

## XII. Acronyms, Abbreviations, and Definitions

~	Approximately	AD	Adsorption; Adsorbent; Anode dew point; Atomically dispersed
@	At	ADF	Annular dark-field imaging
°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 <sup>°</sup> <sub>des</sub>	Desorption enthalpy	AEMFC	Anion exchange membrane fuel cell
ΔK	Stress intensity factor	AEO	Annual Energy Outlook
ΔP	Pressure drop, pressure change	AF1	Autofrettage option 1
≈	Equals approximately	AF2	Autofrettage option 2
>	Greater than	AFCB	American Fuel Cell Bus Project
≥	Greater than or equal to	Ag	Silver
<	Less than	A-h	Amp-hour(s)
≤	Less than or equal to	AHJ	Authority having jurisdiction
μm	Micrometer(s), micron(s)	AHMF	Advanced Hydrogen Mobile Fueler
η	Viscosity	AHP	Absorption heat pump
#	Number	AK	Alkali
Ω	Ohm(s)	a.k.a.	Also known as
Ω/cm <sup>2</sup>	Ohm(s) per square centimeter	Al	Aluminum
Ω-cm <sup>2</sup>	Ohm-square centimeter	Al*	Aluminum particles catalyzed with titanium
%	Percent	Al-AB	Aluminum-ammonia-borane
®	Registered trademark	AlCl <sub>3</sub>	Aluminum chloride
\$	United States dollars	ALD	Atomic layer deposition
<sup>11</sup> B-NMR	Nuclear magnetic resonance of boron with mass number 11	AlH <sub>3</sub>	Aluminum hydride; Alane
<sup>19</sup> FNMR	Nuclear magnetic resonance of fluorine with mass number 19	Al <sub>2</sub> O <sub>3</sub>	Aluminum oxide
1-D, 1D	One-dimensional	ALS	Advanced Light Source at Lawrence Berkeley National Laboratory
1Q	First quarter of the fiscal year	ALT	Accelerated life test
2-D, 2D	Two-dimensional	A/m <sup>3</sup>	Amp(s) per cubic meter
2Q	Second quarter of the fiscal year	AMBER	Advanced Materials Beamline for Energy Research at Advanced Light Source
3-D, 3D	Three-dimensional	AMBH	Ammine metal borohydride
3Q	Third quarter of the fiscal year	AMFC	Anion exchange membrane fuel cell; Alkaline membrane fuel cell
4D	Four-dimensional	AMR	U.S. Department of Energy Hydrogen and Fuel Cells Annual Merit Review; Active magnetic regenerator
4Q	Fourth quarter of the fiscal year	ANL	Argonne National Laboratory
6PGDH	6-phosphogluconate dehydrogenase	ANSI	American National Standards Institute
9MeTTP+	tris(2,4,6-trimethylphenyl) phosphonium	API	American Petroleum Institute
9MeOTTP+	tris(2,4,6-trimethoxyphenyl) phosphonium	APS	Advanced Photon Source
A	Ampere(s), amp(s)	APU	Auxiliary power unit
<i>A</i>	Alkali		
Å	Angstrom(s)		
Abs	Absolute		
AC	Activated carbon; Alternating current		
A/cm <sup>2</sup>	Amp(s) per square centimeter		

AP-XPS	Ambient pressure X-ray photoelectron spectroscopy	BNL	Brookhaven National Laboratory
Ar	Argon	<sup>11</sup> B-NMR	Nuclear magnetic resonance of boron with mass number 11
As	Arsenic	BOC	Best of class
ASME	American Society of Mechanical Engineers	B(OH) <sub>3</sub>	Boric acid
ASPEN	Modeling software, computer code for process analysis	BOL, BoL	Beginning of life
ASR	Area-specific resistance; areal surface resistance	BOP, BoP	Balance of plant
AST	Accelerated stress test; DOE Accelerated Stability Test	BOT	Beginning of test
ASTM	ASTM International, originally known as the American Society for Testing and Materials	BP	Budget Period; Bisphenol; Biphenyl
at%	Atomic percent	BP1	Budget Period 1
A&TM	Atomistic and thermodynamic modeling	BP2	Budget Period 2
atm	Atmosphere(s)	BP-Ar	Perfluoroalkylsulfonate polymer
atmA	Atmosphere(s) pressure, absolute	BPV	Boiler and pressure vessel
ATM-PP	Benzyl trimethyl ammonium functionalized Diels-Alder poly(phenylene)	BPVC	Boiler and Pressure Vessel Code
ATO	Antimony-doped tin oxide	Br	Bromine
ATP	Acceptance test procedure; Adenosine triphosphate; Advanced Technology Program	BTU, Btu	British thermal unit(s)
a.u.	Arbitrary units	BV	Benzyl viologen
Au	Gold	BY	Brewer's yeast
AuS	Gold sulfide	C	Carbon; Coulomb
Avg	Average	C5	Five-carbon sugar
AWARE-US	Available water resource in the United States	C6	Six-carbon sugar
B	Boron	ca.	About, approximately
Ba	Barium	Ca	Calcium
bara	Bar absolute	CAD	Computer-aided design; computer aided drawing
BaSc	Baseline and Scenario Analysis	CaFCP	California Fuel Cell Partnership
B <sub>25</sub> B' <sub>75</sub>	General term to describe AB <sub>0.25</sub> B' <sub>0.75</sub> O <sub>y</sub> , perovskite composition	cal	Calorie(s)
BCV	Benzyl viologen-derived conjugate	CalTech	California Institute of Technology
Be	Beryllium	CAN	Controller area network
BES	Basic Energy Sciences office within the DOE Office of Science	CARB	California Air Resources Board
BET	Brunauer–Emmett–Teller surface area analysis method	CaS	Calcium sulfide
BETO	Bioenergy Technologies Office within the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy	CBET	Division of Chemical, Bioengineering, Environmental, and Transport Systems
BEV	Battery electric vehicle	CBS	Casa Bonita strain; Complete basis set
Bi	Bismuth	cc	Cubic centimeter(s)
BJH	Barrett, Joyner, and Halenda	CCAT	Connecticut Center for Advanced Technology, Inc.
BM	Base metal; Ball-milled, ball mill	CcH <sub>2</sub>	Cryo-compressed hydrogen
BN	Boron–nitrogen	CCL	Cathode catalyst layer
		CCM	Catalyst-coated membrane; Coordinate measuring machine
		Cc/min, ccm	Cubic centimeter(s) per minute
		CCSI	Continuous Codes and Standards Improvement
		Cd	Cadmium

