
Table of Contents

I.	Introduction	I-1
II.	Hydrogen Production	II-1
II.0	Hydrogen Production Sub-Program Overview	II-3
II.A	Distributed Biomass-Derived Liquids Production	II-11
II.A.1	Pacific Northwest National Laboratory: Biomass-Derived Liquids Distributed (Aqueous Phase) Reforming	II-11
II.A.2	National Renewable Energy Laboratory: Distributed Bio-Oil Reforming	II-15
II.B	Biomass Gasification	II-19
II.B.1	Gas Technology Institute: One Step Biomass Gas Reforming-Shift Separation Membrane Reactor	II-19
II.C	Separations	II-23
II.C.1	Media and Process Technology Inc.: Development of Hydrogen Selective Membranes/Modules as Reactors/Separators for Distributed Hydrogen Production	II-23
II.C.2	H2Pump, LLC: Process Intensification of Hydrogen Unit Operations Using an Electrochemical Device	II-28
II.D	Electrolysis	II-31
II.D.1	Giner Electrochemical Systems, LLC: PEM Electrolyzer Incorporating an Advanced Low-Cost Membrane	II-31
II.D.2	Proton OnSite: High Performance, Low Cost Hydrogen Generation from Renewable Energy	II-35
II.D.3	National Renewable Energy Laboratory: Renewable Electrolysis Integrated Systems Development and Testing	II-39
II.D.4	National Renewable Energy Laboratory: Hour-by-Hour Cost Modeling of Optimized Central Wind-Based Water Electrolysis Production	II-43
II.D.5	Proton OnSite: Low-Cost Large-Scale PEM Electrolysis for Renewable Energy Storage	II-46
II.E	Hi-Temp Thermochemical	II-49
II.E.1	Science Applications International Corporation: Solar High-Temperature Water Splitting Cycle with Quantum Boost	II-49
II.E.2	Argonne National Laboratory: Membrane/Electrolyzer Development in the Cu-Cl Thermochemical Cycle	II-56
II.E.3	Sandia National Laboratories: Solar Hydrogen Production with a Metal Oxide-Based Thermochemical Cycle	II-60
II.E.4	University of Colorado: Solar-Thermal ALD Ferrite-Based Water Splitting Cycle	II-64
II.F	Photoelectrochemical	II-68
II.F.1	Stanford University: Directed Nano-Scale and Macro-Scale Architectures for Semiconductor Absorbers and Transparent Conducting Substrates for Photoelectrochemical Water Splitting	II-68
II.F.2	National Renewable Energy Laboratory: Semiconductor Materials for Photoelectrolysis	II-74
II.F.3	Lawrence Livermore National Laboratory: Characterization and Optimization of Photoelectrode Surfaces for Solar-to-Chemical Fuel Conversion	II-79
II.F.4	University of Nevada, Las Vegas: Characterization of Materials for Photoelectrochemical (PEC) Hydrogen Production	II-84
II.F.5	MVSystems, Incorporated: Photoelectrochemical Hydrogen Production	II-89
II.F.6	Midwest Optoelectronics, LLC: Critical Research for Cost-Effective Photoelectrochemical Production of Hydrogen	II-93
II.F.7	University of Texas at Arlington: Photoelectrochemical Materials: Theory and Modeling	II-98

