Index

а

active consumers 7, 12–13, 17, 32, 35, 258, 279 active control systems 25 advanced Industry 4.0 concepts 149 advanced metering infrastructure (AMI) system 188, 219 for LV network management 209 - 210functions of 207 advanced Remote Terminal Unit 197 Advanced Simple Entities (ASENs) 196-198, 209, 211 "2030 Agenda for sustainable development" of United Nations 276–277 air-source heat pumps 57–58 Alkaline Electrolysers (AEL) 78 anaerobic digesters 47 ancillary grid services 84 Artificial Intelligence (AI) 12, 25, 26, 125, 127, 132-133, 140, 142, 144, 153, 207-208, 298 ATELIER project 254 automatic diagnostic functionality 209

b

Batteries Digital Task Force 150 - 151battery electric vehicles (BEV) 43, 85-86, 179-180 battery energy storage systems (BESS) 11, 112, 144, 149 behind-the-meter (BTM) digital devices 127, 187-188 bicycle-sharing system, in urban context 175, 181 bidirectional power flows 133, 215 big data 12, 25, 132, 149, 156–157, 192, 207 Big Data investments 140 biogas 11, 44-47, 275, 279-280, 287 operating systems 45 blockchain 26, 125, 127, 138-139, 153-154, 156 blue hydrogen 77, 78 building energy efficiency 241 building energy flexibility (BEF) 248 - 252building energy management systems (BEMS) 245, 279, 297

Technologies for Integrated Energy Systems and Networks, First Edition. Edited by Giorgio Graditi and Marialaura Di Somma. © 2022 WILEY-VCH GmbH. Published 2022 by WILEY-VCH GmbH. 306 Index

Building Integrated Photovoltaic (BiPV) systems 243, 246 building intelligence 250 Building Intelligence Quotient 250 building monitoring and automation 250–252 bulk energy storage 12, 83, 111 business models and innovation 65–66

С

capital expenditure [CAPEX] 75, 124 central system, for data reception and analysis 206-209 citizen energy communities (CECs) 7, 13, 23, 259, 278, 301 Clean Energy for all European package 258, 277–278 Clean Energy Package 6–7, 10, 17, 23 climate change 1 adaptation strategies for precipitation and temperature 181 EU commitment 6 Climate Target Plan 2030, 9 closed circuit television (CCTV) 297 collaboration 132, 134, 153, 256-257, 259, 260, 275 Combined Heat and Power (CHP) systems 277 plant 19 unit 87 combined solar and wind-driven energy systems 246 communication devices 194–195, 197-198, 209-211, 218

communication lavers, of PLC Prime protocol 200–201 compressed air energy storage (CAES) 21, 111–112, 116 compressed gaseous hydrogen (CGH₂) 79,81 "Congestion Detected" function 232 function output 231–232 connectivity 24-25, 34, 37, 124, 130, 132, 139, 156-157, 248 converted electrical energy 18 COVID-19 pandemic 180, 181 U.S. industrial sector 59 cross-vector sector coupling technologies 279-280, 285, 287-288, 293-295 current energy supply system 31 evolution of 2 current energy system vs. integrated energy system 2-3.33 Customer Centric innovations 155 cybersecurity 132, 152

d

Data Concentrator Unit (DCU) 192, 194 description 204-205 data scientists 140-141 daytime radiative cooling materials 245 decarbonization 1 electrification 2 purposes 18 decentralized distributed systems 154 demand response (DR) programs 5, 117–118 services 218 strategy 239, 246

Data Exchange Platform (DEP) 153 deployment of alternative fuels infrastructure (DAFI) 76 design strategies, high-performance buildings 242-252 smart HVAC systems and services 245-246 digital batteries use cases 148 recommendations for 155 digital communication devices 195, 198, 211 digital cybersecurity recommendations 153-155 Digital DSO 133, 153 digital grid 125-126, 144, 150 digital retail 127 digital technologies 26, 123-127, 130-131, 138-144, 149-151, 157-158, 296 digital transformation 123, 140-141, 155-157 of electricity 136 digital twin 144 technology 142 of LV-network 210-212 digital use cases 144–149, 153 digitalization 12, 127, 130, 154 Artificial Intelligence (AI) 25 big data 25 DLT 26 for market facilitation 134 in mobile field operations 133-134 in network management and operation 133 Internet of Things (IoT) 26 Machine Learning 25–26 Transmission System Operators (TSOs) 131

