

## XII. Acronyms, Abbreviations, and Definitions

$\alpha$ -AlH <sub>3</sub>	Alpha polymorph of aluminum hydride	A-CCS	Activated carbon composite support
~	Approximately	AD	Adsorbent
@	At	ADF	Annular dark-field imaging
°C	Degrees Celsius	ADT	Accelerated degradation test
°F	Degrees Fahrenheit	<i>Ae</i>	Alkaline earth
$\Delta$	Change, delta	AEM	Anion exchange membrane; Analytical electron microscopy
$\Delta G$	Gibbs free energy of reaction	AEMFC	Anion exchange membrane fuel cell
$\Delta H$	Enthalpy of reaction, Enthalpy of hydrogenation	AEO	Annual Energy Outlook
$\Delta H_{des}^{\circ}$	Desorption enthalpy	AFC	Automotive fuel cell
$\Delta K$	Stress intensity factor	AFCB	American Fuel Cell Bus Project
$\Delta P$	Pressure drop, pressure change	AFCC	Automotive Fuel Cell Cooperation
≈	Equals approximately	AFDC	Alternative Fuels Data Center
$\epsilon$	Average pristine fiber failure strain	AFM	Atomic force microscopy
>	Greater than	AFMBR	Anaerobic fluidized bed membrane reactor
≥	Greater than or equal to	Ag	Silver
<	Less than	AHJ	Authorities having jurisdiction
≤	Less than or equal to	AIST	Japanese National Institute of Advanced Industrial Science and Technology
$\mu\text{m}$	Micrometer(s), micron(s)	Al	Aluminum
$\eta$	Viscosity	Al <sub>2</sub> O <sub>3</sub>	Aluminum oxide
#	Number	ALD	Atomic layer deposition
$\Omega$	Ohm(s)	AlH <sub>3</sub>	Aluminum hydride; Alane
$\Omega/\text{cm}^2$	Ohm(s) per square centimeter	ALS	Advanced Light Source at Lawrence Berkeley National Laboratory
$\Omega\text{-cm}^2$	Ohm-square centimeter	AM1.5G	Air Mass 1.5 Global (solar spectrum)
$\rho$	Average fiber density	A/m <sup>3</sup>	Amps per cubic meter
%	Percent	AMFC	Anion exchange membrane fuel cell; Alkaline membrane fuel cell
®	Registered trademark	AMR	Annual Merit Review
$\sigma_f$	Average pristine fiber strength	AMR	Active magnetic regenerator
\$	United States dollars	AMS	Air Management System
1-D, 1D	One-dimensional	ANL	Argonne National Laboratory
1Q	First quarter of the fiscal year	ANOVA	Analysis of variance
2-D, 2D	Two-dimensional	ANSI	American National Standards Institute
2Q	Second quarter of the fiscal year	APCI, APCi	Air Products and Chemicals, Inc.
3-D, 3D	Three-dimensional	API	American Petroleum Institute
3Q	Third quarter of the fiscal year	APRR	Average pressure ramp rates
4Q	Fourth quarter of the fiscal year	APU	Auxiliary power units
A	Ampere, amps	AQ	Actual stack heat load
<i>A</i>	Alkali	Ar	Argon
Å	Angstrom	AR	As received
AB	Ammonia-borane, NH <sub>3</sub> BH <sub>3</sub>		
Abs	Absolute		
ABS	American Bureau of Shipping		
AC	Alternating current		

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AR	Hexamethyl trimethyl ammonium functionalized poly(biphenyl alkylene)	BPV	Boiler and Pressure Vessel
ARPA-E	Advanced Research Projects Agency–Energy	Br	Bromine
ARRA	American Recovery and Reinvestment Act	BSA	Bovine serum albumin
As	Arsenic	BSF	Bloch spectral function
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers	BTT	Baggage tow tractor
ASME	American Society of Mechanical Engineers	BTU, Btu	British thermal unit(s)
ASPEN	Modeling software, computer code for process analysis	BuP	Backup power
ASR	Area-specific resistance; areal surface resistance	BVPC	Boiler and pressure vessel code (ASME)
AST	Accelerated stress test	C	Carbon
ASTM	ASTM International, originally known as the American Society for Testing and Materials	Ca	Calcium
at%	Atomic percent	CAD	Computer-aided design
atm	Atmosphere	CaFCP	California Fuel Cell Partnership
ATM-PP	Benzyl trimethyl ammonium functionalized Diels-Alder poly(phenylene)	cal	Calorie(s)
a.u.	Arbitrary units	CalTech	California Institute of Technology
Au	Gold	CARB	California Air Resources Board
AuS	Gold sulfide	CB	Conduction band
B	Boron	CBA	Cost breakdown analysis
Ba	Barium	CBET	Division of Chemical, Bioengineering, Environmental, and Transport Systems
BAM	Federal Institute for Material Research and Testing	CBN	Carbon-boron-nitrogen
bara	Bar absolute	CBS	Casa Bonita strain; Complete basis set
BaSc	Baseline and Scenario Analysis	cc	Cubic centimeter(s)
BCS	Business Case Scenario	CCL	Cathode catalyst layer
Be	Beryllium	CCM	Catalyst-coated membrane
BES	Basic Energy Sciences office within the DOE Office of Science	Cc/min, ccm	Cubic centimeters per minute
BET	Brunauer-Emmett-Teller surface area analysis method	CCS	Carbon capture and sequestration
BETO	Bioenergy Technologies Office	CCSD(T)	coupled cluster theory with single and double excitations plus a perturbative correction for triple excitations
BEV	Battery electric vehicle	CCSI	Continuous Codes and Standards Improvement
B-H, BH, BH <sub>4</sub>	Borohydride	Cd	Cadmium
Bi	Bismuth	CDO	Codes Development Organization
BM	Base metal	CDP	Constant dew point
BN	Boron-nitrogen	CDP	Composite data product
BNL	Brookhaven National Laboratory	CdS	Cadmium sulfide
Boc	Tert-butoxycarbonyl	Ce	Cerium
BOC	Best of class	CEA	Commissariat à l'Énergie Atomique
BOL	Beginning of life	CEC	California Energy Commission
BOP, BoP	Balance of plant	CEM	Compressor/expander motor (module)
BOT	Beginning of test	CeO <sub>2</sub>	Ceric oxide
BPP	Bipolar plate	CF	Carbon fiber; Carbon foam
		CFD	Computational fluid dynamics
		cfm	Cubic feet per minute
		CGA	Compressed Gas Association
		CH	Chemical hydride

