

**Technology Intelligence:  
Electric Traction Drive Motors**

**Prepared for the Department of Energy**

**Synthesis Partners, LLC**

Contract Number: DE-AD26-07NT43302

August 2009

11250 Roger Bacon Drive ~ Suite 2 ~ Reston, Virginia 20190 USA  
Tel 703 318 6511 ~ Fax 703 318 9553 ~ Email [info@synthesispartners.com](mailto:info@synthesispartners.com)  
[www.synthesispartners.com](http://www.synthesispartners.com)

## **Tasking**

Synthesis Partners was tasked by the Department of Energy (DOE) to undertake research to address the following specific questions regarding the US automotive DC and AC electric motor manufacturing capability.

1. Current state of the US and global industry, to include motor types, location and current inventory
2. Current state of the US industry
  - a. Existing Industry Roadmaps
3. As time permits, the pricing structure for motors being manufactured outside the US, with direct comparison to that of the US to include a description of price drivers affecting US industry competitiveness

## **Sources and Methods**

This research and analysis effort covered a wide range of secondary and primary sources in a short period of time. Table 1 below provides summary information concerning the sources searched during the March to July 2009 timeframe.

We analyzed many targeted secondary sources, including 60 market research reports, 44 companies, a number of trade or professional associations and financial or commodity news sites. Although this work identified a number of market research reports on electric motors, we found through a careful review that none of those we assessed as credible dealt with the traction drive motors used in hybrid or electric vehicles. Specifically, the reports on automotive electric motors covered all forms of motors used in automobiles, from power window and seat controllers to the drive motors used in the audio systems – but not electric traction drives. Some of the reports included general information on traction drive motors, but none provided the detailed current information or projections on costs or production that we were seeking for this study.

We assess that market research reports will appear in the near future to address a growing demand for current information on electric traction drive motors.

Primary research (i.e., telephone interviews and email exchanges) focused on the companies discovered that best represent the US electric motor manufacturing and related technology markets. A number of international manufacturers were found. However, we necessarily focused constrained collection and analysis efforts on those which manufacture motors in the U.S.

Table 1: Research Summary

Source	Number Researched	Percentage Relevant
Market Research Reports	60	0%
Companies	44	80%
Trade/Professional Associations	5	20%
Financial/Commodity Sites	6	67%
Companies Contacted	Negative or No Response	Positive Response
Enova Systems	X	
GE Global Research		X
Hitachi Automotive Products	X	
Raser		X
Remy International	X	
SatCon Applied Technology		X
UQM Technologies, Inc.		X

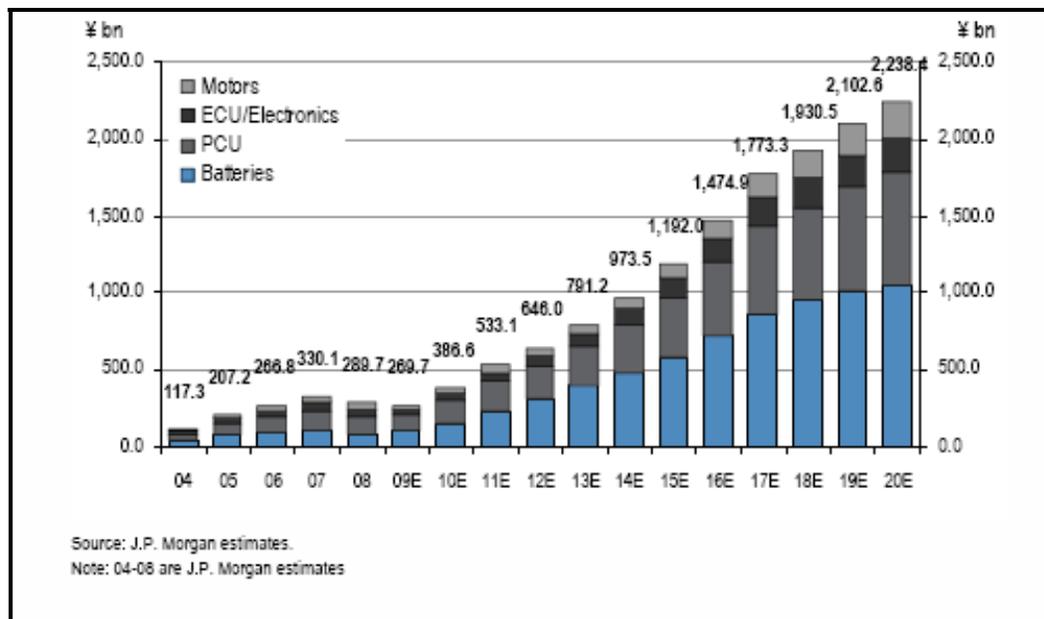
### 1. Current State of the Global Industry

The motors used in hybrid vehicles can be AC or DC powered. DC motors are, generally speaking, used in the more common gas-electric hybrids while PHEV's and EV's typically use AC motors. The AC motors may be induction motors which do not use permanent magnets or may be permanent magnet motors. There is no apparent rule-of-thumb when each type is used. One US manufacturer – Raser of Provo, UT – claims to exclusively produce AC induction motors that do not use permanent magnets. No other manufacturers contacted make this claim for their AC motors.

