

# GLOBAL MARKETS FOR NEW COMPONENTS AND MATERIALS IN ADVANCED ELECTRIC MOTORS



EGY046A  
January 2017

Kevin Gainer  
*Project Analyst*

ISBN: 1-62296-414-4



**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)  
[info@bccresearch.com](mailto:info@bccresearch.com)

## TABLE OF CONTENTS

TOPIC	PAGE NO.
CHAPTER 1 INTRODUCTION	2
STUDY GOALS AND OBJECTIVES	2
REASONS FOR DOING THE STUDY	2
INTENDED AUDIENCE	2
SCOPE OF REPORT	3
METHODOLOGY	3
INFORMATION SOURCES	3
ANALYST'S CREDENTIALS	3
RELATED BCC RESEARCH REPORTS	4
BCC RESEARCH WEBSITE	4
DISCLAIMER	4
CHAPTER 2 SUMMARY	6
<i>SUMMARY TABLE GLOBAL MARKET FOR ADVANCED COMPONENTS AND MATERIALS IN ELECTRIC MOTORS BY TYPE, THROUGH 2021 (\$ MILLIONS)</i>	6
<i>SUMMARY FIGURE GLOBAL MARKET FOR ADVANCED COMPONENTS AND MATERIALS IN ELECTRIC MOTORS BY TYPE, 2015-2021 (\$ MILLIONS)</i>	7
CHAPTER 3 OVERVIEW OF THE ELECTRIC MOTOR MANUFACTURING INDUSTRY	9
MOTOR TYPES	9
ENERGY CONSUMPTION OF MOTORS	9
<i>TABLE 1 SHARE OF ELECTRICITY CONSUMPTION BY MOTOR FUNCTION (%)</i>	10
MOTOR SECTORS BENEFITING FROM ADVANCED MATERIALS	10
PUMPING SYSTEMS	10
FANS	10
COMPRESSED AIR SYSTEMS	11
MARKET DRIVERS	11
DRIVING FORCES BEHIND MOTOR INNOVATION	11
REGULATORY DRIVERS	11
United States	12
Minimum Energy Performance Standards	13
THE SMALL MOTOR RULE	13
CURRENT ESTIMATED MOTOR POPULATION	14
<i>TABLE 2 ESTIMATED POPULATION OF MOTORS BY SIZE, 2016 (BILLION/MILLION/%)</i>	14
CHAPTER 4 MARKET ANALYSIS	16
OVERVIEW	16
<i>TABLE 3 PRIVATE CORPORATE RESEARCH SPENDING ON ELECTRIC MOTORS AND SYSTEMS, THROUGH 2021 (\$ MILLIONS)</i>	16
RESEARCH AND DEVELOPMENT	16
DEPARTMENT OF ENERGY FUNDED RESEARCH	16
National Assessment of Motor Energy Savings Potential	16
Next Generation of Electric Machines Project	17
High-Performance Thermal and Electrical Conductor Manufacturing	17
Low-Loss Silicon Steel Manufacturing	17
Superconducting Wire Manufacturing	18

