

Index

a

- advanced process control (APC)
 - base-layer control system 248
 - controller limits, plant constraints 260–261
 - distributed control system 248
 - dynamic process models 248
 - planning and scheduling activities 248
 - process control hierarchy 247–249
 - production and plant constraints 248
 - real-time optimization 248
- air emissions 60
- ancillary services 309–310
- artificial intelligence (AI) 130

b

- Bayer Climate Check 318
- best demonstrated practice (BDP) 86
 - values 330
- bivariate least squares (BLS) regression 133
- Brundtland report 454
- business clustering
 - business parks and park management 461–462
 - cross-sectorial clustering and cluster management 464–466
 - economic incentives 461
 - industrial ecology 461
 - total site integration and site management 462–464
- business parks 461
- business parks management 462

c

- CasADi 281
- CEN/CENELEC Sector Forum 30
- Chemometrics 137–138
- China's economic growth 23
- circular economy 465
- cleaning-in-place (CIP) subsystem 136
- closed loop methods 235
- CO₂-emissions
 - Agenda 21, 21
 - UNFCCC 21
- Communication on Progress (COP) 51
- composite curves 406
- continuous improvement process (CIP) 76
- continuous stirred tank reactor (CSTR) 269
- cost functions 425
- Covestro 318
- cross-sectorial symbiosis 465
- cumulated energy demand (CED) 394
- cyber physical systems 160

d

- Danish Kalundborg eco-industrial park 450
- data extraction 355
- data pre-treatment
 - “control” pyramid 182
- data reconciliation
 - maximum likelihood principle 188
- mixing streams 191–194
- non-Gaussian measurements
 - errors 189

- data pre-treatment (*contd.*)
 - parametric uncertainty 192
 - structural uncertainty 192
 - dynamic data reconciliation
 - 208–209
 - gross errors detection and removal
 - Robust M-estimators 202–205
 - statistical methods 195–202
 - measurement errors and variable estimation
 - accuracy 183
 - EcosimPro window 186
 - Gaussian distribution 182
 - liquid junction 183
 - precision 183
 - redundant data 184
 - temperature measurements 184
 - and steady state detection 205–208
 - decision support systems (DSS)
 - aggregated tiles 220
 - analysis, of optima 231
 - Bullet chart 216–217
 - dashboard concept, sugar plant
 - case-study 223–224
 - difference charts 218–220
 - exemplary application 226–228, 232–235
 - flexibility 225–226
 - graphical guidance 225
 - information 213
 - multicriterial optimization 231–232
 - plant sections 215
 - real-time performance 231
 - Sankey diagrams 215–216
 - scenario database 226
 - stacked bars and stacked area plots 217–218
 - variability bar 217
 - visual feedback 226
 - visualization elements 220–221
 - visualization techniques 213
 - what-if analysis 224–228
 - demand side response (DSR)
 - additional conventional power plants 299
 - ancillary services 309–310
 - business-motivated goals 294
 - climate issue 295
 - dispatchable demand response 296
 - dynamic demand 296
 - electrical energy 294
 - electricity grid 295
 - energy consumption 294
 - energy efficiency (EE) 301–303
 - energy industry 294
 - energy portfolio optimization 305–306
 - energy sector 294
 - energy shortage 305
 - energy storage capacity 299
 - grid capacity 300
 - history 296–297
 - load management 304
 - load shedding 309
 - load shifting 309
 - market drivers and market barriers 300–301
 - market options 300
 - nondispatchable demand response 295–296
 - peak shaving 309
 - power production and consumption 299
 - renewable energy sources 299–300
 - technology-driven innovations 295
 - utility trigger and price changes 305
 - valorization 310–313
 - differential-algebraic ones (DAE) 208
 - differentiation 479–480
 - distributed control systems (DCS) 167, 265
 - district clusters 465
 - district networks, using process waste heat 443
 - dynamic optimization (DO) 209, 280
- e**
- eco-industrial parks 442
 - eco-management and audit scheme (EMAS) 49
 - economic evaluation constraints 360–361
 - economic incentives 461
 - EcosimPro 186