## XII. Acronyms, Abbreviations, and Definitions

CD	Current density; Compact disk; Charge depleting; Cathode dewpoint	CPV	Composite pressure vessel
CDP	Composite data product	Cr	Chromium
Ce	Cerium	CRADA	Cooperative Research and Development Agreement
CEC	California Energy Commission	Cs	Cesium
CEMI	Clean Energy Manufacturing Initiative	C&S	Codes and standards
CeO <sub>2</sub>	Ceric oxide	CSA	Canadian Standards Association
CF	Carbon fiber	CSL	Corn steep liquor
CFD	Computational fluid dynamics	CSM	Colorado School of Mines; Combined structure & material
cfm	Cubic feet per minute	CSU	California State University
cH <sub>2</sub>	Compressed hydrogen gas	CSULA	California State University, Los Angeles
CH <sub>4</sub>	Methane	CSV	Comma separated values
CHEX	Cold heat exchanger	CT	Computed tomography
CHG	Compressed hydrogen gas	CTE	Coefficient of thermal expansion; Center for Transportation and the Environment
CHP	Combined heat and power	CTL	Cryogenics Test Laboratory
CI	Cathode interlayer	Cu	Copper
CIDI	Compression ignition direct injection	CU	University of Colorado
CIS	CuInSe (alloy of copper, indium, and selenium)	cu in.	Cubic inch(es)
CKAN	Comprehensive Knowledge Archive Network	cu. yd.	Cubic yard(s)
Cl	Chlorine	CV	Cyclic voltammetry; Cyclic voltammogram
CL	Catalyst layer	CVD	Chemical vapor deposition
cm	Centimeter(s)	CVP	Cold vapor pressure
cm <sup>2</sup>	Square centimeter(s)	CWG	Catalysis Working Group
CMK3	Nanoporous carbon prepared with SBA-15	CZO	Ceria-zirconia
CMU	Carnegie Mellon University	d	Day(s)
CNF	Carbon nano-fiber	D <sub>2</sub>	Deuterium
CNG	Compressed natural gas	D-A	Dubinina-Astakhov
CNGV	Compressed natural gas vehicle	DAC	Direct air cooling; Data acquisition and control system
CNT	Carbon nanotube	da/dN	Fatigue crack growth rate
CNxPY	Doped carbon nano-structures	DAE	Diels-Alder ether
Co	Cobalt	DAPP	Diels-Alder poly(phenylene)
CO	Carbon monoxide	DAQ	Data acquisition
CO <sub>2</sub>	Carbon dioxide	DARPA	Defense Advanced Research Projects Agency
COD	Chemical oxygen demand	DC	Direct current
CoE	Center of Excellence	DDCA	Durability descriptor calculation automation
COP	Coefficient of performance	Deg	Degree(s)
COPV	Composite overwrapped pressure vessel	ΔG	Gibbs free energy of reaction
cP	Centipoise	ΔH	Enthalpy of reaction; Enthalpy of hydrogenation
CP	Cross polarization	ΔK	Stress intensity factor
CPA	Coherent potential approximation	ΔP	Pressure drop; Pressure change
CPMAS	Cross polarization magic angle spinning	DFC®	Direct fuel cell
CPR <sup>2</sup>	Cascading pressure receiver reactor	DFM	Design for manufacturing
c.p.s.	Counts per second		
CPU	Computer processing unit		

