

# SOLID OXIDE FUEL CELLS: TECHNOLOGIES AND GLOBAL MARKETS



EGY048C  
January 2014

Donald Saxman  
*Project Analyst*

ISBN: 1-56965-663-0



**BCC Research**  
49 Walnut Park, Building 2  
Wellesley, MA 02481 USA  
866-285-7215 (toll-free within the USA),  
or (+1) 781-489-7301  
[www.bccresearch.com](http://www.bccresearch.com)  
[information@bccresearch.com](mailto:information@bccresearch.com)

**TABLE OF CONTENTS**

<b>TOPIC</b>	<b>PAGE NO.</b>
CHAPTER 1 INTRODUCTION	2
STUDY GOALS AND OBJECTIVES	2
REASONS FOR DOING THE STUDY	2
INTENDED AUDIENCE	2
SCOPE OF REPORT	2
METHODOLOGY	3
INFORMATION SOURCES	3
ANALYST CREDENTIALS	4
RELATED BCC RESEARCH REPORTS	4
BCC RESEARCH ONLINE SERVICES	4
DISCLAIMER	4
CHAPTER 2 SUMMARY	6
<i>SUMMARY TABLE GLOBAL SOFC MARKET BY APPLICATION, CONSENSUS SCENARIO, THROUGH 2018 (\$ MILLIONS)</i>	7
<i>SUMMARY FIGURE 1 GLOBAL SOFC MARKET BY YEAR, 2008-2018 (\$ MILLIONS)</i>	7
<i>SUMMARY FIGURE 2 GLOBAL SOFC MARKET BY APPLICATION, 2013 (%)</i>	8
CHAPTER 3 OVERVIEW	10
FUEL CELL BACKGROUND	10
<i>TABLE 1 SOFC COMPARED TO OTHER FUEL CELLS</i>	10
SOLID OXIDE FUEL CELL BACKGROUND	11
SOFC MATERIALS	12
SOFC Electrodes, Electrolytes, and Interconnects	12
SOFC Glass Seals	13
SOFC Gaskets	14
<i>TABLE 2 SOFC GASKET MATERIALS</i>	15
Recent SOFC Material Developments	15
Georgia Tech SOFC Ceramic Material	15
National Institute of Advanced Industrial Science and Technology and the Fine Ceramics Research Association Electrode Compositions	17
University of Illinois at Urbana-Champaign Ceramic Microreactors	17
Cornell University One-Pot Process	18
West Virginia University Interconnect Coatings	18
Nippon Shokubai Zirconia Sheets	19
<i>TABLE 3 NIPPON SHOKUBAI ZIRCONIA SOFC SHEET SPECIFICATIONS</i>	19
University of Birmingham Electrode Doping	20
Virginia Tech Self-healing Glass Seals	20
SOFC TECHNOLOGY: CURRENT AND DEVELOPMENTAL CONFIGURATIONS	21
Generic Planar SOFC Configuration	22
<i>FIGURE 1 PLANAR SOFC CONFIGURATION</i>	22
Generic Thin-film Configuration	23
<i>FIGURE 2 THIN-FILM SOFC CONFIGURATION</i>	23
Generic Tubular Configuration	24