J.P. Morgan's primary analyst for the Japanese auto industry, including hybrid vehicles, Takaki Nakanishi, predicts the market for hybrid vehicles will experience rapid growth, with annual sales of 11.28 million hybrids by 2020. He estimates 19.5 percent of the new cars sold in the U.S. by 2020 will be hybrids, with HEVs accounting for 13.3 percent of global sales by that time. Synthesis obtained Mr. Nakanishi's full report from him and has obtained permission to provide it to DOE if desired.

Along with the growth in the hybrid market, Nakanishi also predicts the hybrid component market will increase by 298 percent from 2008 levels by 2015, and by 647 percent by 2020. The graph below shows his growth projections for the major components in hybrid vehicles.

Figure 1: Growth Projections in Hybrid Vehicle Components



As the table below indicates, the demand for the motors used in HEVs will grow, but not at the high rate expected for batteries or the highly specialized power control units (PCU). The growth rate for engine control units (ECU) is projected to be somewhat slower than that of electric motors. This is because some manufacturers are integrating the ECUs with other components.

Table 2: Outlook on Demand in HEV Market

Outlook on Demand in HEV Market (¥ billion)						
	CY07	CY08ENew	CY08EOld	CY13E	CY18E	CY20E
<b>Market Size</b>						
Secondary Battery	103.3	80.3	94.0	956.3	766.2	1054.1
LiB	0.8	1.0	1.0	768.3	610.6	937.6
Ni-MH	102.5	79.3	93.0	188.0	155.6	116.5
PCU	131.9	121.7	149.7	591.8	727.3	733.2
ECU	52.8	48.7	59.9	200.3	242.4	225.6
<b>Motor</b>	<b>42.2</b>	<b>38.9</b>	<b>47.9</b>	<b>182.1</b>	<b>201.9</b>	<b>225.6</b>
<b>Growth Rate from CY07</b>						
Secondary Battery		-22%	-9%	826%	642%	921%
LiB		25%	25%	95,939%	76,225%	117,099%
Ni-MH		-23%	-9%	83%	52%	14%
PCU		-8%	14%	349%	451%	456%
ECU		-8%	14%	280%	360%	328%
<b>Motor</b>		<b>-8%</b>	<b>14%</b>	<b>331%</b>	<b>378%</b>	<b>435%</b>

Source: J.P. Morgan Forecasts; CY07 and CY08 data are J.P. Morgan Estimates (22 May 2009)

While there are many companies around the world that manufacture electric motors, there are relatively few companies which manufacture the motors used for electric or hybrid vehicle traction drives. Appendix A contains a list of companies that manufacture motors used in various hybrid vehicle applications.

In terms of advanced R&D, Synthesis notes one non-US company in particular – the start-up Chorus Motors plc of Gibraltar – which appears to offer promise. It is developing motor designs that eliminate

permanent magnets and still delivers high performance. Their Chorus Meshcon motor uses “concentrated, high phase order windings which allows the beneficial use of harmonics” to produce higher torque than standard AC induction motors. One application using their motors is the Wheeltug, in which the motor is installed in the nose wheel of an aircraft and used to taxi the aircraft without the aircraft’s engines. The system is currently being developed for Delta, which will install it on their 737 aircraft. Chorus does not build motors but is looking for licensees for the technology in the automotive industry. Synthesis assesses that this technology could be worth a careful look by US automotive customers.

Automobile manufacturers use electric motors from various manufacturers for their production of hybrid and electric vehicles. The Table below summarizes where automotive manufacturers source their motors. Note that there are no US sources. Of course, these motors are assembled from parts sourced from yet other companies. While it may be useful to know where each of these electric traction drive motor manufacturers obtain key components (especially those of particularly high value, e.g., batteries, the PCUs and ECUs), this would require a detailed end-to-end supply chain analysis. This would likely be a challenging assignment, as this data is considered highly proprietary.