<b>TOPIC</b>	<b>PAGE NO.</b>
Other Enabling Technologies to Improve Efficiency and Power Density Performance	18
Next Generation of Electric Machines Projects in 2015	19
GENERAL ELECTRIC CO.	20
OHIO STATE UNIVERSITY	20
CLEMSON UNIVERSITY	20
CALNETIX TECHNOLOGIES	20
EATON CORP.	20
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION R&D	20
NATIONAL SCIENCE FOUNDATION RESEARCH	21
NATIONAL RENEWABLE ENERGY LABORATORY	22
CANADIAN RESEARCH PROGRAMS	23
<i>TABLE 4 GOVERNMENT-SPONSORED RESEARCH SPENDING ON ELECTRIC MOTORS AND SYSTEMS IN CANADA, THROUGH 2021 (\$ MILLIONS)</i>	23
ADVANCED MOTORS MARKET BY SEGMENT	23
ADVANCED MOTORS IN AIRPLANES AND WATERCRAFT	23
<i>TABLE 5 R &amp; D SPENDING ON MOTORS FOR ADVANCED TRANSPORTATION BY APPLICATION, THROUGH 2021 (\$ MILLIONS)</i>	25
ADVANCED MOTORS IN ELECTRIC VEHICLE MOTORS	25
<i>TABLE 6 U.S. PATENTS RELATED TO ELECTRIC VEHICLES, 2014 TO 2016</i>	25
Battery Barrier	26
<i>TABLE 7 GLOBAL SALES OF ELECTRIC VEHICLES BY TYPE, THROUGH 2021 (UNITS)</i>	27
Sales of Motors for Electric and Hybrid Vehicles	28
<i>TABLE 8 GLOBAL MARKET FOR ELECTRIC AND HYBRID VEHICLE MOTORS BY ELECTRIC VEHICLE TYPE, THROUGH 2021 (\$ MILLIONS)</i>	28
Key Raw Materials Issues	28
Raw Materials Alternatives	29
Oak Ridge National Laboratory	29
Momentum Technologies	30
TDK Corp.	30
Carpenter Powder Products	31
ADVANCED MOTORS IN ELECTRIC TRUCKS	31
NEW ELECTRIC VEHICLE MOTOR CONCEPTS	32
2-in-1 Electric Motor	32
Dyson and Electric Vehicle Motors	32
Other New Market Entrants	33
CHAPTER 5 MARKETS BY TECHNOLOGY TYPE	35
VARIABLE SPEED DRIVES	35
ENERGY SAVINGS AS A DRIVER IN THE VSD MARKET	35
MOTOR CONTROLS	35
PRINCIPAL MOTOR CONTROLS VENDORS	35
TYPES OF DIGITAL MICROPROCESSORS FOR MOTOR CONTROLS	36
MAJOR APPLICATIONS OF MOTOR CONTROLS	36
<i>NOTABLE RECENT MOTOR CONTROL PATENTS</i>	36
BRUSHLESS DC MOTORS	38
FUZZY LOGIC	38
ADVANCED MOTOR CONTROLS MARKET SIZE	39

<b>TOPIC</b>	<b>PAGE NO.</b>
<i>TABLE 9 GLOBAL MARKET FOR ADVANCED MOTOR CONTROLS BY TYPE, THROUGH 2021 (\$ MILLIONS)</i>	39
NANOTECHNOLOGY-BASED MOTORS	39
MOLECULAR MOTORS	40
CARBON NANOTUBES	40
NATIONAL SCIENCE FOUNDATION-SPONSORED NANOMAGNETICS RESEARCH	40
CYCLOCONVERTERS	41
PRINCIPLE OF OPERATION	41
PATENTS	42
VENDORS	42
APPLICATIONS	42
MARKET SIZE	43
<i>TABLE 10 GLOBAL MARKET FOR CYCLOCONVERTER SYSTEMS, THROUGH 2021 (\$ MILLIONS)</i>	43
NEW MOTOR MATERIALS AND TECHNIQUES	43
METAMATERIALS	43
SIMULATION TOOLS	44
3-D PRINTING	44
COPPER AND COPPER-BASED MATERIALS	44
NEW INSULATING MATERIALS	45
SUPERCONDUCTING MATERIALS	45
MAGNETIC BEARINGS	46
<i>TABLE 11 FIFTY MOST RECENT U.S. PATENTS IN THE FIELD OF MAGNETIC MOTOR BEARINGS, NOV. 2013 THROUGH MARCH 2016</i>	46
POLYTETRAFLUOROETHYLENE IN MOTOR BEARINGS	48
SILICON CARBIDE MATERIALS	48
SOFT MAGNETIC COMPOSITE AND AMORPHOUS MAGNETIC MATERIALS	49
Principal Companies	49
General Electric	49
Mitsubishi Electric	49
Toyota	50
TRANSVERSE FLUX MOTORS	50
HYBRID CYLINDRICAL MOTORS	51
HIGH MEGAWATT DRIVE MATERIALS	51
SWITCHED RELUCTANCE MOTORS	52
APPLICATIONS	52
<i>TABLE 12 SELECTED U.S. PATENTS FOR SWITCHED RELUCTANCE TECHNOLOGY, FEB. 2012 TO MAY 2016</i>	53
SWITCHED RELUCTANCE MOTORS	54
MAJOR PRODUCERS	54
Software Motor Corp.	54
SDT Drive Technology	54
NIDEC Corp.	55
MARKET SIZE	55
<i>TABLE 13 PRINCIPAL GLOBAL PRODUCERS OF SWITCHED RELUCTANCE MOTORS</i>	55
SYNCHRONOUS MOTOR DRIVES	56
MAJOR PRODUCERS	56

