

INTRODUCTION	XXI
STUDY GOALS AND OBJECTIVES.....	XXI
REASONS FOR DOING THE STUDY	XXI
CONTRIBUTION OF THE STUDY AND FOR WHOM	XXII
SCOPE AND FORMAT	XXII
METHODOLOGY	XXII
INFORMATION SOURCES.....	XXIII
VALUE OF THE REPORT	XXIV
RELATED BCC, INC. PUBLICATIONS	XXIV
BCC ON-LINE SERVICES.....	XXV
INTERNET	XXV
AUTHOR'S CREDENTIALS	XXV
DISCLAIMER	XXV
SUMMARY.....	XXVI
<i>SUMMARY TABLE GLOBAL HYDROGEN GENERATION, STORAGE AND DELIVERY DEVICE VALUE BY ENERGY APPLICATION, THROUGH 2008 (\$ MILLIONS INCLUDING R&D\$)</i>	XXVII
<i>SUMMARY FIGURE GLOBAL HYDROGEN GENERATION, STORAGE AND DELIVERY DEVICE VALUE BY ENERGY APPLICATION, 2000-2008 (\$ MILLIONS INCLUDING R&D\$)</i>	XXVII
HYDROGEN ENERGY OVERVIEW.....	1
STORAGE AND DELIVERY.....	1
FUEL SOURCES	2
ASSUMPTIONS.....	2
SOURCES	3
REFORMERS.....	4
MARKET VALUE OF HYDROGEN PRODUCTION FOR POWER.....	5
<i>TABLE 1 GLOBAL HYDROGEN FUEL SYSTEMS VALUE AND MARKET SHARE, BY APPLICATION TYPE, 2003 (\$ MILLIONS, INCLUDING R&D\$, %)</i>	6
<i>FIGURE 1 MARKET SHARES FOR GLOBAL HYDROGEN GENERATION, STORAGE AND DELIVERY DEVICES, BY APPLICATION, 2008</i>	7
<i>TABLE 2 HYDROGEN GENERATION, STORAGE AND DELIVERY DEVICES VALUE AND SHARE BY APPLICATION TYPE, 2008 (\$ MILLIONS INCLUDING R&D\$, %)</i>	7
STATIONARY	8
<i>TABLE 3 MARKET FOR HYDROGEN GENERATION, STORAGE AND DELIVERY DEVICES FOR STATIONARY APPLICATIONS, THROUGH 2008 (UNITS, MW, \$ MILLIONS INCLUDING R&D \$)</i>	9
<i>TABLE 4 PER UNIT COMPONENT COSTS OF 50 KW STEAM REFORMING UNIT BY SYSTEM PARTS, 2008 (\$, %)</i>	10
<i>TABLE 5 VALUE OF EACH COMPONENT IN POTENTIAL STATIONARY REFORMER MARKET, 2008 (\$ MILLIONS)</i>	10
VEHICULAR.....	11
<i>TABLE 6 GLOBAL MARKET FOR HYDROGEN GENERATION, STORAGE AND DELIVERY DEVICES FOR VEHICULAR APPLICATIONS, THROUGH 2008 (UNITS, MW, \$ MILLIONS)</i>	12
PORTABLE	12

TABLE 7 GLOBAL MARKETS FOR HYDROGEN GENERATION, STORAGE AND DELIVERY DEVICES FOR PORTABLE APPLICATIONS, THROUGH 2008 (UNITS, MW, \$ MILLIONS).....	13
OTHER HYDROGEN CONSUMPTION MARKET OVERVIEW.....	13
U.S. CONSUMPTION OF HYDROGEN.....	14
TABLE 8 1997 U.S. CONSUMPTION OF HYDROGEN BY INDUSTRIAL AND COMMERCIAL APPLICATIONS (MILLIONS OF CUBIC FEET).....	15
TABLE 9 2003 U.S. CONSUMPTION OF HYDROGEN BY INDUSTRIAL AND COMMERCIAL APPLICATIONS (MILLIONS OF CUBIC FEET).....	16
Merchant Hydrogen.....	16
TABLE 10 MERCHANT HYDROGEN USE BY APPLICATION, 2003.....	17
TABLE 11 INDUSTRIAL HYDROGEN USE, BY APPLICATION 2003 (%).....	17
Merchant Hydrogen (Continued)	18
 HYDROGEN INFRASTRUCTURE OVERVIEW.....	 19
THE DEVELOPMENT RACE.....	19
TABLE 12 STARTING SOURCES OF WORLD HYDROGEN PRODUCTION, 2003 (BILLIONS M ³ , %).....	20
U.S. HYDROGEN INFRASTRUCTURE	20
STATIONARY	21
VEHICULAR.....	21
PORTABLE	22
 FUEL CELL INDUSTRY OVERVIEW.....	 23