DFMA <sup>®</sup>	Design for Manufacturing and Assembly	EENW	Emerald Energy NW, LLC
DFT	Density functional theory	EF	Emission factor
DG	Distributed generation	e.g.	<i>Exempli gratia</i> : for example
DHLA	Dihydrolipoic acid	EG	Ethylene glycol
DI	Diaphorase; Direct injection; Deionized; De-ionized water	EGR	Exhaust gas recirculation
DMA	Dynamic mechanical analysis	eGRID	Emissions & Generation Resource Integrated Database
DME	Dimethyl ether	EH	Electrochemical hydrogen
DMEA	Dimethylethylamine	EHC	Electrochemical hydrogen compressor; Ethylperhydrocarbazole
DMEAA	Dimethylethylamine alane	EIA	Energy Information Administration of the U.S. Department of Energy
DMF	n, n-di-methyl formamide	EIS	Electrochemical impedance spectroscopy
DMFC	Direct methanol fuel cell	EISA	Evaporation induced self assembly
DMR	De-acetylation and mechanically refined	EISF	Elastic incoherent structure factor
DMTA	Dynamic mechanical thermal analysis	ELAT <sup>®</sup>	Registered trademark of De Nora North America, Inc., covers gas diffusion layers and gas diffusion electrodes
DOD	U.S. Department of Defense	ENG	Expanded natural graphite
DOE	U.S. Department of Energy	EOD	Electro-osmotic drag
DOT	U.S. Department of Transportation	EOL, EoL	End of life
DOT/NHTSA	U.S. Department of Transportation National Highway Traffic Safety Administration	EOS	Economies of scale
DP	Dew point	EOT	End of test
DPMAS	Direct polarization magic angle spinning	EP	Economic potential
D-R	Dubinov-Radushkevich	EPA	U.S. Environmental Protection Agency
DRIFTS	Diffuse reflectance infrared Fourier transform spectroscopy	EPDM	Ethylene propylene diene monomer
DSC	Differential scanning calorimetry	EPIC	Energy Policy Institute of Chicago
DSM <sup>™</sup>	Dimensionally stable membrane	EPMA	Electron probe micro analyzer
DSM 1313	Deutsche Sammlung von Mikroorganismen 1313 strain of <i>C. thermocellum</i>	EPR	Electron paramagnetic resonance
DSM-MC	Distance scaling method Monte Carlo	EQCM	Electrochemical quartz crystal microbalance
DSRC	Dedicated short-range wireless communication	eREV	Extended range electric vehicle
e <sup>-</sup>	Electron	ESIF	Energy Systems Integration Facility
E	Activation energy, kJ/mol; Potential	et al.	<i>Et Alii</i> : and others
E85	Fuel blend consisting of 85% ethanol and 15% gasoline	ETC	Electron transport chain
E <sub>a</sub>	Activation energy	etc.	<i>Et cetera</i> : and so on
EC	Electrochemical capacitance	ETFECS	Extended thin-film electrocatalyst structures
ECA	Electrochemical surface area	EU	European Union
ECS	Engineered carbon support	eV	Electron volt(s)
ECSA	Electrochemically active surface area; Electrochemical surface area	EV	Electric vehicle
EDC	Energy distribution curve	EVOH	Ethylene vinyl alcohol
EDPM	Ethylene propylenediamene	EW	Equivalent weight
EDS	Energy dispersive X-ray spectroscopy; Energy dispersive spectrum	EXAFS	Extended X-ray absorption fine structure analysis
EDX	Energy dispersive X-ray	F	Fluorine; Faraday constant, the amount of electric charge in one mole of electrons (96,485.3383 coulomb/mole)
EELS	Electron energy loss spectroscopy	F <sub>6</sub> PBI	Hexafluoro polybenzimidazole

FA	Formic acid	G6PDH	Glucose 6-phosphate dehydrogenase
FC	Fuel cell	Ga	Gallium
FCB	Fuel cell bus	gal	Gallon(s)
FCE	FuelCell Energy	GB	Gigabyte(s)
FCEB	Fuel cell electric bus	GC	Glassy, or vitreous carbon; a pure carbon that is amorphous (non-crystalline)
FCEV	Fuel cell electric vehicle	g/cc	Gram(s) per cubic centimeter
FCGR	Fatigue crack growth rate	GCMC	Grand Canonical Monte Carlo
FCHEA	Fuel Cell Hydrogen Energy Association	GCMS	Gas chromatograph-mass spectroscopy
FCH JU	Fuel Cells and Hydrogen Joint Undertaking	Gd	Gadolinium
FC-PAD	Fuel Cell Performance and Durability Consortium	GDE	Gas diffusion electrode
FCPP	Fuel cell power plant	GDL	Gas diffusion layer
FCRx200	Fuel cell range extended plug-in hybrid utility vehicle	GDS	Galvanodynamic scan
FCS	Fuel cell system	Ge	Germanium
fcc	Face-centered tetragonal	Gen	Generation
FCTO	Fuel Cell Technologies Office within the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy	Gen 1, GEN I	First generation
FCTT	Fuel Cell Technical Team	Gen 2, GEN II	Second generation
FCV	Fuel cell vehicle	Gen 3, GEN III	Third generation
Fd	Ferredoxin	GGE, gge	Gasoline gallon equivalent
Fe	Iron	GH <sub>2</sub>	Gaseous hydrogen
FE	Finite element; U.S. Department of Energy's Office of Fossil Energy	GHG	Greenhouse gas
FEA	Finite element analysis	GISAXS	Grazing-incidence small-angle X-ray scattering; Grazing-incidence small-angle X-ray spectroscopy
FER	Fluoride emission rate	GJ	Gigajoule(s)
FLUENT	Computer code for computational fluid dynamics	g/kW	Gram(s) per kilowatt
FMEA	Failure modes and effects analysis	GLWN	Westside Industrial Retention & Expansion Network
<sup>19</sup> FNMR	Nuclear magnetic resonance of fluorine with mass number 19	gm	Gram(s)
FOA	Funding opportunity announcement	GM	General Motors
FOM	Figure of merit	gm/d	Gram(s) per day
FPGA	Field-programmable gate array	g/min	Gram(s) per minute
ft	Feet	GNG	Go/no-go
ft <sup>2</sup>	Square feet	GNR	Graphene nanoribbon
ft <sup>3</sup>	Cubic feet	GPa	Gigapascal(s)
FTA	Federal Transit Administration of the U.S. Department of Transportation	GPRA	Government Performance and Results Act
FTATR	Fourier transform attenuated total reflection	gps	Gram(s) per second
FT-IR, FTIR	Fourier transform infrared	GrC	Graphitized carbon
FY	Fiscal year	GREET	Greenhouse gases, Regulated Emissions and Energy use in Transportation model
g	Gram; Acceleration of gravity	g/s	Gram(s) per second
G	Graphite	GTI	Gas Technology Institute
G6P	Glucose 6-phosphate	GTR	Global Technical Regulation
		GUI	Graphical user interface