Table of Contents

II.	Hydrogen Production (Continued)	
II.G	Biological	II-103
II.G.1	National Renewable Energy Laboratory: Biological Systems for Hydrogen Photoproduction	II-103
II.G.2	National Renewable Energy Laboratory: Fermentation and Electrohydrogenic Approaches to Hydrogen Production	II-108
II.G.3	J. Craig Venter Institute: Hydrogen from Water in a Novel Recombinant Oxygen-Tolerant Cyanobacterial System	II-113
II.G.4	University of California, Berkeley: Maximizing Light Utilization Efficiency and Hydrogen Production in Microalgal Cultures	II-118
II-H	Production	II-122
II.H.1	Giner Electrochemical Systems, LLC: Unitized Design for Home Refueling Appliance for Hydrogen Generation to 5,000 psi	II-122
II.H.2	Proton Energy Systems: Hydrogen by Wire - Home Fueling System	II-126
III.	Hydrogen Delivery	III-1
III.0	Hydrogen Delivery Sub-Program Overview	III-3
III.1	Sandia National Laboratories: Hydrogen Embrittlement of Structural Steels	III-9
III.2	Argonne National Laboratory: Hydrogen Delivery Infrastructure Analysis	III-13
III.3	Oak Ridge National Laboratory: Vessel Design and Fabrication Technology for Stationary High-Pressure Hydrogen Storage	III-17
III.4	Lawrence Livermore National Laboratory: Failure Analysis, Permeation, and Toughness of Glass Fiber Composite Pressure Vessels for Inexpensive Delivery of Cold Hydrogen	III-22
III.5	Savannah River National Laboratory: Fiber Reinforced Composite Pipeline	III-27
III.6	Lincoln Composites, Inc.: Development of High Pressure Hydrogen Storage Tank for Storage and Gaseous Truck Delivery	III-32
III.7	Concepts NREC: Development of a Centrifugal Hydrogen Pipeline Gas Compressor	III-35
III.8	Mohawk Innovative Technologies, Inc.: Oil-Free Centrifugal Hydrogen Compression Technology Demonstration	III-40
III.9	FuelCell Energy, Inc.: Electrochemical Hydrogen Compressor	III-44
III.10	Oak Ridge National Laboratory: Composite Technology for Hydrogen Pipelines	III-47
III.11	Lawrence Livermore National Laboratory: LLNL/Linde 875 bar Liquid Hydrogen Pump for High Density Cryogenic Vessel Refueling	III-51
IV.	Hydrogen Storage	IV-1
IV.0	Hydrogen Storage Sub-Program Overview	IV-3
IV.A	Metal Hydrides	
IV.A.1	Northwestern University: Efficient Discovery of Novel Multicomponent Mixtures for Hydrogen Storage: A Combined Computational/Experimental Approach	IV-11
IV.A.2	University of Hawaii: Fundamental Studies of Advanced High-Capacity, Reversible Metal Hydrides	IV-18
IV.A.3	Ohio State University: Lightweight Metal Hydrides for Hydrogen Storage	IV-22
IV.A.4	University of Illinois at Urbana-Champaign: Reversible Hydrogen Storage Materials - Structure, Chemistry, and Electronic Structure	IV-27
IV.A.5	Brookhaven National Laboratory: Aluminum Hydride	IV-31
IV.A.6	Savannah River National Laboratory: Electrochemical Reversible Formation of Alane	IV-35
IV.A.7	Delaware State University: Hydrogen Storage Materials for Fuel Cell-Powered Vehicles	IV-39
IV.B	Chemical Hydrogen Storage	IV-44
IV.B.1	University of Oregon: Hydrogen Storage by Novel CBN Heterocycle Materials	IV-44
IV.B.2	Los Alamos National Laboratory: Fluid Phase Chemical Hydrogen Storage Materials	IV-48
IV.B.3	University of Oregon: Novel Carbon(C)-Boron(B)-Nitrogen(N)-Containing H ₂ Storage Materials	IV-51