cH <sub>2</sub>	Compressed hydrogen gas	CSU	California State University
CH <sub>4</sub>	Methane	CSULA	California State University Los Angeles
CH-AB	Chemical hydride-ammonia borane	CT	Computed tomography
CHE	Computational hydrogen electrode	CTD	Composite Technology Development, Inc.
CHEX	Cold heat exchanger	CTE	Coefficient of thermal expansion
CHG	Compressed hydrogen gas	CTE	Center for Transportation and the Environment
CHHP	Combined heat, hydrogen, and power	Cu	Copper
CHP	Combined heat and power	CU	University of Colorado
CI	Combustion ignition	cu in	Cubic inch
Cl	Chlorine	CuInGaS <sub>2</sub>	Copper indium gallium sulfide
CL	Catalyst layer	cu yd	Cubic yard(s)
cm	Centimeter	CV	Cyclic voltammetry; Cyclic voltammogram
CM	Cyanamide	CVD	Chemical vapor deposition
cm <sup>2</sup>	Square centimeter	CWG	Catalysis Working Group
CM-PANI	Cyanamide-polyaniline	d	Day(s)
CMU	Carnegie Mellon University	D <sub>2</sub>	Deuterium
CNG	Compressed natural gas	DAPP	Diels-Alder poly(phenylene)
CNGV	Compressed natural gas vehicle	DC	Direct current
CNT	Carbon nanotube	DDP	Detailed Data Product
Co	Cobalt	ΔG	Gibbs free energy of reaction
CO	Carbon monoxide	ΔH	Enthalpy of reaction
CO <sub>2</sub>	Carbon dioxide	ΔK	Stress intensity factor
CO <sub>2e</sub>	Carbon dioxide equivalent	DFC <sup>®</sup>	Direct fuel cell
COCV	Cyclic open circuit voltage	DFMA <sup>®</sup>	Design for Manufacturing and Assembly
COD	Chemical oxygen demand	DFT	Density functional theory
COMSOL	Multiphysics modeling and engineering simulation software	DG	Distributed generation
COP	Coefficient of performance	DG-BEAT	Distributed Generation Build-out Economic Assessment Tool
COPV	Composite overwrapped pressure vessel	DGE	Diesel gallon equivalent
COV	Coefficient of variation	DM	Diffusion media
cP	Centipoise	DMA	Dynamic mechanical analysis
C/P	Conductivity to permeability (ratio)	DMFC	Direct methanol fuel cell
CPM	Cost per thousand impressions; Cycles per minute; Cost per mile	DMR	De-acetylation and mechanically refined
CPR2	Cascading pressure receiver reactor	DMS	Division of Measurement Standards
CPU	Computer processing unit	DNA	Deoxyribonucleic acid
Cr	Chromium	DOE	Department of Energy
CRF	cumulative fluoride release	DOS	Density of states
Cs	Cesium	DOT	Department of Transportation
CS	Carbon steel	DR	Demand response
C&S	Codes and standards	DSC	Differential scanning calorimetry
CSA	Canadian Standards Association	DSM <sup>™</sup>	Dimensionally stable membrane
CSD	Compression, storage, and delivery	DUT	Device under test
CSM	Colorado School of Mines; Combined structure & material	e <sup>-</sup>	Electron
		E85	85%–15% blend of ethanol with gasoline