Table 3: Global Automotive Motor Suppliers

Motor Supplier	Where Manufactured	Automotive User	Reference
Aisin	Japan	Toyota	<a href="http://wardsautoworld.com/ar/auto_hev_supply_chain/">http://wardsautoworld.com/ar/auto_hev_supply_chain/</a>
		Ford	<a href="http://www.allbusiness.com/transportation/motor-vehicle-parts-manufacturing/784380-1.html">http://www.allbusiness.com/transportation/motor-vehicle-parts-manufacturing/784380-1.html</a>
Bosch	Europe	VW	<a href="http://www.motorauthority.com/bosch-ready-to-sell-diesel-hybrid-tech.html">http://www.motorauthority.com/bosch-ready-to-sell-diesel-hybrid-tech.html</a>
		PSA Peugeot Citroën	<a href="http://www.autonews.com/article/20090309/ANA03/903090301">http://www.autonews.com/article/20090309/ANA03/903090301</a> (requires subscription) <a href="http://www.hybriddieselectric.com/psa-peugeot-citroen-and-bosch-partner-up-for-new-diesel-hybrids/">http://www.hybriddieselectric.com/psa-peugeot-citroen-and-bosch-partner-up-for-new-diesel-hybrids/</a>
Hitachi	Japan (possibly in U.S. at Hitachi facility)	Nissan	<a href="http://wardsautoworld.com/ar/auto_hev_supply_chain/">http://wardsautoworld.com/ar/auto_hev_supply_chain/</a>
		Toyota	JP Morgan Global Environmental Series Volume 3
		GM	Telephone interview with Jim Spellman, Raser Technology
Hyundai	Korea	Hyundai	<a href="http://www.mixedpower.com/phev/hyundai-to-build-hybrid-plug-in-for-2012/">http://www.mixedpower.com/phev/hyundai-to-build-hybrid-plug-in-for-2012/</a>
Keihin Corp.	Japan	Honda	<a href="http://wardsautoworld.com/ar/auto_hev_supply_chain/">http://wardsautoworld.com/ar/auto_hev_supply_chain/</a>
Meidensah	Japan	Mitsubishi	JP Morgan Global Environmental Series Volume 3
Remy International	Mexico	GM	<a href="http://www.remyinc.com/hybrid/hybrid.htm">http://www.remyinc.com/hybrid/hybrid.htm</a> Telephone interview with Jim Spellman, Raser Technology
Tesla	Taiwan	Tesla	<a href="http://www.forbes.com/2007/03/18/tesla-electric-car-tech-cz_ec_0319valleyletter.html?partner=rss">http://www.forbes.com/2007/03/18/tesla-electric-car-tech-cz_ec_0319valleyletter.html?partner=rss</a>
Toshiba	Japan	Ford	<a href="http://car-reviews.automobile.com/news/toshiba-to-produce-electric-motors-for-ford-hybrids/296/">http://car-reviews.automobile.com/news/toshiba-to-produce-electric-motors-for-ford-hybrids/296/</a>
		VW	JP Morgan Global Environmental Series Volume 3
ZF	Europe	Daimler-Benz	<a href="http://www.autobloggreen.com/2008/05/07/german-transmission-builder-zf-producing-hybrid-motors-for-merce/">http://www.autobloggreen.com/2008/05/07/german-transmission-builder-zf-producing-hybrid-motors-for-merce/</a>
		BMW	<a href="http://www.autoweek.com/apps/pbcs.dll/article?AID=/20080507/FREE/615460265/1023/THISWEEKSISSEUE">http://www.autoweek.com/apps/pbcs.dll/article?AID=/20080507/FREE/615460265/1023/THISWEEKSISSEUE</a>  <a href="http://www.autospectator.com/cars/hybrid-technology/0040048-zf-inaugurates-new-production-location-hybrid-drives">http://www.autospectator.com/cars/hybrid-technology/0040048-zf-inaugurates-new-production-location-hybrid-drives</a>

Source: Synthesis Partners, LLC (2009)

Our attempts to contact all of the major motor manufacturers in the above table led to the discovery that their inventory information is considered proprietary or is not available at this time. Based on this experience we have considered the constraints on data collection in this field and assess that there are a number of other collection approaches which could be pursued to gather this information, including:

- Attendance at seminars and conferences where industry representatives speak of trends, new technologies and plans for the future. Table 4 below lists a representative sample of such conferences.

*Table 4: Upcoming Hybrid Vehicle Conferences*

<b>Title</b>	<b>Sponsor</b>	<b>Dates</b>	<b>Location</b>
The 5th IEEE Vehicle Power and Propulsion Conference	IEEE	September 7-11, 2009	Dearborn, Michigan
Hybrid Vehicles Technologies Seminar: Understanding the Issues Critical to HEV and PHEV	SAE	October 12-13, 2009	Shanghai, China
Fundamentals of Hybrid Vehicles	SAE	October 26-28, 2009	Troy, Michigan
SAE 2010 Hybrid Vehicle Technologies Symposium	SAE	February 10-11, 2010	San Diego, California

- Access a subset of motor suppliers via US automotive OEMs which participate in the DOE Automotive Task Force.
- A DOE-sponsored roundtable where representatives from the above companies are invited to discuss their plans and learn about DOE programs. Proprietary data could be shared in break-out sessions with DOE.