TOPIC	PAGE NO.
ABB/BALDOR Synchronous Motor Innovation	56
QM Power Inc.	56
MARKET SIZE	57
<i>TABLE 14 GLOBAL MARKET FOR SYNCHRONOUS MOTORS, THROUGH 2021 (\$ MILLIONS)</i>	58
VARIABLE FREQUENCY DRIVES	58
STANDARDS	58
<i>TABLE 15 REVENUES OF TOP VENDORS OF VARIABLE SPEED DRIVE MOTORS AND CONTROLLERS (\$ MILLIONS)</i>	58
SUPPLIERS	59
TECHNICAL ISSUES ASSOCIATED WITH VFD CONTROLLERS	59
OTHER NEW MOTOR TECHNOLOGIES	60
ELECTROSTATIC FORCE VERSUS MAGNETISM AS A MOTOR DRIVER	60
C-Motive Technologies	60
SMART SYNCHRONOUS MOTORS	60
INNOVATIONS IN PERMANENT MAGNET MOTORS	61
MAGNETIC-BASED DRIVES	62
NEWER HYBRID ELECTRIC VEHICLE MOTORS	62
CHAPTER 6 MARKET BY MATERIALS AND DEVICES USED IN MOTORS	65
OVERVIEW	65
MOTOR DRIVER INTEGRATED CIRCUITS	65
<i>TABLE 16 GLOBAL MARKET FOR ADVANCED SEMICONDUCTORS FOR ELECTRIC MOTOR APPLICATIONS, THROUGH 2021 (\$ MILLIONS)</i>	65
<i>TABLE 17 GLOBAL MARKET FOR ADVANCED SEMICONDUCTORS FOR ELECTRIC MOTOR APPLICATIONS BY REGION, THROUGH 2021 (\$ MILLIONS)</i>	66
GALLIUM NITRIDE	66
<i>TABLE 18 RESEARCH SPENDING ON GALLIUM NITRIDE MOTOR APPLICATIONS BY TYPE, THROUGH 2021 (\$ MILLIONS)</i>	67
POWER SEMICONDUCTOR DEVICES USED IN MOTORS	67
APPLICATIONS	67
MAJOR PRODUCERS	68
DENSO and Toyota	68
Hitachi and Infineon	68
Vincotech	68
SELECTED PATENTS IN THE POWER SEMICONDUCTOR FIELD	69
POWER SEMICONDUCTORS IN THE AUTOMOTIVE AND ELECTRIC VEHICLE MOTOR MARKET	70
<i>TABLE 19 GLOBAL MARKET FOR ELECTRIC VEHICLE IGBTs, THROUGH 2021 (\$ MILLIONS)</i>	70
Major Producers	71
Infineon Technologies	71
ST Microelectronics	71
Freescale Semiconductor	71
NXP Semiconductor	71
Texas Instruments	71
MAJOR POWER ELECTRONICS SUPPLIERS	71
Artesyn	72
Astec	72

