

## XII. Acronyms, Abbreviations, and Definitions

~	Approximately	AD	Adsorption
@	At	ADOPT	Automotive Deployment Options Projection Tool
°C	Degrees Celsius	AE	Acceptability envelope; Acoustic emissions
°F	Degrees Fahrenheit	<i>Ae</i>	Alkaline earth
Δ	Change, delta	AEM	Anion exchange membrane; Analytical electron microscopy
ΔH	Enthalpy of reaction, Enthalpy of hydrogenation	AEMFC	Anion exchange membrane fuel cell
ΔH <sub>des</sub> <sup>o</sup>	Desorption enthalpy	AEO	Annual Energy Outlook
ΔK	Stress intensity factor	AFC	Alkaline fuel cell
ΔP	Pressure drop, pressure change	AFCB	American Fuel Cell Bus Project
≈	Equals approximately	AFDC	Alternative Fuels Data Center
>	Greater than	AFL	Anode functional layer
≥	Greater than or equal to	AFV	Alternative fuel vehicle
<	Less than	Ag	Silver
≤	Less than or equal to	A-h	Amp-hour
μm	Micrometer(s), micron(s)	AHJ	Authorities having jurisdiction
#	Number	AIMD	Ab initio molecular dynamics
Ω	Ohm(s)	Al	Aluminum
Ω/cm <sup>2</sup>	Ohm(s) per square centimeter	Al <sub>2</sub> O <sub>3</sub>	Aluminum oxide
Ω-cm <sup>2</sup>	Ohm-square centimeter	ALD	Atomic layer deposition
ρ	Average fiber density	AlH <sub>3</sub>	Aluminum hydride; Alane
%	Percent	ALS	Advanced Light Source at Lawrence Berkeley National Laboratory
®	Registered trademark	A/m <sup>3</sup>	Amps per cubic meter
\$	United States dollars	AMFC	Anion exchange membrane fuel cell; Alkaline membrane fuel cell
1-D, 1D	One-dimensional	AMR	U.S. Department of Energy Hydrogen and Fuel Cells Annual Merit Review
1Q	First quarter of the fiscal year	AMR	Active magnetic regenerator
2-D, 2D	Two-dimensional	AN	Acrylonitrile
2Q	Second quarter of the fiscal year	ANL	Argonne National Laboratory
III-V	three-five (semiconductor materials)	ANSI	American National Standards Institute
3-D, 3D	Three-dimensional	APEEP	Air Pollution Emission Experiments and Policy model
3Q	Third quarter of the fiscal year	APRR	Average pressure ramp rates
4D	Four dimensional	APU	Auxiliary power unit
4Q	Fourth quarter of the fiscal year	Ar	Argon
6PGDH	6-phosphogluconate dehydrogenase	AR	As received
A	Ampere, amps	ARRA	American Recovery and Reinvestment Act
<i>A</i>	Alkali	As	Arsenic
Å	Angstrom	ASL	Anode support layer
Abs	absolute	ASME	American Society of Mechanical Engineers
AC	Activated carbon		
AC	Alternating current		
A/C	Anode/cathode		
A/cm <sup>2</sup>	Amps per square centimeter		
ACR	Area coverage ratio		

ASPEN	Modeling software, computer code for process	BPV	Boiler and pressure vessel
ASR	Area-specific resistance; areal surface resistance	BPVC	Boiler and Pressure Vessel Code
AST	Accelerated stress test	Br	Bromine
ASTM	ASTM International, originally known as the American Society for Testing and Materials	BTMA	Benzyltrimethyl ammonium hydroxide
at%	Atomic percent	BTT	Baggage tow tractor; Benzene tris-tetrazole
atm	Atmosphere	BTU, Btu	British thermal unit(s)
atmA	Atmospheres pressure, absolute	BV	Benzyl viologen
a.u.	Arbitrary units	BVPC	Boiler and pressure vessel code (ASME)
Au	Gold	C	Carbon
Autonomie	Plug-and-Play Powertrain and Vehicle Model Architecture and Development Environment software model by Argonne National Laboratory to support the rapid evaluation of new powertrain/propulsion technologies for improving fuel economy through virtual design and analysis in a math-based simulation environment	C	Coulomb
Avg	Average	C <sub>2</sub> H <sub>4</sub>	Ethylene
B	Boron	C <sub>2</sub> H <sub>6</sub>	Ethane
B2B	Back-to-back	C <sub>3</sub> H <sub>8</sub>	Propane
Ba	Barium	ca.	About, approximately
bara	Bar absolute	Ca	Calcium
BaSce	Baseline and Scenario Analysis	CaFCP	California Fuel Cell Partnership
BBNO	Barium bismuth niobium oxide	cal	Calorie(s)
BDL	Biomass derived liquid	CARB	California Air Resources Board
Be	Beryllium	CaS	Calcium sulfide
BES	Basic Energy Sciences office within the DOE Office of Science	cc	Cubic centimeter(s)
BESS	Battery energy storage system	CCL	Cathode catalyst layer
BET	Brunauer-Emmett-Teller surface area analysis method	CCM	Catalyst-coated membrane; Coordinate measuring machine
BEV	Battery electric vehicle	Cc/min, ccm	Cubic centimeters per minute
BF	Bright field	ccp	Cubic close-packing
Bi	Bismuth	CCP	Combined cooling and power
BNL	Brookhaven National Laboratory	CCS	Carbon capture and sequestration; catalyst coated substrate
BOC	Best of class	Cd	Cadmium
BOL	Beginning of life	CD	Current density; Compact disk; Charge depleting; Cathode dewpoint
BOM	Bill of materials	CDP	Constant dew point
BOP, BoP	Balance of plant	CDP	Composite data product
BOT	Beginning of test	Ce	Cerium
BP	Budget Period; Bisphenol; Biphenyl	CEA	Commissariat à l'Énergie Atomique
BP1	Budget Period 1	CEC	California Energy Commission
BP2	Budget Period 2	CEM	Compressor/expander/motor
BPP	Bipolar plate	CF	Carbon fiber
		CFD	Computational fluid dynamics
		cfm	Cubic feet per minute
		CFR	Cumulative fluoride release
		CG	Combustible gas sensor
		CH	Chemical hydride
		cH <sub>2</sub>	Compressed hydrogen gas
		CH <sub>4</sub>	Methane