GWe, GW <sub>e</sub>	Gigawatt(s) electric	HiPoD	High power density
h	Hour(s)	HITRF	Hydrogen Infrastructure Testing and Research Facility
H	Hydrogen	HKUST	1 Cu <sub>3</sub> (1,3,5-benzenetricarboxylate) <sub>2</sub>
H <sup>+</sup>	Proton	HMPA	Hexamethylphosphoramide
H <sup>-</sup>	Hydride	HOR	Hydrogen oxidation reaction
H <sub>2</sub>	Diatomic hydrogen	HOV	High occupancy vehicle
H2@Scale	A concept that explores the potential for wide-scale hydrogen production and utilization in the United States	hp	Horsepower
H2A	Hydrogen Analysis project sponsored by DOE	HP	High pressure
H2FAST	Hydrogen Financial Analysis Scenario Tool	HPA	Heteropoly acid
H2I	Hawaii Hydrogen Initiative	HPC	High pressure cell; Highly porous carbon
H <sub>2</sub> O	Water	hr	Hour(s)
H <sub>2</sub> O <sub>2</sub>	Hydrogen peroxide	HRL	Hughes Research Laboratory, HRL Laboratories, LLC
H <sub>2</sub> S	Hydrogen sulfide	HRS	Hydrogen refueling stations
H2SCOPE	Hydrogen Station Cost Optimization and Performance Evaluation	HRSAM	Hydrogen refueling station analysis model
H <sub>2</sub> SO <sub>4</sub>	Sulfuric acid	HR-STEM	High resolution scanning transmission electron microscopy
H2USA	Hydrogen Technology Learning Centers (for California, Florida, and New York)	HRT	Hydraulic retention time
H2VGI	Hydrogen–vehicle–grid integration model	HR-TEM	High resolution transmission electron microscopy
HAADF	High-angle annular dark field	HSA	High surface area
HAADF-STEM	High-angle annular dark field scanning transmission electron microscopy	HSAC	High surface area carbon
HA-FCG	Hydrogen accelerated fatigue crack growth	HSC	High surface area carbon
HAZ	Heat-affected zone	HSECoE	Hydrogen Storage Engineering Center of Excellence
HAZOP	Hazards and Operational Safety Analysis	HT	High throughput; High temperature; Heat-treatment/thermal annealing
HC	Hydrocarbon; High concentration	HTAC	Hydrogen and Fuel Cell Technical Advisory Committee
HCD	High current density; Hydrogen contaminant detector	HTPEM	High-temperature polymer electrolyte membrane
HCl	Hydrochloric acid	HTWS	High temperature water splitting
HDFCV	Heavy-duty fuel cell vehicle	HVAC	Heating, ventilation and cooling
HDPE	High-density polyethylene	HX	Heat exchanger
HDSAM	Hydrogen Delivery Scenario Analysis Model	HyMARC	Hydrogen Storage Materials Advanced Research Consortium
HDTT	Hydrogen Delivery Technical Team	HyRAM	Hydrogen Risk Assessment Models
He	Helium	HyROC-1	pH Matter's down-selected proprietary catalyst with no Pt
HER	Hydrogen evolution reaction	HyS	Hybrid sulfur
HEX	Heat exchanger	HySCORE	Hydrogen Storage Characterization and Optimization Research Effort
Hf	Hafnium	HyStEP	Hydrogen Station Equipment Performance
HFCEV	Hydrogen fuel cell electric vehicle	HyVS	Hydrogen Vehicle Simulator
HFR	High-frequency resistance	Hz	Hertz
HFSF	High-flux solar furnace	i	Current density (mA/cm <sup>2</sup> )
HGV	Hydrogen gaseous vehicle		
HHC	Hawaii Hydrogen Carriers		
HHV	Higher heating value		