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$E_{1/2}$	Half-wave potential	FCEB	Fuel cell electric bus
ECA	Electrochemical area	FCEV	Fuel cell electric vehicle
ECHO	Enforcement and compliance history online	FCHEA	Fuel Cell Hydrogen Energy Association
ECSA	Electrochemically active surface area; Electrochemical surface area; Effective catalyst surface area	FCH JU	Joint Fuel Cell and Hydrogen Energy
EDA	Ethylene diamine; Energy decomposition analysis	FC-PAD	Fuel Cell Performance and Durability
EDS	Energy dispersive X-ray spectroscopy; Energy dispersive spectrum	FCPP	Fuel cell power plant
EDX	Energy dispersive X-ray	FCS	Fuel cell system
EELS	Electron energy loss spectroscopy	FCT	Fuel Cell Technologies
EERE	U.S. DOE Office of Energy Efficiency and Renewable Energy	FCTAC	Fuel Cell Tool for Assessing Costs
EFP	Effective fragment potential	FCTO	Fuel Cell Technologies Office
e.g.	<i>Exempli gratia</i> : for example	FCTT	Fuel Cell Technical Team
EHC	Electrochemical hydrogen compressor	FCV	Fuel cell vehicle
EIA	Energy Information Administration of the U.S. Department of Energy	Fd	Ferredoxin
EIS	Electrochemical impedance spectroscopy	Fe	Iron
ENG	Enhanced natural graphite; expanded natural graphite	FE	U.S. DOE Office of Fossil Energy
EOL	End of life	Fe <sub>2</sub> O <sub>3</sub>	Ferric oxide
EPA	Environmental Protection Agency	FEA	Finite element analysis
EPIC	Energy Policy Institute of Chicago	FEM	Finite element model
ePTFE	Expanded polytetrafluoroethylene	FER	Fluoride emission rate
ESA	Electrochemical surface area	FFV	Flexible fuel vehicle
ESB	Erbium-stabilized bismuth oxide	FID	Flame ionization detector
ESD	Electro-static discharge	FLC	Frequent and long commute
ESIF	Energy Systems Integration Facility	FMC	Ford Motor Company
et al.	<i>Et Alii</i> : and others	FMEA	Failure modes and effects analysis
etc.	<i>Et cetera</i> : and so on	FMECA	Failure Modes Effects and Criticality Analysis
E-TEK	Division of De Nora North America, Inc.	FMVSS	Federal Motor Vehicle Safety Standards
ETFECS	Extended thin-film electrocatalyst structures	FOA	Funding opportunity announcement
EU	European Union	FOM	Figure of merit
eV	Electron volt	FPITT	Fuel Pathway Integration Technical Team (U.S. DRIVE)
EV	Electric vehicle	fpm	Feet per minute
EW	Equivalent weight	FRP	Fiber-reinforced composite piping; Fiber-reinforced polymer; Full rate production
EXAFS	Extended X-ray absorption fine structure analysis	FSC	Frequent and short commute
F	Fluorine	FSW	Friction stir welding
FC	Fuel cell	ft	Feet
FC1	Fluoropolymer nanofiber	ft <sup>2</sup>	Square feet
FC-APOLLO	Fuel Cell Application Package for Open-source Long-Life Operation software	ft <sup>3</sup>	Cubic feet
FCB	Fuel cell bus	FTA	Federal Transit Administration
FCE	FuelCell Energy	FT-IR, FTIR	Fourier transform infrared
		FTO	Fluorine-doped tin oxide
		FWS	Fixed-window scan
		FY	Fiscal year
		FZ	Fusion zone

g	Gram; acceleration of gravity	H+	Proton
G	Graphite	H <sub>2</sub>	Diatomic hydrogen
Ga	Gallium	H2A	Hydrogen Analysis project sponsored by DOE
GaAs	Gallium arsenic	H2FAST	Hydrogen Financial Analysis Scenario Tool
gal	Gallon	H <sub>2</sub> O	Water
GaP	Gallium phosphide	H <sub>2</sub> O <sub>2</sub>	Hydrogen peroxide
GB	Gigabyte	H <sub>2</sub> S	Hydrogen sulfide
GC	Glassy, or vitreous carbon	H2SCOPE	Hydrogen Station Cost Optimization and Performance Evaluation
g/cc	Grams per cubic centimeter		
GCMS	Gas chromatograph-mass spectroscopy	H <sub>2</sub> SO <sub>4</sub>	Sulfuric acid
Gd	Gadolinium	H2ST2	Hydrogen Storage Tech Team
GDC	Gadolinium-doped ceria	H2USA	Hydrogen Technology Learning Centers (for CA, FL, and NY)
GDE	Gas diffusion electrode		
GDL	Gas diffusion layer	HAADF	High-angle annular dark-field
Ge	Germanium	HAADF-STEM	High angle annular dark field scanning transmission electron microscopy
GEN I	First generation	HAMMER	Hazardous Materials Management and Emergency Response
GEN II	Second generation		
GEN III	Third generation	HAVO	Hawaii Volcanoes National Park
GGE, gge	Gasoline gallon equivalent	HAZ	Heat-affected zone
GHG	Greenhouse gas	HCATT	Hawaii Center for Advanced Transportation Technologies
GHSV	Gas hourly space velocity		
GJ	Gigajoule(s)	HCC	Hybrid cathode catalyst
GKB	Grapitized Ketjenblack <sup>®</sup>	HCD	Hydrogen contaminant detector
g/kW	Gram(s) per kilowatt	HCI	Hydrogen Code Improvement
GLWN	Westside Industrial Retention & Expansion Network	HCl	Hydrochloric acid
gm	Gram(s)	HClO <sub>4</sub>	Perchloric acid
GM	General Motors	HDPE	High-density polyethylene
gm/day	Gram(s) per day	HDSAM	Hydrogen Delivery Scenario Analysis Model
g/min	Gram(s) per minute	HDTT	Hydrogen Delivery Technical Team
GOI	Gene of interest	He	Helium
GPa	Gigapascal(s)	HE	Hydrogen embrittlement
GPRA	Government Performance and Results Act	HER	Hydrogen evolution reaction
GREET	Greenhouse gases, Regulated Emissions and Energy use in Transportation model	HEV	Hybrid electric vehicle
g/s	Grams per second	HEX	Heat exchanger
GSE	Ground support equipment	Hf	Hafnium
GTI	Gas Technology Institute	HF	Hydrogen fluoride
GTR	Global Technical Regulations	HF	Hydroforming
GUI	Graphical user interface	HFCV	Hydrogen fuel cell vehicle
GVW	Gross vehicle weight	HFE	Hydrofluoro ether
GWe, GW <sub>e</sub>	Gigawatt(s) electric	HFR	High-frequency resistance
h	Hour(s)	HFSWG	Hydrogen Fueling Station Working Group of H2USA
H	Hydrogen	HGV	Hydrogen gaseous vehicle
H <sup>-</sup>	Hydride	HHV	Higher heating value
		HIB	High-impedance buffer