<b>TOPIC</b>	<b>PAGE NO.</b>
<i>FIGURE 3 TUBULAR SOFC CONFIGURATION</i>	24
Westinghouse Tubular Design	24
Siemens Power Generation Tubular Design	25
Advanced Microtubular Designs	26
<i>FIGURE 4 TUBULAR CELL AND CURRENT PATH WITH SIEMENS CELLS CONFIGURATION</i>	26
<i>FIGURE 5 TUBULAR CELL AND CURRENT PATH WITH A STRAIGHT METAL WIRE AS CURRENT COLLECTOR</i>	28
<i>FIGURE 6 CURRENT PATH IN RADIAL AND AXIAL DIRECTION WITH A SPRING COIL AS CURRENT COLLECTOR</i>	29
National Institute of Advanced Industrial Science and Technology (AIST) Microtubular Design	29
NanoDynamics Energy Microtubular Configuration	31
MIT SOFC Power Plant Design	32
Ceres Power CHP Design	33
Bloom Energy Design	35
<i>TABLE 4 BLOOM ENERGY SERVER SPECIFICATIONS</i>	35
FuelCon SOFC Test Station	36
SOFC Gas Turbine Hybrids	37
<i>FIGURE 7 FUELCELL ENERGY SOFC/T HYBRID SYSTEM AND TORPEDO CONFIGURATION</i>	37
<b>GOVERNMENT REGULATIONS AND SUBSIDIES</b>	39
<b>U.S. FEDERAL FUEL CELL SUBSIDIES AND INCENTIVES</b>	39
U.S. Department of Energy	39
History of U.S. DOE Fuel Cell Subsidies	41
U.S. Fuel Cell Budget Situation in 2009	42
U.S. Fuel Cell Budget Situation in 2010	45
<i>TABLE 5 HYDROGEN AND FUEL CELL TECHNOLOGIES FUNDING PROFILE BY SUBPROGRAM IN 2010 BUDGET (\$ THOUSANDS)</i>	45
U.S. Fuel Cell Budget Situation in 2011	47
<i>TABLE 6 FISCAL FUEL CELL BUDGET, 2010-2012 (\$ MILLIONS)</i>	48
The Sequestration Transparency Act of 2012	48
<i>TABLE 7 FISCAL FUEL CELL BUDGET, 2011-2013 (\$ MILLIONS)</i>	49
U.S. DOE Draft Hydrogen and Fuel Cells Program Plan	50
Office of Science	53
Hydrogen and Fuel Cell Interagency Task Force	54
Federal Excise Tax Exemption for Anti-idling	55
Fuel Cell and Hydrogen Energy Association	55
JOBS FC Model	56
National Science Foundation	56
Department of Defense	57
State Incentives	58
<b>GLOBAL SUBSIDIES AND INCENTIVES</b>	59
Canadian Subsidies and Incentives	59
European Subsidies and Incentives	59
Japanese Subsidies and Incentives	60
South Korean Subsidies and Incentives	60
Australian Subsidies and Incentives	63
<b>SOFC RESEARCH</b>	63

<b>TOPIC</b>	<b>PAGE NO.</b>
ACADEMIC INSTITUTIONS	63
<i>TABLE 8 MAJOR INSTITUTIONAL RESEARCH INTO PEM FUEL CELLS</i>	63
CHAPTER 4 MARKETS BY APPLICATION	66
COMBINED HEAT AND POWER	66
CHP DEVELOPMENTS	67
U.S. DOE EERE CHP Developments	67
<i>TABLE 9 PRELIMINARY TECHNICAL TARGETS: 1 KWE TO 10 KWE RESIDENTIAL COMBINED HEAT AND POWER FUEL CELLS OPERATING ON NATURAL GAS, 2008-2020</i>	67
<i>TABLE 10 PRELIMINARY TECHNICAL TARGETS: 1 KWE TO 10 KWE FUEL CELL AUXILIARY POWER UNITS OPERATING ON STANDARD ULTRA-LOW SULFUR DIESEL FUEL THROUGH 2020</i>	68
European Union SOFC Research Partnership CHP Developments	68
Hydrogen and Fuel Cell Technical Advisory Committee (HTAC) CHP Developments	70
Ceres Power CHP Developments	70
Pacific Northwest National Laboratory	72
GENERATORS, REMOTE POWER, AND AUXILIARY POWER	73
<i>GENERATORS AND PORTABLE POWER PLANTS</i>	74
RECREATIONAL VEHICLE POWER	74
ANTI-IDLING APUS	75
AIRCRAFT APUS	76
MARINE VESSEL APUS	78
<i>PORTABLE PRODUCTS</i>	78
MILITARY	79
EXOTIC	79
CHAPTER 5 SOFC MARKET SUMMARY	82
SOFC SEGMENTS ANALYZED	82
SOFC MARKET DRIVERS AND BASIS FOR SCENARIOS	83
SOFC APPLICATION MARKET DRIVER SCENARIOS	84
<i>TABLE 11 SOFC CONSENSUS, OPTIMISTIC AND PESSIMISTIC SCENARIOS, BY APPLICATION</i>	84
SOFC REGIONAL MARKET DRIVER SCENARIOS	89
<i>TABLE 12 SOFC CONSENSUS, OPTIMISTIC AND PESSIMISTIC SCENARIOS, BY REGION</i>	89
SOFC PRODUCT MARKET DRIVER SCENARIOS	93
<i>TABLE 13 SOFC CONSENSUS, OPTIMISTIC AND PESSIMISTIC SCENARIOS, BY SCALE</i>	93
SOFC MARKETS BY APPLICATION	98
<i>TABLE 14 GLOBAL SOFC MARKET PROJECTIONS BY APPLICATION CONSENSUS SCENARIO, THROUGH 2018 (\$ MILLIONS)</i>	98
<i>FIGURE 8 GLOBAL SOFC MARKET BY APPLICATION CONSENSUS SCENARIO, 2008-2018 (\$ MILLIONS)</i>	98
<i>FIGURE 9 GLOBAL SOFC MARKET BY APPLICATION CONSENSUS SCENARIO, 2013 (%)</i>	99
<i>TABLE 15 GLOBAL SOFC MARKET BY APPLICATION OPTIMISTIC SCENARIO THROUGH 2018 (\$ MILLIONS)</i>	100
<i>TABLE 16 GLOBAL SOFC MARKET BY APPLICATION PESSIMISTIC SCENARIO THROUGH 2018 (\$ MILLIONS)</i>	100

