

Table of Contents

Introduction	1
Hydrogen Fuel R&D	10
Hydrogen Production R&D	12
P-102: Analysis of Advanced Hydrogen Production Pathways	12
P-143: High-Temperature Alkaline Water Electrolysis	18
P-177: Proton-Conducting Ceramic Electrolyzers for High-Temperature Water Splitting	22
P-178: Industrially Scalable Waste Carbon Dioxide Reduction to Useful Chemicals and Fuels.....	26
Hydrogen Production R&D: HydroGEN Seedling	32
P-148: HydroGEN Overview: A Consortium on Advanced Water-Splitting Materials	32
P-152: Proton-Conducting Solid Oxide Electrolysis Cells for Large-Scale Hydrogen Production at Intermediate Temperatures	38
P-153: Degradation Characterization and Modeling of a New Solid Oxide Electrolysis Cell Utilizing Accelerated Life Testing	43
P-154: Thin-Film, Metal-Supported High-Performance and Durable Proton–Solid Oxide Electrolyzer Cell.....	48
P-155: High-Efficiency Polymer Electrolyte Membrane Water Electrolysis Enabled by Advanced Catalysts, Membranes, and Processes	52
P-156: Developing Novel Platinum-Group-Metal-Free Catalysts for Alkaline Hydrogen and Oxygen Evolution Reactions	58
P-157: Platinum-Group-Metal-Free Oxygen Evolution Reaction Catalysts for Polymer Electrolyte Membrane Electrolyzer	64
P-158: High-Performance Ultralow-Cost Non-Precious-Metal Catalyst System for Anion Exchange Membrane Electrolyzer.....	70
P-159: Scalable Elastomeric Membranes for Alkaline Water Electrolysis	76
P-160: Best-in-Class Platinum-Group-Metal-Free Catalyst Integrated Tandem Junction Photoelectrochemical Water-Splitting Devices.....	80
P-161: Protective Catalyst Systems on III-V and Silicon-Based Semiconductors for Efficient, Durable Photoelectrochemical Water-Splitting Devices	85
P-162: Novel Chalcopyrites for Advanced Photoelectrochemical Water Splitting.....	90
P-163: Monolithically Integrated Thin-Film/Silicon Tandem Photoelectrodes for High-Efficiency and Stable Photoelectrochemical Water Splitting.....	94
P-165: Accelerated Discovery of Solar Thermochemical Hydrogen Production Materials via High-Throughput Computational and Experimental Methods.....	98
P-166: Computationally Accelerated Discovery and Experimental Demonstration of High-Performance Materials for Advanced Solar Thermochemical Hydrogen Production	104
P-167: Transformative Materials for High-Efficiency Thermochemical Production of Solar Fuels.....	109
P-168: Mixed Ionic Electronic Conducting Quaternary Perovskites: Materials by Design for Solar Thermochemical Hydrogen	114
P-169: High-Temperature Reactor Catalyst Material Development for Low-Cost and Efficient Solar-Driven Sulfur-Based Processes	118