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HIL	Hardware in loop	IEC	Ion exchange capacity, milliequivalents of acid groups per gram of material
HITRF	Hydrogen Infrastructure Testing and Research Facility	IEEE	Institute of Electrical and Electronics Engineers, Inc.
HNEI	Hawaii Natural Energy Institute	IET	Institute for Energy and Transport
HOP	Hydrogen Optimal Pressure model	IFC	International Fire Code
HOR	Hydrogen oxidation reaction	IIT	Illinois Institute of Technology
HPA	Heteropoly acid	IL	Illinois
HPTB	High powered test bay at NREL	ILS	Inter-laboratory studies; Integrated laboratory scale, Instrument landing systems
hr	Hour(s)	IMM	Inverted metamorphic multijunction
HRS	Hydrogen refueling station	In	Indium
HRSAM	Hydrogen refueling station analysis model	In., in	Inch
HRT	Hydraulic retention time	in <sup>2</sup>	Square inch
HR-TEM	High resolution transmission electron microscopy	INL	Idaho National Laboratory
HS	Hydrogen storage	INTEGRATE	Integrated Network Testbed for Energy Grid Research and Technology Experimentation
HSA	High surface area	IP	Intellectual property
HSAC	High surface area carbon	IR	Infrared
HSC	Database name derived from the letters for enthalpy, entropy and heat capacity	iR	Internal resistance
HSCoE	Hydrogen Sorption Center of Excellence	Ir	Iridium
HSDC	Hydrogen Secure Data Center	IR/DC	Infrared diagnostic system with direct current excitation
HSECoE	Hydrogen Storage Engineering Center of Excellence	IrDA	Infrared Data Association
HSP	Hydrogen Safety Panel	IrO <sub>x</sub>	Iridium oxide
HT	High throughput; High temperature; heat-treatment/thermal annealing	IR/RIF	Infrared/reactive impinging flow
HTF	Heat transfer fluid	ISO	International Organization for Standardization
HTFC	High-temperature fuel cell	ISO TC197	International Standards Organization Technical Committee
HX	Heat exchanger	IT	Information technology
HyCoRA	Hydrogen Contaminant Risk Assessment	ITC	Investment tax credit
HyRam	Hydrogen Risk Assessment Models	ITO	Indium tin oxide
HyS	Hybrid sulfur	IV, iV	Current-voltage
HyStEP	Hydrogen Station Equipment Performance	J	Current
Hz	Hertz	J	Joule(s)
I	Current	JARI	Japan Automobile Research Institute
I <sub>2</sub>	Diatomic iodine	JPBHH	Joint Base Pearl Harbor-Hickman (Hawaii)
I2CNER	International Institute for Carbon-Neutral Energy Research	JPL	Jet Propulsion Laboratory
I/C	Ionomer to catalyst	JRC	Joint Research Centre
ICC	International Code Council	J-V, JV	Current density-voltage
ICE	Internal combustion engine	K	Kelvin, absolute temperature
ICEV	Internal combustion engine vehicle	K	Potassium
ICHS	International Conference on Hydrogen Safety	kÅ	1,000 angstroms
i.e.	<i>id est</i> : that is	kA/m <sup>2</sup>	Kilo-ampere(s) per square meter
IEC	International Electrotechnical Commission	kcal	Kilocalorie(s)