IV.	Hydrogen Storage (Continued)	
IV.B	Chemical Hydrogen Storage (Continued)	
IV.B.4	Hawaii Hydrogen Carriers, LLC: Development of a Practical Hydrogen Storage System Based on Liquid Organic Hydrogen Carriers and a Homogeneous Catalyst	IV-55
IV.C	Hydrogen Sorption	IV-60
IV.C.1	Texas A&M University: A Biomimetic Approach to Metal-Organic Frameworks with High H ₂ Uptake	IV-60
IV.C.2	University of California, Los Angeles: A Joint Theory and Experimental Project in the Synthesis and Testing of Porous COFs for Onboard Vehicular Hydrogen Storage	IV-67
IV.C.3	University of Missouri: Multiply Surface-Functionalized Nanoporous Carbon for Vehicular Hydrogen Storage	IV-72
IV.C.4	Northwestern University: New Carbon-Based Porous Materials with Increased Heats of Adsorption for Hydrogen Storage	IV-78
IV.C.5	Pennsylvania State University: Hydrogen Trapping through Designer Hydrogen Spillover Molecules with Reversible Temperature and Pressure-Induced Switching	IV-82
IV.C.6	National Renewable Energy Laboratory: Weak Chemisorption Validation	IV-89
IV.C.7	HRL Laboratories, LLC: Room Temperature Hydrogen Storage in Nano-Confined Liquids	IV-95
IV.C.8	Lawrence Berkeley National Laboratory: Hydrogen Storage in Metal-Organic Frameworks	IV-97
IV.C.9	Oak Ridge National Laboratory: The Quantum Effects of Pore Structure on Hydrogen Adsorption	IV-100
IV.C.10	Northwestern University: Metal- and Cluster-Modified Ultrahigh-Area Materials for the Ambient Temperature Storage of Molecular Hydrogen	IV-105
IV.C.11	National Renewable Energy Laboratory: Hydrogen Sorbent Measurement Qualification and Characterization	IV-109
IV.D	H ₂ Storage Engineering Center of Excellence	IV-114
IV.D.1	Savannah River National Laboratory: Hydrogen Storage Engineering Center of Excellence	IV-114
IV.D.2	National Renewable Energy Laboratory: System Design, Analysis, Modeling, and Media Engineering Properties for Hydrogen Energy Storage	IV-119
IV.D.3	Los Alamos National Laboratory: Chemical Hydride Rate Modeling, Validation, and System Demonstration	IV-126
IV.D.4	Jet Propulsion Laboratory: Key Technologies, Thermal Management, and Prototype Testing for Advanced Solid-State Hydrogen Storage Systems	IV-129
IV.D.5	Pacific Northwest National Laboratory: Systems Engineering of Chemical Hydride, Pressure Vessel, and Balance of Plant for Onboard Hydrogen Storage	IV-134
IV.D.6	United Technologies Research Center: Advancement of Systems Designs and Key Engineering Technologies for Materials-Based Hydrogen Storage	IV-140
IV.D.7	General Motors Company: Thermal Management of Onboard Cryogenic Hydrogen Storage Systems	IV-147
IV.D.8	Ford Motor Company: Ford/BASF SE/UM Activities in Support of the Hydrogen Storage Engineering Center of Excellence	IV-151
IV.D.9	Oregon State University: Microscale Enhancement of Heat and Mass Transfer for Hydrogen Energy Storage	IV-156
IV.D.10	Lincoln Composites, Inc.: Development of Improved Composite Pressure Vessels for Hydrogen Storage	IV-160
IV.E	Storage Testing, Safety and Analysis	IV-164
IV.E.1	Argonne National Laboratory: System Level Analysis of Hydrogen Storage Options	IV-164
IV.E.2	H ₂ Technology Consulting LLC: Best Practices for Characterizing Engineering Properties of Hydrogen Storage Materials	IV-170
IV.E.3	National Institute of Standards and Technology: Neutron Characterization in Support of the DOE Hydrogen Storage Sub-Program	IV-176