<b>TOPIC</b>	<b>PAGE NO.</b>
SOFC MARKETS BY REGION	101
<i>TABLE 17 GLOBAL SOFC MARKET BY REGION CONSENSUS SCENARIO THROUGH 2018 (\$ MILLIONS)</i>	101
<i>FIGURE 10 GLOBAL SOFC MARKET BY REGION CONSENSUS SCENARIO, 2013 (%)</i>	101
<i>TABLE 18 GLOBAL SOFC MARKET BY REGION OPTIMISTIC SCENARIO THROUGH 2018 (\$ MILLIONS)</i>	102
<i>TABLE 19 GLOBAL SOFC MARKET BY REGION PESSIMISTIC SCENARIO, THROUGH 2018 (\$ MILLIONS)</i>	102
SOFC MARKETS BY PRODUCT	103
<i>TABLE 20 GLOBAL SOFC MARKET PROJECTIONS BY PRODUCT CONSENSUS SCENARIO, THROUGH 2018 (\$ MILLIONS)</i>	103
<i>FIGURE 11 GLOBAL SOFC MARKET BY PRODUCT CONSENSUS SCENARIO, 2013 (%)</i>	103
<i>TABLE 21 GLOBAL SOFC MARKET BY PRODUCT OPTIMISTIC SCENARIO THROUGH 2018 (\$ MILLIONS)</i>	104
<i>TABLE 22 GLOBAL SOFC MARKET BY PRODUCT PESSIMISTIC SCENARIO THROUGH 2018 (\$ MILLIONS)</i>	105
CHAPTER 6 INDUSTRY STRUCTURE AND COMPETITIVE ANALYSIS	107
COMPETITION	107
CONVENTIONAL TURBINE-BASED POWER GENERATION	107
INTERNAL COMBUSTION ENGINES	108
ULTRACAPACITORS	108
OTHER FUEL CELLS	108
<i>TABLE 23 COMPETING FUEL CELLS</i>	109
Alkaline Fuel Cells	109
Phosphoric Acid Fuel Cells	109
Molten Carbonate Fuel Cells	110
Proton Exchange Membrane Fuel Cells	110
BATTERIES	110
<i>TABLE 24 BATTERIES THAT COULD COMPETE WITH SOFCs</i>	112
Lead-acid Batteries	112
Nickel-metal Hydride Batteries	112
Lithium-ion and Lithium-ion polymer Batteries	113
Metal-air Batteries	114
Nickel-hydrogen Secondary Batteries	115
Sodium-sulfur Batteries	115
Redox and Flow Batteries	116
Nickel-iron Batteries	116
Nickel-Zinc Batteries	117
INDUSTRY LEADERS	117
<i>TABLE 25 SOFC COMPANIES AND STATUS</i>	118
<i>TABLE 26 SOFC COMPANY SHIPMENT STATUS</i>	121
MARKET TIERS	122
LEADING CHP SOFC COMPANIES	122
<i>TABLE 27 LEADING SOFC CHP COMPANIES</i>	122
LEADING SOFC GENERATOR, REMOTE AND APU COMPANIES	122
<i>TABLE 28 LEADING SOFC GENERATOR, REMOTE AND APU COMPANIES</i>	123
LEADING MILITARY SOFC COMPANIES	123
<i>TABLE 29 LEADING MILITARY SOFC COMPANIES</i>	123