CHES	Corral Hollow Experimental Station	CV	Conventional vehicle; Cyclic voltammetry; Cyclic voltammogram
CHEX	Cold heat exchanger	CVD	Chemical vapor deposition
CHG	Compressed hydrogen gas	CY	Calendar year
CHHP	Combined heat, hydrogen, and power	d	Day(s)
CHMC	Compressed Hydrogen Materials Compatibility	D-A	Dubinin-Astakhov
CHP	Combined heat and power	da/dN	Fatigue crack growth rate
Cl	Chlorine	DAPP	Diels-Alder poly(phenylene)
CL	Catalyst layer	DARPA	Defense Advanced Research Projects Agency
cm	Centimeter	DC	Direct current
CM	Controls module	DCDA	Dicyanamide
CM	Cyanamide	DDP	Detailed data product
cm <sup>2</sup>	Square centimeter	ΔG	Gibbs free energy of reaction
CNG	Compressed natural gas	ΔH	Enthalpy of reaction; Enthalpy of hydrogenation
CNGV	Compressed natural gas vehicle	ΔK	Stress intensity factor
CNII	Cold neutron imaging instrument	ΔP	Pressure drop; Pressure change
CNT	Carbon nanotube	DF	Dark fermentation
Co	Cobalt	DFC <sup>®</sup>	Direct fuel cell
CO	Carbon monoxide	DFM	Design for manufacturing
CO <sub>2</sub>	Carbon dioxide	DFMA <sup>®</sup>	Design for Manufacturing and Assembly
CoE	Center of Excellence	DFT	Density functional theory
COMSOL	Multiphysics modeling and engineering simulation software	dhcp	Double hexagonal close-packing
COP	coefficient of performance	DI	Deionized; De-ionized water
COPV	Composite overwrapped pressure vessel	DM	Diffusion media
COV	Coefficient of variation	DMA	Dynamic mechanical analysis
cP	Centipoise	DMAc	Dimethyl acetamide
CPP	Clean Power Plant	DME	Dimethyl ether
CPR2	Cascading pressure receiver reactor	DMF	n, n-di-methyl formamide
CPU	Computer processing unit	DMFC	Direct methanol fuel cell
CPV	Composite pressure vessel	DMS	Division of Measurement Standards
Cr	Chromium	DMSO	Dimethyl sulfoxide
CR	Compression ratio	DNA	Deoxyribonucleic acid
CRADA	Cooperative Research and Development Agreement	dobdc	2,5-dioxido-1,4-benzenedicarboxylate
Cs	Cesium	DOD	Department of Defense
CSA	Canadian Standards Association	DOE	Department of Energy
CSD	Compression, storage, and delivery	DOT	Department of Transportation
CSM	Colorado School of Mines	d-PtNi, d-PtNi/C	Dealloyed platinum-nickel alloy cathode electrocatalyst supported on high surface area carbon
CSULA	California State University, Los Angeles	DR	Demand response
CTD	Composite Technology Development, Inc.	DRIFTS	Diffuse reflectance infrared Fourier transform spectroscopy
CTE	Coefficient of thermal expansion	DRP	Disaster Recovery Plan
CTE	Center for Transportation and the Environment	DRTS	Digital real-time simulator
Cu	Copper		
CU	University of Colorado		