P-170:	Benchmarking Advanced Water-Splitting Technologies: Best Practices in Materials Characterization	124
P-175:	Intermediate-Temperature Proton-Conducting Solid Oxide Electrolysis Cells with Improved Performance and Delivery	131
P-176:	Development of Durable Materials for Cost-Effective Advanced Water Splitting Utilizing All-Ceramic Solid Oxide Electrolyzer Stack Technology	135
Hydrogen Storage R&D		139
ST-001:	System-Level Analysis of Hydrogen Storage Options	139
ST-100:	Hydrogen Storage Cost Analysis.....	144
ST-127:	Hydrogen Materials–Advanced Research Consortium (HyMARC): A Consortium for Advancing Hydrogen Storage Materials	148
ST-128:	Hydrogen Materials–Advanced Research Consortium (HyMARC): Sandia National Laboratories Technical Activities	156
ST-129:	Hydrogen Materials–Advanced Research Consortium (HyMARC): Lawrence Livermore National Laboratory Technical Activities.....	163
ST-130:	Hydrogen Materials–Advanced Research Consortium (HyMARC): Lawrence Berkeley National Laboratory Technical Activities.....	168
ST-131:	Hydrogen Materials–Advanced Research Consortium (HyMARC): National Renewable Energy Laboratory Technical Activities	174
ST-132:	Hydrogen Materials–Advanced Research Consortium (HyMARC): Pacific Northwest National Laboratory Technical Activities.....	179
ST-137:	Hydrogen Materials–Advanced Research Consortium (HyMARC) Seedling: Electrolyte-Assisted Hydrogen Storage Reactions.....	184
ST-143:	Hydrogen Materials–Advanced Research Consortium (HyMARC) Seedling: Atomic Layer Deposition Synthesis of Novel Nanostructured Metal Borohydrides	189
ST-144:	Hydrogen Materials–Advanced Research Consortium (HyMARC) Seedling: Optimized Hydrogen Adsorbents via Machine Learning and Crystal Engineering	194
ST-146:	Precursor Processing Development for Low-Cost, High-Strength Carbon Fiber for Composite Overwrapped Pressure Vessel Applications	200
ST-147:	Developing a New Polyolefin Precursor for Low-Cost, High-Strength Carbon Fiber.....	205
ST-148:	Novel Plasticized Melt-Spinning Process of Polyacrylonitrile Fibers Based on Task-Specific Ionic Liquids	209
Fuel Cell R&D		213
FC-017:	Fuel Cell System Modeling and Analysis	215
FC-135:	FC-PAD: Fuel Cell Consortium for Performance and Durability	220
FC-140:	Tailored High-Performance Low-Platinum-Group-Metal Alloy Cathode Catalysts	227
FC-141:	Platinum Monolayer Electrocatalysts.....	231
FC-144:	Highly Accessible Catalysts for Durable High-Power Performance	236
FC-145:	Corrosion-Resistant Non-Carbon Electrocatalyst Supports for Proton Exchange Fuel Cells.....	242
FC-146:	Advanced Materials for Fully Integrated Membrane Electrode Assemblies in Anion Exchange Membrane Fuel Cells	247

FC-147:	Advanced Ionomers and Membrane Electrode Assemblies for Alkaline Membrane Fuel Cells.....	251
FC-155:	Novel Ionomers and Electrode Structures for Improved Polymer Electrolyte Membrane Fuel Cell Electrode Performance at Low-Platinum-Group-Metal Loadings	255
FC-156:	Durable High-Power Membrane Electrode Assemblies with Low Platinum Loading.....	261
FC-157:	High-Performance Polymer Electrolyte Fuel Cell Electrode Structures.....	267
FC-158:	Fuel Cell Membrane Electrode Assemblies with Ultralow-Platinum Nanofiber Electrodes.....	272
FC-160:	ElectroCat (Electrocatalysis Consortium).....	278
FC-161:	Advanced Electrocatalysts through Crystallographic Enhancement	285
FC-162:	Vapor Deposition Process for Engineering of Dispersed Polymer Electrolyte Membrane Fuel Cell Oxygen Reduction Reaction Pt/NbOx/C Catalysts	289
FC-163:	Fuel Cell Systems Analysis	294
FC-170:	ElectroCat: Durable Manganese-Based Platinum-Group-Metal-Free Catalysts for Polymer Electrolyte Membrane Fuel Cells	299
FC-171:	ElectroCat: Advanced Platinum-Group-Metal-Free Cathode Engineering for High Power Density and Durability	303
FC-172:	ElectroCat: Highly Active and Durable Platinum-Group-Metal-Free Oxygen Reduction Reaction Electrocatalysts through the Synergy of Active Sites	307
FC-173:	ElectroCat: Platinum-Group-Metal-Free Engineered Framework Nanostructure Catalysts.....	313
FC-174:	Highly Efficient and Durable Cathode Catalyst with Ultralow Platinum Loading through Synergetic Platinum-/Platinum-Group-Metal-Free Catalytic Interaction.....	318
FC-178:	Lab Call Fiscal Year 2018 (Membrane): Spirocyclic Anion Exchange Membranes for Improved Performance and Durability	322
FC-179:	Lab Call Fiscal Year 2018 (Membrane): Stable Alkaline Membrane Based on Proazaphosphatranes Organic Super Base.....	327
FC-180:	Lab Call Fiscal Year 2018 (Membrane): High-Performing and Durable Pyrophosphate-Based Composite Membranes for Intermediate-Temperature Fuel Cells	332
FC-181:	Lab Call Fiscal Year 2018 (Reversible Fuel Cells): Microstructured Electrodes and Diffusion Layers for Enhanced Transport in Reversible Fuel Cells	337
FC-182:	Lab Call Fiscal Year 2018 (Reversible Fuel Cells): Bipolar Membrane Development to Enable Regenerative Fuel Cells	341
FC-183:	Lab Call Fiscal Year 2018 (Reversible Fuel Cells): Technology-Enabling Materials, Cell Design for Reversible Polymer Electrolyte Membrane Fuel Cells.....	346
FC-302:	Developing Platinum-Group-Metal-Free Catalysts for Oxygen Reduction Reaction in Acid: Beyond the Single Metal Site	350
FC-303:	Mesoporous Carbon-Based Platinum-Group-Metal-Free Catalyst Cathodes	353
FC-304:	Fuel Cell Membrane Electrode Assemblies with Platinum-Group-Metal-Free Nanofiber Cathodes	357
FC-305:	Active and Durable Platinum-Group-Metal-Free Cathodic Electrocatalysts for Fuel Cell Application	360
FC-306:	High-Performance Non-Platinum-Group-Metal Transition Metal Oxide Oxygen Reduction Reaction Catalysts of Polymer Electrolyte Membrane Fuel Cells	363