<b>TOPIC</b>	<b>PAGE NO.</b>
<i>LEADING PORTABLE SOFC COMPANIES</i>	124
<i>TABLE 30 LEADING PORTABLE SOFC COMPANIES</i>	124
<i>LEADING EXOTIC SOFC COMPANIES</i>	124
<i>TABLE 31 LEADING EXOTIC SOFC COMPANIES</i>	124
<i>NO LONGER ACTIVE SOFC COMPANIES</i>	125
<i>TABLE 32 NO LONGER ACTIVE SOFC COMPANIES</i>	125
<i>CHANNELS OF DISTRIBUTION</i>	126
<i>TABLE 33 SOFC DISTRIBUTION CHANNELS</i>	126
<i>PURCHASING INFLUENCES</i>	127
<i>PRICE INFLUENCE</i>	127
<i>TABLE 34 SOFC PURCHASING INFLUENCES</i>	127
<i>PRICE TRENDS</i>	128
<i>FIGURE 12 DRIVING DOWN COSTS FOR FUEL CELLS (ORDER OF MAGNITUDE COST REDUCTION)</i>	128
<i>TECHNOLOGY LIFE CYCLE</i>	130
<i>MANUFACTURING PROCESS</i>	131
<i>FIGURE 13 SOFC MANUFACTURING TREE</i>	131
<i>FIGURE 14 SOFC MANUFACTURING FLOW</i>	131
<i>SOFC PATENT ANALYSIS</i>	133
<i>TABLE 35 U.S. SOFC PATENTS</i>	133
<i>TABLE 36 RECENT U.S. SOFC PATENT ASSIGNEES</i>	139
<b>CHAPTER 7 COMPANY PROFILES</b>	143
<i>ACUMENTRICS HOLDING CORP.</i>	143
<i>ADELAN U.K. LTD.</i>	145
<i>ADVANCED MATERIALS TECHNOLOGIES (ACCURON TECHNOLOGIES)</i>	146
<i>ADVANCED MEASUREMENTS INC.</i>	147
<i>ALPPS FUEL CELL SYSTEMS</i>	147
<i>ALSTOM TECHNOLOGY INC.</i>	148
<i>ALTAIR NANOTECHNOLOGIES INC.</i>	148
<i>AMERICAN ELEMENTS</i>	148
<i>BLASCH PRECISION CERAMICS</i>	149
<i>BLOOM ENERGY</i>	149
<i>BTU INTERNATIONAL INC.</i>	151
<i>CERAMATEC INC.</i>	152
<i>CERAMIC FUEL CELLS LTD.</i>	153
<i>CERES POWER HOLDINGS</i>	160
<i>CHAO ZHOU THREE-CIRCLE (GROUP) CO. LTD.</i>	164
<i>CHUBU ELECTRIC POWER COMPANY INC.</i>	165
<i>CMR PROTOTECH</i>	165
<i>CONVION OY</i>	166
<i>TABLE 37 CONVION SOFC TECHNOLOGY GOALS</i>	167
<i>CUMMINS POWER GENERATION INC.</i>	168
<i>DANA HOLDING CORPORATION</i>	170
<i>DANA CANADA CORP.</i>	170
<i>DELPHI CORP.</i>	171
<i>EBZ ENTWICKLUNGS</i>	172
<i>ELCOGEN AS</i>	173