TABLE 13 GLOBAL VALUES OF FUEL CELL SYSTEMS, BY APPLICATION, 2008 (\$ MILLIONS).....	23
FIGURE 2 GLOBAL VALUES OF FUEL CELL SYSTEMS, BY APPLICATION, 2008 (\$ MILLIONS).....	24
TABLE 14 APPLICATION OF REFORMERS AND HYDROGEN STORAGE.....	24
FUEL CELL TYPES	24
PROTON-EXCHANGE MEMBRANE—PEM.....	25
Direct-Methanol Fuel Cells—DMFC	26
PHOSPHORIC ACID FUEL CELL—PAFC	26
Other Developments.....	27
ALKALINE FUEL CELLS—AFC	27
Other Developments.....	28
MOLTEN-CARBONATE FUEL CELLS—MCFC.....	28
Other Developments.....	28
SOLID-OXIDE FUEL CELLS—SOFC.....	28
Other Developments.....	29
REGENERATIVE FUEL CELLS	29
VALUE OF THE FUEL CELL MARKET.....	29
TABLE 15 GLOBAL SALES AND PROJECTIONS FOR HYDROGEN FUEL CELL SYSTEMS BY CHEMISTRY TYPE, THROUGH 2008 (\$ MILLIONS).....	30
STATIONARY	31
TABLE 16 GLOBAL FUEL CELL MARKET FOR STATIONARY APPLICATIONS, THROUGH 2008 (\$ MILLIONS).....	31
VEHICULAR.....	31

<i>TABLE 17 GLOBAL FUEL CELL MARKET FOR VEHICULAR APPLICATIONS, THROUGH 2008 (\$ MILLIONS)</i>	32
PORTABLE	32
<i>TABLE 18 GLOBAL EXPENDITURES FOR PORTABLE FUEL CELLS AND HYDROGEN DELIVERY DEVICES INCLUDING R&D VALUES, THROUGH 2008 (\$ MILLIONS)</i>	33
MARKET EVOLUTION	33
FUNDING AND GOVERNMENT.....	34
U.S. GOVERNMENT ACTIVITY AND REGULATIONS	34
<i>TABLE 19 TOTAL GLOBAL PUBLIC AND PRIVATE FC AND H₂ INFRASTRUCTURE SPENDING, INCLUDING R&D VALUES, THROUGH 2008 (\$ MILLIONS)</i>	34
<i>FIGURE 3 TOTAL GLOBAL PUBLIC AND PRIVATE FC AND H₂ INFRASTRUCTURE SPENDING, INCLUDING R&D VALUES, 2002-2008 (\$ MILLIONS)</i>	35
<i>TABLE 20 GOVERNMENT FUNDS FOR RESEARCH AND DEMONSTRATION OF FUEL CELLS AND HYDROGEN INFRASTRUCTURE, THROUGH 2008</i>	36
<i>TABLE 21 PRIVATE R&D FUEL CELL AND HYDROGEN INFRASTRUCTURE SPENDING, THROUGH 2008 (\$ MILLIONS)</i>	36
FREEDOMCAR.....	37
CLEAN AIR LAWS	38
DOE AND DOD FUEL CELL PROGRAMS	38
HOUSE AND SENATE BILLS 2003.....	38
H.R. 6	39
<i>TABLE 22 SUMMARY EXPECTED H.R. 6 FUEL CELL AND HYDROGEN INFRASTRUCTURE FUNDING, 2004-2008 (\$ MILLIONS)</i>	39
<i>TABLE 23 H.R. 6 TOTAL FUNDING FOR ENERGY RESEARCH BY THE U.S. GOVERNMENT ACCORDING TO BILL SUBSECTIONS, 2004-2008 (\$ MILLIONS)</i>	40
<i>TABLE 23 (CONTINUED)</i>	41
H.R. 6 (Continued)	42
H.R. 6 (Continued)	43
H.R. 6 (Continued)	44
Hydrogen and FreedomCAR.....	45
Hydrogen and FreedomCAR (Continued).....	46
<i>TABLE 24 H.R. 6 EXPECTED U.S. FUEL CELL AND HYDROGEN R&D FUNDING BY THE U.S. GOVERNMENT EXTRAPOLATED FROM BILL SUBSECTIONS, 2004-2008 (\$ MILLIONS)</i>	47
<i>TABLE 24 (CONTINUED)</i>	48
H.R.238 Energy Research, Development, Demonstration, and Commercial Application Act of 2003	48
CLEAR Act.....	49
H.R. 1299 & S. 587, The Hydrogen Transportation Wins Over Growing Reliance on Oil (H2 GROW) Act.....	50
H.R. 1335, The National Parks Fuel Cell and Hydrogen Act	50
H.R. 1395	50
H.R. 1436, Energy Independence and Security Act of 2003	51