digitalization across energy value chain 132 digitalization and energy 124, 137 digitalization of energy 129, 296 digitalization of European economy 125 digitization of asset inventory 191 Distributed Control System (DCS) 298 distributed energy resources (DERs) 11, 129, 138, 187, 212, 215-235, 246, 277 distributed generation (DG) 215 energy model of 4 large-scale deployment of 3-4 technologies 289-291 distributed ledgers technologies (DLT) 26-27 distribution system operators (DSO) 32, 132-133, 136, 144, 157, 191, 209-210, 215, 220, 226-231 distribution-level natural gas systems 47 3D-VtGW system 244

е

edge computing 204, 207, 209, 251 electric power distribution company, distribution network of 189 electrical system 191 European type network 190 remote management system 191, 192 simple entities (SENs) 192–194 electric vehicles (EVs) 3, 8, 10, 12, 25, 28, 37, 43, 47, 72, 76, 85–86, 109–111, 123, 125, 127, 179–180, 187, 219, 249–250, 279 electrical cabinets of LV transformer station 197 electrical energy carrier 18, 36 electricity cost reduction options 63 electrification 2-3, 10, 12, 18, 42, 57, 60-62, 71, 74, 85, 131, 179, 180, 182, 276-277, 279-280, 287-288 electrochemical compressors 80 electrochemical energy conversion pathway 87 electrochemical energy storage systems 108, 112–113 electrochemical N₂ fixation 48 electrolyzers high-temperature 50-51 low-temperature 49-50 electromagnetic energy storage systems 110-112 electromechanical energy storage systems 110-111 Embedded Personal Computer 298 EMD II, 10, 23, 277–278 directive 7 end user sector coupling technologies 288, 291-293 end-user engagement and empowerment 5, 22-24, 36 energy conservation strategies 243-246 energy consumers 4, 17, 24, 127 role of energy consumer, evolution of 4 energy conversion processes 18 Energy Efficiency Directive (EED) 7, 24, 258 energy hub 116-118 defined 116

energy management systems (EMS) 12, 30, 32, 84, 127, 219, 240, 245, 253, 277, 279, 297-298 Energy Market Mechanisms 223 energy model of distributed generation 4 energy network operators 131 **Energy Performance of Buildings** Directive (EPBD) 8, 24, 241 **Energy Sector Management** Assistance Program (ESMAP) 277 energy storage systems (ESSs) 19, 20, 105, 117, 118 advantages 113–115 classification of 110 cumulative capacity of continent 106 current situations 115 ownership type 108 in power systems 106–108 projects based on storage type and services 114 technologies application, in multi-energy systems 116-118 types of 108-113 energy transition 1–13, 15–37, 71, 90, 126, 130-131, 142, 149, 151, 165-182, 215-216, 255, 259, 275-279, 285, 297-301 Energy Union, dimensions of 8 ETIP Batteries Digital Taskforce 142 ETIP SNET Vision 2050, 1, 16 ETIP SNET WG4 Digital Energy group 149, 162 ETP SmartGrids Strategic Research Agenda 130 EU level partnership 283 EU strategy on climate adaptation 9

European and International Projects 2000-2020, 100-104 European climate agreement 9 European climate law 9, 242, 282 European decarbonization objectives 18 European Green Deal 8, 9, 17, 282 action plan 242 strategy 281 European sustainable urban mobility indicators (SUMI) 167 European Union (EU) 15, 61, 124, 180, 253, 258, 276-278, 280-282, 301 as leader in energy transition 6-11 EXESS project 253

f

Federally-Owned projects 108 flexibility services 11, 27, 83, 296, 298 flexible alternating current transmission systems (FACTS) 218 Flexiciency project 144, 147, 149, 157 flywheel energy storage systems 111 Frequency Containment Function 230 Frequency Instability Detection Function 230 fuel cell electric vehicles (FCEV) 47, 76, 85-86 future-proof nZEB paradigms 252 fuzzy controllers 251