<b>TOPIC</b>	<b>PAGE NO.</b>
EMPRISE CORPORATION	173
ENERGIENED	174
ENRG INC.	174
FCO POWER INC.	175
FEV MOTORENTECHNIK GMBH	176
FIDERIS	177
<i>TABLE 38 TYPICAL TURN-KEY, SOFC FUEL CELL TEST SYSTEMS THAT UTILIZE THE FIDERIS INNOVATOR SERIES MODULES</i>	177
FORSCHUNGSZENTRUM JULICH	178
FUELCELL ENERGY INC.	179
GENERAL ELECTRIC COMPANY	182
GEORGE WESTINGHOUSE RESEARCH AND TECHNOLOGY PARK	182
HABCO INC.	182
HALDOR TOPSOE A/S/ TOPSOE FUEL CELL	183
HC STARCK GMBH	186
<i>FIGURE 15 AMPERIT AND AMPERGY POWDERS FOR SOLID OXIDE FUEL CELLS</i>	186
HEXIS LTD.	187
<i>TABLE 39 HEXIS GALILEO FUEL CELL SYSTEM</i>	189
HOSOKAWA POWDER TECHNOLOGY RESEARCH INSTITUTE	190
ITN ENERGY SYSTEMS INC.	190
K-STYLE ADVANCED CERAMICS CO. LTD.	190
KANSAI ELECTRIC POWER CO. INC.	191
KERAFOL (KERAMISCHE FOLIEN GMBH)	191
LG FUEL CELL SYSTEMS INC. (ROLLS-ROYCE FUEL CELL SYSTEMS LTD.)	191
LILLIPUTIAN SYSTEMS	193
LITHUANIAN ENERGY INSTITUTE	194
LOGANENERGY CORP.	194
MATERIALS & SYSTEMS RESEARCH INC.	194
MEIDENSHA CORP.	196
MERIDIAN ENERGY LTD.	196
MERLONI TERMOSANITARI SPA (ARISTON THERMO GROUP)	197
NATIONAL FUEL CELL RESEARCH CENTER	197
NEXTECH MATERIALS LTD.	198
FUELCELLMATERIALS.COM DIVISION	198
NGIMAT CO.	201
NGK INSULATORS LTD.	201
NIPPON SHOKUBAI CO. LTD.	202
NIPPON TELEGRAPH & TELEPHONE CORP.	202
NOAH TECHNOLOGIES CORP.	203
ONTARIO POWER GENERATION INC.	204
PLANSEE SE	204
PLUG POWER INC.	205
POHANG IRON AND STEEL COMPANY (POSCO)	205
POINT SOURCE POWER INC.	206
PRECISION FLOW TECHNOLOGIES	207
PRESIDIO COMPONENTS INC.	207
PROTONEX	207
MESOSCOPIC DEVICES SUBSIDIARY	207

<b>TOPIC</b>	<b>PAGE NO.</b>
RAGAN TECHNOLOGIES INC.	209
REDOX POWER SYSTEMS	211
RISO DTU NATIONAL LABORATORY	211
SAFCELL	213
SAINT-GOBAIN	214
SANDVIK	214
SIEMENS POWER GENERATION INC.	215
SIENERGY SYSTEMS (ALLIED MINDS)	217
SOFCPOWER	218
SOLID STATE ENERGY CONVERSION ALLIANCE	219
<i>FIGURE 16 SECA ADVANCED POWER SYSTEM COST COMPARISON</i>	220
STANFORD MATERIALS CORP.	222
SUMITOMO CORP.	223
SUNFIRE GMBH (STAXERA)	223
<i>TABLE 40 MK200 SOFC TECHNICAL DATA</i>	224
TERMINUS ENERGY INC.	225
TOKYO GAS CO. LTD.	226
TOSOH CORP. CERAMICS DIVISION	227
TOTO LTD.	227
TOYOTA	228
<i>TABLE 41 TOYOTA POWER GENERATING UNIT SPECIFICATIONS</i>	229
ULTRA ELECTRONICS AMI	230
VAILLANT GMBH	232
VIOLET FUEL CELL STICKS	232
WATT FUEL CELL CORP.	233
WEBASTO AG	234
ZIRCAR ZIRCONIA INC.	234
ZTEK CORP.	234
CHAPTER 8 APPENDIX U.S. PATENTS THAT MENTION SOFCS	237
<i>TABLE 42 U.S. SOFC PATENTS</i>	237