## XII. Acronyms, Abbreviations, and Definitions

I2CNER	International Institute for Carbon-Neutral Energy Research	K	Sievert's constant, ml/[cm <sup>2</sup> -min-atm <sup>1/2</sup> ]; Kelvin, absolute temperature; Potassium
IACMI	Institute for Advanced Composite Manufacturing Innovation	kÅ	1,000 angstroms
I/C	Ionomer to carbon ratio; Ionomer to catalyst	kA/m <sup>2</sup>	Kilo-ampere(s) per square meter
ICE	Internal combustion engine	kb	Kilo-base pair, a unit of measurement used in genetics equal to 1,000 nucleotides
ICP	Inductively coupled plasma	KBr	Potassium bromide
ICP-MS, ICP/MS	Inductively coupled plasma mass spectrometry	kcal	Kilocalorie(s)
ICP-OES	Inductively coupled plasma optical emission spectroscopy	kcal/mol	Kilocalorie(s) per mole
iCVD	Initiated chemical vapor deposition	kg	Kilogram(s)
ID	Inside diameter	kg/d	Kilogram(s) per day
i.e.	<i>id est</i> : that is	kg/hr	Kilogram(s) per hour
IEA	International Energy Agency	kg/m <sup>3</sup>	Kilogram(s) per cubic meter
IEC	International Electrotechnical Commission; Ion exchange capacity, milliequivalents of acid groups per gram of material	KH	Potassium hydride
IEEE	Institute of Electrical and Electronics Engineers, Inc.	kHz	Kilohertz
IL	Ionic liquid	kJ	Kilojoule(s)
IMM	Inverted metamorphic multijunction	KJ300	Ketjen Black EC 300J, a high surface-area carbon support
In	Indium	kJ/mol	Kilojoule(s) per mole
In., in	Inch(es)	km	Kilometer(s)
in <sup>2</sup>	Square inch(es)	kMC	Kinetic Monte Carlo
INL	Idaho National Laboratory	KODTE	Knock-on displacement threshold energy
INTEGRATE	Integrated Network Testbed for Energy Grid Research and Technology Experimentation	KOH	Potassium hydroxide
IPA	Isopropyl alcohol	kPa	Kilopascal(s)
IR	Infrared	kph	Kilometer(s) per hour
IR, iR	Internal resistance	ksi	1,000 pounds-force per square inch
Ir	Iridium	kT/y	Kiloton(s) per year
IrDA	Infrared Data Association	kW	Kilowatt(s)
IRIG	Inter-Laboratory Research Integration Group	kWe, kW <sub>e</sub>	Kilowatt(s) electric
IRMOF	Isorecticular metal organic framework	kWh	Kilowatt-hour(s)
ISO	International Organization for Standardization	kWh/kg	Kilowatt-hour(s) per kilogram
ISO/TC197	International Standards Organization Technical Committee 197	kWh/L	Kilowatt-hour(s) per liter
IV, iV	Current-voltage	kW/kg	Kilowatt(s) per kilogram
J	Joule(s)	kWt	Kilowatt(s) thermal
JARI	Japan Automobile Research Institute	L, l	Liter(s), length
JMC	Japan Metals and Chemicals	La	Lanthanum
JPL	Jet Propulsion Laboratory	LAG	Liquid assisted grinding
JRC	Joint Research Centre	LANL	Los Alamos National Laboratory
J-V, JV	Current density-voltage	lb	Pound(s)
		LBL	Lawrence Berkeley National Laboratory
		lbmol	Pound-mole(s)
		LBNL	Lawrence Berkeley National Laboratory
		LCA	Life cycle assessment; Life-cycle analysis
		LCD	Low current density
		L/D	Length-to-diameter ratio
		LDV	Light-duty vehicle

LEIS	Low-energy ion scattering	MDR	Manufacturer's design report
L/h, l/h	Liter(s) per hour	MEA	Membrane electrode assembly
LH2, LH <sub>2</sub>	Liquid hydrogen	MEC	Microbial electrolysis cell; Minimum explosive concentration
LHV	Lower heating value	MFC	Microbial fuel cell; Mass flow controller
Li	Lithium	μg	Microgram(s)
LiOH	Lithium hydroxide	mg	Milligram(s)
LLC	Limited Liability Company	MGCLP	Multi-gas canonical linear programming
LLNL	Lawrence Livermore National Laboratory	mg/cm <sup>2</sup>	Milligram(s) per square centimeter
L/min, l/min	Liter(s) per minute	MH	Metal hydride
LMRC	Linear motor reciprocating compressor	MHC	Metal hydride-based compressor
LP	Low pressure	MHDV	Medium- and heavy-duty vehicle
LPG	Liquefied petroleum gas	MHz	Megahertz
LPM	Liter(s) per minute	mi	Mile(s)
LT	Low-temperature	mi/kg	Mile(s) per kilogram
m	Meter(s)	mil	Millimeter(s)
M	Mole(s), molar; Million	min	Minute(s); Minimum
m <sup>2</sup>	Square meter(s)	MJ	Megajoule(s)
m <sup>3</sup>	Cubic meter(s)	mL, ml	Milliliter(s)
m <sup>2</sup> /g	Square meter(s) per gram	ML	Monolayer
m <sup>2</sup> /s	Square meter(s) per second	MLI	Multi-layer vacuum insulation
μA	Microampere(s)	MLS	Milestone
mA	Milliampere(s)	μm	Micrometer(s); micron(s)
MA	Mass activity	μM	Micromolar
μA/cm <sup>2</sup>	Microampere(s) per square centimeter	mM	Millimolar
mA/cm <sup>2</sup>	Milliampere(s) per square centimeter	mm	Millimeter(s)
MAE	Modal acoustic emissions	mmol	Millimole(s)
MAS	Magic angle spinning	μmol	Micromole(s)
MAS <sup>11</sup> B-NMR	Magic angle spinning boron-11 nuclear magnetic resonance spectroscopy	MMT	Million metric tonne(s)
MAS NMR	Magic angle spinning nuclear magnetic resonance	Mn	Manganese
MASC	Multi-acid side chain	MnO	Manganese oxide
MATI	Modular adsorption tank insert	mΩ	Milli-ohm(s)
MAWP	Maximum allowable working pressure	MΩ	Mega-ohm(s)
MB	Megabyte(s)	mΩ/cm <sup>2</sup>	Milli-ohm(s) per square centimeter
mbar	Millibar	μΩ-cm <sup>2</sup>	Micro-ohm(s) - square centimeter
MBRC	Miles between roadcall	Mo	Molybdenum
MC	Monte Carlo; Metal carbide	MOF	Metal-organic framework
MCF	Mesostructured cellular foam	mol	Mole(s)
MCHL	Magnetocaloric hydrogen liquefier	MOL	Middle of life
μCHP	Micro-combined heat and power	mol%	Mole percent
MCM	Mobile crystalline material	mol/min	Mole(s) per minute
MCP	Microchannel plate	MoP	Molybdenum phosphide
MD	Molecular dynamics	MPa	Megapascal(s)
<i>m</i> -dobdc <sup>4-</sup>	4,6-Dioxido-1,3-benzenedicarboxylate	MPG, mpg	Mile(s) per gallon
		mph	Mile(s) per hour