## **2. Current State of the US Industry**

Research revealed six companies in the US which state that they are involved in producing motors for hybrid vehicles (including buses and large trucks), or in hybrid motor R&D. One (Hitachi Automotive Products) is a wholly-owned subsidiary of a Japanese company and another (Remy) manufactures motors in Mexico. Two of the six are involved primarily in research into hybrid motor technology, while four manufacture motors for various hybrid applications. The following provides a summary. Appendix A contains more detailed information on US and international companies which manufacture these motors.

### R&D Companies in the US

GE Global Research  
 1 Research Circle  
 Niskayuna, NY 12309  
 URL: [http://www.ge.com/research/grc\\_7\\_1\\_30.html](http://www.ge.com/research/grc_7_1_30.html)  
 POC: Todd Alhart  
 Email: [alhart@research.ge.com](mailto:alhart@research.ge.com)  
 Phone: 518-387-7914  
 Notes: Conducting research into advanced hybrid drivetrain motors for a variety of vehicles.

Raser  
 5152 North Edgewood Drive  
 Provo, Utah 84604  
<http://www.rasertech.com/category/motors-and-drives/motors>  
 POC: Jim Spellman  
 Email: [jim.spellman@rasertech.com](mailto:jim.spellman@rasertech.com)  
 Phone: 1-801-765-1200  
 Notes: Research and development of AC induction motors for traction drives and other hybrid applications "without PM materials". Built prototype PHEV HUMMER H3 to showcase technology; looking for companies to license technology.  
<http://www.rasertech.com/media/videos/the-electric-h3>.

## Manufacturers in the US

Hitachi Automotive Products (USA), Inc.  
OEM Manufacturing and Corporate Office  
955 Warwick Road  
P.O. Box 510  
Harrodsburg, KY 40330  
URL: <http://www.hitachi-hap.com/products/Motors/index.html>  
POC: Doug Bowling  
Email: [doug.bowling@hap.com](mailto:doug.bowling@hap.com)  
Phone: (859) 734-9451 x 6087  
Notes: Produces HEV traction motors, HEV starter/generators, HEV electric oil pumps for CVTs, motor/inverter for small EVs. Wholly-owned subsidiary of Hitachi.

Remy International  
World Headquarters & U.S. Technical Center  
600 Corporation Drive  
Pendleton, IN 46064  
URL: <http://www.remyinc.com/hybrid/hybrid.htm>  
POC: Kent Jones  
Email: [kent.jones@remyinc.com](mailto:kent.jones@remyinc.com)  
Phone: (765) 778-6499, (800)372-3555  
Note: Manufactures and distributes hybrid motor modules and components for start-stop BAS and hybrid electric transmissions for GM vehicles. Motors for GM hybrid SUVs and light trucks are made in Mexico; motors for BAS vehicles are purchased from Hitachi.

SatCon Applied Technology  
27 Drydock Avenue  
Boston, MA  
URL: <http://www.satcon.com/apptech/hev/dcservo.php>  
POC: Denny Mahoney  
Email: [dennis.mahoney@satcon.com](mailto:dennis.mahoney@satcon.com)  
Phone: 617-897-2448  
Note: Produces high-voltage DC servo motor and other HEV components. Web site didn't specify if they build traction drive motors.

UQM Technologies, Inc.  
7501 Miller Drive  
PO Box 439  
Frederick, Colorado 80530  
URL: <http://www.uqm.com/index.php>  
POC: Jon F. Lutz  
Email: [jlutz@uqm.com](mailto:jlutz@uqm.com)  
Phone: 303-278-2002  
Note: Produces permanent-magnet AC and DC electric motors for hybrid-electric vehicles and EVs; output ranges from 67-200 HP; power electronics for hybrids and EVs; motors for aerospace use; and actuators for RVs. The recently announced Coda electric car (<http://www.autoblog.com/2009/06/03/miles-ev-launches-coda-automotive-for-full-speed-electric-sedan/>) is slated to use UQM motors.

## No Surplus Capacity

According to UQM's Jon Lutz there is presently no surplus production capacity. Motors are designed for specific cars and production capacity is scaled to projected vehicle sales.

A number of academic institutions are involved in hybrid vehicle research as a part of a larger vehicle or transportation research program. However, they are focused on a wide range of policy issues and do not – with one exception noted below – publicly demonstrate any expertise in the development of electric traction drives.

Synthesis identified one academic program aimed specifically at hybrid vehicle research and development. It is the Hybrid and Plug-in Hybrid Electric Vehicle Research program in the Power Electronics and Motor Drives Laboratory at the Illinois Institute of Technology (<http://hybrid.iit.edu/index.php>). Their research appears to be centered more on motor controls and other aspects of hybrid technology than with the actual design of the motor. The program is in the process of setting up an Industry Multi-university Consortium on Advanced Automotive Systems (IMCAAS), through which they are hoping to facilitate “international collaboration between academic and research institutions, automotive industry, non-profit organizations, and government agencies/laboratories.”