DSC	Differential scanning calorimetry	ESOL	Extruded shell with overlaid head liner
dsbdc	2,5-disulfido-benzene-1,4-dicarboxylate	et al.	<i>Et Alii:</i> and others
DSM™	Dimensionally stable membrane	etc.	<i>Et cetera:</i> and so on
$E_{1/2}$	Half-wave potential	ETFECS	Extended thin-film electrocatalyst structures
E85	85%-15% blend of ethanol with gasoline	eV	Electron volt
ECA	Electrochemical surface area	EW	Equivalent weight
ECS	Electrochemical Society	EX	Hazardous area due to possible flammable gas concentration
ECSA	Electrochemically active surface area; Electrochemical surface area	EXAFS	Extended X-ray absorption fine structure analysis
EDAX	Manufacturer of energy dispersive X-ray hardware and software	F	Fluorine
EDS	Energy dispersive X-ray spectroscopy; Energy dispersive spectrum	F	Faraday constant, the amount of electric charge in one mole of electrons (96,485.3383 coulomb/mole)
EDX	Energy dispersive X-ray	f	Frequency
EEA	Energy & Environmental Analysis, Inc.	F <sup>-</sup>	Fluorine ion
EEA	Electrode/electrode assembly	FASTSim	Fugure Automotive Systems Technology Simulator
EELS	Electron energy loss spectroscopy	FC	Fuel cell
EENW	Emerald Energy NW, LLC	FCB	Fuel cell bus
EERE	U.S. DOE Office of Energy Efficiency and Renewable Energy	FCC	Face-centered cubic; Fuel Cell Catalyst; Fluid catalytic cracking
e.g.	<i>Exempli gratia:</i> for example	FCE	FuelCell Energy
EG	Ethylene glycol	FCEB	Fuel cell electric bus
EGR	Exhaust gas recirculation	F-Cell	Daimler Fuel Cell vehicle
eGRID	Emissions & Generation Resource Integrated Database	FCET	Fuel cell electric truck
EHC	Electrochemical hydrogen compressor; Ethylperhydrocarbazole	FCEV	Fuel cell electric vehicle
EHS	Environmental Health and Safety	FCGR	Fatigue crack growth rate
EIA	Energy Information Administration of the U.S. Department of Energy	FCHEA	Fuel Cell Hydrogen Energy Association
EIN	Energy Independence Now	FCH JU	Joint Fuel Cell and Hydrogen Energy
EIS	Electrochemical impedance spectroscopy	FC-PAD	Fuel Cell Performance and Durability
EM	Electron mediator	FCS	Fuel cell system
EOL	End of life	FCT	Fuel Cell Technologies
EOT	End of test	FCTO	Fuel Cell Technologies Office
EPA	Environmental Protection Agency	FCTT	Fuel Cell Technical Team
ER	Emergency responder	FCV	Fuel cell vehicle
ER	Energy recovery	Fe	Iron
eREV	Extended range electric vehicles	FEA	Finite element analysis
ES	Energy storage	FEC	Front end controller
ESA	Electrochemical surface area	FEM	Finite element model
ESB	Erbium-stabilized bismuth oxide	FER	Fluoride emission rate
ESD	Electro-static discharge; emergency shutdown device	FLUENT	Computer code for computational fluid dynamics
ESIF	Energy Systems Integration Facility	FMEA	Failure modes and effects analysis
ESLL	Extruded shell with loose head liner	F-MEC	Fermentation and microbial electrolysis cell
		FOA	Funding opportunity announcement

FOM	Figure of merit	GHG	Greenhouse gas
ft	Feet	GIS	Geographic information system
ft <sup>2</sup>	Square feet	GJ	Gigajoule(s)
ft <sup>3</sup>	Cubic feet	GKB	Graphitized Ketjenblack®
FPR	Falling particle receiver	g/kW	Gram(s) per kilowatt
FRCC	Florida Reliability Coordinating Council	GLWN	Westside Industrial Retention & Expansion Network
FSLL	Formed shell with loose head liner	gm	Gram(s)
FSOL	Formed shell with overlaid head liner	GM	General Motors
F-SPEEK	Fluorosulfonic acid of polyetheretherketone	gm/day	Gram(s) per day
ft	Feet	g/min	Gram(s) per minute
ft <sup>2</sup>	Square feet	GN2	Gaseous nitrogen
ft <sup>3</sup>	Cubic feet	GNR	Graphene nanoribbon
FTIR	Fourier transform infrared	GO	Graphene oxide
FTO	Fluorine-doped tin oxide	GPa	Gigapascal(s)
FY	Fiscal year	GREET	Greenhouse gases, Regulated Emissions and Energy use in Transportation model
FZ	fusion zone	g/s	Grams per second
g	Gram; acceleration of gravity	G-S	Gas-solid
G	Graphite	GTI	Gas Technology Institute
G6P	Glucose 6-phosphate	GUI	Graphical user interface
G6PDH	Glucose 6-phosphate dehydrogenase	GWe, GW <sub>e</sub>	Gigawatt(s) electric
Ga	Gallium	h	Hour(s)
GAAP	Generally accepted accounting principles	H	Hydrogen
gal	Gallon	H <sup>+</sup>	Proton
GaP	Gallium phosphide	H <sup>-</sup>	Hydride
GB	Gigabyte	H <sub>2</sub>	Diatomic hydrogen
GBL	γ-Butyrolactone	H2A	Hydrogen Analysis project sponsored by DOE
GC	Gas chromatograph; General computational	H2FAST	Hydrogen Financial Analysis Scenario Tool
GC	Glassy, or vitreous carbon; a pure carbon that is amorphous (non-crystalline)	H2I	Hawaii Hydrogen Initiative
g/cc	Grams per cubic centimeter	H <sub>2</sub> O	Water
GCLP	Grand-canonical linear programming	H <sub>2</sub> O <sub>2</sub>	Hydrogen peroxide
GCMC	Grand Canonical Monte Carlo	H <sub>2</sub> S	Hydrogen sulfide
GCNT	Graphitized carbon nanotubes	H <sub>2</sub> SO <sub>4</sub>	Sulfuric acid
GCTool	Software package developed at ANL for analysis of fuel cells and other power systems	H2USA	Hydrogen Technology Learning Centers (for CA, FL, and NY)
Gd	Gadolinium	HAADF	High-angle annular dark field
GDC	Gadolinium-doped ceria	HAADF-STEM	High angle annular dark field scanning transmission electron microscopy
GDE	Gas diffusion electrode	HA-FCG	Hydrogen accelerated fatigue crack growth
GDL	Gas diffusion layer	HAVO	Hawaii Volcanoes National Park
GDM	Gas diffusion media	HAZ	Heat-affected zone
Ge	Germanium	HC	Hydrocarbon
Gen	Generation	HCD	Hydrogen contaminant detector
GEN I	First generation	HCER	High Energy Coil Reservoir, LLC
GEN II	Second generation		
GEN III	Third generation		
GGE, gge	Gasoline gallon equivalent		
GH <sub>2</sub>	Gaseous hydrogen		