kcal/mol	Kilocalorie(s) per mole	L/min, l/min	Liter(s) per minute
kg	Kilogram(s)	LMRC	Linear motor reciprocating compressor
kg/d	Kilogram(s) per day	LN <sub>2</sub>	Liquid nitrogen
kg/hr	Kilogram(s) per hour	LNG	Liquefied natural gas
kg/m <sup>3</sup>	Kilogram(s) per cubic meter	LP	Lattice parameter
kHz	Kilohertz	LSAC	Low surface area carbon
kJ	Kilojoule(s)	LSM	Lanthanum strontium manganate
kJ/mol	Kilojoule(s) per mole	LSV	Lanthanum strontium vanadate; Linear sweep voltammetry
km	Kilometer(s)	LT	Low-temperature
kN	Peak load	L/T	Lookup tables
KOH	Potassium hydroxide	LTC	Low temperature coolant
kPa	Kilopascal(s)	LTPEM	Low temperature polymer electrolyte membrane
kph	Kilometer(s) per hour		
ksi	1,000 pound-force per square inch	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)
L, l	Liter(s)	MA	Mass activity
La	Lanthanum	MA3T	Market Acceptance of Advanced Automotive Technologies
λ	Lambda, hydration number	μA	Micro ampere(s)
LAMOX	Lanthanum molybdenum oxide ( <i>e.g.</i> , La <sub>2</sub> Mo <sub>2</sub> O <sub>9</sub> )	mA	MilliAmps (s)
LANL	Los Alamos National Laboratory	MA	Mass activity
LAX	Los Angeles International Airport	μA/cm <sup>2</sup>	Micro ampere(s) per square centimeter
lb	Pound(s)	mA/cm <sup>2</sup>	Milliamp(s) per square centimeter
lb mol	Pound-mole(s)	MARAD	Department of Transportation Maritime Administration
LBNL	Lawrence Berkeley National Laboratory	MAS	Magic angle spinning
LCA	Life cycle assessment; Life-cycle analysis	MASC	Multi-acid side-chain
L/D	Length to diameter ratio	MAS NMR	Magic angle spinning nuclear magnetic resonance
LD	Learning demonstration	MATI	Modular Adsorption Tank Insert
LDV	Light-duty vehicle	MAWP	Maximum allowable working pressure
L/h, l/h	Liter(s) per hour	MB	Megabyte
LH2, LH <sub>2</sub>	Liquid hydrogen	MBRC	Miles between roadcall
LHV	Lower heating value	MCFC	Molten carbonate fuel cell
LI	Leaching index	m-CFDE	Multi-electrode channel flow double electrode
Li	Lithium	MCHL	Magnetocaloric hydrogen liquefier
Li <sub>3</sub> N	Lithium nitride	MD	Molecular dynamics
	LiBH <sub>4</sub>	MEA	Membrane electrode assembly
	Lithium borohydride	MEC	Microbial electrolysis cell
LiH	Lithium hydride	meq	Milliequivalents
LLC	Limited Liability Company		
LLNL	Lawrence Livermore National Laboratory		

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meq/g	Milliequivalents/gram	MRH	Hexamethyl trimethyl ammonium functionalized Diels-Alder poly(phenylene)
MES	Microstructured electrode scaffold	MRL	Manufacturing readiness level
MeV	Mega electron volt	ms	Millisecond(s)
MFC	Microbial fuel cell, Mass flow controller	mS/cm	Milli-Siemen(s) per centimeter
Mg	Megagram(s)	MSM	Macro-System Model
μg	Microgram(s)	MSRP	Manufacturer's suggested retail price
mg	Milligram(s)	MSTF	Mesostructured thin films
mg/cm <sup>2</sup>	Milligram(s) per square centimeter	MSU	Montana State University
mg Pt/cm <sup>2</sup>	Milligram (s) of platinum per square centimeter	MTA	Mass Transportation Agency
MH	Metal hydride	mtorr	Millitorr
MHE	Material handling equipment	MTU	Michigan Technological University
MHz	Megahertz	μV	Microvolt(s)
mi	Mile(s)	mV	Millivolt(s)
mi/kg	Mile(s) per kilogram	mW	Milliwatt(s)
mil	Millimeter(s)	MW	Megawatt(s)
min	Minute(s)	MW	Molecular weight
MJ	Megajoule(s)	mW/cm <sup>2</sup>	Milliwatt(s) per square centimeter
mL, ml	Milliliter(s)	MWCNT	Multiple-wall carbon nanotube
ML	Monolayer	MWe	Megawatt(s) electric
μm	Micrometer(s); micron(s)	MWh	Megawatt-hour(s)
μM	Micromolar	MWNT	Multi-wall carbon nanotube
mM	Millimolar	MYPP	Multi-Year Program Plan (the Fuel Cell Technologies Program's Multi-Year Research, Development and Demonstration Plan)
mm	Millimeter(s)	MYRDD, MYRD&DP	Multi-Year Research, Development and Demonstration Plan
MMBtu	Million British thermal units	N	Nitrogen atom
mmol	Millimole(s)	N	Newton (unit of force)
μmol	Micromole(s)	N112	Nafion <sup>®</sup> 1100 equivalent weight, 2 millimeter thick membrane
Mn	Manganese	N <sub>2</sub>	Diatomic nitrogen
mΩ	Milli-ohm(s)	N <sub>2</sub> O	Nitrous oxide
MΩ	Mega-ohm(s)	Na	Sodium
mΩ/cm <sup>2</sup>	Milli-ohm(s) per square centimeter	NA	North American
μΩ-cm <sup>2</sup>	Micro-ohm(s) - square centimeter	Nafion <sup>®</sup>	Registered Trademark of E.I. DuPont de Nemours
Mo	Molybdenum	NaOH	Sodium hydroxide
MOF	Metal-organic framework	NASA	National Aeronautics and Space Administration
mol	Mole(s)	Nb	Niobium
mol%	Mole percent	N/cm <sup>2</sup>	Newton(s) per square centimeter
mol/min	Mole(s) per minute	NCNT	Nitrogen doped carbon nanotube
MPa	Megapascal(s)	NDE	Non-destructive examination
MPG, mpg	Mile(s) per gallon	NE	U.S. DOE Office of Nuclear Energy, Science and Technology
MPGGE	Miles per gasoline gallon equivalent		
mph	Mile(s) per hour		
MPL	Microporous layer		
MREC	Microbial reverse-electrodialysis electrolysis cell		