g

Gartner survey 139 Global e-Sustainability Initiative (GESI) 125 global energy transformation 1 gray hydrogen 75, 77–78 Green Deal 8-9, 17, 125, 167, 242, 299.301 Green Deal going local 280–285 green hydrogen 73, 75, 77–79, 84, 90, 179, 182 greenhouse gas (GHG) emissions 8, 15, 17, 41-43, 57-58, 60, 64, 89, 131, 137, 167, 170, 174, 177, 179, 240, 244, 255, 282, 284, 299 ground-level ozone indicator 178-179

h

Haber–Bosch process 48 hard-to-abate sectors 11, 71–73, 84-85 hardware-in-the-loop testing 133 Heating, Ventilation, and Air Conditioning (HVAC) 243, 245, 247, 249, 297 high concentration photovoltaics (HCPV) 247 high temperature electrolysers (HTE) 49–51, 54–55, 78 high temperature fuel cells (HTFC) 83, 86, 87, 89 high voltage direct current (HVDC) 218-219 high-performance buildings design strategies energy conservation strategies 243-246 energy flexibility 248–250

high-performance buildings (contd.) energy generation strategies 246-248 innovative materials, for buildings envelope 243-245 smart HVAC systems and services 245-246 status and research directions on 253 - 259hydrogen definition 72 economy and policy in Europe and Worldwide 74-77 implementation sector coupling enabler 74 stochastic Renewable Energy Sources (RES) 73 Integrated Energy Systems and Networks 83-89 production pathways 77–79 transmission and distribution 79-83 value chain 72 hydrogen compression technologies 80 hydrogen drivers 73 hydrogen economy 74-77 hydrogen energy storage 112 hydrogen refueling stations (HRS) 76, 86, 88 hydrogen storage and transportation 83

i

Industrial Internet of Things (IIoT) 125, 139, 144 Industry 4.0 132, 149 information and communication technologies (ICT) 17, 29, 35, 123–125, 150, 157, 165,

216-218, 225, 234, 245, 248, 255 innovative materials, for buildings envelope 243 integrated energy systems 1 benefits and challenges of 27, 28 conceptualizing local 28-29 digitalization enabler 24 - 27efficient energy use in buildings 12 emerging energy paradigm 17 enabling technological 29–31 end-user engagement and empowerment 22 energy storage 11 future 11 hydrogen as a vector 11 implementation of 17 mitigating environmental impacts of 15 policy and regulatory barriers 35 - 36socio-economic barriers 35 stakeholders 31-33 storage and conversion technologies 18 techno-economic barriers 34-35 integrated energy systems and networks ancillary grid services 84 bulk energy storage 83 flexibility services 83 industrial applications Battery Electric Vehicles (BEV) 85-86 chemical plants 84 combined Heat and Power (CHP) 84-85 fuel cells 86-87 HTFC technologies 88 industrial heat 84

iron and steel manufacturing 85 LTFC technologies 88 oil refineries 84 integration of renewable technologies in buildings or districts 248 intelligent energy management 243 Internal Electricity Market Directive (EMD II) 23, 277 International Energy Agency (IEA) 45-46, 76, 79, 124, 137, 221, 254 International Telecommunications Union (ITU) 124 Internet of Things (IoT) 25–26, 131-132, 139, 149, 158, 206-207, 248, 251, 284, 297 investment cost, of ASEN 198 investor-owned projects 108 IRENA 2, 72, 73, 75

k

Key Performance Indicators (KPI) of urban mobility in European Cities 169–175 sustainable mobility 167–169