FC-307:	Cyclic Olefin Copolymer-Based Alkaline Exchange Polymers and Reinforced Membranes.....	366
FC-308:	Advanced Anion Exchange Membranes with Tunable Water Transport for Platinum-Group-Metal-Free Anion Exchange Membrane Fuel Cells.....	369
FC-309:	Polymerized Ionic Liquid Block Copolymers and Ionic Liquids (PILBCP-IL) Composite Ionomers for High Current Density Performance	374
FC-310:	Composite Polymer Electrolyte Membranes from Electrospun Crosslinkable Poly (Phenylene Sulfonic Acid)s.....	378
FC-311:	Novel Non-Perfluorosulfonic Acid Proton Exchange Membrane for Fuel Cell Application	381
FC-312:	Molten Hydroxide Dual-Phase Membranes for Intermediate-Temperature Anion Exchange Membrane Fuel Cells	385
FC-313:	Novel Bifunctional Electrocatalysts, Supports, and Membranes for High-Performing and Durable Unitized Regenerative Fuel Cells.....	388
FC-314:	Efficient Reversible Operation and Stability of Novel Solid Oxide Cells.....	392
FC-315:	High-Efficiency Reversible Alkaline Membrane Fuel Cells.....	396
FC-316:	Durable, High-Performance Unitized Reversible Fuel Cells Based on Proton Conductors	399
FC-317:	Stationary Direct Methanol Fuel Cells Using Pure Methanol.....	403
FC-318:	Lab Call Fiscal Year 2019: Accessible Platinum-Group-Metal-Free Catalysts and Electrodes: ElectroCat.....	407
FC-319:	Lab Call Fiscal Year 2019: Low-Cost Gas Diffusion Layer Materials and Treatments for Durable High-Performance Polymer Electrolyte Membrane Fuel Cells	410
FC-320:	Lab Call Fiscal Year 2019: Electrode Ionomers for High-Temperature Fuel Cells.....	414
FC-321:	Lab Call Fiscal Year 2019: Solid Phase Processing for Reduced Cost and Improved Efficiency of Bipolar Plates	418
FC-322:	Lab Call Fiscal Year 2019: Polymer Electrolyte Fuel Cell Electrode Structures with Encased Catalysts to Eliminate Ionomer Adsorption on Catalytic Sites.....	421
Infrastructure and Systems R&D		424
Hydrogen Infrastructure R&D		426
IN-001:	Hydrogen Materials Compatibility Consortium (H-Mat) Overview: Steels	426
IN-004:	Magnetocaloric Hydrogen Liquefaction	430
IN-005:	Electrochemical Compression	434
IN-007:	Metal Hydride Compression	438
IN-008:	Dispenser Reliability	442
IN-009:	Advancing Hydrogen Dispenser Technology by Using Innovative Intelligent Networks.....	447
IN-010:	Cryogenically Flexible, Low-Permeability Hydrogen Delivery Hose	450
IN-011:	Coatings for Compressor Seals.....	453
IN-012:	Low-Cost Magnetocaloric Materials Discovery.....	457