NEU	Northeastern University	O	Oxygen
NFCBP	National Fuel Cell Bus Program	O <sub>2</sub>	Diatomic oxygen
NFCTEC	National Fuel Cell Technology Evaluation Center, at NREL	OCP	Open circuit potential
NFPA	National Fire Protection Association	OCS	Orange County Sanitation District
ng	Nanogram	OCV	Open-circuit voltage
NG	Natural gas	o.d.,OD	Outer diameter
NGNP	Next Generation Nuclear Plant	OEM	Original equipment manufacturer
NG-SR	Natural gas steam reforming	OER	Oxygen evolution reaction
NGV	Natural gas vehicle	O&M	Operation and maintenance
NH <sub>3</sub>	Ammonia	ORNL	Oak Ridge National Laboratory
NHTS	National Household Transportation Survey	ORR	Oxygen reduction reaction
NHTSA	National Highway Traffic Safety Administration of the U.S. Department of Transportation	OSU	Ohio State University
Ni	Nickel	OSU	Oregon State University (Microproducts Breakthrough Institute)
NIST	National Institute of Standards and Technology	P	Phosphorus
NIST FACT	National Institute of Standards and Technology, Facility for Adsorbent Characterization and Testing	Pa	Pascal(s)
nm	Nanometer(s)	PA	Polyamide
NM	Noble metal; nanomaterial	PAFC	Phosphoric acid fuel cell
nmol	Nanomole(s)	PAN	Peroxyacetyl nitrate; Polyacrylonitrile
NMR	Nuclear magnetic resonance	P&D	Production and delivery
Non-PGM	Non-precious metal group	P&ID	Piping and instrumentation diagram
NO <sub>x</sub> , NO <sub>x</sub>	Oxides of nitrogen	PANI	Polyaniline
NP	Nanoparticle	PAN-MA	Polyacrylonitrile with methyl acrylate
NPD	Neutron powder diffraction	Pb	Lead
NPT	Normal pressure and temperature	PBCTF	Pressurized button cell test facility
NR211	Nafion <sup>®</sup> 211 membrane	PBD	Performance-based design
NR212	Nafion <sup>®</sup> 212 membrane	PBI	Polybenzimidazole
NREL	National Renewable Energy Laboratory	PC	Precharged (hydrogen)
NRELFAT	NREL Fleet Analysis Toolkit	PCR	Polymerase chain reaction
NRVS	Nuclear resonance vibrational spectroscopy	PCT	Pressure-composition-temperature
NSF	National Science Foundation	Pd	Palladium
NSTF	Nano-structured thin-film	Pd/C	Palladium on carbon
NT	Nanotube	PEC	Photoelectrochemical
NTCNA	Nissan Technical Center, North America	PEFC	Proton exchange fuel cell; Polymer electrolyte fuel cell
NTR	National Hydrogen and Fuel Cell Emergency Response Training Resource	PEGS	Prototype electrostatic ground state
NV	Neutron vibrational	PEM	Proton exchange membrane; Polymer electrolyte membrane
NVS	Neutron vibrational spectroscopy	PEMFC	Polymer electrolyte membrane fuel cell; Proton exchange membrane fuel cell
NW	Nanowire	PEO	Poly(ethylene oxide)
Ω	Ohm(s)	PF	Perfluoro; Phenolic
Ωcm <sup>2</sup>	Ohm(s) - square centimeter	PFCB	Perfluorocyclobutyl
		PFCT	Porvair Fuel Cell Technology, Inc.
		PFD	Process flow diagram
		PFIA	Perfluoroimide acid