IV.	Hydrogen Storage (Continued)	
IV.E	Storage Testing, Safety and Analysis (Continued)	
IV.E.4	Strategic Analysis, Inc.: Hydrogen Storage Cost Analysis, Preliminary Results	IV-182
IV.E.5	Pacific Northwest National Laboratory: Early Market TRL/MRL Analysis	IV-186
IV.F	Tanks	IV-191
IV.F.1	Oak Ridge National Laboratory: High Strength Carbon Fibers	IV-191
IV.F.2	Oak Ridge National Laboratory: Lifecycle Verification of Polymeric Storage Tank Liners	IV-197
IV.F.3	Oak Ridge National Laboratory: Development of Low-Cost, High Strength Commercial Textile Precursor (PAN-MA)	IV-200
IV.F.4	Pacific Northwest National Laboratory: Synergistically Enhanced Materials and Design Parameters for Reducing the Cost of Hydrogen Storage Tanks	IV-205
IV.G	Cross-Cutting	IV-208
IV.G.1	University of Nevada, Las Vegas: HGMS: Glasses and Nanocomposites for Hydrogen Storage	IV-208
IV.H	Basic Energy Sciences	IV-210
IV.H.1	University of Pennsylvania: From Fundamental Understanding to Predicting New Nanomaterials for High-Capacity Hydrogen Storage	IV-210
IV.H.2	University of Texas at Dallas: Novel theoretical and experimental approaches for understanding and optimizing hydrogen-sorbent interactions in metal organic framework materials	IV-213
IV.H.3	Virginia Commonwealth University: Design and Synthesis of Chemically and Electronically Tunable Nanoporous Organic Polymers for Use in Hydrogen Storage Applications	IV-216
IV.H.4	Oak Ridge National Laboratory: Atomistic Mechanisms of Metal-Assisted Hydrogen Storage in Nanostructured Carbons	IV-220
IV.H.5	Savannah River National Laboratory: Elucidation of Hydrogen Interaction Mechanisms with Metal-Doped Carbon Nanostructures	IV-226
IV.H.6	University of California, Riverside: Synthetic Design of New Metal-Organic Framework Materials for Hydrogen Storage	IV-229
IV.H.7	University of Missouri: New Pathways and Metrics for Enhanced, Reversible Hydrogen Storage in Boron-Doped Carbon Nanospaces	IV-233
IV.H.8	Carnegie Institute of Washington: Novel Molecular Materials for Hydrogen Storage Applications	IV-236
IV.H.9	Colorado School of Mines: Metastability of Clathrate Hydrates for Energy Storage	IV-239
IV.H.10	Pennsylvania State University: Exploration of Novel Carbon-Hydrogen Interactions	IV-243
IV.H.11	Ames Laboratory: Complex Hydrides - A New Frontier for Future Energy Applications	IV-245
IV.H.12	Brookhaven National Laboratory: Atomistic Transport Mechanisms in Aluminum-Based Hydrides	IV-249
IV.H.13	Northwestern University: Theory of Hydrogen Storage in Complex Hydrides	IV-253
IV.H.14	University of California, Santa Barbara: Computational studies of hydrogen interactions with storage materials	IV-256
IV.H.15	Washington University: In Situ NMR Studies of Hydrogen Storage Systems	IV-259
IV.H.16	Pacific Northwest National Laboratory: Activation of Hydrogen with Bi-Functional Ambiphilic Catalyst Complexes	IV-263
IV.H.17	University of California, Davis: Heavy Cycloadditions: Reactions of Diagailene with Cyclic Polyolefins	IV-267
IV.H.18	University of Pennsylvania: Mechanistic Studies of Activated Hydrogen Release from Ammonia-Borane	IV-270
IV.H.19	Florida International University: Influence of Pressure on Physical Property of Ammonia Borane and its Re-Hydrogenation	IV-274

