

## XII. Acronyms and Abbreviations

°C	Degrees Celsius	A <sub>0</sub>	Arrhenius constant, ml/[cm <sup>2</sup> -min-atm <sup>1/2</sup> ]
°F	Degrees Fahrenheit	AP	As prepared
1-D, 1D	One-dimensional	APC	Ambient pressure cell
2-D, 2D	Two-dimensional	APCI	Air Products and Chemicals, Inc.
3-D, 3D	Three-dimensional	APR	Aqueous-phase reforming
1Q	First quarter of the fiscal year	APS	Advanced Photon Source
2Q	Second quarter of the fiscal year	APS	Arizona Public Service
3Q	Third quarter of the fiscal year	APU	Auxiliary power unit
4Q	Fourth quarter of the fiscal year	Ar	Argon
A	Amps	a-Si	Amorphous silicon
Å	Angstrom	a-SiC	Amorphous silicon carbide
AB	Ammonia borane, NH <sub>3</sub> BH <sub>3</sub>	ASCM	Automotive Systems Cost Model
ABI	Automated ball indentation	ASME	American Society of Mechanical Engineers
ABI	Agent-based investment	ASMSS	Anode side membrane support structure
ABM	Agent-based modeling	ASPEN	Modeling software, computer code for process analysis
ABMS	Agent-based modeling and simulation	ASR	Area-specific resistance
AC	Alternating current	AST	Accelerated stress testing
ACEM	Aberration-corrected electron microscopy	ASTM	American Society for Testing and Materials
ACNT	Aligned carbon nanotube	AT	Ammonia triborane
ACR	Autothermal cyclic reforming	at%	Atomic percent
AC-Transit	Alameda Contra Costa Transit	ATG	Adenine,Thymine,Guanine, the 3 base combinations that indicate the first translatable amino acid on the DNA molecule
AD	Anode dew point	ATR	Autothermal reformer; autothermal reforming
ADG	Anaerobic digester gas	Au	Gold
ADGT	Anaerobic digester gas treatment skid	Avg	Average
ADM	Archer Daniels Midland Company	B	Boron
AE	Acoustic emissions	Ba	Barium
AECL	Atomic Energy Canada, Limited	barg	Bar gauge
AEO	Annual Energy Outlook	bcc	Body-centered cubic
AFM	Atomic force microscopy	Be	Beryllium
AFR	Aerosol flow reactor	BE	Bloom Energy
Ag	Silver	BEAMR	Bioelectrochemically assisted microbial reactor
AISI	American Iron and Steel Institute	BES	Basic Energy Sciences office within the DOE Office of Science
AK	Alkali	BESR	Bio-ethanol steam reforming
Al	Aluminum	BET	Bruner-Emmett-Teller surface area analysis method
AlCl <sub>3</sub>	Aluminum chloride	B-H	Borohydride
ALD	Atomic layer deposition		
AlH <sub>3</sub>	Aluminum hydride; alane		
Al <sub>2</sub> O <sub>3</sub>	Aluminum oxide		
ALS	Advanced light source at Lawrence Berkeley National Laboratory		
ANL	Argonne National Laboratory		
ANS	American Nuclear Society		
ANSI	American National Standards Institute		

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BH <sub>4</sub>	Borohydride	CANMET	Canada Center for Mineral and Energy Technology
B-G	Boron doped graphitic material		
BisSF	Bisphenol-Sulfone	CaO	Calcium oxide
BM	Ball-milled, ball mill	CaS	Calcium sulfide
BMG	Bulk metallic glasses	CBS	Casa Bonita strain
bmimBF <sub>4</sub>	1-butyl-3-methyl-imidazolium tetrafluoroborate	cc	Cubic centimeter(s)
bmimCl	1-butyl-3-methyl-imidazolium chloride	CCC	Columbian Chemical Company
bmimPF <sub>6</sub>	1-butyl-3-methyl-imidazolium hexafluorophosphate	CCD	Charge-coupled device
BMPFFP	1-butyl-1-methyl-pyrrolidinium tris(pentafluoroethyl)trifluorophosphate	CFF	Complex coolant fluid
BN	Boron-nitrogen	CCHSS	Complex compound hydrogen storage system
BNHx	Dehydrogenated ammonia-borane	CCM	Catalyst-coated membrane
BNL	Brookhaven National Laboratory	cc/min	Cubic centimeter(s) per minute
B-O	Any oxidized boron species, borate	CCS	Carbon capture and storage
B <sub>2</sub> O <sub>3</sub>	Boron oxide; diboron trioxide	Cd	Cadmium
B(OH) <sub>3</sub>	Boric acid	CD	Cathode dew point
BOL	Beginning of life	CDP	Constant dew point
BOM	Bill of materials	CDP	Composite data product
BOP	Balance-of-plant	CDO	Code development organization
<sup>11</sup> B-NMR	Boron 11 nuclear magnetic resonance	Ce	Cerium
BP	British Petroleum, British Petroleum America Production Company	CEA	Commissariat a Energie Atomique
BPM	Brushless permanent magnet	CEM	Compressor/expander/motor
BPP	Bipolar plate	CeO <sub>2</sub>	Ceric oxide
BPS	Bi Phenyl Sulfone	CEQA	California Environmental Quality Act
BPSH	Block polysulfone ether polymers	CFD	Computational fluid dynamics
BPSH	Bi Phenyl Sulfone: H Form	CFFLS	Consortium for Fossil Fuel Liquefaction Science
Br	Bromine	cfm	Cubic feet per minute
Br <sub>2</sub>	Diatomic bromine	CFS	Catalyzed framework structures
BSF	Back surface field	CGH2	Compressed gaseous hydrogen
BSS	Bootstrap start	CGO	Cerium gadolinium oxide, Gd-doped CeO <sub>2</sub>
BTU, Btu	British thermal unit(s)	CH <sub>2</sub>	Compressed hydrogen gas
BxHy	Polyhedral boranes	CH <sub>4</sub>	Methane
C	Carbon	C <sub>2</sub> H <sub>4</sub>	Ethylene
Ca	Calcium	C <sub>2</sub> H <sub>6</sub>	Ethane
CA	Carbon aerogel	C <sub>3</sub> H <sub>8</sub>	Propane
CA	Chronoamperometry	Chl	Chlorophyll
CaBr <sub>2</sub>	Calcium bromide	CHP	Combined heat and power
CaCO <sub>3</sub>	Calcium carbonate	CIRRUS	Cell ice regulation & removal upon start-up
CAD	Computer-aided design	CIS	CuInSe (alloy of copper, indium, and selenium)
CAE	Computer-assisted engineering	Cl	Chlorine
CaFCP	California Fuel Cell Partnership	cm	Centimeter(s)
CAFE	Corporate Average Fuel Economy	cm <sup>2</sup>	Square centimeter(s)
Calphad	Calculation of phase diagrams	CMU	Carnegie Mellon University
Caltech	California Institute of Technology		