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PFICE	Perfluoro ionene chain extended	Q	Heat load estimate
PFSA	Perfluorinated sulfonic acid, perfluorosulfonic acid, poly(fluorosulfonic acid)	Q1, Q2, Q3, Q4	Quarters of the fiscal year
PF-SFP	Perfluoro sulfonyl fluoride precursor	Q/ΔT	Heat rejection constraint
PG	Porous graphene	QC	Quality control
PG&E	Pacific Gas and Electric Company	QE	Quantum efficiency
PGM	Precious group metal; Platinum-group metal	QENS	Quasielastic neutron scattering
PGV	Puna Geothermal Ventures	QMED	Quantum based materials exploration and design
PHEV	Plug-in hybrid electric vehicle	QR	Quick response
PHIL	Power hardware in the loop	QRA	Quantitative risk assessment
PI	Principal investigator	R	Universal or ideal gas constant, 8.314472 J · K <sup>-1</sup> · mol <sup>-1</sup>
P&ID	Process and instrumentation diagram	RBS	Ribosome binding site
PID	Proportional, integral, derivative	RCS	Regulations codes and standards
PITM	Platinum in the membrane	R&D	Research and development
PLC	Programmable logic controller	RD&D, R,D&D	Research, development, and demonstration
PLD	Pulsed laser deposition	RDE	Rotating disk electrode
PM	Particulate matter	Re	Rhenium
PMMA	Poly(methyl methacrylate)	Ref	Reference
PNNL	Pacific Northwest National Laboratory	REP	Reformer-Electrolyzer-Purifier; Representative performance
POM	Polyoxometallate	RF, rf	Radio frequency
POP	Porous organic polymers	RGA	Residual gas analyzer (analysis)
PPA	Polyphthalamide	rGO	Reduced graphene oxide
ppb	Part(s) per billion	Rh	Rhodium
ppbv	Part(s) per billion by volume	RH	Relative humidity
PPC	Pajarito Powder	R-HC-HEW	Partially fluorinated hydrocarbon high equivalent weight
ppm, PPM	Part(s) per million	R-HC-LEW	Partially fluorinated hydrocarbon low equivalent weight
ppmv	Part(s) per million by volume	RHE	Reference hydrogen electrode; Reversible hydrogen electrode
ppmw	Part(s) per million by weight	RIE	Reactive ion etching
PRD	Pressure relief device	RIF	Reactive impinging flow
PSA	Pressure swing adsorption, adsorber	RNG	Renewable natural gas
PSD	Particle size distribution, pore size distribution	ROI	Return on investment
psi, PSI	Pound(s) per square inch	R-PFSA-HEW	Reinforced perfluorinated sulfonic acid high equivalent weight membrane
psia	Pound(s) per square inch absolute	R-PFSA-LEW	Reinforced perfluorinated sulfonic acid low equivalent weight membrane
psig, PSIG	Pound(s) per square inch gauge	rpm	Revolution(s) per minute
Pt	Platinum	RPN	Risk priority number
Pt/C	Platinum/carbon	RRDE	Rotating ring disc electrode
PTFE	Teflon <sup>®</sup> – poly-tetrafluoroethylene	RT	Room temperature
PtO	Platinum oxide	RTDS <sup>®</sup>	Real time digital simulation
PtO <sub>2</sub>	Platinum dioxide	RTO	Ruthenium-titanium oxide
PtRu	Platinum ruthenium		
PUC	Public Utility Commission		
PV	Photovoltaic; Present value		
PVD	Physical vapor deposition		
PXRD	Powder X-ray diffraction		

Ru	Ruthenium	slpm, slm, sL/min	
s	Second(s)		Standard liter(s) per minute
S	Siemen(s)	SMR	Steam methane reformer; Steam methane reforming
S	Sulfur		
SA	Solvay Amodel PPA; Strategic Analysis, Inc.	Sn	Tin
SAE	SAE International, originally known as the Society of Automotive Engineers	SNL	Sandia National Laboratories
SBIR	Small Business Innovation Research	SnO	Tin oxide
Sc	Scandium	SnO <sub>2</sub>	Tin oxide
S/C	Steam to carbon ratio	SO <sub>2</sub>	Sulfur dioxide
SCAQMD	South Coast Air Quality Management District	SOC	State-of-charge
sccm, SCCM	Standard cubic centimeter(s) per minute	SOEC	Solid oxide electrolyzer cell
SCCV	Steel/concrete composite vessel	SOFC	Solid oxide fuel cell
SCF, scf	Standard cubic feet	SOPO	Statement of project objectives
scfd	Standard cubic feet per day	SOSS	Station Operational Status System
SCFH, scfh	Standard cubic feet per hour	SPWG	Stationary Power Working Group
SCFM	Standard cubic feet per minute	sq. in.	Square inch(es)
S/cm	Siemen(s) per centimeter	Sr	Strontium
SDAPP	Sulfonated Diels-Alder polyphenylene	SR	Stoichiometric ratio
SDAPPe	Sulfonated Diels-Alder polyphenylene ether	SRNL	Savannah River National Laboratory
SDD	Si-drift detector	SrO	Strontium oxide
SDE	SO <sub>2</sub> -depolarized electrolyzer	SS	Stainless steel
SDO	Standards development organization	SSA	Specific surface area
SD/SU	Shut-down/start-up	STCH	Solar thermochemical hydrogen
Se	Selenium	STEM	Scanning transmission electron microscopy
SEBS	Benzyl trimethyl ammonium functionalized polystyrene- <i>b</i> -poly(ethylene- <i>co</i> -butylene)- <i>b</i> -polystyrene triblock copolymers	STH	Solar-to-hydrogen
sec	Second(s)	STREET	Spatially and Temporally Resolved Energy and Environment Tool
SEM	Scanning electron microscopy; Scanning electron microscope	STWS	Solar thermal water splitting
SEM	Secondary electron microscopy	STXM	Scanning transmission X-ray microscopy
SERA	Scenario Evaluation, Regionalization and Analysis	SwRI <sup>®</sup>	Southwest Research Institute <sup>®</sup>
SFE	Stacking fault energy	T	Temperature
SFR	Stagnation flow reactor	T, t	Ton, tonne
SGA	Sales, general, administration	T	Tesla (unit of magnetic induction)
SGIP	Self-Generation Incentive Program	t	Time
SHE	Standard hydrogen electrode	Ta	Tantalum
Si	Silicon	TAMU	Texas A&M University
S-I	Sulfur-iodine	TBD	To be determined
SI	Spark ignition	TC	Thermal conductivity
SiO <sub>2</sub>	Silicon dioxide	TC	Thermocouple; Thermal conditioning
SKKR	Screened Korringa-Kohn-Rostoker method	TCO	Transparent conductive oxide; Total cost of ownership
sL	Standard liter (0°C, 1 atm)	Te	Tellurium
		TEDA	Triethylenediamine
		TEM	Transmission electron microscopy
		TFVE	Trifluorovinyl ether