- electricity 423–424
 - investment and operating costs 425–428
 - life-cycle assessment 428
 - nomenclature 424
 - non-negativity of grid interactions 423
 - transportation 424–425
- electricity laws 28
- EN 16247 29–31
- energy and resource
 - company-specific environmental indicator systems 7
 - definition 4
 - energy efficiency 6–8, 11
 - ISO 50001
 - 2011 and standards ISO 50002 to 50015 12
 - primary energy 5
 - real-time, concept of 8
 - resource efficiency 6–8, 11–15
- energy and resource efficiency 404
- energy and resource management
 - continual improvement process (CIP) 34
 - employee participation 38
 - energy storage 36
 - EnPI development 34–36
 - ISO 50001 38
 - low usage/consumption 36
 - self-generation 37
- energy balance constraints 358–360
- Energy-Capital trade-off 407
- energy clustering, at business parks 462
- energy conversion units 435–437
- energy efficiency
 - CO₂-emissions 20–21
- EN 16247 and ISO 50002 29–31
 - EnMS standards 25
 - EU concern 23–24
 - EU goals 21–22
 - in worldwide 22–23
 - IPMVP 31
 - ISO 17741 and ISO 50047 31
 - ISO 50001 28
 - and dissemination 26–27
 - precursors towards 25–26
 - ISO 50004 28
 - measurement and verification plan (M&V plan) 31
- energy efficiency audits
 - basis analysis 67–69
 - current energy status 66–67
 - detailed analysis and collection of ideas 69–72
 - energy performance 65
 - evaluation and selection of measures 72–76
 - extension to resource consumption 77
 - realization and monitoring 76–77
- Energy Efficiency Check 318
- energy flow analysis (EFA) 83, 85, 86
- energy influencing variables (EIVs) 321, 329, 336
- energy laws 28
- Energy Management and Production Planning approach 311
- Energy Performance Indicators (EnPI) 332
- energy portfolio optimization 305–306
- energy requirement, of process unit operation 416
 - electricity 416
 - exergy analysis 417
 - heat transfer 416
 - support materials 416
- energy savings portfolio 326
- energy shortage 305
- enterprise resource planning (ERP) 162
- environmental declarations 55
- e*-constraint scheme 428
- EU Commission 24
- EU-EMAS Regulation 46
- Europe 2020 strategy 446
- European Commission 33
- European Energy Efficiency Directive 463
- European R&D 151–152
- European Strategic Energy Technology (SET) plan 460
- exergy analysis 405, 417

f

fossil fuel sources 23

g

Gaussian distribution 132
 German power grid 294
 German Renewable Energy Act 27
 GHG Protocol Corporate Standard 54
 Global Reporting Initiative (GRI) 7,
 51–52
 Goldbeck's circus model 475
 graphene-based sensors 150
 greenhouse gas (GHG) emissions 11,
 340
 greenhouse gas (GHG) Protocol 47,
 54
 GreenPAT strategies 146

h

H2020's SPIRE programme 151
 heat cascade 420
 heat exchanger network 350
 heat integration 405–416
 advanced heat integration technology
 application 413–416
 chemical production site 413–416
 composite and grand composite
 curves 409–411
 ΔT_{\min} determination 406–408
 energy conversion units, optimization
 of 435–437
 heat recovery targets, improvements
 of 412–413
 penalising heat exchangers 411–412
 heat pump (HP) 412
 heat recovery improvement potentials
 432–435
 heat recovery system 70
 heat transfer requirements 418
 detailed-model analysis 419
 black-box analysis 418
 grey-box analysis 418
 simple-model analysis 418–419
 white-box analysis 418
 hybrid methods 364
 hydrogen pinch analysis 351
 hyperspectral imaging (HSI) 138–139

i

industrial ecology 460
 industrial process, description 404
 industrial symbiosis (IS) 449
 business clustering, *see* business
 clustering 460
 European Strategic Energy
 Technology (SET) plan 460
 innovation potential 458
 multidisciplinary nature 459
 industrial symbiosis parks 450
 industrial symbiosis policies 454
 industrial symbiosis research 454
 industrial symbiosis services 453
 industrial symbiosis technologies 451
 information technology
 context awareness 167–168
 process industries
 control and monitoring algorithms
 160
 control and supervisory functions
 160
 cyber physical systems 160
 ERP and SCM systems 162
 internal sensors and embedded
 logic controller 160
 material and energy efficiency
 162
 plant control strategies 162
 sensors and actuators 160
 resource managed units 163–164
 3-tier information modelling
 approach
 meta model 164
 properties 167
 RMU 165–166
 Type Model 164
 integrated development environment
 (IDE) 168
 Intelligent Manufacturing Systems
 (IMS) 130
 Interior point methods 278
 International Energy Agency 10
 International Integrated Reporting
 Council (IIRC) 52
 Internet-of-Things (IoT) devices 148