CNG	Compressed natural gas	DFMA	Design for Manufacturing and Assembly
CNT	Carbon nanotube	DFT	Density functional theory
CO	Carbon monoxide	DGAC	Dangerous Goods Advisory Council
Co	Cobalt	DI	Deionized
CO <sub>2</sub>	Carbon dioxide	DMA	Dynamic mechanical analysis
CoE	Center of Excellence	DMAc	Dimethyl acetamide
COG	Coke oven gas	DMFC	Direct methanol fuel cell
CoH	Cost of hydrogen	dmimMeSO <sub>4</sub>	1,3-dimethyl-imidazolium methylsulfate
COPV	Composite overwrapped pressure vessel	DMSO	Dimethyl sulfoxide
CoT	City of Taylor	DNA	Deoxyribonucleic acid
CPB	Cyclopentaborazane	DOE	U.S. Department of Energy
CPMAS	Cross polarization magic angle spinning	DOS	Density of states
CPO	Catalytic partial oxidation	DOT	U.S. Department of Transportation
Cr	Chromium	DOT/NHTSA	Department of Transportation/National Highway Traffic Safety Administration
CR	Compression ratio	DP	Dew point
CRBJT	Combined reverse-Brayton Joule-Thompson	DRIFTS	Diffuse reflectance infrared Fourier transform spectroscopy
CS	Constant stoichiometry	DS	Dielectric spectroscopy
Cs	Cesium	DSC	Differential scanning calorimetry
CSA	Canadian Standards Association	DSM	Dimensionally stable membrane
CSA	Cell stack assembly	DST	Dynamic stress test
CSM	Colorado School of Mines	DTA	Differential thermal analysis
CSP	Concentrating solar power	DTE	DTE Energy Ventures
CT	Cell temperature	EAN	Ethylammonium nitrate
CTAB	Cetyl trimethyl ammonium bromide	E-BOP	Electrical balance of plant
CTC	Concurrent Technologies Corporation	EC	European Community
CTE	Coefficient of thermal expansion	EC	Electrochemical
CTFE	Chlorotrifluoroethylene	ECA	Electrochemical area
CTV	Chevron Technology Ventures LLC	ECHEM FTIR	Electrochemical Fourier transform infrared spectroscopy
Cu	Copper	ECS	Electrochemical Society
CuO	Cupric oxide, copper(II) oxide	ECSA	Electrochemically active surface area, Electrochemical surface area
Cu <sub>2</sub> O	Cuprous oxide	edmimCl	2-ethyl-1,3-dimethyl-imidazolium ethylsulfate
CV	Cyclic voltammetry; cyclic voltammogram	EDS	Energy dispersive X-ray spectroscopy, energy dispersive spectrum
CVD	Chemical vapor deposition	EDTA	Ethylenediamine tetraacetic acid
CVS	Chemical vapor synthesis	EDX	Energy dispersive X-ray
CY	Calendar year	EEA	Energy & Environmental Analysis, Inc.
d	Day(s)	EELS	Electron energy loss spectroscopy
DACS	Data acquisition and control system	EERE	U.S. DOE Office of Energy Efficiency and Renewable Energy
DADB	Diammoniate of diborane, [(NH <sub>3</sub> ) <sub>2</sub> BH <sub>2</sub> ][BH <sub>4</sub> ]	EFR-AHJ	Emergency first responder-authorities having jurisdiction
DC	Direct current	EIS	Electrochemical impedance spectroscopy
DDU	Desorption data utility	EMI	Electro magnetic interference
DFC	Direct fuel cell		
DEF	Diethylformamide		
Deg	Degree		
DFM	Design for manufacturing		

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eNMR	Electrochemical nuclear magnetic resonance	FOM	Federated object modeling
EOL	End of life	FPA	Fluorophosphonic acid
EOR	Enhanced oil recovery	FPM	First principles modeling
EOS	Economies of scale	FRAE	Frictional acoustic emissions
EOS	Earth Observatory System	FRP	Fiber-reinforced polymer
EP	Electrochemical polarization	FRR	Fluoride release rate
EPA	U.S. Environmental Protection Agency	FS	Free surface
EPC	Elevated pressure electrochemical cell	FSEC	Florida Solar Energy Center
EPDM	Ethylene propylene diene monomer	F-SPEEK	Fluorosulfonic acid of polyetheretherketone
EPR	Electron paramagnetic resonance	F/T	Freeze/thaw
eRAM	Enterprise remote access monitoring	ft	Feet
ESA	Estimated surface area	ft <sup>2</sup>	Square feet
ETFE	Ethylene-tetrafluoroethylene	ft <sup>3</sup>	Cubic feet
EU	European Union	FTA	Federal Transit Administration
eV	Electron volt	FTI	Fueling Technologies, Inc.
EW	Equivalent weight	FTIR	Fourier transform infrared
F	Fluorine	FW	Formula weight
F	Fahrenheit	FWHM	Full width at half maximum
F	Fluorine ion	FY	Fiscal year
FBMR	Fluidized bed membrane reactor	ΔG	Free energy of reaction
FC	Fuel cell	g	Gram(s)
FCB	Fuel cell bus	g	Acceleration of gravity
fcc	Face-centered cubic	g/cc	Gram(s) per cubic centimeter
FCCJ	Fuel Cell Commercialization Conference of Japan	g/min	Gram(s) per minute
FCE	FuelCell Energy	g/s	Gram(s) per second
FCFP	FreedomCAR and Fuel Partnership	Ga	Gallium
FCS	Fuel cell system	GA	General Atomics
FCTES <sup>QA</sup>	Fuel Cell Testing, Safety and Quality Assurance (an international effort to harmonize fuel cell testing procedures)	gal	Gallon(s)
FCTESTNET	Fuel Cell Testing and Standardization Network	GaP	Gallium phosphide
FCTS	Fuel cell test station	GAS-PASS/H	Simulation code for gas-cooled nuclear reactors
FCV	Fuel cell vehicle	GB	Grain boundary
FDA	Fleet Data Acquisition	GC	Gas chromatograph
FE	U.S. DOE Office of Fossil Energy	GCMC	Grand Canonical Monte Carlo
Fe	Iron	GC/MS	Gas chromatograph/mass spectroscopy
Fe <sub>2</sub> O <sub>3</sub>	Ferric oxide	GCTool	Software package developed at Argonne National Laboratory for analysis of fuel cells and other power systems
FEA	Finite element analysis	Gd	Gadolinium
FEP	Fluorinated ethylene propylene; Teflon <sup>®</sup>	GDC	Gadolinium-doped ceria
FLiNaK	LiF-NaF-KF eutectic salt	GDE	Gas diffusion electrode
FLUENT	Computer code for computational fluid dynamics	GDL	Gas diffusion layer
FMEA	Failure modes and effects analysis	GDM	Gas diffusion media
FNGP	Freudenberg-NOK General Partnership	GDS	Galvanodynamic scan
<sup>19</sup> FNMR	<sup>19</sup> Fluorine nuclear magnetic resonance	Ge	Germanium
		GE	General Electric