HCl	Hydrochloric acid	HTC	High temperature coolant
HClO <sub>4</sub>	Perchloric acid	HTE	High-temperature electrolysis
hcp	Hexagonal close-packing	HTF	Heat transfer fluid
HDPE	High-density polyethylene	HTGR	High-temperature gas-cooled reactor
HDSAM	Hydrogen Delivery Scenario Analysis Model	HTP	High throughput
He	Helium	HTPEM	High-temperature polymer electrolyte membrane
HE	Hydrogen embrittlement	HX	Heat exchanger
H-E-B	H-E-B Grocery Company, Inc.	HyCoRA	Hydrogen Contaminant Risk Assessment
HER	Hydrogen evolution reaction	HyMARC	Hydrogen Storage Materials Advanced Research Consortium
HEV	Hybrid electric vehicle	HyRAM	Hydrogen Risk Assessment Models
HEX	Heat exchanger	HyRes	Hydrogen Regional Sustainability framework
Hf	Hafnium	HyS	Hybrid sulfur
HFCTF	Hawaii Fuel Cell Test Facility	HyStEP	Hydrogen Station Equipment Performance
HFCV	Hydrogen fuel cell vehicle	HYSYS®	Process simulation software by AspenTech, computer code for flowsheet analysis
HFR	High-frequency resistance	HyTRANS	Hydrogen Transition Model
HGV	Hydrogen gaseous vehicle	Hz	Hertz
HHV	Higher heating value	i	Current density (mA/cm <sup>2</sup> )
HIP	High performance	I	Current
HiPoD	High power density	I2CNER	International Institute for Carbon-Neutral Energy Research
HITRF	Hydrogen Infrastructure Testing and Research Facility	I/C	Ionomer to catalyst
HNEI	Hawaii Natural Energy Institute	ICC	International Code Council
HOR	Hydrogen oxidation reaction	ICE	Internal combustion engine
HOV	High occupancy vehicle	ICEV	Internal combustion engine vehicle
hp	Horsepower	iCVD	Initiated chemical vapor deposition
HPA	Heteropoly acid	ID	Inside diameter
HPTB	High powered test bay at NREL	i.e.	<i>id est</i> : that is
hr	Hour(s)	IEC	International Electrotechnical Commission
HRS	Hydrogen refueling station	IEC	Ion exchange capacity, milliequivalents of acid groups per gram of material
HRSAM	Hydrogen refueling station analysis model	IFRS	International financial reporting standards
HR-STEM	High resolution scanning transmission electron microscopy	IFWG	Investment and Finance Working Group
HRT	Hydraulic retention time	IL	Illinois
HR-TEM	High resolution transmission electron microscopy	IL	Ionic liquid
HSA	High surface area	ILS	Inter-laboratory studies
HSAC	High surface area carbon	IMM	Inverted metamorphic multijunction
HSC	Database name derived from the letters for enthalpy, entropy and heat capacity	In	Indium
HSE	High surface area electrode	In., in	Inch
HSECoE	Hydrogen Storage Engineering Center of Excellence	in <sup>2</sup>	Square inch
HSP	Hydrogen Safety Panel	INL	Idaho National Laboratory
HT	High throughput; High temperature	I-O	Input-output
HTAC	Hydrogen and Fuel Cell Technical Advisory Committee	IR, iR	Internal resistance
		Ir	Iridium