## Industry Roadmaps

Extensive collection efforts revealed no industry roadmaps for or by any of the manufacturers or trade associations discussed in this report. This finding reflects the lack of coverage of this topic in the secondary literature, including the dearth of technical data in market research reports. Synthesis expects that, as attention and funding levels increase, industry roadmaps are likely to be developed.

### **3. Pricing Structure and Price Drivers Affecting US Industry Competitiveness**

#### Traction Drive Motors Present Unique Manufacturing Challenges

It is notable that sources with varying perspectives on the apparent competitiveness of US-based motor manufacturing had similar views on the challenges which face the large-scale production of traction drive electric motors, irrespective of location.

According to Jim Spellman of Raser Technologies, industrial motor manufacturers typically produce large motors and do not have expertise in manufacturing units as small as a hybrid motor. On the other hand, companies that manufacture the smaller motors used in a variety of automotive systems are not well-versed in building something as large as a hybrid vehicle motor. There seems to be a no-man's land in the middle that only a few companies are willing to operate in. There appear to be a number of reasons for this, including:

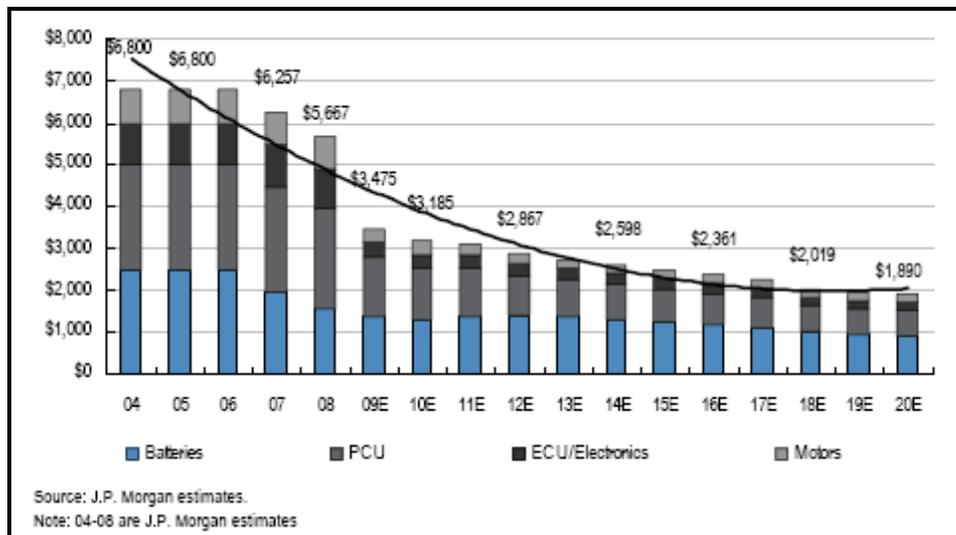
- The motors used for traction drives typically are not commodities. While industrial motors come in standard sizes and outputs and are essentially interchangeable, hybrid motors are designed specifically for a particular vehicle. Hybrid motors manufacturing volumes run in the neighborhood of 10,000 – 20,000 per year, while in the industrial motor industry, it would take production of “a million or more per year to be considered a commodity,” according to Mr. Spellman.
- A higher level of quality control and testing is required by the automotive industry. Based on his experience working with GM's dual-mode hybrid program, Mr. Spellman stated that it would take a “significant engineering effort” by a manufacturer to set up testing to qualify motors for automotive applications.

- The equipment used to manufacture motors for HEVs is different from that used to manufacture motors for general industrial purposes, according to Mr. Lutz. Therefore, manufacturers cannot use the standard equipment and lamination designs used for industrial-grade motors. Mr. Lutz stated it would take new investments for industrial motor manufacturers to make a changeover to manufacture automotive traction drive motors.
- The demands placed on HEV motors – lightweight, small, rugged, and high efficiency operations across a wide range of environmental conditions – are considerable and different than those placed on industrial motors.

### Cost Summary and Drivers

As with most any other technology, the cost of producing hybrid systems will drop as production quantities increase. J.P. Morgan predicts overall hybrid production costs per vehicle will drop by 66 percent from 2008 levels by 2020.

Figure 2: Hybrid Production Costs per Vehicle



The production cost of the electric motor component is currently approximately 13.8 percent of the cost of the hybrid system. By 2020, J.P. Morgan estimates the motor will account for only about 8.75 percent of the cost.

While industry associations often characterize cost and price points and trends, contact with the Small Motor and Motion Association (SMMA) and the National Electrical Manufacturers Association revealed no such data or planned initiatives to collect it. Other collection efforts concerning the pricing structure of hybrid motors resulted in no information.