V.	Fuel Cells	V-1
V.0	Fuel Cells Sub-Program Overview	V-3
V.A	Analysis/Characterization	V-11
V.A.1	National Renewable Energy Laboratory: Analysis of Laboratory Fuel Cell Technology Status – Voltage Degradation	V-11
V.A.2	Strategic Analysis, Inc.: Mass-Production Cost Estimation for Automotive Fuel Cell Systems	V-16
V.A.3	Strategic Analysis, Inc.: Stationary Fuel Cell System Cost Analysis	V-20
V.A.4	Argonne National Laboratory: Performance of Automotive Fuel Cell Systems with Low-Pt Nanostructured Thin Film Catalysts at High Power Densities	V-25
V.A.5	Oak Ridge National Laboratory: Characterization of Fuel Cell Materials	V-32
V.A.6	National Institute of Standards and Technology: Neutron Imaging Study of the Water Transport in Operating Fuel Cells	V-37
V.A.7	Los Alamos National Laboratory: Technical Assistance to Developers	V-43
V.A.8	National Renewable Energy Laboratory: Enlarging the Potential Market for Stationary Fuel Cells Through System Design Optimization	V-47
V.A.9	Battelle: Stationary and Emerging Market Fuel Cell System Cost Analysis	V-51
V.A.10	Lawrence Berkeley National Laboratory: A Total Cost of Ownership Model for Design and Manufacturing Optimization of Fuel Cells in Stationary and Emerging Market Applications	V-53
V.B	Impurities	V-57
V.B.1	National Renewable Energy Laboratory: Effect of System Contaminants on PEMFC Performance and Durability	V-57
V.B.2	Hawaii Natural Energy Institute: The Effect of Airborne Contaminants on Fuel Cell Performance and Durability	V-63
V.C	Membranes	V-68
V.C.1	University of Central Florida: Lead Research and Development Activity for DOE’s High Temperature, Low Relative Humidity Membrane Program	V-68
V.C.2	Giner Electrochemical Systems, LLC: Dimensionally Stable High Performance Membrane (SBIR Phase III)	V-71
V.C.3	FuelCell Energy, Inc.: High-Temperature Membrane with Humidification-Independent Cluster Structure	V-76
V.C.4	Ion Power Inc.: Corrugated Membrane Fuel Cell Structures	V-80
V.D	Catalysts	V-84
V.D.1	3M Company: Advanced Cathode Catalysts and Supports for PEM Fuel Cells	V-84
V.D.2	UTC Power: Highly Dispersed Alloy Catalyst for Durability	V-95
V.D.3	3M Company: Durable Catalysts for Fuel Cell Protection during Transient Conditions	V-100
V.D.4	National Renewable Energy Laboratory: Extended, Continuous Pt Nanostructures in Thick, Dispersed Electrodes	V-107
V.D.5	Argonne National Laboratory: Nanosegregated Cathode Catalysts with Ultra-Low Platinum Loading	V-111
V.D.6	Brookhaven National Laboratory: Contiguous Platinum Monolayer Oxygen Reduction Electrocatalysts on High-Stability Low-Cost Supports	V-117
V.D.7	Los Alamos National Laboratory: The Science and Engineering of Durable Ultralow PGM Catalysts	V-121
V.D.8	Lawrence Berkeley National Laboratory: Molecular-Scale, Three-Dimensional Non-Platinum Group Metal Electrodes for Catalysis of Fuel Cell Reactions	V-126
V.D.9	National Renewable Energy Laboratory: Tungsten Oxide and Heteropoly Acid Based System for Ultra-High Activity and Stability of Pt Catalysts in PEM Fuel Cell Cathodes	V-133
V.D.10	Illinois Institute of Technology: Synthesis and Characterization of Mixed-Conducting Corrosion Resistant Oxide Supports	V-138