GES	Giner Electrochemical Systems, LLC	HCNG	Hydrogen-compressed natural gas
GGA	Generalized gradient approximation	hcp	Hexagonal close-packed
GGE, gge	Gasoline gallon equivalent	HDPE	High-density polyethylene
GH <sub>2</sub>	Gaseous hydrogen	HDSAM	Hydrogen Delivery Scenario Analysis Model
GHG	Greenhouse gas	He	Helium
GHSV	Gas hourly space velocity	HEI	HyPerComp Engineering Inc.
GIS	Geographic information system	HER	Hydrogen evolution reaction
GJ	Gigajoule(s)	HES	Hydrogen energy station
g/kW	Gram(s) per kilowatt	HEV	Hybrid electric vehicle
GLAD	Glancing angle deposition	Hf	Hafnium
GM	General Motors	HF	Hydrogen fluoride
gm	Gram(s)	HFCI	Hydrogen, Fuel Cells and Infrastructure
gm/day	Gram(s) per day	HFCIT	Hydrogen, Fuel Cells and Infrastructure Technologies
g/min	Gram(s) per minute	HFCTF	Hawaii Fuel Cell Test Facility
GPa	Gigapascal(s)	HFCV	Hydrogen fuel cell vehicle
GPS	Global positioning system	HFR	High-frequency resistance
GREC	Graphite reinforced epoxy composite	HFS	Hydrogen fueling station
GREET	Greenhouse gases, Regulated Emissions and Energy use in Transportation model	HGEF	Hawaii Gateway Energy Center
GRPE	Working Party on Pollution and Energy	HGMs	Hollow glass microspheres
GTI	Gas Technology Institute	HHICE	Hybrid hydrogen internal combustion engine
GTR	Global Technical Regulations	HHV	Higher heating value
GUI	Graphical user interface	HI	Hydrogen iodide, hydriodic acid
GW	An approximation permitting practical calculation of excitation energies in metals, semi-conductors and insulators	HIA	Hydrogen-induced amorphization
GWS	Glenn W. Scheffler	HIA	Hydrogen Implementing Agreement
h	Hour(s)	HIC	Hydrogen-induced cracking
H	Hydrogen	HIPOC	Hydrogen Industry Panel on Codes
ΔH	Enthalpy of reaction, Enthalpy of hydrogenation	HIx	Blend of hydrogen iodide, iodine, and water
H <sub>2</sub>	Diatomic hydrogen	HKUST	1 Cu <sub>5</sub> (1,3,5-benzenetricarboxylate) <sub>2</sub>
H2A	Hydrogen Analysis project sponsored by DOE	HLA	High level architecture
HAADF	High-angle annular dark-field	HMC	Hyundai Motor Company
HAMMER	Hazardous Materials Management and Emergency Response	HMM	Hidden Markov Model
HATCI	Hyundai-KIA America Technical Center Inc.	HNEI	Hawaii Natural Energy Institute
HAVO	Hawaii Volcanoes National Park	HNO <sub>3</sub>	Nitric acid
HAZ	Heat activated zone	H <sub>2</sub> ICE	Hydrogen internal combustion engine
HAZID	Hazard identification analysis	H <sub>2</sub> O	Water
HAZOP	Hazards and operability	H <sub>2</sub> O <sub>2</sub>	Hydrogen peroxide
HBr	Hydrogen bromide	H2QWG	DOE Hydrogen Quality Working Group
HBU	Hydrogen based unit	H <sub>2</sub> S	Hydrogen sulfide
HCG	Hydrogen Coordinating Group	HOD™	Hydrogen on Demand™
HCl, HCL	Hydrochloric acid, Hydrogen chloride	HOPG	Highly-ordered pyrolytic graphite
HClO <sub>4</sub>	Perchloric acid	HOV	High occupancy vehicle
		HP	High-pressure
		hp	Horsepower