### Supply Constraints

The primary raw materials used for electric motor manufacturing are iron, aluminum, copper and the rare earth metals used for the magnets. Of these, only the rare earth metals face any known supply constraints. We assess that the non-rare earth metals should continue to meet market demands, given current production and consumption levels.

When asked about supply constraints or raw material choke points in the foreseeable future, UQM’s Vice President of Technology, Jon Lutz, noted that he saw none other than “normal market fluctuations.” He also stated that they were having no problems with the supply of neodymium magnets used in their

motors, nor did he foresee any for the future. UQM gets their magnets from “five active suppliers, which are located in China, Japan, and the US.” However, Lutz declined to name the suppliers or where the magnets are manufactured.

### US Competitiveness

Enova Systems builds hybrid drive systems for a variety of hybrid vehicle applications and is partnering with Hyundai to develop hybrid-electric vehicles. When asked about the source of the electric motors they use, Enova Financial Reporting and Compliance Manager Gilbert Hernandez reported they use “other” (non-U.S.) sources due to the cost of US-made motors. He did not specify the locations of their sources.

In contrast to Mr. Hernandez’ assertion that they use foreign-made motors because of lower cost, UQM’s Jon Lutz states that they are competitive “for the volumes [they’re] producing” and have “about fifteen different automakers” (some are startup companies) interested in their motors. However, their current production is in the range of “hundreds per year” and they cannot “produce in a volume that would be competitive with large companies that produce 50,000 motors per year” with their current production facilities. Lutz admitted there is a “deficiency in supply [of motors]” due to their limited production mode but stated if they expanded their capacity to meet an increased demand they could still be competitive.

On the other hand, Raser’s Mr. Spellman expressed concerns over the U.S. industry’s competitiveness. He stated that from both a labor and material standpoint the US manufacturers are at a disadvantage, and that the magnet supply is “only going to get worse.” When asked about a cost breakdown for labor vs. materials vs. development costs, he replied there was no industry average that he knew of and that this type of information on specific companies would be proprietary.

The lack of consensus on this issue is not surprising, given the different perspectives of producers and consumers. The apparent lack of industry cost benchmark or averages to compare relative costs makes it even more difficult to reach a common baseline. However, it is safe to assert that labor, material, and regulatory costs are lower overseas than the US, excepting Western Europe.

## Appendix A Hybrid Motor Manufacturers

### US

Name	URL	Contact	Title	Address	Phone	Email	Product(s)	Manufacturing Capacity
Enova Systems	<a href="http://www.enovasytems.com/index.cfm?section=Products&amp;linkID=1">http://www.enovasytems.com/index.cfm?section=Products&amp;linkID=1</a>	Gilbert Hernandez		1560 West 190th St. Torrance, CA (USA) 90501	310.527.2800	<a href="mailto:ghernandez@enovasystems.com">ghernandez@enovasystems.com</a>	Electric and HEV drive systems and components	Manufactures hybrid drive system using motors from "various suppliers"
GE Global Research	<a href="http://www.ge.com/research/grc_7_1_3_0.html">http://www.ge.com/research/grc_7_1_3_0.html</a>	Todd Alhart	Communications & Public Relations	1 Research Circle Niskayuna, NY 12309	518-387-7914	<a href="mailto:alhart@research.ge.com">alhart@research.ge.com</a>	Research into advanced hybrid drivetrain motors; produces motors for golf cars, neighborhood vehicles, buses, vans, locomotives, mine haul trucks	Declined to discuss manufacturing capacity
Hitachi Automotive Products (USA), Inc.	<a href="http://www.hitachi-hap.com/products/Motors/index.html">http://www.hitachi-hap.com/products/Motors/index.html</a>	Doug Bowling	VP Operations	OEM Manufacturing and Corporate Office 955 Warwick Road P.O. Box 510 Harrodsburg, KY 40330	(859) 734-9451 x 6087	<a href="mailto:doug.bowling@hap.com">doug.bowling@hap.com</a>	HEV traction motor, HEV starter/generator, HEV electric oil pump for CVT, motor/inverter for small EV	Did not respond to request for information
Raser	<a href="http://www.rasertech.com/motors-drives">http://www.rasertech.com/motors-drives</a>	Thomas Kaporch		5152 North Edgewood Drive Provo, Utah 84604	1-801-765-1200 x 218	<a href="mailto:Thomas.Kaporch@rasertech.com">Thomas.Kaporch@rasertech.com</a>	AC induction motors for traction drives and other hybrid applications "without PM materials"	Builds prototypes to license to other manufacturers; "too much capital required" to manufacture automotive motors
Remy International	<a href="http://www.remyinc.com/hybrid/hybrid.htm">http://www.remyinc.com/hybrid/hybrid.htm</a>	Kent Jones		World Headquarters & U.S. Technical Center 600 Corporation Drive Pendleton, IN 46064	(765) 778-6499, (800)372-3555	<a href="mailto:kent.jones@remyinc.com">kent.jones@remyinc.com</a>	Hybrid motor modules. Start-stop BAS, hybrid electric transmissions	Did not respond to request for information
SatCon Applied Technology	<a href="http://www.satcon.com/apptech/hev/dcservo.php">http://www.satcon.com/apptech/hev/dcservo.php</a>	Denny Mahoney		27 Drydock Avenue Boston, MA	617-897-2448	<a href="mailto:dennis.mahoney@satcon.com">dennis.mahoney@satcon.com</a>	High-voltage DC servo motor	Builds only prototypes; could manufacture "small quantities"
UQM Technologies, Inc.	<a href="http://www.uqm.com/index.php">http://www.uqm.com/index.php</a>	Jon F. Lutz	VP, Technology	7501 Miller Drive PO Box 439 Frederick, Colorado 80530	303-278-2002	<a href="mailto:jlutz@uqm.com">jlutz@uqm.com</a>	DC electric motors for hybrid-electric vehicles and EVs; output ranges from 67-200 HP; power electronics for hybrids and EVs	Produce "hundreds per year." Could expand production capacity to undisclosed level with undisclosed capital investment