V.	Fuel Cells (Continued)	
V.D	Catalysts (Continued)	
V.D.11	Northeastern University: Development of Novel Non-PGM Electrocatalysts for Proton Exchange Membrane Fuel Cell Applications	V-143
V.D.12	General Motors Company: High-Activity Dealloyed Catalysts	V-149
V.D.13	University of South Carolina: Development of Ultra-Low Platinum Alloy Cathode Catalyst for PEM Fuel Cells	V-153
V.D.14	National Renewable Energy Laboratory: High Aspect Ratio Nano-Structured Pt-based PEM Fuel Cell Catalysts (EERE Post-Doc Fellowship).	V-159
V.D.15	Pacific Northwest National Laboratory: Development of Alternative and Durable High Performance Cathode Supports for PEM Fuel Cells	V-162
V.E	Degradation Studies	V-168
V.E.1	Argonne National Laboratory: Polymer Electrolyte Fuel Cell Lifetime Limitations: The Role of Electrocatalyst Degradation	V-168
V.E.2	Los Alamos National Laboratory: Durability Improvements through Degradation Mechanism Studies.	V-175
V.E.3	Nuvera Fuel Cells, Inc.: Durability of Low Platinum Fuel Cells Operating at High Power Density	V-182
V.E.4	UTC Power: Improved Accelerated Stress Tests Based on Fuel Cell Vehicle Data	V-186
V.E.5	Los Alamos National Laboratory: Accelerated Testing Validation	V-190
V.E.6	Ballard Power Systems: Development of Micro-Structural Mitigation Strategies for PEM Fuel Cells: Morphological Simulations and Experimental Approaches	V-195
V.E.7	E. I. du Pont de Nemours and Company: Analysis of Durability of MEAs in Automotive PEMFC Applications	V-201
V.F	Transport Studies	V-206
V.F.1	Plug Power Inc.: Air-Cooled Stack Freeze Tolerance	V-206
V.F.2	Lawrence Berkeley National Laboratory: Fuel Cell Fundamentals at Low and Subzero Temperatures	V-211
V.F.3	Sandia National Laboratories: Development and Validation of a Two-Phase, Three-Dimensional Model for PEM Fuel Cells	V-217
V.F.4	Nuvera Fuel Cells, Inc.: Transport Studies Enabling Efficiency Optimization of Cost-Competitive Fuel Cell Stacks	V-222
V.F.5	CFD Research Corporation: Water Transport in PEM Fuel Cells: Advanced Modeling, Material Selection, Testing, and Design Optimization	V-226
V.F.6	Giner Electrochemical Systems, LLC: Transport in PEMFC Stacks	V-230
V.F.7	General Motors Company: Investigation of Micro- and Macro-Scale Transport Processes for Improved Fuel Cell Performance	V-235
V.G	Portable Power	V-242
V.G.1	Arkema Inc.: Novel Materials for High Efficiency Direct Methanol Fuel Cells	V-242
V.G.2	University of North Florida: New MEA Materials for Improved Direct Methanol Fuel Cell (DMFC) Performance, Durability, and Cost	V-246
V.G.3	Los Alamos National Laboratory: Advanced Materials and Concepts for Portable Power Fuel Cells	V-250
V.H	Hardware	V-257
V.H.1	TreadStone Technologies, Inc.: Low-Cost PEM Fuel Cell Metal Bipolar Plates	V-257
V.I	Balance of Plant	V-261
V.I.1	W.L. Gore & Associates, Inc.: Materials and Modules for Low-Cost, High-Performance Fuel Cell Humidifiers	V-261
V.I.2	Dynalene Inc.: Large Scale Testing, Demonstration and Commercialization of the Nanoparticle-Based Fuel Cell Coolant (SBIR Phase III).	V-266

V.	Fuel Cells (Continued)	
V.I	Balance of Plant (Continued)	
V.I.3	Tetramer Technologies, LLC: New High Performance Water Vapor Membranes to Improve Fuel Cell Balance of Plant Efficiency and Lower Costs (SBIR Phase I)	V-270
V.J	Distributed Energy	V-272
V.J.1	Intelligent Energy: Development and Demonstration of a New-Generation High Efficiency 10-kW Stationary Fuel Cell System	V-272
V.J.2	Acumentrics Corporation: Development of a Low-Cost 3-10 kW Tubular SOFC Power System	V-277
V.J.3	Versa Power Systems: Advanced Materials for Reversible Solid Oxide Fuel Cell (RSOFC), Dual-Mode Operation with Low Degradation	V-281
V.J.4	InnovaTek: Power Generation from an Integrated Biomass Reformer and Solid Oxide Fuel Cell (SBIR Phase III)	V-285
V.J.5	IdaTech, LLC: Research and Development for Off-Road Fuel Cell Applications	V-289
V.J.6	UTC Power: 150 kW PEM Stationary Power Plant Operating on Natural Gas	V-291
V.K	Cross-Cutting	V-295
V.K.1	University of Akron: Development of Kilowatt-Scale Coal Fuel Cell Technology	V-295
V.K.2	University of Southern Mississippi: Alternative Fuel Cell Membranes for Energy Independence	V-300
V.K.3	Colorado School of Mines: Biomass Fuel Cell Systems	V-305
V.K.4	University of Connecticut Global Fuel Cell Center: Improving Reliability and Durability of Efficient and Clean Energy Systems	V-310
VI.	Manufacturing R&D	VI-1
VI.0	Manufacturing R&D Sub-Program Overview	VI-3
VI.1	National Renewable Energy Laboratory: Fuel Cell Membrane Electrode Assembly Manufacturing R&D	VI-7
VI.2	W. L. Gore & Associates, Inc.: Manufacturing of Low-Cost, Durable Membrane Electrode Assemblies Engineered for Rapid Conditioning	VI-11
VI.3	Rensselaer Polytechnic Institute: Adaptive Process Controls and Ultrasonics for High-Temperature PEM MEA Manufacture	VI-17
VI.4	National Institute of Standards and Technology: Non-Contact Sensor Evaluation for Bipolar Plate Manufacturing Process Control and Smart Assembly of Fuel Cell Stacks	VI-24
VI.5	BASF Fuel Cell: High Speed, Low Cost Fabrication of Gas Diffusion Electrodes for Membrane Electrode Assemblies	VI-28
VI.6	Quantum Fuel Systems Technologies Worldwide, Inc.: Development of Advanced Manufacturing Technologies for Low Cost Hydrogen Storage Vessels	VI-31
VI.7	National Institute of Standards and Technology: Cause and Effect: Flow Field Plate Manufacturing Variability and its Impact on Performance	VI-36
VI.8	National Institute of Standards and Technology: Optical Scatterfield Metrology for Online Catalyst Coating Inspection of PEM (Fuel Cell) Soft Goods	VI-41
VII.	Technology Validation	VII-1
VII.0	Technology Validation Sub-Program Overview	VII-3
VII.1	National Renewable Energy Laboratory: Controlled Hydrogen Fleet and Infrastructure Analysis	VII-11
VII.2	Air Products and Chemicals, Inc.: Validation of an Integrated Hydrogen Energy Station	VII-18
VII.3	National Renewable Energy Laboratory: Technology Validation: Fuel Cell Bus Evaluations	VII-22
VII.4	Air Products and Chemicals, Inc.: California Hydrogen Infrastructure Project	VII-26
VII.5	Hawaii Natural Energy Institute: Hawaii Hydrogen Power Park	VII-30
VII.6	University of Central Florida: Florida Hydrogen Initiative (FHI)	VII-33