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HPA	Heteropoly acid	ICC	International Code Council
HPC	High pressure cell	ICE	Internal combustion engine
HPE	Hybrid photoelectrode	ICE/FC	Internal combustion engine/fuel cell
H-PEMFC	Hydrogen polymer electrolyte membrane fuel cell	ICONE	International Conference on Nuclear Energy
HPLC	High performance liquid chromatography	ICP	Inductively coupled plasma
hr	Hour(s)	ICPAE	Inductively coupled plasma atomic emission
HRL	Hughes Research Laboratory, HRL Laboratories, LLC	ICP-AES	Inductively coupled plasma atomic emission spectroscopy
HRTEM	High-resolution transmission electron microscopy	ICSD	Inorganic Crystal Structure Database
HSCoE	Hydrogen Sorption Center of Excellence	ID	Inside diameter
HSDC	Hydrogen Secure Data Center	IE	Intelligent Energy
HSM	Hydrogen storage materials	IEA	International Energy Agency
HSM	Hot stage microscope	IEC	International Electrotechnical Commission
H <sub>2</sub> SO <sub>4</sub>	Sulfuric acid	IEC	Ion exchange capacity
HT	High-temperature	IFE	Institute for Energy Technology (Norway)
HTE	High-temperature electrolysis	IGCC	Integrated gasification combined cycle
HTFC	High-temperature fuel cell	ILS	Integrated laboratory scale
HTGR	High-temperature gas-cooled reactor	INER	Institute of Nuclear Energy Research
HTHX	High-temperature heat exchanger	INERI	International Nuclear Energy Research Initiative
HTM	High-temperature membrane	INL	Idaho National Laboratory
HTM	Hydrogen transport membrane	INS	Inelastic neutron scattering
HTMWG	High Temperature Membrane Working Group	IOS	Intelligent Optical Systems, Inc.
HTS	High-temperature shift	IP	Intellectual property
HTSE	High temperature steam electrolysis	IPCE	Incident photon conversion to electrons, incident photon conversion efficiency
HX	Heat exchanger	IP COE	Isostatically pressed closed one end
HyARC	Hydrogen Analysis Resource Center	IPHE	International Partnership for the Hydrogen Economy
HyDIVE	Hydrogen Dynamic Infrastructure and Vehicle Evolution model	IPTG	Isopropyl β-D-1-thiogalactopyranoside
HyDS	Hydrogen Deployment System model	IR	Infrared
HyDRA	Hydrogen Demand and Resource Analysis model	Ir	Iridium
HYDROGENIUS	Hydrogen Industrial Use and Storage	IRMOF	Isorecticular metal organic framework
HyPEP	Hydrogen production efficiency calculation program	IRR	Internal rate of return
HyPro, HYPRO	Analysis tool	ISO	International Organization for Standardization; International Standards Organization
HyS	Hybrid sulfur	ISPRA	Location of the European Joint Research Centre
HYSYS®	Process simulation software by AspenTech, computer code for process analysis	ITM	Ion transport membrane
HyTRANS	Hydrogen transition model	ITO	Indium tin oxide
Hz	Hertz	IV	Current-voltage
I	Current	J	Joule(s)
ICAO	International Civil Aviation Organization	JARI	Japan Automobile Research Institute
ICAPP	International Congress on Advances in Nuclear Power Plants	JMFC	Johnson-Matthey Fuel Cells, Inc.

JPL	Jet Propulsion Laboratory	LH2, LH <sub>2</sub>	Liquid hydrogen
K	Kelvin	LHS	Lawrence Hall of Science
K	Potassium	LHSV	Liquid hourly space velocity, h <sup>-1</sup>
KAERI	Korea Atomic Energy Research Institute	LHV	Lower heating value
kcal	Kilocalorie(s)	Li	Lithium
kcal/mol	Kilocalorie(s) per mole	LiBH <sub>4</sub>	Lithium borohydride
kg	Kilogram(s)	LIBS	Laser-induced breakdown spectroscopy
kg/d	Kilogram(s) per day	LiH	Lithium hydride
kg/hr	Kilogram(s) per hour	LIM	Liquid injection molding, liquid injection moldable
kg/m <sup>3</sup>	Kilogram(s) per cubic meter	Li <sub>3</sub> N	Lithium nitride
KH	Potassium hydride	LLC	Limited Liability Company
kHz	Kilohertz	LLNL	Lawrence Livermore National Laboratory
KIA	Kia Motor Company	LMWO	Lanthanum molybdenum tungsten oxide ( <i>e.g.</i> , La <sub>2</sub> Mo <sub>1.8</sub> W <sub>0.2</sub> O <sub>9-x</sub> )
kJ	Kilojoule(s)	L/min, l/min	Liter(s) per minute
kJ/mol	Kilojoule(s) per mole	LN <sub>2</sub>	Liquid nitrogen
km	Kilometer(s)	LQ*	Carrier liquid
KOH	Potassium hydroxide	LRS	Laser raman spectroscopy
kPa	Kilopascal(s)	LSC	Lanthanum strontium cobalt oxide, (La, Sr)CoO <sub>3</sub> , strontium-doped lanthanum cobaltite, La <sub>0.8</sub> Sr <sub>0.2</sub> CoO <sub>3+δ</sub>
kph	Kilometer(s) per hour	LSCF	Lanthanum strontium cobalt iron oxide, (La, Sr)(Co, Fe)O <sub>3</sub>
kW	Kilowatt(s)	LSCM	Lanthanum strontium chromium manganese oxide, (La, Sr)(Cr, Mn)O <sub>3</sub>
kW <sub>e</sub>	Kilowatt(s) electric	LSM	Lanthanum strontium manganese oxide, (La, Sr)MnO <sub>3</sub> , strontium-doped lanthanum manganite, La <sub>0.8</sub> Sr <sub>0.2</sub> MnO <sub>3+δ</sub>
kWh	Kilowatt-hour(s)	LST	Lanthanum strontium titanium oxide, (La, Sr)TiO <sub>3</sub>
kWh/kg	Kilowatt-hour(s) per kilogram	LSV	Lanthanum strontium vanadate
kWh/L	Kilowatt-hour(s) per liter	LT	Low-temperature
kW/kg	Kilowatt(s) per kilogram	LTDMS	Laser induced thermal desorption mass spectrometry
kWt	Kilowatt(s) thermal	LWR	Light water reactor
L, l	Liter(s)	LVVWD	Las Vegas Valley Water District
La	Lanthanum	m	Meter(s)
LA	Los Angeles	M	Mole, molar
LAMOX	Lanthanum molybdenum oxide ( <i>e.g.</i> , La <sub>2</sub> Mo <sub>2</sub> O <sub>9</sub> )	M	Million
LANL	Los Alamos National Laboratory	m <sup>2</sup>	Square meter(s)
LAX	Los Angeles International Airport	m <sup>3</sup>	Cubic meter(s)
lb	Pound(s)	m <sup>2</sup> /g	Square meter(s) per gram
lbmol	Pound-mole(s)	m <sup>2</sup> /s	Square meter(s) per second
LBNL	Lawrence Berkeley National Laboratory	M31	Arkema's first-generation membrane candidate
LC	Liquid carrier	M41	Arkema's second-generation membrane candidate
LCH <sub>2</sub>	Hydrogenated liquid carrier		
LCHPP	Low Cost Hydrogen Production Platform		
LC-MS	Liquid chromatography-mass spectroscopy		
L/D	Length to diameter ratio		
LDV	Light-duty vehicle		
LED	Light emitting diode		
LEL	Lower explosion limit		
LFL	Lower flammability limit		
L/h, l/h	Liter(s) per hour		