<b>TOPIC</b>	<b>PAGE NO.</b>
AVX	72
Bergquist Co.	72
Bosch Rexroth	72
Coilcraft	72
Delta Electronics	72
Fairchild Semiconductor	73
Infineon Technologies	73
International Rectifier	73
IXYS	73
Linear Technology	73
Maxim Integrated Products, Dallas Semiconductor	73
Micrel	74
Microsemi	74
Motorola Semiconductor Products Sector: Freescale Semiconductor	74
Motorola Semiconductor Products Sector: ON Semiconductor	74
Microchip Technology	74
National Semiconductor	74
Philips Semiconductors	74
Power Integrations	75
Power-One	75
Pulse	75
Rockwell Automation (ElectroCraft and Allen-Bradley)	75
STMicroelectronics	75
Supertex	75
SynQor	76
Texas Instruments	76
Toshiba	76
Vicor Corp.	76
Vishay Intertechnology (Siliconix)	76
<b>CHAPTER 7 PATENT ANALYSIS AND COMPANY PROFILES</b>	<b>78</b>
<b>OVERVIEW</b>	<b>78</b>
<b>SELECTED RECENT PATENTS</b>	<b>78</b>
<b>COMPANY PROFILES</b>	<b>83</b>
<i>TABLE 20 PRINCIPAL MANUFACTURING ACTIVITIES WITHIN NAICS CODE 335312: MOTOR AND GENERATOR MANUFACTURING</i>	<b>83</b>
ABB LTD.	<b>85</b>
ADVANCED MOTORS AND DRIVES	<b>85</b>
ACTOM (PTY) LTD.	<b>85</b>
ALLIED MOTION TECHNOLOGIES INC.	<b>86</b>
ALTRA INDUSTRIAL MOTION	<b>86</b>
AMETEK INC.	<b>86</b>
ARC SYSTEMS INC.	<b>87</b>
ASMO CO. LTD.	<b>87</b>
BALDOR ELECTRIC CO.	<b>87</b>
BAUER GEAR MOTOR	<b>88</b>
BROOK CROMPTON UK LTD.	<b>88</b>
BROSE FAHRZEUGTEILE GMBH & CO. KG	<b>89</b>

<b>TOPIC</b>	<b>PAGE NO.</b>
CROMPTON GREAVES LTD.	89
DANAHER MOTION	89
DENSO	90
FRANKLIN ELECTRIC CO. INC.	90
GENERAL ELECTRIC CO.	90
HITACHI LTD.	91
INCREMOTION ASSOCIATES INC.	91
HYOSUNG CORP.	91
JOHNSON ELECTRIC HOLDINGS LTD.	91
KIRLOSKAR ELECTRIC CO. LTD.	92
KLD ENERGY TECHNOLOGIES	92
LEESON ELECTRIC	92
MINEBEA CO. LTD.	93
MITSUMI ELECTRONICS CO. LTD.	93
MOOG ANIMATICS	93
NANYANG EXPLOSION PROTECTION GROUP CO. LTD.	93
NIDEC CORP.	94
ORIENTAL MOTOR	94
PANASONIC CORP.	94
REGAL BELOIT CORP.	95
ROBERT BOSCH GMBH	95
ROCKWELL AUTOMATION INC.	95
SANYO DENKI AMERICA INC.	95
SHINANO KENSHI CORP.	96
SIEMENS AG	96
SOFTWARE MOTOR CORP.	96
SOMFY GROUP	97
TECO-WESTINGHOUSE MOTOR CO.	97
TOSHIBA CORP.	97
TOSHIBA MITSUBISHI-ELECTRIC INDUSTRIAL SYSTEMS CORP.	98
WEG ELECTRIC CORP.	98
WOLONG HOLDING GROUP	98
ZHEJIANG WOLONG HOME APPLIANCE	99
ZHONGSHAN BROAD-OCEAN MOTOR CO. LTD.	99