Table of Contents

VII.	Technology Validation (Continued)	
VII.7	California State University, Los Angeles: Sustainable Hydrogen Fueling Station, California State University, Los Angeles	VII-38
VII.8	National Renewable Energy Laboratory: Renewable Electrolysis Integrated System Development and Testing	VII-40
VII.9	National Renewable Energy Laboratory: Stationary Fuel Cell Evaluation	VII-44
VII.10	National Renewable Energy Laboratory: Next Generation H2 Station Analysis	VII-46
VIII.	Safety, Codes & Standards	VIII-1
VIII.0	Safety, Codes & Standards Sub-Program Overview	VIII-3
VIII.1	Sandia National Laboratories: Hydrogen Safety, Codes and Standards R&D – Release Behavior	VIII-9
VIII.2	Sandia National Laboratories: Risk-Informed Safety Requirements for H2 Codes and Standards Development	VIII-15
VIII.3	National Renewable Energy Laboratory: Component Standard Research and Development	VIII-18
VIII.4	Sandia National Laboratories: Hydrogen Materials and Components Compatibility	VIII-22
VIII.5	Sandia National Laboratories: Component Testing for Industrial Trucks and Early Market Applications	VIII-25
VIII.6	National Renewable Energy Laboratory: National Codes and Standards Coordination	VIII-28
VIII.7	National Renewable Energy Laboratory: Codes and Standards Outreach for Emerging Fuel Cell Technologies	VIII-33
VIII.8	Los Alamos National Laboratory: Leak Detection and H2 Sensor Development for Hydrogen Applications	VIII-36
VIII.9	Los Alamos National Laboratory: Hydrogen Fuel Quality Research and Development	VIII-42
VIII.10	Pacific Northwest National Laboratory: Hydrogen Safety Panel	VIII-45
VIII.11	Pacific Northwest National Laboratory: Hydrogen Safety Knowledge Tools	VIII-49
VIII.12	Pacific Northwest National Laboratory: Hydrogen Emergency Response Training for First Responders	VIII-52
IX.	Education	IX-1
IX.0	Education Sub-Program Overview	IX-3
IX.1	South Carolina Hydrogen and Fuel Cell Alliance: Development of Hydrogen Education Programs for Government Officials	IX-7
IX.2	Ohio Fuel Cell Coalition: Raising H2 and Fuel Cell Awareness in Ohio	IX-11
IX.3	University of California, Berkeley: Hydrogen Technology and Energy Curriculum (HyTEC)	IX-13
IX.4	Connecticut Center for Advanced Technology, Inc.: State and Local Government Partnership	IX-16
X.	Market Transformation	X-1
X.0	Market Transformation Sub-Program Overview	X-3
X.1	Hawaii Natural Energy Institute: Hydrogen Energy Systems as a Grid Management Tool	X-7
X.2	Pacific Northwest National Laboratory: Fuel Cell Combined Heat and Power Industrial Demonstration	X-10
X.3	National Renewable Energy Laboratory: Direct Methanol Fuel Cell Material Handling Equipment Demonstration	X-15
X.4	South Carolina Hydrogen and Fuel Cell Alliance: Landfill Gas-to-Hydrogen	X-20
XI.	Systems Analysis	XI-1
XI.0	Systems Analysis Sub-Program Overview	XI-3
XI.1	National Renewable Energy Laboratory: Infrastructure Analysis of Early Market Transition of Fuel Cell Vehicles	XI-11
XI.2	Argonne National Laboratory: Life-Cycle Analysis of Vehicle and Fuel Systems with the GREET Model	XI-15