## XII. Acronyms and Abbreviations

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mA	Milliamp(s)	mL, ml	Milliliter(s)
$\mu$ A	Micro ampere(s)	MLA	Mineral liberation analysis
$\text{mA}/\text{cm}^2$	Milliamp(s) per square centimeter	$\mu\text{m}$	Micrometer(s); micron(s)
$\mu\text{A}/\text{cm}^2$	Micro ampere(s) per square centimeter	MMP	MetaMateria Partners LLC
MACRS	Modified Accelerated Cost Recovery Schedule	MM-SE	Mueller matrix spectro-ellipsometry
M-BOP	Mechanical balance of plant	MMSCFD	Million standard cubic feet/day
MAS	Magic angle spinning	Mn	Manganese
MAS $^{11}\text{B}$ -NMR	Magic angle spinning boron-11 nuclear magnetic resonance	MnO	Manganese oxide
MAS-NMR	Magic angle spinning nuclear magnetic resonance	$\text{Mn}_2\text{O}_3$	Manganese oxide
MBMS	Molecular beam mass spectrometry	MOF	Metal-organic framework
MC	Monte Carlo	mol	Mole(s)
MC	Model compound	MPa	Megapascal(s)
MCEL	Millenium Cell, Inc.	MPG, mpg	Mile(s) per gallon
MCFC	Molten carbonate fuel cell	mph	Mile(s) per hour
MD	Molecular dynamics	MPL	Microporous layer
$M_d$	Temperature for formation of strain-induced martensite	mpy	Mils per year
MDES	Methyl-diethoxy silane	MQMAS	Multiple quantum magic angle spinning
MEA	Membrane electrode assembly	MR	Membrane reactor
MeAB	Methylamine borane	MRCAT	Materials Research Collaborative Access Team
MEI	Makel Engineering	MRT	Membrane Reactor Technologies
MEIC	Mixed electronic and ionic conducting (membranes)	ms	Millisecond(s)
MFI	A zeolite structure code	$\text{mS}/\text{cm}$	Milli-Siemen(s) per centimeter
Mg	Megagram(s)	MS	Mass spectroscopy, mass spectrometry
$\mu\text{g}$	Microgram(s)	MSA	Metropolitan statistical area
mg	Milligram(s)	MS-EVB	Multi-state empirical valence bond
$\text{mg}/\text{cm}^2$	Milligram(s) per square centimeter	MSM	Macro-System Model
$\text{MgCl}_2$	Magnesium chloride	MSP	Molten state processing
MGD	Media gravimetric density	MSR	Metal-steam reforming
$\text{MgH}_2$	Magnesium hydride	MTI	Mechanical Technology, Inc.
$\text{mgPt}/\text{cm}^2$	Milligram(s) of platinum per square centimeter	mtorr	Millitorr
MH	Membrane humidifier	MTS	Membrane test system, material test system
MH	Metal hydride	$\mu\text{V}$	Micro-volt(s)
MHC	Metal hydride-based compressor	mV	Millivolt(s)
MHCoE	Metal Hydride Center of Excellence	mW	Milliwatt(s)
MHz	Megahertz	MW	Megawatt(s)
mi	Mile(s)	MW	Molecular weight
MIEC	Mixed ionic and electronic conduction	$\text{m}\Omega$	Milli-ohm(s)
mi/kg	Mile(s) per kilogram	$\text{M}\Omega$	Mega-ohm(s)
mil	Millimeter(s)	$\text{m}\Omega/\text{cm}^2$	Milli-ohm(s) per square centimeter
min	Minute(s)	$\mu\Omega\text{-cm}^2$	Micro-ohm(s) - square centimeter
MJ	Megajoule(s)	$\text{mW}/\text{cm}^2$	Milliwatt(s) per square centimeter
		MWCNT	Multiple-wall carbon nanotube
		MWe	Megawatt(s) electric
		MWNT	Multi-wall carbon nanotubes