H.R. 1458, The Homeland Infrastructure Power Security & Assurance Incentives Act of 2003	51
H.R. 1461, Clean School Buses Act.....	52

H.R.1491, Securing Transportation Energy Efficiency for Tomorrow Act	52
H.R. 1531, Energy Tax Policy Act of 2003	52
H.R. 1644, Energy Policy Act of 2003	53
H.R.1773 & S.739 The George E. Brown, Jr. and Robert S. Walker Hydrogen Future Act of 2003	53
H.R.1774, The FreedomCAR and Hydrogen Fuel Act of 2003.....	54
H.R.1777	54
S. 461, The Hydrogen Fuel Cell Act of 2003.....	54
<i>TABLE 25 HYDROGEN FUEL CELL ACT OF 2003 FUNDING 2004-2008 (\$ MILLIONS)</i>	55
S.758.....	55
S.821, The Hydrogen and Fuel Cell Energy Act of 2003.....	56
<i>TABLE 26 APPROPRIATIONS OF THE HYDROGEN AND FUEL CELL ENERGY ACT OF 2003, 2004-2010</i>	57
STATE ACTIVITY AND REGULATIONS	57
CA, NY, MA VEHICLE REGULATIONS	57
THE CALIFORNIA FUEL CELL PARTNERSHIP (CAFCEP)	57
The California Fuel Cell Partnership (CAFCEP) (Continued).....	58
CALIFORNIA AIR RESOURCES BOARD—CARB	59
CONNECTICUT CLEAN ENERGY FUND.....	59
ILLINOIS.....	60
MICHIGAN NEXTENERGY INITIATIVE—MEDC	61
NEW YORK STATE FUEL CELL PARTNERSHIP	62
OHIO.....	63
Ohio (Continued)	64
PENNSYLVANIA.....	65
TEXAS FUEL CELL PARTNERSHIP	66
Texas Fuel Cell Partnership (Continued).....	67
OTHER STATES	68
FOREIGN ACTIVITY	68
INTERNATIONAL PARTNERSHIP FOR THE HYDROGEN ECONOMY.....	69
KYOTO TREATY	70
EUROPE.....	70
JAPAN	71
Molten Carbonate Fuel Cells (MCFCs)	71
Solid Oxide Fuel Cell (SOFCs).....	72
Polymer Electrolyte Membrane Fuel Cells (PEMFCs)	72
CHINA	73
DEVELOPING NATIONS	74
THE IEA HYDROGEN AGREEMENT.....	74
EUROPEAN INTEGRATED HYDROGEN PROJECT—EIHP.....	75

JAPANESE FUEL CELL VEHICLE REGULATIONS	76
REFORMING AND GENERATING TECHNOLOGIES	77
REFORMING AND GENERATING TECHNOLOGIES (CONTINUED)	77
REFORMING AND GENERATING TECHNOLOGIES (CONTINUED)	78
STEAM REFORMING	79
METHANOL STEAM REFORMING	80
STEAM REFORMING NATURAL GAS	80
TABLE 27 STEAM METHANE REFORMING HYDROGEN PRODUCTION COSTS	
(\$/KG).....	81
PARTIAL OXIDATION	81
TABLE 28 COST OF NONCATALYTIC PARTIAL OXIDATION (\$/GJ)	82
AUTOTHERMAL REFORMING	83
TABLE 29 ESTIMATED COST OF METHANOL AUTOTHERMAL REFORMER (\$)	84
CATALYTIC STEAM REFORMING	85
PLASMA REFORMERS	85
PURIFICATION REFORMING	86
PYROLYSIS	86
OTHER HYDROGEN PRODUCTION TECHNOLOGIES	86
BIOLOGICAL PRODUCTION OF HYDROGEN	86
TABLE 30 BIOLOGICAL HYDROGEN PRODUCTION COSTS (\$/GJ; \$/DRY TON)	87
Recent Developments	87
Soil Bacteria	88
Photobiological Mutant Clones.....	88
Photobiological Mutant Clones (Continued).....	89
Hydrogen Power Systems	90
General Atomics.....	91
University of North Dakota.....	91
Pyrolysis of Biomass	92
Production of Hydrogen from Peanut Shells	93
Oak Ridge National Laboratory	94
Supercritical Gasification of Biomass	95
Other.....	95