l

LanzaTech biocatalyst 62 large-scale deployment, of distributed generation (DG) 3 life cycle analysis 64–65, 170 life cycle zero energy building (LC-ZEB) 241 Liquid air energy storage (LAES) 21, 108–109 Local Energy Communities (LEC) 153 "2030 Agenda for sustainable development" of United Nations 276 bottom-up model 279-280 cross-vector sector coupling technologies 293-295 digitalisation 296-298 distributed generation technologies 289-291 end user sector coupling technologies 291-293 energy transition 298-299 game-changer of the Green Deal 280 - 282Green Deal going local 283-284 human capital for 278 integrated energy systems at local level optimal medium-long term planning 287–288 sector coupling 285–287 neighbourhood approach and local energy communities, Green Deal 284–285 storage technologies 296 low temperature fuel cells (LTFC) 86.87 low voltage (LV) network 187 AMI for 209-210 digital twin of 210-212 management, functionalities for 212-213 monitoring 188, 208

m

Machine Learning 25–26, 125, 136, 207, 224 material-based storage 79 312 Index

metering equipment 193–194, 196–197, 199, 207 methanation processes 45–47 methanation technologies 44 micro-wind 277 microbial electrosynthesis (MES) 49, 51–52, 54 mitigating environmental impacts of energy systems 15 multi-energy structure 117 multi-energy systems 105 energy storage technologies application in 116–118 or hybrid energy systems 16

n

National Integrated Energy and Climate Plan 8 National Recovery and Resilience and Plans 284-285 near-term economic viability, of Power-to-X technologies 64 nearly zero energy building (NZEB) 240, 241 transition to positive energy districts 258-259 net zero energy building (nZEB) 240 balance 241 case studies 253–256 challenges, drivers, and best practices 256–258 definition 241 paradigms and flexibility through building monitoring and automation 250-252 net zero-energy districts (nZEDs) 254 non-thermal plasma (NTP) 49, 52 - 53

0

O&M costs reduction 137 one-stop-shop integrated digital platform 149, 150 open data 132, 167, 169, 175, 177 optimization problems (OPs) 223–224 Operational Technology (OT) 126 OT/IT cyber security architecture 154

р

package air source heat pump water heater 58 Paris Agreement 1, 41, 43, 281 PED Labs 254, 260 peer-to-peer (P2P) 17, 25–27, 125, 138, 217 people sustainable mobility indicator systems 168 personal data innovation 132 photovoltaic (PV) 28, 47, 55, 63, 116, 187, 212, 226, 243, 247, 275, 277 physical storage methods 79 PLC PRIME communication technology 192, 200-204, 206 PLC Prime version 1.4 protocol 206 policy advocacy 283 policy and regulatory barriers 33, 35-37 polymeric electrolyte membrane electrolysers (PEMEL) 78-79 positive energy building (PEB) 12-13, 239-260 across Europe 254

positive energy districts (PEDs) 248, 253-260, 284 power demand, of electrochemical Power-to-Chemicals conversion 54 power line communication (PLC) based technology 188 portable supervisors 199 power to heat/cooling (PtH/C) 19 Power-to-Chemicals-and-Fuels biochemical and thermochemical conversion 53–54 defining 43 energy demand, installed cost, and land usage 56 high-temperature electrolysis 50 - 51implications on power generation 54 - 57integration challenges and opportunities 54 lignocellulosic biomass and N₂ 48 low-temperature electrolysis 49 - 50market and demand 48-49 microbial electrosynthesis 51 - 52non-thermal plasma 52-53 via CO_2 48 Power-to-Gas (PtG) technologies 3,21 defining 43 H_2 production 44–45 identification and overview 46-47 integration challenges and opportunities 47-48 natural gas market demand fossil 45 renewable 45-46

Power-to-Heat (PtH) technologies 2, 6, 43 for process-level integration 61 identification and overview 60 integration challenges and opportunities 60-62 market and demand 57-60 supply-level substitution with 60 Power-to-Liquids (PtL) 18, 21, 41 - 66Power-to-X categories 43 Power-to-X technologies 11, 41 business model and innovation 65-66 components 42 feedstocks (CO₂, N₂, H₂O, Biomass) 62 goal of 44 life cycle analysis 64 near-term economic viability 64 operational flexibility for grid integration and revenue 63 Techno-Economic Analysis (TEA) 64 transformational R&D 64-65 predictive analytics 133, 139–140, 149, 154, 157-158 predictive controls 243, 245, 251, 298 Programmable Logic Controller (PLC) 188–189, 192, 194-195, 197-210, 298 prosumers 4, 13, 15, 17, 25, 27, 34-35, 127, 131-132, 134, 153, 187-188, 192-194, 197, 213, 216, 223, 249, 251, 258-259, 277-280, 284, 287-288, 297-300 Public-Owned ESS projects 108