MWth	Megawatt(s) thermal	NG	Natural gas
MYPP	Multi-Year Program Plan (the HFCIT Program's Multi-Year Research, Development and Demonstration Plan), Multi-Year Product Plan	NGNP	Next Generation Nuclear Plant
MYRDD, MYRD&D	Multi-Year Research, Development and Demonstration Plan	NH <sub>3</sub>	Ammonia
N	Nitrogen atom	NHA	National Hydrogen Association
N	Newton (unit of force)	NHE	Normal hydrogen electrode
N/cm <sup>2</sup>	Newton(s) per square centimeter	NHFC4	National Hydrogen and Fuel Cells Codes and Standards Coordinating Committee
N112	Nafion <sup>®</sup> 1100 equivalent weight, 2 millimeter thick membrane	NHI	Nuclear Hydrogen Initiative
N <sub>2</sub>	Diatomic nitrogen	NHTSA	National Highway Traffic Safety Administration of the U.S. Department of Transportation
Na	Sodium	Ni	Nickel
NA	North American	NILS	Normal interstitial lattice sites
Na <sub>3</sub> AlH <sub>6</sub>	Trisodium hexahydroaluminate	NiMH	Nickel metal hydride
NaAlH <sub>4</sub>	Sodium aluminum hydride; sodium tetrahydroaluminate; sodium alanate	NIST	National Institute of Standards and Technology
NaBH <sub>4</sub>	Sodium borohydride	NL	Normal liter(s)
NaBO <sub>2</sub>	Sodium metaborate	nm	Nanometer(s)
NaCl	Sodium chloride	NMP	N-methylpyrrolidone
Nafion <sup>®</sup>	Registered Trademark of E.I. DuPont de Nemours	NMR	Nuclear magnetic resonance
NaH	Sodium hydride	Nm <sup>3</sup>	Normal cubic meter(s)
NaOH	Sodium hydroxide	NNA	Non-North American
Na <sub>2</sub> S	Sodium sulfide	NNA NG	Non-North American natural gas
NASFM	National Association of State Fire Marshals	NNIF	NIST neutron imaging facility
NASA	National Aeronautics and Space Administration	NO <sub>2</sub>	Nitric oxide
NCMS	National Center for Manufacturing Sciences	N <sub>2</sub> O	Nitrous oxide
NCN	Nano capillary network	NOx	Oxides of nitrogen
NCNR	NIST Center for Neutron Research	NPC	Nanoporous carbon
NDC	New delivery concept	NPD	Neutron powder diffraction
NDTE	Non-destructive testing and evaluation	NPM	Nanostructured polymeric materials
NE	U.S. DOE Office of Nuclear Energy, Science and Technology	NPS	National Park Service
NEB	Nudged elastic band	NPT	Normal pressure and temperature
NEDO	New Energy and Industrial Technology Development Organization (Japan)	NPV	Net present value
NEED	National Energy Education Development Project	NRC	National Research Council
NEMS	National Energy Modeling System	NRC-IFCI	National Research Council's Institute for Fuel Cell Innovation
NERI	Nuclear Energy Research Initiative	NREL	National Renewable Energy Laboratory
NETL	National Energy Technology Laboratory	NSTF	Nanostructured thin film
NFCRC	National Fuel Cell Research Center	NSTFC	Nano-structured thin film catalyst
NFPA	National Fire Protection Association	NTP	Negative thermal expansion
NFS	Nano-framework structured	NVS	Neutron vibrational spectroscopy
		NYC	New York City
		NZVI	Nano zerovalent iron
		O	Oxygen
		O <sub>2</sub>	Diatomic oxygen
		O/C	Oxygen-to-carbon ratio
		OCP	Open circuit potential

## XII. Acronyms and Abbreviations

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OCS	Orange County Sanitation District	PEM	Polymer electrolyte membrane
OCV	Open circuit voltage	PEM	Proton exchange membrane
o.d.,OD	Outer diameter	PEMFC	Polymer electrolyte membrane fuel cell
OEC	Oxygen evolving complex	PEMFC	Proton exchange membrane fuel cell
OEM	Original equipment manufacturer	PES	Polyether sulfone
OER	Oxygen evolution reaction	PES	Potential energy surface
OH <sup>-</sup>	Hydroxyl radical	PES	Polyethersulfone-polyimide copolymer
OHFCIT	Office of Hydrogen, Fuel Cells, and Infrastructure Technologies	PET	Polyethylene terephthalate
O&M	Operation and maintenance	PFD	Process flow diagram
O/O	Oxygen to oxygen	PFGE	Pulse field gradient spin echo
ORNL	Oak Ridge National Laboratory	PFSA	Perfluorinated sulfonic acid, perfluorosulfonic acid
ORR	Oxygen reduction reaction	PGE	Platinum group element
OSC	Oxygen storage capability	PGM	Precious group metal, Platinum group metal
OSHA	U.S. Occupational Safety and Health Administration	PHA	Process hazard analysis, preliminary hazard analysis
OSM	Oregon Steel Mills	PI	Principal investigator
OSU	Ohio State University	P&ID	Piping and instrumentation diagram, process and instrumentation diagram
OTM	Oxygen transport membrane	PIL	Protic ionic liquid
ΔP	Pressure drop, pressure change	PIM	Protic ionic membrane
P	Phosphorus	PM	Precious metal, such as platinum
P	Pressure	PM	Peroxide mitigation
Pa	Pascal(s)	PM <sub>10</sub>	Particulate matter with diameters of 10 micrometers or less
PADD	Petroleum Administration for Defense District	PM <sub>2.5</sub>	Particulate matter with diameters of 2.5 micrometers or less
PAFC	Phosphoric acid fuel cell	PNNL	Pacific Northwest National Laboratory
PANI	Polyaniline	POC	Proof of concept
PAS	Photoactive semiconductor	POCOP	<i>P,P-bis(1,1-dimethylethyl)-3-[[bis(1,1-dimethylethyl)phosphino]oxy]phenyl ester</i>
PAW	Projector augmented wave	POGT	Partial oxidation gas turbine
Pb	Lead	POM	Polyoxometallate
PB	Polyborazylene	POSS	Polyhedral oligomeric silsesquioxane
PBI	Polybenzimidazole	POX	Partial oxidation
PC	Personal computer	ppb	Part(s) per billion
PCHD	Poly(cyclohexadiene)	ppbv	Part(s) per billion by volume
PCI	Pressure-composition isotherm	PPDSA	Poly (p-phenylene disulfonic acid)
PCM	Power control module	PPI	Plug Power, Inc.
PCT	Pressure concentration temperature	PPI	Pore(s) per inch
Pd	Palladium	ppm, PPM	Part(s) per million
PEAR	Power and Energy Analytic Resources	ppmv	Part(s) per million by volume
PEC	Photoelectrochemical, Photoelectrochemical cell	ppmw	Part(s) per million by weight
PECVD	Plasma-enhanced chemical vapor deposition	PPO	Phenyl phosphine oxide
PEEK	Polyether ether ether ketone	PPS	Polyphenylenesulfide
PEFC	Polymer electrolyte fuel cell	PPSA	Poly (p-phenylene sulfonic acid)
PEFC	Proton exchange fuel cell		
PEKK	Poly (ether ketone ketone)		