TABLE 31 BIOLOGICAL HYDROGEN PRODUCTION RESEARCH.....	96
Photobiological Systems	96
National Renewable Energy Laboratory – NREL	96
National Renewable Energy Laboratory –	
NREL (Continued)	97
Molecular Photocatalytic Hydrogen Production	98
Melis Energy’s Algae	99
Research Institute of Innovative Technology for the	
Earth	99
Other Biological Production Projects	100
TABLE 32 RENEWABLE HYDROGEN PRODUCTION PROJECTS.....	100
MARKET SHARE BY TECHNOLOGY	100

TABLE 33 STATIONARY REFORMING MARKET BY COMPANY TECHNOLOGY FOCUS AND PERCENT OF MARKET FOR MAJOR REFORMING TECHNOLOGIES (%).....	101
TABLE 34 HYDROGEN REFORMERS FOR STATIONARY FUEL CELLS BY FUEL TYPE AND ELECTROLYZERS, THROUGH 2008 (\$ MILLIONS)	102
ELECTROLYZERS AND ELECTROLYSIS.....	103
PROTON EXCHANGE MEMBRANE ELECTROLYZERS	103
ELECTROLYSIS TECHNIQUES	104
HIGH TEMPERATURE STEAM ELECTROLYSIS.....	104
REVERSIBLE HYDROBROMIC ACID ELECTROLYSIS	104
ELECTROLYSIS OF METHANOL.....	105
ELECTROLYZER APPLICATIONS	105
TABLE 35 GLOBAL ELECTROLYZER VALUE VS REFORMER VALUE FOR ALL HYDROGEN DELIVERY DEVICE APPLICATIONS, 2008 (\$ MILLIONS, %).....	106
FIGURE 4 GLOBAL ELECTROLYZER MARKET SHARES, BY AREA OF APPLICATIONS, 2008.....	107
TABLE 36 ELECTROLYSIS FOR HYDROGEN ENERGY APPLICATIONS, BY END USE APPLICATION, THROUGH 2008 (\$ MILLIONS).....	107
FIGURE 5 ELECTROLYSIS FOR HYDROGEN ENERGY APPLICATIONS, BY END USE APPLICATION, 2000-2008 (\$ MILLIONS).....	108
TABLE 37 ELECTROLYSIS FOR HYDROGEN ENERGY MARKET SHARES BY END USE APPLICATION, 2003-2008 (\$ MILLIONS, %)	108
INDUSTRIAL.....	109
COMMERCIAL/UPS.....	109
RESIDENTIAL MARKET	110
REMOTE ELECTROLYSIS.....	110
REVERSIBLE SOFC FOR GRID INDEPENDENT BUILDINGS ...	110
Reversible SOFC for Grid .. (Continued).....	111
TABLE 38 OFF GRID ENGINE VS. REVERSIBLE SOFC SUPPLY (\$/KWH/TONS).....	112
TABLE 39 TRADITIONAL UPS INSTALLED COSTS (\$).....	112
TABLE 40 TYPICAL DISTRIBUTED POWER TECHNOLOGIES COSTS, 2003 (\$ PER KW)	113
TRANSPORTATION.....	113
Fuel Cell Vehicle Fueling	113
Fuel Cell Vehicle Fueling (Continued).....	114
TABLE 41 HYDROGEN VEHICLES AND FUELING STATIONS (SCENARIO #1), THROUGH 2008.....	115
TABLE 42 HYDROGEN VEHICLES AND FUELING STATIONS (SCENARIO #2), THROUGH 2008.....	115
TABLE 43 HYDROGEN VEHICLES AND FUELING STATIONS (SCENARIO #3), THROUGH 2008.....	116
TABLE 44 HYDROGEN VEHICLES AND FUELING STATIONS (SCENARIO #4), THROUGH 2008.....	116
TABLE 45 SCENARIOS FOR ELECTROLYZER SHARE OF THE 2008 HYDROGEN VEHICLE REFUELING MARKET* (\$ MILLIONS)	117
OTHER DEVELOPMENTS	117
Helios Prototype	117
Fleet Fueling.....	118

Prototype P3-1A	118
Prototype P3-1B LP	119
Prototype P3-1B HP	119
Prototype P3-5 Cell Stack Assembly	119
Air Products/Plug Power Fueling Station	119
Sunlight Station	120
BMW Hydrogen Station	121
Desert Research Institute	121