XI. Systems Analysis (Continued)

- XI.3 National Renewable Energy Laboratory: Hydrogen Refueling Infrastructure Cost Analysis. XI-19
- XI.4 National Renewable Energy Laboratory: Comparing Infrastructure Costs for Hydrogen and Electricity. XI-23
- XI.5 National Renewable Energy Laboratory: Infrastructure Costs Associated with Central Hydrogen Production from Biomass and Coal. XI-27
- XI.6 Oak Ridge National Laboratory: Sensitivity Analysis of H₂-Vehicles' Market Prospects, Costs and Benefits XI-31
- XI.7 National Renewable Energy Laboratory: Effects of Technology Cost Parameters on Hydrogen Pathway Succession. XI-35
- XI.8 Oak Ridge National Laboratory: Impact of DOE Program Goals on Hydrogen Vehicles: Market Prospect, Costs, and Benefits. XI-39
- XI.9 National Renewable Energy Laboratory: Resource Analysis for Hydrogen Production XI-43
- XI.10 National Renewable Energy Laboratory: Cost, Energy Use, and Emissions of Tri-Generation Systems XI-47
- XI.11 Argonne National Laboratory: Employment Impacts of Early Markets for Hydrogen and Fuel Cell Technologies XI-52

XII. American Recovery and Reinvestment Act. XII-1

- XII.0 American Recovery and Reinvestment Act Activities. XII-3
- XII.1 Delphi Automotive Systems, LLC: Solid Oxide Fuel Cell Diesel Auxiliary Power Unit Demonstration XII-9
- XII.2 Sprint Nextel: Demonstrating Economic and Operational Viability of 72-Hour Hydrogen PEM Fuel Cell Systems to Support Emergency Communications on the Sprint Nextel Network . . XII-12
- XII.3 National Renewable Energy Laboratory: Analysis Results for ARRA Projects: Enabling Fuel Cell Market Transformation XII-16
- XII.4 FedEx Freight: Fuel Cell-Powered Lift Truck FedEx Freight Fleet Deployment. XII-21
- XII.5 Sysco of Houston: Fuel Cell-Powered Lift Truck Sysco Houston Fleet Deployment XII-24
- XII.6 GENCO Infrastructure Solutions: GENCO Fuel Cell-Powered Lift Truck Fleet Deployment . . . XII-28
- XII.7 Plug Power Inc.: Highly Efficient, 5-kW CHP Fuel Cells Demonstrating Durability and Economic Value in Residential and Light Commercial Applications. XII-30
- XII.8 Plug Power Inc.: Accelerating Acceptance of Fuel Cell Backup Power Systems. XII-34

XIII. Small Business Innovation Research XIII-1

XIV. Acronyms, Abbreviations and Definitions: XIV-1

XV. Primary Contacts Index XV-1

XVI. Hydrogen and Fuel Cells Program Contacts XVI-1

XVII. Project Listings by State XVII-1

XVIII. Project Listings by Organization: XVIII-1