**LIST OF TABLES**

<b>TABLE HEADING</b>	<b>PAGE NO.</b>
SUMMARY TABLE GLOBAL MARKET FOR ADVANCED COMPONENTS AND MATERIALS IN ELECTRIC MOTORS BY TYPE, THROUGH 2021 (\$ MILLIONS)	6
TABLE 1 SHARE OF ELECTRICITY CONSUMPTION BY MOTOR FUNCTION (%)	10
TABLE 2 ESTIMATED POPULATION OF MOTORS BY SIZE, 2016 (BILLION/MILLION/%)	14
TABLE 3 PRIVATE CORPORATE RESEARCH SPENDING ON ELECTRIC MOTORS AND SYSTEMS, THROUGH 2021 (\$ MILLIONS)	16
TABLE 4 GOVERNMENT-SPONSORED RESEARCH SPENDING ON ELECTRIC MOTORS AND SYSTEMS IN CANADA, THROUGH 2021 (\$ MILLIONS)	23
TABLE 5 R & D SPENDING ON MOTORS FOR ADVANCED TRANSPORTATION BY APPLICATION, THROUGH 2021 (\$ MILLIONS)	25
TABLE 6 U.S. PATENTS RELATED TO ELECTRIC VEHICLES, 2014 TO 2016	25
TABLE 7 GLOBAL SALES OF ELECTRIC VEHICLES BY TYPE, THROUGH 2021 (UNITS)	27
TABLE 8 GLOBAL MARKET FOR ELECTRIC AND HYBRID VEHICLE MOTORS BY ELECTRIC VEHICLE TYPE, THROUGH 2021 (\$ MILLIONS)	28
TABLE 9 GLOBAL MARKET FOR ADVANCED MOTOR CONTROLS BY TYPE, THROUGH 2021 (\$ MILLIONS)	39
TABLE 10 GLOBAL MARKET FOR CYCLOCONVERTER SYSTEMS, THROUGH 2021 (\$ MILLIONS)	43
TABLE 11 FIFTY MOST RECENT U.S. PATENTS IN THE FIELD OF MAGNETIC MOTOR BEARINGS, NOV. 2013 THROUGH MARCH 2016	46
TABLE 12 SELECTED U.S. PATENTS FOR SWITCHED RELUCTANCE TECHNOLOGY, FEB. 2012 TO MAY 2016	53
TABLE 13 PRINCIPAL GLOBAL PRODUCERS OF SWITCHED RELUCTANCE MOTORS	55
TABLE 14 GLOBAL MARKET FOR SYNCHRONOUS MOTORS, THROUGH 2021 (\$ MILLIONS)	58
TABLE 15 REVENUES OF TOP VENDORS OF VARIABLE SPEED DRIVE MOTORS AND CONTROLLERS (\$ MILLIONS)	58
TABLE 16 GLOBAL MARKET FOR ADVANCED SEMICONDUCTORS FOR ELECTRIC MOTOR APPLICATIONS, THROUGH 2021 (\$ MILLIONS)	65
TABLE 17 GLOBAL MARKET FOR ADVANCED SEMICONDUCTORS FOR ELECTRIC MOTOR APPLICATIONS BY REGION, THROUGH 2021 (\$ MILLIONS)	66
TABLE 18 RESEARCH SPENDING ON GALLIUM NITRIDE MOTOR APPLICATIONS BY TYPE, THROUGH 2021 (\$ MILLIONS)	67
TABLE 19 GLOBAL MARKET FOR ELECTRIC VEHICLE IGBTs, THROUGH 2021 (\$ MILLIONS)	70
TABLE 20 PRINCIPAL MANUFACTURING ACTIVITIES WITHIN NAICS CODE 335312: MOTOR AND GENERATOR MANUFACTURING	83



**LIST OF FIGURES**

<b>FIGURE TITLE</b>	<b>PAGE NO.</b>
SUMMARY FIGURE GLOBAL MARKET FOR ADVANCED COMPONENTS AND MATERIALS IN ELECTRIC MOTORS BY TYPE, 2015-2021 (\$ MILLIONS)	7