PPSU	Polyphenylsulfone	RDE	Rotating disk electrode
PPy	Polypyrrole	Re	Rhenium
PrOx	Preferential oxidation	RF, rf	Radio frequency
PS	Photosystem	RF	Roughness factor
PS	Proton sponge (bis- (dimethylamino)naphthalene)	RGA	Residual gas analyzer
PSA	Pressure sensitive adhesive	RH	Relative humidity
PSA	Pressure swing adsorption	Rh	Rhodium
PSAT	Powertrain Systems Analysis Toolkit, a vehicle simulation software package developed at Argonne National Laboratory	RIXS	Resonant inelastic X-ray scattering spectra
PSD	Particle size distribution	RHE	Reference hydrogen electrode; reversible hydrogen electrode
psi	Pound(s) per square inch	ROW	Right of way
psia	Pound(s) per square inch absolute	rpm	Revolution(s) per minute
psig, PSIG	Pound(s) per square inch gage	RPM	Renewable Planning Model
PSII	Photosystem II	RRDE	Rotating ring disc electrode
PSOFC	Planar solid oxide fuel cell	RPSA	Rapid pressure swing adsorption
PSU	Pennsylvania State University	RSOFC	Reversible solid oxide fuel cell
Pt	Platinum	RT	Room temperature
Pt-MM	Platinum mixed metal	Ru	Ruthenium
P-T	Pressure-temperature	s	Second(s)
PTA	Phosphotungstic acid	S	Siemen(s)
Pt/C	Platinum/carbon	S	Sulfur
PTFE	Teflon <sup>®</sup> – poly-tetrafluoroethylene	SA	Surface area
Pt-NH	Platinum decorated carbon nano-horns	SAE	Society of Automotive Engineers
PtO	Platinum oxide	SAM	Scanning Auger microscopy
PtO <sub>2</sub>	Platinum dioxide	SANS	Small angle neutron scattering
PtRu	Platinum ruthenium	SAS	Styrene-acrylonitrile-vinylsulfate
Pt-SWNH	Platinum decorated single-walled nanohorns	SASSP	Solvent assisted solid state processing
PTW	Pump-to-wheels	SAXS	Small angle X-ray scattering
PV	Photovoltaic	SBH	Sodium borohydride
PVD	Physical vapor deposition	SBIR	Small Business Innovative Research
PVDF	Polyvinylidene fluoride	SBP	Solution based processing
PVP	Polyvinylpyrrolidone	SBU	Secondary building units
PVT	Pressure-Volume-Temperature	Sc	Scandium
PXD	Powder X-ray diffraction	S/C	Steam to carbon ratio
Q1, Q2, Q3, Q4	Quarters of the fiscal year	sccm, SCCM	Standard cubic centimeter(s) per minute
QCM	Quartz crystal microbalance	SCF, scf	Standard cubic feet
QRA	Quantitative risk assessment	scfd	Standard cubic feet per day
R	Universal or ideal gas constant, 8.314472 J · K <sup>-1</sup> · mol <sup>-1</sup>	SCFH	Standard cubic feet per hour
RA	Reduction of area	SCFM	Standard cubic feet per minute
R&D	Research and development	SCPO	Staged catalytic partial oxidation
RDC	Resource Dynamics Corporation	SCR	Selective catalytic reduction
RD&D	Research, development & demonstration	S/cm	Siemen(s) per centimeter
		ScSZ	Scandia-stabilized zirconia
		SDAPP	Sulfonated diels-alder polyphenylene
		SDC	Samarium doped ceria

## XII. Acronyms and Abbreviations

SDE	SO <sub>2</sub> -depolarized electrolyzer	sPEEK	Sulfonated poly(ether ether ketone)
SDO	Standards Development Organization	SPEX	Brand of milling machine
SDT	Simultaneous differential scanning calorimeter and thermalgravimetric analyzer	SPM	Scanning probe microscope
Se	Selenium	SPR	Solid particle receiver
sec	Second(s)	sq. in.	Square inch(es)
SEC	Size exclusion chromatography	Sr	Strontium
SECA	Solid State Energy Conversion Alliance	SRM	Steam reforming
SEM	Scanning electron microscopy, scanning electron microscope	SRNL	Savannah River National Laboratory
SEM	Secondary electron microscopy	SS	Stainless steel
SERC	Schatz Energy Research Center	SSM	Stress strain microprobe
SFC	Smart fuel cell	SSNMR	Solid-state nuclear magnetic resonance
SFC2	SrFeCo <sub>0.5</sub> O <sub>x</sub>	SSP	Solid state processing
SFT	Sr-Fe-Ti oxide	SSR <sup>TM</sup>	Stackable Structural Reactor
SFA	Sulfonic acid	SSRL	Stanford Synchrotron Radiation Laboratory
SGD	System gravimetric density	SSV	Shift space velocity
SHE	Standard hydrogen electrode	SSY	Small scale yielding
Si	Silicon	STEM	Scanning transmission electron microscopy
S-I	Sulfur-iodine	STH	Solar-to-hydrogen
SI	Sulfur-iodine cycle	STM	Scanning tunneling microscopy
SiC	Silicon carbide	STP	Standard temperature and pressure
SiO <sub>2</sub>	Silicon dioxide	STS	Scanning tunneling spectroscopy
slpm, slm	Standard liter(s) per minute	STTR	Small Business Technology Transfer
SMEC	Study of matter at extreme conditions	SUNY	State University of New York
SMR	Steam methane reformer; steam methane reforming	SV	Space velocity
SMUD	Sacramento Municipal Utility District	SVD	System volumetric density
Sn	Tin	SWCNT	Single-walled carbon nanotube
SNL	Sandia National Laboratories	SWNH	Single-walled nanohorn
SNLL	Sandia National Laboratory Livermore	SWNT	Single-wall nanotube
SLPH	Standard liter(s) per hour	SwRI	Southwest Research Institute
SLPM	Standars liter(s) per minute	SYT	Yttrium-doped strontium titanate
SO <sub>2</sub>	Sulfur dioxide	T	Temperature
SOC	State of charge	T <sub>1bar</sub>	Temperature at which equilibrium pressure of hydrogen is 1 bar for a hydrogen exchange reaction
SOEC	Solid oxide electrolysis cell; solid oxide electrolyzer cell	t	Time
SOFC	Solid oxide fuel cell	Ta	Tantalum
SOFEC	Solid oxide fuel-fed electrolysis cell	TAMU	Texas A&M University
SOW	Statement of work	TBA-PF <sub>6</sub>	Tetra- <i>n</i> -butylammonium hexafluorophosphate
SOx	Oxides of sulfur	TBD	To be determined
sPAES	Sulfonated poly(arylene ether sulfone)	TBR	Trickle bed reactor
SPE	Solid phase epitaxial	TC	Thermocouple
SPEK	Sulfonated poly-etherketone-ketone	TC	Technical committee
SPEKK	Sulfonated polyether(ether ketone ketone)	TCCR	Transparent, conducting and corrosion resistant