pumped hydro storage technology 108 pumped hydroelectric storage (PHS) 110–112

r

radio frequency (RF) technologies 206 rated power, of ESS technology 109 real-time event management 207-208 reduction/modulation, of energy consumption 5 Remote Terminal Unit (RTU) 130, 197-198, 204, 207, 211 renewable energy communities (RECs) 7, 13, 17, 23, 246, 278 Renewable Energy Directive (RED II) 7, 10, 23, 24, 258, 277 - 278renewable energy production 240, 243, 246, 276-278, 280, 285, 287 renewable energy sources (RES) 3, 17, 48, 73, 105, 125, 256, 275 electricity 75 stochastic 73 renewable natural gas (RNG) 44-47,65 research activities, for prefabricated building envelope elements 243 research and development (R&D) 58, 64–65, 77, 88, 105, 158, 226 resilience indicators 182

S

Sabatier reaction 46 science fiction technologies 138

SDG 7, 165–166, 276–277, 298 second generation 275, 277 sector coupling 11, 17, 41–42, 73, 74, 130–131, 153, 279–280, 285-288, 291-295 self-consumption 5, 7, 187, 258, 278-280, 297 service abstraction layer (SAL) 250-251 shipping 83, 85 simple entities (SEN) 192-194, 196-199, 204, 209, 212 small level CHP plants 247 Smart Grid Architecture Model (SGAM) 141-142, 223, 224, 230, 235 smart grid reference architecture (SGAM) 223, 239 smart grids 12, 130, 134, 187 advanced control mechanisms for architecture and grid model 225-226 congestion issues in the TSO domain 226-228 frequency instability, TSO domain 230 advanced control mechanisms for congestion issues in the DSO domain 228 - 229case studies congestion events at distribution level 232 congestion events at transmission level 231–232 frequency instability issues 233-234 definition 216 electricity system 216 infrastructure of 216, 217 multi-domain optimization in 221, 223-224

requirements per stakeholder 128 services and functionalities of 219-222 technological areas of 218-219 smart home energy management systems (SHEMSs) 240 smart HVAC systems and services 245.246 "smartization" of electricity networks 234 smart meters 134, 187, 205 description 205–206 with hybrid communication 206 smart mobility 12 applied to bicycle-sharing in urban context 175, 177 and SDGs 165 Smart Networks for Energy Transition 130, 142, 149, 152 Smart Readiness Indicator (SRI) 8 calculation 250 socio-economic barriers 35 state/municipal-owned projects 108 static-occupancy assessment methods 249 steam methane reforming (SMR) 77,84 stochastic Renewable Energy Sources (RES) 73 storage 19 and conversion technologies 18 - 22technologies 296 superconducting magnetic energy storage (SMES) 112, 127 supervisory control and data acquisition (SCADA) 157, 207.298 sustainable built environment 253, 276

Sustainable Development Goals (SDG) 1, 276–277, 288, 298 smart mobility and 165–167 sustainable energy systems 71, 106, 156, 223 sustainable mobility indicators and metrics 165, 167 sustainable mobility KPI 167 synthetic electro-fuels (e-fuels) 85

t

Techno-Economic Analysis (TEA) 46, 63–64 techno-economic barriers 34 thermal energy storage (TES) systems 6, 110, 113, 249 thermal storage solutions 12 three-phase supply 195 traditional storage technologies 19 transmission system operator (TSO) 32, 126, 131, 225, 226, 228, 230 turbo compressors 80

u

unmanned aerial vehicle (UAV) 126, 138

V

valley of death 76 von Neumann computer concept 139

W

water source heat pumps 57 wide area monitoring system (WAMS) 218 wide-area adaptive protection, control and automation (WAAPCA) 218 wide-area situation consciousness (WASA) 218 WTW GHG emissions 177

Ζ

zero energy building (ZEB) 17, 240–243 definition 241 ZERO-PLUS project 253–257