ms	Millisecond(s)	NDP	Neutron depth profiling
MSAC	Mid-range carbon support; Medium surface area carbon	NDTE	Non-destructive testing and evaluation
MSC	Medium surface area carbon	NE	U.S. Department of Energy's Office of Nuclear Energy, Science and Technology
mS/cm	Milli-Siemen(s) per centimeter	NEB	Nudged elastic band
MSU	Montana State University	NEF	n-Ethylformamide
MT	Mass transfer	NEI	National Emission Inventory
mtorr	Millitorr	NETL	National Energy Technology Laboratory
MTPD	Metric tonne(s) per day	NEU	Northeastern University
MTU	Michigan Technological University	NEXAFS	Near edge X-ray absorption fine structure
μV	Microvolt(s)	NFCRC	National Fuel Cell Research Center
mV	Millivolt(s)	NFCTEC	National Fuel Cell Technology Evaluation Center, at National Renewable Energy Laboratory
mW	Milliwatt(s)		
MW	Megawatt(s); Molecular weight	NFPA	National Fire Protection Association
mW/cm <sup>2</sup>	Milliwatt(s) per square centimeter	NG	Natural gas
MWCNT	Multiple-wall carbon nanotube	NGO	Non-government organization
MWe	Megawatt(s) electric	NGV	Natural gas vehicle
MWh	Megawatt-hour(s)	NH <sub>3</sub>	Ammonia
MYRDD, MYRD&DP	Multi-Year Research, Development, and Demonstration Plan	NHFCCSCC	National Hydrogen and Fuel Cells Codes and Standards Coordinating Committee
N	Nitrogen atom; Newton (unit of force)	Ni	Nickel
N112	Nafion <sup>®</sup> 1100 equivalent weight, 2 millimeter thick membrane	NIST	National Institute of Standards and Technology
Na	Sodium	nm	Nanometer(s)
NA	North American; Not applicable	nmol	Nanomole(s)
NaCl	Sodium chloride	NMR	Nuclear magnetic resonance
NAD	Nicotinamide adenine dinucleotide	NMSU	New Mexico State University
NADH	(reduced) Nicotinamide adenine dinucleotide	NNIF	NIST Neutron Imaging Facility
NADP	Nicotinamide adenine dinucleotide phosphate	NNPC	Nitrogen-doped nanoporous carbons
NADPH	Nicotinamide adenine dinucleotide phosphate	NO <sub>2</sub>	Nitric oxide
Nafion <sup>®</sup>	Registered trademark of E.I. DuPont de Nemours	NO <sub>x</sub> , NO <sub>x</sub>	Oxides of nitrogen
NASA	National Aeronautics and Space Administration	NP	Nanoparticle
NAU	Northern Arizona University	NPC	Nanoporous carbon
Nb	Niobium	NPTF	Nanoporous thin film
NBR	Nitrile butyl rubber	NPV	Net present value
NC	Nanocrystals; Nano-carbon; Nanocomposite	NR211	Nafion <sup>®</sup> 211 membrane
N/cm <sup>2</sup>	Newton(s) per square centimeter	NR212	Nafion <sup>®</sup> 212 membrane
NCMK3	CMK3 carbons containing nitrogen	NREL	National Renewable Energy Laboratory
NDA	Non-disclosure agreement	NROR	NADPH rubredoxin oxidoreductase
NDC	New delivery concept; Naphthalene-2,6-dicarboxylate	NRVS	Nuclear resonance vibrational spectroscopy
nDDB	n-Dodecyl benzene	NSF	National Science Foundation
NDE	Non-destructive examination	NSTF	Nanostructured thin film
		NT	Nanotube
		NTCNA	Nissan Technical Center, North America
		NUWC	Naval Underwater Warfare Center