- investment and operating costs 425–428
- ISO 14000 series 54
- ISO 14000 standards 55
- ISO 14001 46
- ISO 50002 30
- ISO 50006 34
- ISO 50015 34
- ISO labelling standards 55
- k**
- Kalundborg collaboration 451
- key performance indicators (KPIs) 59, 83, 181, 326, 332
- l**
- LESTS survey 456
- life cycle assessment methodology 405
- life cycle impact assessment indicator 428
- linear multivariable model predictive control (LMPC) 247
- load shifting 309
- low-carbon economy 447
- low grade heat 70
- m**
- Management Systems (MSs) 24–25
- market barriers 300
- market-corrected energy consumption (MEC) 332
- market drivers 300
- mass balance constraints 357–358
- mass integration 420–423
- material flow analysis (MFA) 83, 85, 86
- maximum energy recovery (MER) 412
- maximum likelihood principle 188
- mechanical vapour recompression (MVR) 412, 413–416
- MEMS-based sensors 147–148
- MILP model 421
- MISO Energy 305
- mixed integer linear programming (MILP) formulation 419
- model predictive control (MPC) 266
- Modern consumption meters 70
- MORE RACER evaluation framework
 - contribution factor 101–102
 - interdependent influencing factors 102
 - performance contribution 100
 - performance indicators 101
 - utility integration and energy provider 105–106
- moving horizon estimation (MHE) 209
- multi-level energy requirement
 - definition 418–419
- multivariable predictive control (MPC) technology
 - base-layer controllers 258–259
 - constraint control
 - additive constraints 245–246
 - closed-loop optimization 246–247
 - depropanizer column 240–244
 - graphical representation 244–245
 - large-scale continuous chemical processes 240
 - skilled and experienced operators 240
 - control solution 260
 - features 249–254
 - financial benefits 254–256
 - justification and benefit estimation 256–258
 - limitations 259
 - ongoing maintenance and training 261–262
 - product quality measurement and inferentials 259–260
 - utility and product values 260
- n**
- NAMUR survey 73
- NAMUR Worksheet NA140 70
- necessary conditions of optimality (NOC) 281
- non-linear programming
 - interior point methods 278–279
 - KKT optimality conditions 276–277
 - Lagrange multipliers 275

non-linear programming (*contd.*)
 sequential quadratic programming
 (SQP) 277–278
 non-renewable energy resources 22

O

OCAP project 452
 offline realtime optimization 247
 oil crisis 22
 online approach 136
 Organisation Environmental Footprint
 (OEF) 59
 oxygen depolarized cathode (ODC)
 technology 320

P

Pareto curve 429
 Pareto principle 476
 People-Planet-Profit triangle 446
 pinch analysis principles 406
 pinch technology 350–351
 piping and instrumentation diagrams
 (PandID) 66
 Plant Information Management Systems
 162
 plus-minus principle 412
 power consumption 72
 principal component analysis (PCA)
 195
 Principles and Guidance on
 Communication of Footprint
 Information 55
 process analytical technologies (PAT)
 130
 data mining of historians 143
 definition 142
 GreenPAT strategies 146
 integration tasks 145
 maintenance and after-sales support
 policies 145
 metrological constraints 144
 online/inline analytical probes 143
 output data format 145
 parameters 144
 QbD procedure 143
 ranges 144
 sample nature and features 144

sampling frequency 144–145
 scope 144
 sources of problems 145
 timeframe 145
 validation 144
 wider business context 145
 process flow diagram 404
 process industry
 chemical industry 9
 definition 8
 EU chemical industry 9
 primary and secondary energy 5
 raw materials 5, 9–10
 resource-efficient production 4
 separation processes 4
 Product Environmental Footprint (PEF)
 59
 ProPAT 151
 Pyomo 281