IRDA	Infrared data acquisition	L, l	Liter(s)
IrDA	Infrared Data Association	La	Lanthanum
IRMOF	Isorecticular metal organic framework	LA	Los Angeles
IRR	Internal rate of return	$\lambda$	Lambda, hydration number
ISO	International Organization for Standardization	LANL	Los Alamos National Laboratory
IT	Intermediate temperature	LAX	Los Angeles International Airport
IUPUI	Indiana University–Purdue University Indianapolis	lb	Pound(s)
IV	Current-voltage	LBL	Lawrence Berkeley National Laboratory
J	Current	lbmol	Pound-mole(s)
J	Joule(s)	LBNL	Lawrence Berkeley National Laboratory
JARI	Japan Automobile Research Institute	LC	Levelized cost; Liquid carrier; Low concentration
JM	Johnson Matthey	LCA	Life cycle assessment; Life-cycle analysis
JMFC	Johnson-Matthey Fuel Cells, Inc.	LCC	Life cycle cost
JRC	Joint Research Centre	LCIA	Life-cycle impact assessment
J-T	Joule-Thompson	LDH	Lactate dehydrogenase
K	Kelvin, absolute temperature	LDV	Light-duty vehicle
K	Potassium	LEIS	Low-energy ion scattering
kA/m <sup>2</sup>	Kilo-ampere(s) per square meter	LFL	Lower flammability limit
kcal	Kilocalorie(s)	L/h, l/h	Liter(s) per hour
kcal/mol	Kilocalorie(s) per mole	LH <sub>2</sub> , LH <sub>2</sub>	Liquid hydrogen
KeV	Kilo electron volt(s)	LHSV	Liquid hourly space velocity, h <sup>-1</sup>
kg	Kilogram(s)	LHV	Lower heating value
kg/d	Kilogram(s) per day	Li	Lithium
kg/hr	Kilogram(s) per hour	LLC	Limited Liability Company
kg/m <sup>3</sup>	Kilogram(s) per cubic meter	LLNL	Lawrence Livermore National Laboratory
kHz	Kilohertz	L/min, l/min	Liter(s) per minute
kJ	Kilojoule(s)	LMRC	Linear motor reciprocating compressor
KJ300	Ketjen Black EC 300J; a high surface-area carbon support	LN <sub>2</sub>	Liquid nitrogen
kJ/mol	Kilojoule(s) per mole	LNG	Liquefied natural gas
km	Kilometer(s)	LP	Lattice parameter; low pressure
KMC, kMC	Kinetic Monte Carlo; Kilauea Military Camp; Kia Motors Corporation	LSAC	Low surface area carbon
kPa	Kilopascal(s)	LSM	Lanthanum strontium manganate
kph	Kilometer(s) per hour	LT	Low-temperature
ksi	1,000 pound-force per square inch	LTPEM	Low temperature polymer exchange membrane
kVA	Kilovolt-amp (units of apparent power)	m	Meter(s)
kW	Kilowatt(s)	M	Mole, molar
kWe, kW <sub>e</sub>	Kilowatt(s) electric	M	Million
kWh	Kilowatt-hour(s)	m <sup>2</sup>	Square meter(s)
kWh/kg	Kilowatt-hour(s) per kilogram	m <sup>2</sup> /g	Square meter(s) per gram
kWh/L	Kilowatt-hour(s) per liter	m <sup>2</sup> /s	Square meter(s) per second
kW/kg	Kilowatt(s) per kilogram	m <sup>3</sup>	Cubic meter(s)
kWt	Kilowatt(s) thermal	$\mu$ A	Micro ampere(s)
		mA	MilliAmps (s)

MA	Mass activity	ML	Monolayer; mono atomic layer
$\mu\text{A}/\text{cm}^2$	Micro ampere(s) per square centimeter	$\mu\text{m}$	Micrometer(s); micron(s)
$\text{mA}/\text{cm}^2$	Milliamp(s) per square centimeter	$\mu\text{M}$	Micromolar
MASC	Multi-acid side-chain	mM	Millimolar
MA3T	Market Acceptance of Advanced Automotive Technologies Model	mm	Millimeter(s)
MATI	Modular Adsorption Tank Insert	MMOF	Microporous metal-organic framework
MAWP	Maximum allowable working pressure	mmol	Millimole(s)
MB	Megabyte	$\mu\text{mol}$	Micromole(s)
MBRC	Miles between roadcall	Mn	Manganese
MC	Monte Carlo	$\text{m}\Omega$	Milli-ohm(s)
MC	Microchannel	$\text{M}\Omega$	Mega-ohm(s)
MCC	Materials Characterization Center	$\text{m}\Omega/\text{cm}^2$	Milli-ohm(s) per square centimeter
MCF	Mesostructured cellular foam	$\mu\Omega\text{-cm}^2$	Micro-ohm(s) - square centimeter
MCFC	Molten carbonate fuel cell	Mo	Molybdenum
MCHL	Magnetocaloric hydrogen liquefier	MO	metal oxide
$\mu\text{CHP}$	Micro-combined heat and power	MOF	Metal-organic framework
mCHP	Micro-combined heat and power	mol	Mole(s)
$\mu\text{CHX}$	Microscale combustor/heat exchanger	MOL	Middle of life
MEA	Membrane electrode assembly	mol%	Mole percent
MEC	Microbial electrolysis cell	mol/min	Mole(s) per minute
MeCN	Acetonitrile	MOPS	3-morpholinopropane-1-sulfonic acid
meGo	Microwave exfoliated graphene oxide	MPa	Megapascal (s)
MeOH	Methanol	MPG, mpg	Mile(s) per gallon
meq	Milliequivalents	MPGGE	Miles per gasoline gallon equivalent
meq/g	Milliequivalents/gram	mph	Mile(s) per hour
MES	Microstructured electrode scaffold	MPL	Microporous layer; monoporous layer
MeV	Mega electron volt	MRCAT	Materials Research Collaborative Access Team
MFC	Microbial fuel cell, Mass flow controller	MREC	Microbial reverse-electrodialysis electrolysis cell
Mg	Megagram(s)	MRL	Manufacturing readiness level
$\mu\text{g}$	Microgram(s)	ms	Millisecond(s)
mg	Milligram(s)	mS/cm	Milli-Siemen(s) per centimeter
MGCLP	Multi-gas canonical linear programing	MSM	Macro-System Model
$\text{mg}/\text{cm}^2$	Milligram(s) per square centimeter	MSU	Montana State University
MgO	Magnesium oxide	mtorr	Millitorr
$\text{mgPt}/\text{cm}^2$	Milligram (s) of platinum per square centimeter	MTPD	Metric tonne per day
MH	Metal hydride	$\mu\text{V}$	Microvolt(s)
MHE	Material handling equipment	mV	Millivolt(s)
MHz	Megahertz	mW	Milliwatt(s)
mi	Mile(s)	MW	Megawatt(s)
mi/kg	Mile(s) per kilogram	MW	Molecular weight
min	Minute(s), minimum	MWAP	Maximum allowable workable pressure
MJ	Megajoule(s)	$\text{mW}/\text{cm}^2$	Milliwatt(s) per square centimeter
mL, ml	Milliliter(s)	MWCNT	Multiple-wall carbon nanotube