TDV	Technology demonstration vehicle	UCB	University of California, Berkeley
TEAB	Tetraethyl ammonium borohydride	UCI	University of California, Irvine
TEDA	Triethylenediamine	UCLA	University of California, Los Angeles
TEAH	Tetraethylammonium hydroxide	UCONN	University of Connecticut
TEM	Transmission electron microscopy	UCSB	University of California, Santa Barbara
TEOM	Tapered element oscillating microbalance	UH	University of Hawaii
Tf	Trifluoromethane sulfonate, or triflate anion (CF <sub>3</sub> SO <sub>3</sub> <sup>-</sup> )	UHP	Ultra-high purity
TFAc	Trifluoroacetate	UHV	Ultra-high vacuum
TFE	Tetrafluoroethylene	UIUC	University of Illinois, Urbana-Champaign
TFSI	Trifluorosulfimide	UL	Underwriters Laboratory
TFVE	Trifluorovinyl ether	um	Micrometer(s)
tf-Si	Thin film silicon	UM	University of Michigan
TG	Thermogravimetric	UNC	University of North Carolina
TGA	Thermal gravimetric analysis; thermogravimetric analysis; thermogravimetric analyzer	UNECE	United Nations Economic Commission for Europe
TGA-DSC	Thermo-gravimetric analysis-differential scanning calorimetry	UNLV	University of Nevada Las Vegas
TGA-MS	Thermogravimetric analysis-mass spectrometer	UNLVRF	UNLV Research Foundation
TG-DTA	Thermo-gravimetric/differential thermal analyzer	UNM	University of New Mexico
THF	Tetrahydrofuran	UNR	University of Nevada, Reno
Ti	Titanium	UPS	Ultraviolet photoelectron spectroscopy
Tla	Truncated light-harvesting chlorophyll antenna	U.S.	United States
tla1	Mutant of the Tla1 gene (GenBank Assession No. AF534570)	USCAR	United States Council for Automotive Research
tlaX	Mutant of unknown gene with a truncated light-harvesting chlorophyll antenna	USFCC	United States Fuel Cell Council
TM	Transition metal	USPP	Ultrasoft pseudopotentials
TMAH	Tetramethylammonium hydroxide	UT	Ultrasonic testing
TMB	Trimethylborate	UTC	United Technologies Corporation
TMPS	Trimethoxyl phenyl silane	UTR	Untranslated region
TMS	Thermal management system	UTRC	United Technologies Research Center
TOF	Turnover frequency	UV	Ultraviolet
TPA	Tripropylamine	UV-vis	Ultraviolet-visual
TPAH	Tetra-n-propylammonium hydroxide	V	Vanadium
TPD	Ton(s) per day	V	Volt
TPD	Temperature-programmed desorption	VAC	Volts alternating current
TNA	Titania nanotube array	VANTA	Vertically aligned nanotube arrays
TPO	Temperature-programmed oxidation	VASP	Vienna ab initio simulation package
TPR	Temperature-programmed reduction	VDC	Volts direct current
tr. oz.	Troy ounce	VDF	Vinylidene fluoride
TSA	Temperature swing adsorption	vdW	van der Waals
UC	University of California	VFS	Vehicle fueling station
		VHTR	Very high temperature gas-cooled nuclear reactor
		VHTS	Virtual high-throughput screening
		VI	Venter Institute
		V-I	Voltage – current
		VIS	Visible light at 400-700 nm

## XII. Acronyms and Abbreviations

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VMT	Vehicle miles travelled	Wt	Watt(s) thermal
VOC	Volatile organic compound	wt	Weight
VOC	Voltage open circuit	wt%	Weight percent (percent by weight)
vol	Volume	WTP	Well-to-pump
vol%	Volume percent	WTW	Well-to-wheels
VTA	Santa Clara Valley Transportation Authority	WU	Water uptake
$\Omega$	Ohm(s)	XC72	High-surface-area carbon support made by Cabot
W	Tungsten	XAFS	X-ray absorption fine structure
W	Watt(s)	XANES	X-ray absorption near-edge spectroscopy
WAXD	Wide-angle X-ray diffraction	XAS	X-ray absorption spectroscopy
WBS	Work breakdown schedule	XPS	X-ray photoelectron spectroscopy, X-ray photon spectroscopy
WC	Tungsten carbon, tungsten carbide	XPS-UPS	X-ray photoelectron-ultraviolet photoelectron spectroscopy
We	Watt(s) electric	XRD	X-ray diffraction
W/F	Ratio of catalyst dosage to feed flow rate	XRF	X-ray fluorescence
WG-12	Working Group 12	Y	Yttrium
WGS	Water-gas shift	yr, YR	Year
Wh	Watt-hour(s)	YSZ	Ytria-stablized zirconia
W-h/kg	Watt-hour(s) per kilogram	Z	Atomic number
W-h/L, Wh/liter, Wh/L	Watt-hour(s) per liter	ZEV	Zero emission vehicle
WHSV	Weight hourly space velocity	Zn	Zinc
Wind2H2	Wind to hydrogen demonstration project	ZnO	Zinc oxide
W/kg	Watt(s) per kilogram	zpp	Zirconium phenyl phosphonate
W/L, W/l	Watt(s) per liter	Zr	Zirconium
WO <sub>3</sub>	Tungsten trioxide	ZrO <sub>2</sub>	Zirconium dioxide
WOL	Wedge opening load	ZrSPP	Zirconium phosphate sulfophenylphosphonate
WP.29	Working Party 29 - World Forum for Harmonization of Vehicle Regulations	ZVI	Zerovalent iron
Wppm	Weight part(s) per million		
WRI	Western Research Institute		