Technology Acceleration	461
TA-001: Membrane Electrode Assembly Manufacturing Research and Development	461
TA-005: In-Line Quality Control of Polymer Electrolyte Membrane Materials	464
TA-007: Roll-to-Roll Advanced Materials Manufacturing Lab Consortium	468
TA-008: Material–Process–Performance Relationships in Polymer Electrolyte Membrane Catalyst Inks and Coated Layers.....	473
TA-009: Maritime Fuel Cell Generator Project	476
TA-011: FedEx Express Hydrogen Fuel Cell Extended-Range Battery Electric Vehicles.....	479
TA-012: Northeast Demonstration and Deployment of FCRx200	482
TA-013: Fuel Cell Bus Evaluations.....	485
TA-014: Hydrogen Station Data Collection and Analysis	490
TA-015: Dynamic Modeling and Validation of Electrolyzers in Real-Time Grid Simulation.....	496
TA-016: Fuel Cell Hybrid Electric Delivery Van.....	501
TA-017: Innovative Advanced Hydrogen Mobile Fueler	505
TA-018: High-Temperature Electrolysis Test Stand.....	509
TA-019: Modular Solid Oxide Electrolyzer Cell System for Efficient Hydrogen Production at High Current Density	514
TA-020: Optimal Stationary Fuel Cell Integration and Control (Energy Dispatch Controller).....	518
TA-021: Integrated Systems Modeling of the Interactions between Stationary Hydrogen, Vehicle, and Grid Resources.....	522
TA-022: H2@Scale: Experimental Characterization of Durability of Advanced Electrolyzer Concepts in Dynamic Loading	527
TA-023: Hydrogen Stations for Urban Sites	532
TA-024: Analysis of Fuel Cells for Trucks	537
Systems Analysis	542
SA-044: Cost–Benefit Analysis of Technology Improvement in Medium- and Heavy-Duty Fuel Cell Vehicles.....	542
SA-169: Market Segmentation Analysis of Medium- and Heavy-Duty Trucks with a Fuel Cell Emphasis.....	546
SA-170: Analysis of Cost Impacts of Integrating Advanced Onboard Storage Systems with Hydrogen Delivery	551
SA-171: H2@Scale Analysis	555
SA-172: Hydrogen Demand Analysis for H2@Scale.....	560
Safety, Codes and Standards	565
SCS-001: National Codes and Standards Deployment and Outreach.....	567
SCS-005: Research and Development for Safety, Codes and Standards: Materials and Component Compatibility	573
SCS-007: Fuel Quality Assurance Research and Development and Impurity Testing in Support of Codes and Standards	576

SCS-010:	Research and Development for Safety, Codes and Standards: Hydrogen Behavior	580
SCS-011:	Hydrogen Quantitative Risk Assessment	585
SCS-019:	Hydrogen Safety Panel, Safety Knowledge Tools, and First Responder Training Resources	589
SCS-021:	National Renewable Energy Laboratory Hydrogen Sensor Testing Laboratory	593
SCS-022:	Fuel Cell and Hydrogen Energy Association Codes and Standards Support.....	598
SCS-026:	Hydrogen Materials Compatibility Consortium (H-Mat) Overview: Polymers	603
Appendix A: Program and Sub-Program Review Comments		606
Appendix B: Attendee List		627
Appendix C: Evaluation Forms		656
Appendix D: Projects Not Reviewed.....		677