## XII. Acronyms, Abbreviations, and Definitions

MWe	Megawatt(s) electric	NHTSA	National Highway Traffic Safety Administration of the U.S. Department of Transportation
MWh	Megawatt-hour(s)	Ni	Nickel
MWNT	Multi-wall carbon nanotube	NiMH	Nickel metal hydride
MYPP	Multi-Year Program Plan (the Fuel Cell Technologies Program's Multi-Year Research, Development, and Demonstration Plan)	NIST	National Institute of Standards and Technology
MYRDD	Multi-Year Research, Development, and Demonstration	nm	Nanometer(s)
N	Nitrogen atom	NMN	Nicotinamide mononucleotide
N	Newton (unit of force)	nmol	Nanomole(s)
N112	Nafion <sup>®</sup> 1100 equivalent weight, 2 millimeter thick membrane	NMP	N-methylpyrrolidone
N <sub>2</sub>	Diatomic nitrogen	NMR	Nuclear magnetic resonance
N <sub>2</sub> O	Nitrous oxide	NO <sub>2</sub>	Nitric oxide
Na	Sodium	NO <sub>x</sub> , NO <sub>x</sub>	Oxides of nitrogen
NA	North American	Non-PGM	Non-precious metal group
Na <sub>2</sub> S	Sodium sulfide	NP	Nanoparticle
NAD	Nicotinamide adenine dinucleotide	NPCC	Northeast Power Coordinating Council
NADP	Nicotinamide adenine dinucleotide phosphate	NPS	National Park Service
NADPH	Nicotinamide adenine dinucleotide phosphate	NPTF	Nanoporous thin film
Nafion <sup>®</sup>	Registered Trademark of E.I. DuPont de Nemours	NR	Nicotinamide riboside
NASA	National Aeronautics and Space Administration	NR211	Nafion <sup>®</sup> 211 membrane
Nb	Niobium	NR212	Nafion <sup>®</sup> 212 membrane
N-C	Nitrogen doped porous carbon	NREL	National Renewable Energy Laboratory
N/cm <sup>2</sup>	Newton(s) per square centimeter	NROR	NADPH rubredoxin oxidoreductase
NCNT; N-CNT	Nitrogen doped carbon nanotube	NSF	National Science Foundation
NEC	National Electrical Code	NSTF	Nanostructured thin film
NECSA	South African Nuclear Energy Corporation	NT	Nanotube
NELHA	Natural Energy Laboratory Hawaii Authority	NUWC	Naval Underwater Warfare Center
NERC	North American Electric Reliability Corporation	NW	Nanowire
NEU	Northeastern University	NYSERDA	New York State Energy Research and Development Authority
NFCTEC	National Fuel Cell Technology Evaluation Center, at NREL	Ω	Ohm(s)
NFPA	National Fire Protection Association	Ωcm <sup>2</sup>	Ohm(s) - square centimeter
ng	Nanogram	O	Oxygen
NG	Natural gas	O <sub>2</sub>	Diatomic oxygen
N-GT	Nitrogen doped graphene nanotube	O/C	Oxygen-to-carbon ratio
NGV	Natural gas vehicle	OCP	Open circuit potential
NH <sub>3</sub>	Ammonia	OCV	Open-circuit voltage
NHE	Normal hydrogen electrode	o.d.,OD	Outer diameter
		OEM	Original equipment manufacturer
		OER	Oxygen evolution reaction
		O&M	Operation and maintenance
		ORNL	Oak Ridge National Laboratory
		ORR	Oxygen reduction reaction
		OSU	Ohio State University