Proton Energy and UPS	121
Stirling Cycle Engines	122
ELECTROLYZER/ELECTROLYSIS MARKET STRUCTURE	122
FIGURE 6 ELECTROLYZER MARKET, BY NUMBER OF COMPANIES	123
TABLE 46 ELECTROLYSIS TECHNOLOGY BY NUMBER OF COMPANIES	123
STRUCTURE OF THE ELECTROLYZER INDUSTRY	123
TABLE 47 2003 MARKET SHARES OF ENERGY ELECTROLYZER INDUSTRY INCLUDING REVENUES PLUS R&D EXPENSES (\$ MILLIONS, %)	124
ELECTOLYZER INDUSTRY COMPANY PROFILES	125
American Energy Power Systems, Inc.	125
Anuvu	125
Arizona Hydrogen Manufacturing Inc.	125
ChevronTexaco	125
Analytic Energy Systems LLC	125
ChevronTexaco/Ovonic Fuel Cell Company LLC	126
Element 1 Power Systems Inc.	126
Elwatec GmbH	126
Emission Controls	127
FST, Inc.	127
Gaskatel GmbH	128
GenCell Corporation	129
Genesis World Energy	129
Genesis World Energy (Continued)	130
Genesis World Energy (Continued)	131
Genesis World Energy (Continued)	131
Genesis World Energy (Continued)	132
Giner, Inc.	133
GreenVOLT Power Corp	133
Hamilton Sundstrand	134
Honda/Plug Power	134
Hydrogenics Corporation	135
Hydrogen Systems N.V.	136
Lynntech	136
NovArs Gesellschaft für neue Technologien GmbH	137
Natural Resources Canada	137
Parker/Chromtech	138
Proton Energy Systems	139

Nicholas Roe and Arthur Roe.....	139
Nicholas Roe and Arthur Roe (Continued)	140
Stuart Energy Systems	141
Tathacus Resources Ltd	142
Technology Management Inc (TMI).....	143
Teledyne Energy Systems, Inc. (TES)	143
Via-Tek.....	144
Wellman CJB Ltd.	145
Xogen Power Inc.	145
Xogen Power Inc. (Continued).....	146
STORAGE	147
STORAGE TECHNOLOGIES	147
CYLINDERS.....	147
<i>TABLE 48 COMPRESSED PRESSURE VESSEL PRICING (\$)</i>	<i>147</i>
<i>TABLE 49 HYDROGEN TRANSPORT COSTS (\$)</i>	<i>148</i>
HYDRIDES.....	149
Costs.....	150
CARBON.....	151
<i>TABLE 50 HYDROGEN STORAGE IN CARBON</i>	<i>152</i>
Costs.....	153
GLASS MICROSPHERES	154
MAGNESIUM	154
PIPELINE INFRASTRUCTURE	155
MARKET SHARE	155
<i>TABLE 51 VALUE OF HYDROGEN STORAGE TECHNOLOGIES FOR FUEL CELLS,</i> <i>THROUGH 2008 (\$ MILLIONS).....</i>	<i>156</i>
<i>FIGURE 7 VALUE OF HYDROGEN STORAGE TECHNOLOGIES FOR FUEL CELLS,</i> <i>2000-2008 (\$ MILLIONS).....</i>	<i>156</i>
<i>TABLE 52 PROJECTED MARKET SHARE OF VARIOUS STORAGE TECHNOLOGIES</i> <i>INCLUSIVE OF R&D VALUES, 2003 AND 2008 (\$ MILLIONS, %).....</i>	<i>157</i>
STRUCTURE OF THE HYDROGEN STORAGE INDUSTRY.....	157
<i>TABLE 53 ESTIMATED 2003 MARKET SHARES OF HYDROGEN STORAGE (\$</i> <i>MILLIONS).....</i>	<i>158</i>
INDUSTRY PROFILES	158
A.D. Little/Nuvera	158
Air Products/Japan Metals and Chemicals Company, Ltd.....	159
Advanced Technical Products, Inc.	159
Asia Pacific Fuel Cell Technologies, Ltd.	160
BMW and Magna Hydrogen Storage Tank	160
Catalytic Materials.....	161
Dynetek.....	161
ChevronTexaco Ovonic Hydrogen Systems	161
Energy Conversion Devices (ECD)	162