Q

Quality Management Systems (QMS)
 26
 quality-by-design (QbD) 143, 151

R

real-time energy indicators 311
 real-time optimization (RTO) systems
 continuous stirred tank reactor
 (CSTR) 269
 data reconciliation (DR) 272
 DCS 265
 dynamic optimization (DO)
 280–281
 economic optimizer 269
 global process efficiency and economy
 271
 gross errors 272
 implementation, of solutions 274
 MPC 266, 268
 multiple-effect evaporation process
 data reconciliation 286–289
 optimal operation 289–290
 resource efficiency indicators
 290
 steady-state modelling 283–285
 non-linear programming

- interior point methods 278–279
- KKT optimality conditions 276–277
- Lagrange multipliers 275
- sequential quadratic programming (SQP) 277–278
- non-linear programming (NLP)
 - problem 271
- process-model gap problem 274
- software and practice 279–280
- real-time resource efficiency indicators
 - baseline indicators 91
 - baseline, definition 88, 91
 - batch resource efficiency indicators 113–114
 - energy efficiency 114–115
 - energy performance indicator (EnPI) 88
 - environmental impact 86
 - evaluation method 93
 - external economic factors 87
 - gate-to-gate approach 85
 - generic indicators 88
 - generic resource efficiency indicators 87
 - key production phases 116–117
 - life-cycle analysis (LCA) 87–88
 - long-term storage effects 86
 - material and energy flow analysis 85
 - material efficiency 115–116
 - MORE RACER evaluation framework
 - aggregation 98–105
 - application 95–98
 - definition 93–95
 - non-influenceable factors 91
 - plant-wide contributions 118–119
 - pre-selected indicators 92–93
 - process analytical technology 84
 - process industries 84
 - product-oriented REI 106–107
 - propagation and aggregation 119
 - purification efficiency 117–118
 - questionnaire method 92
 - reaction efficiency 117
 - transition from batch to continuous operation 122–124
 - transition from batch to continuous production 124
 - water and waste efficiency 116
- reporting mechanisms, resource efficiency
 - eco-management and audit scheme (EMAS) 49
 - environmental challenges 46
 - environmental labels and declarations 55–59
 - environmental management systems 46
 - EU-directive on industrial emissions (IED) 47–48
 - EU-directive on non-financial reporting 48–49
 - European Union 46
 - Global reporting Initiative (GRI) 51–52
 - greenhouse gas (GHG) Protocol 47, 54
 - International Integrated Reporting Council (IIRC) 52, 54
 - KPI 59–60
 - OECD Guidelines for multinational enterprises 49–50
 - PEF and OEF guidelines 59
 - sustainability reporting 46
 - United Nation's Global Compact Initiative 50–51
- resource and energy integration
 - formulation 419
- resource efficiency 82
 - normative approach 32–33
- resource efficiency indicators (REI) 36, 181
 - application design process 168–171
 - industrial installations
 - batch-continuous-process 171–175
 - integrated chemical production complex 175–178
 - supplementary model-based approaches 224
 - what-if analysis 224
- resource integration, constraints for 421