NW	Nanowire	PF	Perfluoro
$\Omega$	Ohm(s)	PFD	Process flow diagram
$\Omega\text{cm}^2$	Ohm(s) - square centimeter	PFIA	Perfluoroimide acid
O	Oxygen	PFICE	Perfluoro ionene chain extended
O <sub>2</sub>	Diatomic oxygen	PFSA	Perfluorinated sulfonic acid, perfluorosulfonic acid, poly(fluorosulfonic acid)
OCV	Open-circuit voltage	PGM	Precious group metal; Platinum group metal
o.d., OD	Outer diameter	PHEV	Plug-in hybrid electric vehicle
OEM	Original equipment manufacturer	P&ID	Piping and instrumentation diagram
OER	Oxygen evolution reaction	PM	Particulate matter
OFCC	Ohio Fuel Cell Coalition	PM <sub>10</sub>	Particulate matter with diameter of 10 micrometers or less
O&M	Operation and maintenance	PM <sub>2.5</sub>	Particulate matter with diameter of 2.5 micrometers or less
ORNL	Oak Ridge National Laboratory	PNNL	Pacific Northwest National Laboratory
ORR	Oxygen reduction reaction	ppb	Part(s) per billion
P	Phosphorus; Pressure	ppbv	Part(s) per billion by volume
Pa	Pascal(s)	PPC	Pajarito Powder
PAA	Poly(acrylic acid)	PPI	Plug Power, Inc.
PADD	Petroleum Administration for Defense District	ppm, PPM	Part(s) per million
PAN	Peroxyacetyl nitrate; Polyacrylonitrile	PPO	Phenyl phosphine oxide
PANI	Polyaniline	PRD	Pressure relief device
PAN-MA	Polyacrylonitrile with methyl acrylate	PRV	Pressure relief valve
PA/PBI	Phosphoric-acid-doped polybenzimidazole	PS	Particle source chamber; Photosystem
Pb	Lead	PSD	Particle size distribution; Pore size distribution
PBI	Polybenzimidazole	psi, PSI	Pound(s) per square inch
PBPA-Br	Bromoalkyl-tethered aromatic polymer	psia	Pound(s) per square inch absolute
PBS	Phosphate buffer solution	PSU	Pennsylvania State University
PCET	Proton-coupled electron transfer	Pt	Platinum
PCI	Phase-change induced	Pt/C	Platinum/carbon, carbon-supported platinum catalyst
PCT	Pressure-composition-temperature	PTFE	Teflon <sup>®</sup> – poly-tetrafluoroethylene
Pd	Palladium	Pt-MC	Platinum metal carbide
PD	Particle drain chamber; Pressure decay	Pt-TF	Platinum thin film
PDOS	Partial density of state	PTW	Pump to wheels
PEC	Photoelectrochemical; Photoelectrocatalyst; Photoelectrochemical cell	PV	Photovoltaic; Pressure vessel; Present value
PECVD	Plasma-enhanced chemical vapor deposition	PVD	Physical vapor deposition
PEEK	Polyether ether ketone	PVP	Pressure vessel and piping
PEFC	Polymer electrolyte fuel cell; Proton exchange fuel cell	Q1, Q2, Q3, Q4	Quarters of the fiscal year
PEG	Polyethylene glycol	QD	Quantum dot
PEGS	Prototype electrostatic ground state	QE	Quantum efficiency
PEM	Proton exchange membrane; Polymer electrolyte membrane	QENS	Quasielastic neutron scattering
PEMFC	Polymer electrolyte membrane fuel cell; Proton exchange membrane fuel cell	QMC	Quantum Monte Carlo
PET	Photosynthetic electron transport	R	Load ratio(s)
PEV	Plug-in electric vehicle	RAMAN	A spectroscopic technique

## XII. Acronyms, Abbreviations, and Definitions

RBS	Rutherford back scattering	SEM	Scanning electron microscopy; Scanning electron microscope; Secondary electron microscopy
RCS	Regulations, codes and standards		
R&D	Research and development		
RDA	Rotating disk atomization	SERA	Scenario Evaluation, Regionalization and Analysis
RD&D	Research, development, and demonstration	SERC	Schatz Energy Research Center
RDE	Rotating disk electrode	SFE	Stacking fault energy
Re	Rhenium	SFR	Stagnation flow reactor
RE	Rare earth metal	SGD	Spontaneous galvanic displacement; System gravimetric density
REMI	Regional Economic Models, Inc.		
RF, rf	Radio frequency	SHI	Soluble [FeNi]-hydrogenase 1
RFO	Residual fuel oil	Si	Silicon
RGA	Residual gas analyzer (analysis)	SI	Spark ignition; Sulfur-iodine cycle; Spectrum image
rGO	Reduced graphene oxide		
Rh	Rhodium	SIA	Structural Integrity Associates
RH	Relative humidity	Si-BH	Silicon-based borohydrides
RHE	Reference hydrogen electrode; Reversible hydrogen electrode	SIU	Southern Illinois University
ROI	Return on investment	sL	Standard liter (0°C, 1 atm)
RPI	Rensselaer Polytechnic Institute	SLMA	Strontium- and manganese-doped $\text{LaAlO}_3$ , general term to describe $\text{Sr}_x\text{La}_{1-x}\text{Mn}_y\text{Al}_{1-y}\text{O}_3$ perovskite compositions
rpm	Revolution(s) per minute	SLPH	Standard liter(s) per hour
RPN	Risk priority number	SLPM; slpm	Standard liter(s) per minute
RRDE	Rotating ring disc electrode	SMR	Steam methane reformer; Steam methane reforming
RT	Room temperature		
Ru	Ruthenium	SMYS	Specified minimum yield strength
RWS	RijksWaterStaat	Sn	Tin
s	Second(s)	SNL	Sandia National Laboratories
S	Siemen(s); Sulfur	SNLL	Sandia National Laboratory Livermore
SA	Strategic Analysis, Inc.	SOA	State of the art
SAD	Selected area diffraction	SOEC	Solid oxide electrolyzer cell
SAE	SAE International, originally known as the Society of Automotive Engineers	SOFC	Solid oxide fuel cell
SANS	Small angle neutron scattering	SOPO	Statement of project objectives
SAXS	Small angle X-ray scattering	SOTA	State of the art
SBA-15	Nanostructured silica template used for synthesis of carbons	SOW	Statement of work
SBIR	Small Business Innovation Research	SOx	Oxides of sulfur
Sc	Scandium	S-PEEK	Sulfonated poly(ether ether ketone)
sccm, SCCM	Standard cubic centimeter(s) per minute	sq. in.	Square inch(es)
scfd	Standard cubic feet per day	Sr	Strontium
SCFM	Standard cubic feet per minute	SR	Stoichiometric ratio
S/cm	Siemen(s) per centimeter	SS	Stainless steel
Se	Selenium	SSIM	4-lamp, 20 kW <sub>ele</sub> solar simulator
sec	Second(s)	SSM	Sacrificial support method
SECA	Solid State Energy Conversion Alliance	SSNMR	Solid-state nuclear magnetic resonance
SEF	Surface enhancement factor	S&T	Shell and tube
		STCH	Solar thermochemical hydrogen