## International

Name	URL	Contact	Title	Address	Phone	Email	Product(s)
Aisin	<a href="http://www.aisin.com/product/automotive/drivetrain/ot.html">http://www.aisin.com/product/automotive/drivetrain/ot.html</a>			2-1, Asahi-machi, Kariya, Aichi, 448-8650 JAPAN	+81-566-24-8441		2-motor hybrid system; traction drive motors
BRUSA Elektronik AG	<a href="http://www.brusa.biz/products/e_motoren108.htm">http://www.brusa.biz/products/e_motoren108.htm</a>			Neudorf 14 Postfach 55 CH - 9466 Sennwald Switzerland	+41 (0)81 758 19 00	info@brusa.biz	Induction motors, transaxles
Chorus Meshcon	<a href="http://www.choruscars.com/">http://www.choruscars.com/</a>	Chris Bourne	Public Relations	Box 575, Suite 3-G, Eurolife Building 1 Corral Road Gibraltar	+350 2005 9995	<a href="mailto:pr@chorusmotors.gi">pr@chorusmotors.gi</a>	Motor design to eliminate PMs but deliver performance of a PM motor
Continental	<a href="http://www.conti-online.com/generator/www/de/en/continental/automotive/the_mes/passenger_cars/powertrain/hybrid/hybrid_en;tabNr=3.html">http://www.conti-online.com/generator/www/de/en/continental/automotive/the_mes/passenger_cars/powertrain/hybrid/hybrid_en;tabNr=3.html</a>	Dagmar Weiner	Vice President Automotive Group Trade Media Relations Vice President Chassis & Safety Communications	Guerickestraße 7 60488 Frankfurt am Main Germany	+49 69 7603-6000	dagmar.weiner@continental-corporation.com	Electric motors fully integrated in the powertrain and hybrid transmissions
PML	<a href="http://www.pmlflightlink.com/about.html">http://www.pmlflightlink.com/about.html</a>			PML Flightlink (Electric Motor Works Ltd.) Newman Lane Alton Hampshire GU34 2QW	+44 (0) 1420 594140	Web form at <a href="http://www.pmlflightlink.com/enquiries.html">http://www.pmlflightlink.com/enquiries.html</a>	Electric motors and drive systems
Robert Bosch GmbH	<a href="http://csr.bosch.com/content/language2/downloads/Fehrenbach_BPK_07_en.pdf">http://csr.bosch.com/content/language2/downloads/Fehrenbach_BPK_07_en.pdf</a> (see page 11)	Bernhard Schwager		Dept. C/ PS P.O. Box 10 60 50 D-70049 Stuttgart Germany			Motors for gas and diesel hybrid systems
Siemens	<a href="http://www.automation.siemens.com/ld/bahnen/html_76/elfa/elfa-08.html">http://www.automation.siemens.com/ld/bahnen/html_76/elfa/elfa-08.html</a>			Siemens Aktiengesellschaft Wittelsbacherplatz 2 80333 Munich Germany	+49 89 636-00	<a href="mailto:contact@siemens.com">contact@siemens.com</a>	Traction drive motors
Toshiba	<a href="http://www.toshiba.co.jp/worldwide/about/company/as_ns.htm">http://www.toshiba.co.jp/worldwide/about/company/as_ns.htm</a>	Jay Bugbee			800.231.1412 x3665	<a href="mailto:transportation@tic.toshiba.com">transportation@tic.toshiba.com</a> <a href="mailto:jay.bugbee@tic.toshiba.com">jay.bugbee@tic.toshiba.com</a>	Traction motors, motor/generator for HEV
VDO	<a href="http://www.vdo.com/-+archive+/-powertrain/hybrid/#">http://www.vdo.com/-+archive+/-powertrain/hybrid/#</a>	Dagmar Weiner	Vice President Automotive Group Trade Media Relations Vice President Chassis & Safety Communications	Guerickestraße 7 60488 Frankfurt am Main Germany	+49 69 7603-6000	dagmar.weiner@continental-corporation.com	