Ergenics.....	162
FIBA Technologies, Inc.	163

HERA Hydrogen Storage Systems, Inc	163
Hydro Environmental Resources, Inc. (HERI)	163
Hughes Electronics	164
Hydrogen Components, Inc.	165
JMC (USA), Inc.	165
Labtech International Ltd.	165
Linde Group	166
Magna International	166
Manhattan Scientifics, Inc.	167
Materials and Electrochemical Research Corp. (MER)	167
National Renewable Energy Laboratory (NREL)	168
National Energy Technology Laboratory (NETL)	169
National University of Singapore	169
Palcan Fuel Cell Co. Ltd.	170
Powerball	170
Powerball (Continued)	171
Quantum Technologies WorldWide, Inc.	172
Safe Hydrogen, LLC	172
Safe Hydrogen, LLC (Continued)	173
Savannah River Company	174
ChevronTexaco Ovonic Hydrogen Systems LLC	175
Thermo Power Corporation	175
Thiokol Propulsion	176
Linde Gas AG	177
UCAR International Inc	177
UNITED TECHNOLOGIES	178
RECENT DEVELOPMENTS	178
Doped Carbon Nanotubes for Hydrogen Storage	178
University of Hawaii	179
Other	179
<i>TABLE 54 ADVANCED SOLID STORAGE RESEARCH PROJECTS</i>	180
FOREIGN STORAGE	180
Metal Hydride Alloy	180
Hydrogen/Absorbing Tank	180
Hydrogen Purification System	181
Liquid Hydride	181
Nanohorns	182
Nanohorns (Continued)	183
HYDROGEN COSTS	184
<i>TABLE 55 HYDROGEN ENERGY CONVERSION (KWH)</i>	184
<i>TABLE 56 HYDROGEN PRICES BY DELIVERY METHOD AND ON SITE</i> <i>PRODUCTION METHODS FOR CONVENTIONAL AND ENERGY USES (\$/LB.)</i>	185
STATIONARY REFORMER COSTS	185
<i>TABLE 57 SUMMARY KW COSTS FOR 50 KW PEM STATIONARY FUEL CELL AND</i> <i>REFORMER SYSTEMS* (\$)</i>	186

TABLE 58 SUBSYSTEMS COSTS BREAKDOWN OF 50 KW PEM STATIONARY FUEL CELL AND REFORMER SYSTEM* (\$)	187
TABLE 59 COSTS PER KW FOR REFORMER SUBSYSTEMS AND PERCENTAGE OF HYDROGEN FUEL SYSTEM COSTS (\$/KW, %)	187
OFF-SITE STEAM REFORMING OF NATURAL GAS	188
ELECTROLYSIS COSTS	188
TABLE 60 ELECTROLYZER CAPITAL COSTS AND ON-SITE HYDROGEN PRODUCTION COSTS VIA ELECTROLYSIS VS. REFORMING CAPITAL COSTS AND REFORMING OPERATIONAL COSTS (\$/GJ)	189
VEHICLE REFORMER COSTS	189
VEHICLE REFORMER COSTS (CONTINUED)	190
DISTRIBUTED ONSITE GENERATION OF HYDROGEN	191
TABLE 61 MASS PRODUCTION CAPITAL COSTS FOR REFUELING STATIONS (\$)	191
TABLE 62 CAPITAL COSTS ESTIMATES FOR STEAM AND AUTOTHERMAL REFORMERS (\$)	192
TABLE 63 HYDROGEN COSTS AT REFUELING STATIONS (\$/GJ)	193
TABLE 64 HYDROGEN AND GASOLINE EQUIVALENT PRICING EUROPE AND U.S. (\$/GALLON)	194
TABLE 65 HYDROGEN/GASOLINE/ELECTRICITY PRICE EQUIVALENTS	195
PORTABLE COSTS	195
GENERATION AND STORAGE SYSTEMS COST SUMMARY	195
FIGURE 8 REFORMING COSTS VS. STORAGE COSTS (%)	196
TABLE 66 MARKET VALUE AND SHARES FOR HYDROGEN GENERATION, STORAGE AND DISPENSING SUBSYSTEMS INCLUSIVE OF R&D EXPENDITURES, THROUGH 2008 (\$ MILLIONS/\$ PER KW)	196