- resource optimal chemical processes
 - applications, of synthesis 363–364
 - biological and thermochemical
 - biomass conversion processes 348
 - crude oil and natural gas reserves 347
 - data extraction 355–356
 - decomposition procedure 352
 - environmental factors 365–366
 - global consumptions, of fossil fuels 348
 - hybrid methods 364–365
 - liquid transportation fuel 349
 - mathematical model
 - economic evaluation constraints 360–361
 - energy balance constraints 358–360
 - mass balance constraints 356–358
 - objective function 361–362
 - optimal kind 349
 - optimal quantity 349–350
 - Pinch technology 350–351
 - resource crisis 347
 - social factors 366
 - solution methods 362–363
 - superstructure generation 353–355
 - uncertainty issue 366
 - responsibility diffusion 488
 - Rio Earth Summit 1992, 20
 - Russian Federation 22–23
- S**
- sensing technology
 - accuracy 132–134
 - electricity consumption 136
 - European R&D 151–152
 - graphene-based sensors 150
 - industrial energy metering 137
 - “Industry-4.0-grade” sensing 132
 - milling process 131
 - PAT technologies 131
 - precision 132
 - production process 130
 - quantum cascade lasers (QCL) 149–150
 - sampling 135–136
 - spectroscopy technology,
 - process-monitoring-based efficiency
 - chemometrics 137
 - hyperspectral imaging (HSI) 138–139
 - MEMS-based sensors 147–148
 - process analytical technologies (PAT) 142–146
 - soft-sensors 146–147
 - time-gated Raman 139–142
 - standard IR thermometer 134–135
 - sequential approach 281
 - sequential quadratic programming (SQP) 277
 - single process integration (SPI) 430–432
 - site scale integration
 - heat recovery improvement potentials 432–435
 - single process integration 430–432
 - total site integration 430, 432
 - small and medium-sized enterprises (SME) 74
 - smart grids 295
 - soft-sensors 146–147
 - SPIRE 445
 - standard 486
 - steady state detection 205–208
 - steam loss cascades 335
 - steel and petrochemical symbiosis 458
 - steel production 312–213
 - strokes 478
 - STRUCtESE™ system
 - best demonstrated practice (BDP) values 330
 - current energy consumption of the plant (CEC) 328
 - energy consumption 323
 - Energy Efficiency Check (EE Check) 321, 323–327
 - energy loss cascade 327–336
 - energy loss cascade and online monitor 334

- energy management cycle 322
 - energy scope 322
 - implementation results 338–341
 - improvement plan 325
 - integrated energy efficiency
 - management tool 333
 - ISO 50001 certification 320, 321
 - online monitor (OM) and daily energy
 - protocol (DEP) 322, 336–338
 - open issues and research topics
 - 341–342
 - operational energy optimum (OEO)
 - 328
 - PDCA-cycle for Energy Management Systems 321
 - PDCA-cycle of energy 320
 - real-time energy efficiency 319
 - simple data analysis 320
 - theoretical energy optimum (TEO)
 - 328
 - superstructure configuration constraints
 - 356–357
 - supply chain management (SCM)
 - systems 162
 - sustainability management 444
 - sustainability reporting 46
 - Swedish Standards Institute (SIS) 25
 - symbiosis and synergy 441
- t**
- tax cap Efficiency System Regulation (SpaEfV) 28
 - thermal imaging camera 70
 - time-gated Raman 139–142
 - Total Polyphenol Index (TPI) 136
 - Total Site Analysis 463
 - total site integration (TSI) 430, 432
 - Type Model 164
- u**
- ultrasound-measuring instrument 70
 - United Nations Framework Convention on Climate Change (UNFCCC)
 - 21
 - utility systems
 - computational effort 376
 - conventional optimization models
 - 390
 - cost savings 373
 - decision support 387–390
 - definition 375
 - design and operation strategy 373
 - energyPRO 390
 - industrial case study
 - multi-objective optimization
 - 394–395
 - near-optimal solutions 395–396
 - optimal solution 393
 - plant layout 392
 - TOP-Energy® 390
 - MINLP problems 376
 - model complexity
 - decomposition 380–381
 - part-load performance 379–380
 - time representation 378–379
 - multi-objective optimization 388
 - near-optimal solutions 388–390
 - optimal synthesis 376
 - superstructure-based synthesis
 - 383–385
 - superstructure-free synthesis
 - 385–387
 - synthesis of 376
 - time-series aggregation 381–382
- v**
- VDI 4800, 33
 - visualization method 220
 - visualization techniques 213
- w**
- working/company culture
 - appreciation 479
 - common sense 477
 - criticism 479
 - desired result 481–485
 - differentiation 479–480
 - fairness 476
 - feedback loops 491
 - incentives 489–490
 - integration 485–486
 - justice 476
 - leadership principles 481

working/company culture (*contd.*)
 measures 486, 487
 motivation 475
 orientation 479
 performance 488
 personal comfort zone 475
 praise 478

 resistance 488–489
 rules 487
 standard 486
 strokes 478
 trust 474, 476, 477
World Business Council for Sustainable
 Development (WBCSD) 83