ZF	<a href="http://www.zf.com/corporate/en/homepage/homepage.html">http://www.zf.com/corporate/en/homepage/homepage.html</a>	Holger Kirsch	Trade Press Passenger Cars		+49 7541 77-2488	holger.kirsch@zf.com	Traction drives, integrated drive motors/transmissions,
----	---	---------------	-------------------------------	--	------------------	----------------------	---

## Appendix B

### Professional/Trade Associations

Small Motor and Motion Association (SMMA)  
Post Office Box P182  
S. Dartmouth, Massachusetts 02748  
508-979-5935  
[info@smma.org](mailto:info@smma.org)  
<http://www.smma.org/>

National Electrical Manufacturers Association  
NEMA Premium Motors  
1300 North 17th Street  
Suite 1752  
Rosslyn, Virginia 22209  
703-841-3200  
<http://www.nema.org/gov/energy/efficiency/premium/>

Copper Development Association  
260 Madison Avenue  
New York, NY 10016  
212-251-7200  
[questions@cda.copper.org](mailto:questions@cda.copper.org)  
<http://www.copper.org/homepage.html>

Electric Drive Transportation Association  
1101 Vermont Avenue, NW  
Suite 401  
Washington, DC 20005  
202-408-0774  
[info@electricdrive.org](mailto:info@electricdrive.org)  
<http://www.electricdrive.org/>

## Appendix C

### Bibliography

Abuelsamid, Sam: “German Transmission Builder ZF Producing Hybrid Motors for Mercedes,” <http://www.autobloggreen.com/2008/05/07/german-transmission-builder-zf-producing-hybrid-motors-for-merce/>

Corcoran, Elizabeth: “Can Silicon Valley Reinvent The Car?” [http://www.forbes.com/2007/03/18/tesla-electric-car-tech-cz\\_ec\\_0319valleyletter.html?partner=rss](http://www.forbes.com/2007/03/18/tesla-electric-car-tech-cz_ec_0319valleyletter.html?partner=rss)

D’Orazio, Mike: “ZF to Build Electric Motors for Mercedes Hybrid,” <http://www.autoweek.com/apps/pbcs.dll/article?AID=/20080507/FREE/615460265/1023/THISWEEKSISSUE>

“Ford to Buy Hybrid Engine Parts From Toyota Affiliate,” <http://www.allbusiness.com/transportation/motor-vehicle-parts-manufacturing/784380-1.html>

Hernandez, Gilbert: Enova Systems (telephone interview)

“Hyundai to Build Hybrid Plug-In for 2012,” <http://www.mixedpower.com/phev/hyundai-to-build-hybrid-plug-in-for-2012/>

Kauffmann, Alex: “VW Will Build Its Own Hybrid Assemblies, Not Outsource Them,” <http://www.motorauthority.com/vw-will-build-its-own-hybrid-assemblies-not-outsource-them.html>

Lutz, Jon: UQM Technologies, Inc. (telephone interview)

Martinez, James: “Bosch Ready to Sell Diesel-Hybrid Tech,” <http://www.motorauthority.com/bosch-ready-to-sell-diesel-hybrid-tech.html>

Mayer, Bettina: “Expecting Explosive Growth, Bosch Beefs Up Hybrid Team,” <http://www.autonews.com/article/20090309/ANA03/903090301>

Mayer, Bettina: “Bosch Strengthens Hybrid Team,” <http://www.autonews.com/apps/pbcs.dll/article?AID=/20090302/ANE03/903019986/1186>

Nakanashi, Takaki: “Global Environmental Series Volume 3: HEV’s Potential Reconsidered in Economic Crisis,” May 22, 2009

“PSA Peugeot Citroën and Bosch Partner Up for New Diesel Hybrids,” <http://www.hybriddieselectric.com/psa-peugeot-citroen-and-bosch-partner-up-for-new-diesel-hybrids/>

Schreffler, Rodger: “HEV Supply Chain Vast,” [http://wardsautoworld.com/ar/auto\\_hev\\_supply\\_chain/](http://wardsautoworld.com/ar/auto_hev_supply_chain/)

Spellman, Jim: Raser Technologies (telephone interview)

“Toshiba to Produce Electric Motors for Ford Hybrids,” <http://car-reviews.automobile.com/news/toshiba-to-produce-electric-motors-for-ford-hybrids/296/>

“ZF Inaugurates New Production Location for Hybrid Drives,”

<http://www.autospectator.com/cars/hybrid-technology/0040048-zf-inaugurates-new-production-location-hybrid-drives>