FIGURE 9 MARKET VALUE AND SHARES FOR HYDROGEN GENERATION, STORAGE AND DISPENSING SUBSYSTEMS INCLUSIVE OF R&D EXPENDITURES, 2003 AND 2008	197
COSTS FOR THE FUTURE	197
STATIONARY MARKET SIZE AND GROWTH	198
FIGURE 10 HYDROGEN ENERGY MARKET SHARE, 2008	198
TABLE 67 ESTIMATED HYDROGEN ENERGY MARKET SHARE, 2008 (%)	199
U.S. ELECTRICAL DEMAND	199
FIGURE 11 U.S. ELECTRIC CONSUMPTION, BY SECTOR	199
TABLE 68 U.S. ELECTRIC CONSUMPTION, BY SECTOR, 2000	200
TABLE 69 RESIDENTIAL, COMMERCIAL AND INDUSTRIAL VALUE AND GENERATION SCENARIOS* (\$ MILLIONS AT \$1,000 PER KW)	200
TABLE 70 FORECAST OF STATIONARY HYDROGEN GENERATION, STORAGE AND DISPENSING EQUIPMENT VALUES*, THROUGH 2008	201
TABLE 71 FORECAST OF HYDROGEN GENERATION AND STORAGE EQUIPMENT VALUES,* 2008 (\$ MILLIONS)	202
TABLE 72 HYDROGEN DEMAND KILOGRAMS AND VALUE FOR NEW ELECTRIC GENERATION*, THROUGH 2008	203
MARKET SIZE AND GROWTH OF HYDROGEN DELIVERY	204
SYSTEMS FOR STATIONARY APPLICATIONS	204
TABLE 73 VALUE OF U.S. SALES OF HYDROGEN DELIVERY SYSTEMS FOR STATIONARY APPLICATIONS, BY ELECTRICITY SECTOR, THROUGH 2008 (\$ MILLIONS AT \$1,000 PER KW)	205

<i>FIGURE 12 VALUE OF U.S. SALES OF HYDROGEN DELIVERY SYSTEMS FOR STATIONARY APPLICATIONS, BY ELECTRICITY SECTOR, 2000-2008 (\$ MILLIONS AT \$1,000 PER KW)</i>	205
INDUSTRIAL SITES	206
<i>TABLE 74 INDUSTRIAL SCENARIOS FOR HYDROGEN CONSUMPTION AND GENERATION, 2008 (%)</i>	206
COMMERCIAL BUILDINGS	206
<i>TABLE 75 COMMERCIAL, SCENARIOS FOR HYDROGEN CONSUMPTION AND GENERATION, 2008 (MW, %)</i>	207
U.S. Remote Telecommunications Backup	208
<i>TABLE 76 U.S. REMOTE POWER BACKUP, THROUGH 2008 (\$ BILLIONS)</i>	208
Uninterruptible Power Supplies	208
RESIDENTIAL BUILDINGS	209
<i>TABLE 77 RESIDENTIAL SCENARIOS FOR HYDROGEN CONSUMPTION, 2008 (MW, %)</i>	210
Residential Electrolysis	210
<i>TABLE 78 COSTS OF HYDROGEN FROM ELECTROLYSIS IN LARGE AND SMALL PLANTS (\$/GJ)</i>	211
Remote Buildings	211
Remote Buildings (Continued)	212
U.S. ELECTRICITY DEMAND 2000 – 2020	213
<i>TABLE 79 HYDROGEN DELIVERY DEVICE AND ELECTRIC GENERATION (MW/%)</i>	214
<i>TABLE 80 ANNUAL CONSUMPTION OF ELECTRICITY VS. HYDROGEN GENERATED ELECTRICITY, 2008 (KWH, %)</i>	215
COST OF POWER OUTAGES	215
ENVIRONMENTAL AND HEALTH MARKET DRIVERS	216
DEREGULATION OF THE ELECTRIC INDUSTRY	216
CONSUMER SENTIMENT	217
TECHNICAL AND LOGISTICAL OBSTACLES	218
FUTURE TRENDS	218
DOE PROJECTS STATIONARY MARKET	219
<i>TABLE 81 HYDROGEN PROGRAM BENEFITS, 2000-2020</i>	220
FOREIGN	221
RWE AG	221
<i>TABLE 82 EUROPEAN HYDROGEN MARKET (KW, \$ MILLIONS)</i>	222
ICELAND'S HYDROGEN INFRASTRUCTURE	222
FRONTIER IS A \$2.5 TRILLION MARKET	223
Frontier Is a \$2.5 Trillion Market (Continued)	224
STRUCTURE OF THE STATIONARY INDUSTRY	225
<i>TABLE 83 ESTIMATED MARKET SHARES U.S. SALES AND RESEARCH SPENDING FOR HYDROGEN DELIVERY SYSTEMS FOR STATIONARY APPLICATIONS, 2003 (\$ MILLIONS)</i>	225