OSU	Oregon State University (Microproducts Breakthrough Institute)	PFSI	Perfluorosulfonate ionomer
P	Phosphorus	PG	Propylene glycol
P	Pressure	PG&E	Pacific Gas and Electric Company
Pa	Pascal(s)	PGM	Precious group metal; Platinum-group metal
PA	Phosphoric acid, Phenylacetylene; Polyamide	pH	Power of the hydronium ion
P&D	Production and delivery	PHEV	Plug-in hybrid electric vehicle
PAFC	Phosphoric acid fuel cell	PHIL	Power hardware in the loop
PAN	Polyacrylonitrile	PI	Principal investigator
P&ID	Piping and instrumentation diagram	P&ID	Piping and instrumentation diagram; Process and instrumentation diagram
PANI	Polyaniline	PID	Proportional, integral, derivative; Process identifier number
PAN-MA	Polyacrylonitrile with methyl acrylate	PM	Particulate matter; permanent magnet
PAN-VA	Polyacrylonitrile with vinyl acetate	PNNL	Pacific Northwest National Laboratory
Pb	Lead	POC	Point of contact; Proof of concept
PB	Polyborazylene	POM	Polyoxometallate
PbA	Lead acid	ppb	Part(s) per billion
PBCTF	Pressurized button cell test facility	ppbv	Part(s) per billion by volume
PBI	Polybenzimidazole	PPC	Pajarito Powder
PBPA	Hexamethyl ammonium functionalized poly(biphenyl alkylene)	PPI	Plug Power, Inc.
PBS	Phosphate buffer solution	ppm, PPM	Part(s) per million
PCN	Porous coordination network	ppmv	Part(s) per million by volume
PCR	Polymerase chain reaction	ppmw	Part(s) per million by weight
PCT	Pressure-composition-temperature	PPO	Phenyl phosphine oxide
PCTFE	Polychlorotrifluoroethylene	ppt	Parts per trillion
Pd	Palladium	PREP	Plasma rotating electrode process
PEC	Photoelectrochemical; Photoelectrocatalyst; Photoelectrochemical cell	PS	Polysiloxane; polystyrene
PECVD	Plasma-enhanced chemical vapor deposition	PSA	Pressure swing adsorption, adsorber
PEEK	Polyether ether ether ketone	PSf	Poly(arylene ether sulfone)
PEFC	Polymer electrolyte fuel cell	psi, PSI	Pound(s) per square inch
PEGS	Prototype electrostatic ground state	psia	Pound(s) per square inch absolute
PEM	Proton exchange membrane; Polymer electrolyte membrane	psid	Pound(s) per square inch differential
PEMFC	Polymer electrolyte membrane fuel cell	psig, PSIG	Pound(s) per square inch gauge
PEMFC	Proton exchange membrane fuel cell	PSS	Potentiostatic scan
PEV	Plug-in electric vehicle	PSU	Polysulfone
PF	Perfluoro; Phenolic	PSU	Pennsylvania State University
PFAEM	Perfluorinated anion exchange membranes	PSV	Pressure safety valve
PFD	Process flow diagram	Pt	Platinum
PFIA	Perfluoroimide acid	Pt/C	Platinum/carbon
PFICE	Perfluoro ionene chain extended	PTFE	Teflon <sup>®</sup> – poly-tetrafluoroethylene
PFL	Pyruvate formate lyase	PtO	Platinum oxide
PFSA	Perfluorinated sulfonic acid, perfluorosulfonic acid, poly(fluorosulfonic acid)	PV	Photovoltaic; Present value
PF-SFP	perfluoro sulfonyl fluoride precursor	PVD	Physical vapor deposition
		PVP	Pressure vessel and piping
		PVT, P-V-T	Pressure-Volume-Temperature

Q1, Q2, Q3, Q4	Quarters of the fiscal year	S/C	Steam to carbon ratio
QC	Quality control	SCADA	Supervisory Control and Data Acquisition system
QENS	Quasielastic neutron scattering	SCAQMD	South Coast Air Quality Management District
QMC	Quantum Monte Carlo	sccm, SCCM	Standard cubic centimeter(s) per minute
R	Universal or ideal gas constant, $8.314472 \text{ J} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}$	SCCV	Steel/concrete composite vessel
RAMAN	A spectroscopic technique	SCF, scf	Standard cubic feet; Supercritical fluid
RCF	RCF Economic & Financial Consulting, Inc.	scfd	Standard cubic feet per day
RCS	Regulations codes and standards	SCFM	Standard cubic feet per minute
R&D	Research and development	S/cm	Siemen(s) per centimeter
RD&D, R,D&D	Research, development & demonstration	SDE	SO <sub>2</sub> -depolarized electrolyzer
RDE	Rotating disk electrode	SD/SU	Shut-down/start-up
Re	Rhenium	Se	Selenium
RE	Rare earth metal	sec	Second(s)
Ref	Reference	SECA	Solid State Energy Conversion Alliance
REMI	Regional Economic Models, Inc.	SEF	Surface enhancement factor
REP	Reformer-Electrolyzer-Purifier; Representative performance	SEHP	Sorption Enhanced Hydrogen Production
RFB	Redox flow battery	SEM	Scanning electron microscopy; Scanning electron microscope
RFC	Regenerative fuel cell	SERA	Scenario Evaluation, Regionalization and Analysis
RFDT	Reactive spray deposition technique	SFE	Stacking fault energy
rGO	Reduced graphene oxide	SFR	Stagnation flow reactor
Rh	Rhodium	SG&A	Sales, general, and administration
RH	Relative humidity	SGD	Spontaneous galvanic displacement; System gravimetric density
RHE	Reference hydrogen electrode; Reversible hydrogen electrode	SH1	Soluble [FeNi]-hydrogenase 1
RIE	Reactive ion etching	SHE	Standard hydrogen electrode
ROI	Return on investment	Si	Silicon
RPI	Rensselaer Polytechnic Institute	S-I	Sulfur-iodine
rpm	Revolution(s) per minute	slpm, slm, sL/min	Standard liter(s) per minute
RRDE	Rotating ring disc electrode	SLMA	Sr- and Mn-doped LaAlO <sub>3</sub>
RT	Room temperature	SMR	Steam methane reformer; Steam methane reforming
RTO	Titanium dioxide-ruthenium dioxide	SMSI	Strong metal support interaction
Ru	Ruthenium	SMYS	Specified minimum yield strength
s	Second(s)	Sn	Tin
S	Siemen(s)	SNL	Sandia National Laboratories
S	Sulfur	SLPH	Standard liter(s) per hour
SA	Strategic Analysis, Inc.	SLPM	Standars liter(s) per minute
SA	Specific amperage	SnO	Tin oxide
SAE	SAE International, originally known as the Society of Automotive Engineers	SnO <sub>2</sub>	Tin oxide
SAINC	Strategic Analysis, Inc.	SO <sub>2</sub>	Sulfur dioxide
SBA	Santa Barbara Amorphous	SO <sub>3</sub>	Sulfur trioxide
SBIR	Small Business Innovation Research	SOA	State of the art

