, 891, 913
  - world production, grain 488
  - WSHP (water source heat pumps) 57
  - WTT (well-to-tank) analysis 840–841
- x**
- XLPE (cross-linked polyethylene) insulation 711–712, 716
- y**
- Yangtze River Basin, residential energy consumption 902
  - yawing system, hydraulic 367
  - yeast 529
  - yttria-stabilized zirconia (YSZ) 437
- z**
- Zechstein formation 646, 651
  - Zero Carbon Home approach 877
  - zero-emission mobility 183, 217, 587
  - Zero Emission Vehicle (ZEV) standard 861–862, 864–866
  - zero energy buildings (ZEB) 875–889
  - zero gap configuration 815
  - Zn–Ce redox-flow battery 593
  - ZSW methanation plant 821–822