<i>TABLE 83 (CONTINUED)</i>	226
COMPANY PROFILES	227
AIRGAS INC.	227
AIR LIQUIDE	227
AIR PRODUCTS AND CHEMICALS, INC.	228

Air Products and Chemicals, Inc. (Continued).....	229
Air Products and Chemicals, Inc. (Continued).....	230
ARGONNE NATIONAL LABORATORY.....	231
ARIZONA HYDROGEN MANUFACTURING INC.	231
ASPEN SYSTEMS, INC.	232
BALLARD POWER SYSTEMS INC.	232
BOC GASES	232
DAIS ANALYTIC INC/TELEDYNE.....	233
GASTEC.....	234
GENESIS TECHNOLOGIES, LLC	234
GLOBAL THERMOELECTRIC INC	235
H2FUEL, LLC	235
HARVEST REFORMER/HET	236
HYDROGEN BURNER TECHNOLOGY INC. /HBT	237
HYRADIX INC.	238
IDATECH	239
HYDROGEN SOURCE, LLC.....	240
JOHNSON MATTHEY FUEL CELLS AND ELECTROCATALYSTS.....	240
MATSUSHITA ELECTRIC WORKS.....	241
MCDERMOTT TECHNOLOGY	241
MESOSYSTEMS TECHNOLOGY	242
MIT PLASMA SCIENCE AND FUSION CENTER	243
MOTOROLA LABS	243
NIAGARA MOHAWK POWER CORPATION.....	244
NUVERA FUEL CELLS.....	245
PACIFIC NORTHWEST NATIONAL LABORATORY	246
PRAXAIR.....	246
STARTECH ENVIRONMENTAL CORP.	247
SYNERGY TECHNOLOGIES	247
CHEVRONTEXACO ENERGY SYSTEMS INC–TESI	248
WANGTEC	249
ZTEK CORPORATION.....	250
FOREIGN STATIONARY REFORMER COMPANY PROFILES	251
ALSTROM BALLARD	251
CALORIC ANLAGENBAU GMBH	251
FRAUNHOFER ISE.....	251
FUJI ELECTRIC.....	252
GAZ DE FRANCE	252
H POWER JAPAN	252
H2OR COMPANY, LTD.....	253
MITSUBISHI ELECTRIC	254
MITSUBISHI HEAVY INDUSTRIES LTD	254
NGK REFORMER.....	255

SK CORPORATION.....	255
SK Corporation (Continued)	256
OSAKA NATURAL GAS REFORMER	257
TOSHIBA CORP.	257
TOKYO GAS.....	258
REFORMING TECHNOLOGIES ONBOARD VEHICLES.....	259
REFORMING TECHNOLOGIES ONBOARD VEHICLES	259
REFORMATE GENERATOR.....	260
HIGH AND LOW TEMPERATURE SHIFT REACTOR AND CATALYST.....	260
<i>TABLE 84 CATALYSTS FOR HYDROCARBON STEAM REFORMING.....</i>	261
<i>TABLE 85 CATALYSTS FOR GAS PURIFICATION.....</i>	262
Non-Precious Metal Water-Gas Shift Catalysts	262
SULFUR REMOVER	263
LOW TEMPERATURE SHIFT (LTS) REACTOR AND CATALYST.....	264
Steam Generator	265
Air Preheater	265
Steam Superheater.....	265
Reformate Conditioner	265
Sensors	265
REFORMATE CONDITIONER SUBSYSTEMS	265
Ammonia Remover	266
Partial Oxidation Chamber and Catalyst.....	266
Tailgas Burner.....	266
APPENDIX: RECENT DEVELOPMENTS	267
VIRENT LOWERS COST DRAMATICALLY.....	267
SOLAR CHEAPLY REPLACES FOSSIL FUELS AS H ₂ SOURCE	268
ALCHEMIX AND HIMELT TO TEST HYDROMAX PROCESS	269
OXIDE MATERIALS “EXHALE AND INHALE” MAY FACILITATE SMALL-SCALE H ₂ PRODUCTION.....	270
OXIDE MATERIALS .. (CONTINUED).....	271
PROTOTYPE LIQUID HYDROCARBON MARKS IDATECH MILESTONE	272
DAIMLERCHRYSLER FEATURES FUTURE FUELS RESEARCH	273
DIMETHYL ETHER (DME) PROPOSED AS FUEL SOURCE.....	273
BACTERIA FOR POWER.....	274
GE SEEKS CLEAN PATH TO H ₂ USING FOSSIL FUELS.....	275