SOC	State-of-charge	TCO	Transparent conductive oxide; Total cost of ownership
SOEC	Solid oxide electrolyzer cell	Te	Tellurium
SOFC	Solid oxide fuel cell	TEM	Transmission electron microscopy
SOFEC	Solid oxide fuel-assisted electrolysis cell	tf	Thin film
SOSS	Station Operational Status System	TF-RDE	Thin film rotating disk electrode
SOTA	State of the art	TGA	Thermal gravimetric analysis; Thermogravimetric analysis; Thermogravimetric analyzer
SOW	Statement of work	THF	Tetrahydrofuran
S-PEEK	Sulfonated poly(ether ether ketone)	Ti	Titanium
SPP	Southwest Power Pool; strategic partnership project	TIR	Technical information report
S-PSU	Sulfonated polysulfone	TKK	Tanaka Kikinzoku Kogyo K. K.
sq. in.	Square inch(es)	TMAOH	Tetramethyl ammonium hydroxide
Sr	Strontium	TPB	Triple phase boundary
SR	Steam reformer; Steam reforming; Stoichiometric ratio	TPD	Tonne(s) per day
SRNL	Savannah River National Laboratory	TPR	Through plate resistance;
SrO	Strontium oxide	TPRD	Thermally-activated pressure relief device
SS	Stainless steel	TR	Thermal reduction chamber
SSA	Specific surface area	TRL	Technology readiness level
SSFF	Stainless steel fiber felt	TRU	Trailer refrigeration unit
SSM	Sacrificial support method; Stainless steel mesh; Stress strain microprobe	UAV	Unmanned aerial vehicle
SSNMR	Solid-state nuclear magnetic resonance	UC	University of California
SSW	Stainless steel wool	UCB	University of California, Berkeley
STEB	Standard test evaluation bottles	UCDavis	University of California, Davis
STEM	Scanning transmission electron microscopy	UCI	University of California, Irvine
STEM	Science, technology, engineering, and mathematics	UCLA	University of California, Los Angeles
STH	Solar-to-hydrogen	UCONN	University of Connecticut
STREET	Spatially and Temporally Resolved Energy and Environment Tool STTRSmall Business Technology Transfer	UGA	University of Georgia, Athens
STWS	Solar thermal water splitting	UH	University of Hawaii
SUNY	State University of New York	UM	University of Michigan
SU/SD	Start up and shut down	UNLV	University of Nevada, Las Vegas
SwRI <sup>®</sup>	Southwest Research Institute <sup>®</sup>	UNM	University of New Mexico
T	Temperature	UPS	United Parcel Service
T, t	Ton, tonne	UQTR	Université du Québec à Trois-Rivières
T	Tesla (unit of magnetic induction)	U.S.	United States
t	Time	USA	United States of America
Ta	Tantalum	USAXS	Ultra-small angle X-ray scattering
TAMU	Texas A&M University	USC	University of South Carolina
TBD	To be determined	USC	University of Southern California
TC	Thermocouple	USCAR	United States Council for Automotive Research, U.S. Cooperative Automotive Research
TC	Technical committee; Thermal conditioning	U.S. DRIVE	United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability

## XII. Acronyms, Abbreviations, and Definitions

UT	Utah	W/kg	Watt(s) per kilogram
UT	University of Tennessee	W/L, W/l	Watt(s) per liter
UTF	Ultrathin film	W/m-K, W/mK	
UTRC	United Technologies Research Center		Watt(s) per meter-Kelvin (unit of thermal conductivity)
UTS	Ultimate tensile strength		
UUV	Unmanned underwater vehicle	Wppm	Weight part(s) per million
UW	University of Washington	WPS	Wearable power system
V	Vanadium	WS	Water splitting
V	Volt; Vulcan	WSU	Washington State University
VAC	Volts alternating current	wt	Weight
VACD	Variable area control device	Wt	Watt(s) thermal
VC	Venture capitalist; Vulcan carbon	wt%, wt.%	Weight percent (percent by weight)
VCC	Virginia Clean Cities at James Madison University	WTW	Well-to-wheels
VDC	Volts direct current	w/v	Weight by volume
vdW	van der Waals	WWTP	Waste water treatment plant
V-I, V/I	Voltage – current	XAFS	X-ray absorption fine structure
VOC	Voltage open circuit	XANES	X-ray absorption near-edge spectroscopy
Vol., vol.	Volume	XAS	X-ray absorption spectroscopy
vol%	Volume percent	XCT	X-ray computed tomography
W	Tungsten	XES	X-ray emission spectroscopy
W	Watt(s)	XPS	X-ray photoelectron spectroscopy, X-ray photon spectroscopy, XRD X-ray diffraction
WAXS	Wide angle X-ray scattering	XRF	X-ray fluorescence
WCF	Water consumption factor	XRT	X-ray tomography
W/cm <sup>2</sup>	Watt(s) per square centimeter	Y	Yttrium
We, W <sub>e</sub>	Watt(s) electric	yr, YR	Year
WECC	Western Electric Coordinating Council	YSZ	Yttria-stabilized zirconia
WG	Working group	ZEV	Zero emission vehicle
Wh	Watt-hour(s)	Zn	Zinc
W-h/kg	Watt-hour(s) per kilogram	ZnO	Zinc oxide
W-h/L, Wh/L	Watt-hour(s) per liter	Zr	Zirconium