**LIST OF TABLES**

<b>TABLE HEADING</b>	<b>PAGE NO.</b>
SUMMARY TABLE GLOBAL SOFC MARKET BY APPLICATION, CONSENSUS SCENARIO, THROUGH 2018 (\$ MILLIONS)	7
TABLE 1 SOFC COMPARED TO OTHER FUEL CELLS	10
TABLE 2 SOFC GASKET MATERIALS	15
TABLE 3 NIPPON SHOKUBAI ZIRCONIA SOFC SHEET SPECIFICATIONS	19
TABLE 4 BLOOM ENERGY SERVER SPECIFICATIONS	35
TABLE 5 HYDROGEN AND FUEL CELL TECHNOLOGIES FUNDING PROFILE BY SUBPROGRAM IN 2010 BUDGET (\$ THOUSANDS)	45
TABLE 6 FISCAL FUEL CELL BUDGET, 2010-2012 (\$ MILLIONS)	48
TABLE 7 FISCAL FUEL CELL BUDGET, 2011-2013 (\$ MILLIONS)	49
TABLE 8 MAJOR INSTITUTIONAL RESEARCH INTO PEM FUEL CELLS	63
TABLE 9 PRELIMINARY TECHNICAL TARGETS: 1 KWE TO 10 KWE RESIDENTIAL COMBINED HEAT AND POWER FUEL CELLS OPERATING ON NATURAL GAS, 2008-2020	67
TABLE 10 PRELIMINARY TECHNICAL TARGETS: 1 KWE TO 10 KWE FUEL CELL AUXILIARY POWER UNITS OPERATING ON STANDARD ULTRA-LOW SULFUR DIESEL FUEL THROUGH 2020	68
TABLE 11 SOFC CONSENSUS, OPTIMISTIC AND PESSIMISTIC SCENARIOS, BY APPLICATION	84
TABLE 12 SOFC CONSENSUS, OPTIMISTIC AND PESSIMISTIC SCENARIOS, BY REGION	89
TABLE 13 SOFC CONSENSUS, OPTIMISTIC AND PESSIMISTIC SCENARIOS, BY SCALE	93
TABLE 14 GLOBAL SOFC MARKET PROJECTIONS BY APPLICATION CONSENSUS SCENARIO, THROUGH 2018 (\$ MILLIONS)	98
TABLE 15 GLOBAL SOFC MARKET BY APPLICATION OPTIMISTIC SCENARIO THROUGH 2018 (\$ MILLIONS)	100
TABLE 16 GLOBAL SOFC MARKET BY APPLICATION PESSIMISTIC SCENARIO THROUGH 2018 (\$ MILLIONS)	100
TABLE 17 GLOBAL SOFC MARKET BY REGION CONSENSUS SCENARIO THROUGH 2018 (\$ MILLIONS)	101
TABLE 18 GLOBAL SOFC MARKET BY REGION OPTIMISTIC SCENARIO THROUGH 2018 (\$ MILLIONS)	102
TABLE 19 GLOBAL SOFC MARKET BY REGION PESSIMISTIC SCENARIO, THROUGH 2018 (\$ MILLIONS)	102
TABLE 20 GLOBAL SOFC MARKET PROJECTIONS BY PRODUCT CONSENSUS SCENARIO, THROUGH 2018 (\$ MILLIONS)	103
TABLE 21 GLOBAL SOFC MARKET BY PRODUCT OPTIMISTIC SCENARIO THROUGH 2018 (\$ MILLIONS)	104
TABLE 22 GLOBAL SOFC MARKET BY PRODUCT PESSIMISTIC SCENARIO THROUGH 2018 (\$ MILLIONS)	105
TABLE 23 COMPETING FUEL CELLS	109
TABLE 24 BATTERIES THAT COULD COMPETE WITH SOFCs	112
TABLE 25 SOFC COMPANIES AND STATUS	118
TABLE 26 SOFC COMPANY SHIPMENT STATUS	121
TABLE 27 LEADING SOFC CHP COMPANIES	122
TABLE 28 LEADING SOFC GENERATOR, REMOTE AND APU COMPANIES	123
TABLE 29 LEADING MILITARY SOFC COMPANIES	123
TABLE 30 LEADING PORTABLE SOFC COMPANIES	124
TABLE 31 LEADING EXOTIC SOFC COMPANIES	124
TABLE 32 NO LONGER ACTIVE SOFC COMPANIES	125
TABLE 33 SOFC DISTRIBUTION CHANNELS	126