STD	Soon to demonstrate	UAV	Unmanned aerial vehicle
STEB	Standard test evaluation bottle	UC	University of California
STEM	Scanning transmission electron microscopy	UCB	University of California, Berkeley
STH	Solar-to-hydrogen	UCF	University of Central Florida
STP	Standard temperature and pressure	UCI	University of California, Irvine
STTR	Small Business Technology Transfer	UCLA	University of California, Los Angeles
STWS	Solar thermal water splitting	UCONN	University of Connecticut
STXM	Scanning transmission X-ray microscopy	UGA	University of Georgia, Athens
SUNY	State University of New York	UH	University of Hawaii
SU/SD	Start up and shut down	UHPR	Ultra-High-Pressure Reactor at Sandia National Laboratories
SUSD	Startup-shutdown	UM	University of Michigan
SwRI®	Southwest Research Institute®	UNLV	University of Nevada, Las Vegas
sys/yr	Systems per year	UNM	University of New Mexico
T	Temperature	UNM IMID	Blended imidazole-based material
T, t	Ton, tonne	UPL	Upper potential limit
TAMU	Texas A&M University	UPS	United Parcel Service
TBD	To be determined	UQTR	University of Québec, Trios Rivieres
Te	Tellurium	U.S.	United States
TEA	Techno-economic analysis	USA	United States of America
TEM	Transmission electron microscopy	USC	University of South Carolina; University of Southern California
TG	Thermogravimetric	USCAR	United States Council for Automotive Research, U.S. Cooperative Automotive Research
TGA	Thermal gravimetric analysis; Thermogravimetric analysis; Thermogravimetric analyzer	U.S. DRIVE	United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability
TGA-DSC	Thermogravimetric analysis-differential scanning calorimetry	UT	University of Tennessee
THF	Tetrahydrofuran	UTF	Ultrathin film
Ti	Titanium	UTRC	United Technologies Research Center
TiO <sub>2</sub>	Titanium dioxide (anatase)	UUV	Unmanned underwater vehicle
TIR	Technical information report	UV	Ultraviolet
TKK	Tanaka Kikinzoku Kogyo K. K.	V	Vanadium; Volt; Vulcan
TM	Transition metal	VA	Vinyl acetate
TON	Turnover number	VCC	Vapor compression cycle; Virginia Clean Cities at James Madison University
TOU	Time of use	VDC	Volt(s) direct current
TPD	Tonne(s) per day; Thermally programmed desorption; Temperature-programmed desorption	VOC	Volatile organic compound
TPRD	Thermally-activated pressure relief device	VOC, Voc	Voltage open circuit
TPV	Total present value; Through-plate voltage	Vol., vol.	Volume
TR	Thermal reduction chamber; Traditional reactor	vol%	Volume percent
TRL	Technology readiness level	VP	Variable pressure
TRR	Technically recoverable resource	VT	Virginia Polytechnic Institute and State University (Virginia Tech)
TT/A	Technology transfer and agreement	W	Tungsten; Watt(s)
TTN	Total turnover number		
UALR	University of Arkansas at Little Rock		

## XII. Acronyms, Abbreviations, and Definitions

WaMM	Water management membrane	WTW	Well-to-wheels
WAXS	Wide angle X-ray scattering	XAFS	X-ray absorption fine structure
W/cm <sup>2</sup>	Watt(s) per square centimeter	XANES	X-ray absorption near-edge spectroscopy
We, W <sub>e</sub>	Watt(s) electric	XAS	X-ray absorption spectroscopy
WG	Working group	XCT, X-CT	X-ray computed tomography
WG-12	Working Group 12	XES	X-ray emission spectroscopy
Wh	Watt-hour(s)	XPS	X-ray photoelectron spectroscopy; X-ray photon spectroscopy; X-ray photoemission spectroscopy; X-ray photoluminescence spectroscopy
W-h/kg	Watt-hour(s) per kilogram		
W-h/L, Wh/liter, Wh/L	Watt-hour(s) per liter	XRD	X-ray diffraction
W/kg	Watt(s) per kilogram	XRF	X-ray fluorescence
W/L, W/l	Watt(s) per liter	Y	Yttrium
W/m.K, W/mK	Watt(s) per meter-Kelvin (unit of thermal conductivity)	yr, YR	Year
WS	Water splitting	YSZ	Yttria-stabilized zirconia
WSU	Washington State University	ZEBA	Zero Emission Bay Area
wt	Weight	ZEV	Zero emission vehicle
Wt	Watt(s) thermal	Zn	Zinc
wt%, wt.%	Weight percent (percent by weight)	ZnO	Zinc oxide
		Zr	Zirconium