## XII. Acronyms, Abbreviations, and Definitions

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TGA	Thermal gravimetric analysis; Thermogravimetric analysis; Thermogravimetric analyzer	U.S. DRIVE	United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability
Ti	Titanium	UTRC	United Technologies Research Center
TIA	Telecommunications Industry Association	UTS	Ultimate tensile strength
TIR	Technical information report	UV	Ultraviolet
TKK	Tanaka Kikinzoku Kogyo K. K.	UV-vis	Ultraviolet-visual
TM	Transition metal	V	Vanadium
TMB	Trimethylborate	V	Volt
TOC	Total organic carbon	VAC	Volts alternating current
TOS	Time on stream	VB	Valence band
TOU	Time of use	VC	Volumetric capacity
TPD	Tonne(s) per day	VDC	Volts direct current
TPD	Thermally programmed desorption; Temperature-programmed desorption	V-I, V/I	Voltage – current
TPR	Through plate resistance; Temperature programmed reaction	Vol., vol.	Volume
TPRD	Thermally-activated pressure relief device	vol%	Volume percent
TPRE	Through-plane reactive excitation	VPN	Virtual private network
TPS	Transient plane source	VSM	Value stream mapping
TRL	Technology readiness level	VTO	Vehicles Technologies Office
TRU	Trailer refrigeration unit	W	Tungsten
TTS	Time-temperature superpositioning	W	Watt(s)
TVS	Twin Vortices Series	W/cm <sup>2</sup>	Watt(s) per square centimeter
UAV	Unmanned aerial vehicle	We, W <sub>e</sub>	Watt(s) electric
UCB	University of California, Berkeley	WG	Working group
UCSD	University of California, San Diego	Wh	Watt-hour(s)
U <sub>F</sub>	Fuel Utilization	W-h/kg	Watt-hour(s) per kilogram
UFC	Uniform Fire Code	W-h/L, Wh/liter, Wh/L	Watt-hour(s) per liter
UH	University of Hawaii	W/kg	Watt(s) per kilogram
μm	Micrometer(s)	W/L, W/l	Watt(s) per liter
UM	University of Michigan	W/m-K, W/m.K, W/mK	Watt(s) per meter-Kelvin (unit of thermal conductivity)
UNLV	University of Nevada, Las Vegas	Wppm	Weight part(s) per million
UNM	University of New Mexico	WS	Water splitting
UPD	Underpotential deposition	wt	Weight
UPS	United Parcel Service	Wt	Watt(s) thermal
UQTR	Université du Québec à Trois-Rivières	wt%, wt.%	Weight percent (percent by weight)
URFC	Unitized regenerative fuel cell	WTE	Well-to-engine
U.S.	United States	WTF	Water treatment facility
USAXS	Ultra-small angle X-ray scattering	WTT	Well-to-tank
USC	University of South Carolina	WTW	Well-to-wheels
USCAR	United States Council for Automotive Research, U.S. Cooperative Automotive Research	WWTP	Waste water treatment plant
USCG	U.S. Coast Guard	XAFS	X-ray absorption fine structure

## XII. Acronyms, Abbreviations, and Definitions

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XANES	X-ray absorption near-edge spectroscopy	YB	Young Brothers Ltd.
XAS	X-ray absorption spectroscopy	yr, YR	Year
XES	X-ray emission spectroscopy	YSZ	Yttria-stablized zirconia
XPS	X-ray photoelectron spectroscopy, X-ray photon spectroscopy, X-ray photoemission spectroscopy, X-ray photoluminescence spectroscopy	ZEBA	Zero Emission Bay Area
		ZEV	Zero emission vehicle
		ZIF	Zeolitic imidazolate framework
XRD	X-ray diffraction	Zn	Zinc
XRF	X-ray fluorescence	ZnO	Zinc oxide
XRPD	X-ray powder diffractions	ZPE	Zero point energy
XRT	X-ray tomography	Zr	Zirconium
Y	Yttrium	ZrO <sub>2</sub>	Zirconium dioxide