<b>TABLE HEADING</b>	<b>PAGE NO.</b>
TABLE 34 SOFC PURCHASING INFLUENCES	127
TABLE 35 U.S. SOFC PATENTS	133
TABLE 36 RECENT U.S. SOFC PATENT ASSIGNEES	139
TABLE 37 CONVION SOFC TECHNOLOGY GOALS	167
TABLE 38 TYPICAL TURN-KEY, SOFC FUEL CELL TEST SYSTEMS THAT UTILIZE THE FIDERIS INNOVATOR SERIES MODULES	177
TABLE 39 HEXIS GALILEO FUEL CELL SYSTEM	189
TABLE 40 MK200 SOFC TECHNICAL DATA	224
TABLE 41 TOYOTA POWER GENERATING UNIT SPECIFICATIONS	229
TABLE 42 U.S. SOFC PATENTS	237

**LIST OF FIGURES**

<b>FIGURE TITLE</b>	<b>PAGE NO.</b>
SUMMARY FIGURE 1 GLOBAL SOFC MARKET BY YEAR, 2008-2018 (\$ MILLIONS)	7
SUMMARY FIGURE 2 GLOBAL SOFC MARKET BY APPLICATION, 2013 (%)	8
FIGURE 1 PLANAR SOFC CONFIGURATION	22
FIGURE 2 THIN-FILM SOFC CONFIGURATION	23
FIGURE 3 TUBULAR SOFC CONFIGURATION	24
FIGURE 4 TUBULAR CELL AND CURRENT PATH WITH SIEMENS CELLS CONFIGURATION	26
FIGURE 5 TUBULAR CELL AND CURRENT PATH WITH A STRAIGHT METAL WIRE AS CURRENT COLLECTOR	28
FIGURE 6 CURRENT PATH IN RADIAL AND AXIAL DIRECTION WITH A SPRING COIL AS CURRENT COLLECTOR	29
FIGURE 7 FUELCELL ENERGY SOFC/T HYBRID SYSTEM AND TORPEDO CONFIGURATION	37
FIGURE 8 GLOBAL SOFC MARKET BY APPLICATION CONSENSUS SCENARIO, 2008-2018 (\$ MILLIONS)	98
FIGURE 9 GLOBAL SOFC MARKET BY APPLICATION CONSENSUS SCENARIO, 2013 (%)	99
FIGURE 10 GLOBAL SOFC MARKET BY REGION CONSENSUS SCENARIO, 2013 (%)	101
FIGURE 11 GLOBAL SOFC MARKET BY PRODUCT CONSENSUS SCENARIO, 2013 (%)	103
FIGURE 12 DRIVING DOWN COSTS FOR FUEL CELLS (ORDER OF MAGNITUDE COST REDUCTION)	128
FIGURE 13 SOFC MANUFACTURING TREE	131
FIGURE 14 SOFC MANUFACTURING FLOW	131
FIGURE 15 AMPERIT AND AMPERGY POWDERS FOR SOLID OXIDE FUEL CELLS	186
FIGURE 16 SECA ADVANCED POWER SYSTEM COST COMPARISON	220