Sustainable mobility is set to reshape the automotive industry over the next few years. The framework for engine technologies has changed fundamentally as volatile oil prices, strict CO₂ regulations and increasing consumer demand for “green” vehicles have emerged as important issues. The global automotive industry faces a pivotal question: Which technology will become the powertrain of the future?

As the automotive industry navigates the economic downturn, automakers are searching for secrets to long-term success. Determining the powertrain of the future will be critical, but there are many unknowns.¹ When will alternative powertrains achieve significant market share? Which alternative technologies will become the powertrain of the future? What are the advantages and risks of each technology? How will a long-term global recession affect alternative powertrain development?

To help answer these questions and others, a recent A.T. Kearney study examines the current and future landscape to 2020 for alternative powertrain technologies and outlines the implications for automotive manufacturers and suppliers (see sidebar: About the Study).

The Powertrain Landscape

There are several major alternative technologies with the potential to become the powertrain of the future. One possibility is reengineered conventional combustion engine technology. This engine uses various components to reduce fuel consumption, such as start-stop systems called micro-hybrids, electric supports known as mild-hybrids, and natural-gas engines. Other candidates include full hybrids, with an electric-only drive mode, and powertrains with electric primary engines, including plug-in hybrids. These electric vehicles use generators to increase range. The other full-electric options are pure-electric and fuel-cell vehicles.

Four major factors are influencing the growth of these alternative powertrain technologies:

Consumer demand. Consumers are demanding alternative powertrains. In fact, if market share was based on consumer demand alone, green technologies would likely hold 60 to 80 percent by 2020. Typically, drivers consider total costs, functionality, comfort

¹ Powertrain is the total package of engine, transmission and exhaust gas aftertreatment.
In terms of costs, alternative engines will soon be competitive with conventional engines (see figure 1). For example, our study reveals that a plug-in hybrid in Europe in 2020 would have an average total-cost advantage of $140 to $280 per year over a diesel vehicle, and in operating costs alone, the owner would save up to $700 annually. The advantage will derive mainly from decreasing unit prices, such as lithium-ion batteries, which will cost about 40 percent less than they do today. High gas prices are spurring alternative engine proliferation even in China, where the government will soon discontinue fuel subsidies. Conversely, if oil prices stay below $70 per barrel long-term, demand for alternative engines will decrease substantially.

Regardless of future oil prices, fuel cells won’t be a strong competitor in the powertrain race for the foreseeable future. The price will be so unattractive that buyers will stay away, at least in the passenger-car sector.

About the Study

A.T. Kearney developed, researched and analyzed the 2008-2009 Powertrain of the Future study for manufacturers and suppliers in the global automotive industry. The research team employed a comprehensive analytical model to analyze nearly 100 variables that dominate the industry. The findings were validated by global automotive experts in Europe, Asia Pacific and the Americas. The result is an across-the-board look at the powertrain landscape in 2020 within the context of three potential scenarios:

The moderate change scenario simulates powertrain development by 2020 if oil prices are hovering at about $128 per barrel, state-of-the-art battery costs are relatively reasonable, global CO2 and other emission-control legislations are strict and average time-to-market considerations are reasonably favorable. This scenario augurs well for marketplace acceptance of “green” or alternative-engine technology.

The slow change scenario considers the decidedly negative impact of a long-term global recession, with oil prices, for example, stagnating at about $70 per barrel. These circumstances would slow development of alternative-engine technologies to a virtual standstill.

At the other end of the spectrum is the enforced change scenario, in which oil prices skyrocket, accelerating the development of alternative-engine technologies.

FIGURE 1: Alternative engines will be cost competitive by 2020

Total car owner costs, 2020 (US$ thousands)

<table>
<thead>
<tr>
<th>Engine Type</th>
<th>Depreciation</th>
<th>Fuel costs, including tax</th>
<th>Vehicle tax</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>9.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diesel</td>
<td>9.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CNG</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LPG</td>
<td>9.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gasoline hybrid</td>
<td>10.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diesel hybrid</td>
<td>10.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plug-in hybrid</td>
<td>9.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric</td>
<td></td>
<td></td>
<td>17.2</td>
</tr>
<tr>
<td>Fuel cells</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: Four-year ownership period; 15,000 km annual mileage; 80kW segment; for study scenario “Europe, moderate drive for change.” CNG is compressed natural gas; LPG is liquefied petroleum gas.

Source: A.T. Kearney analysis
Of course, the situation differs for each technology (see figure 2). European manufacturers are the leaders when it comes to natural-gas vehicles, while Japanese and American manufacturers lead the race for hybrids, already having some in their portfolios. This year, European manufacturers will launch their first hybrids, but they will likely offer just a few models before 2011. While manufacturers in some nations are only in the planning stages of offering electric versions of existing models, Japanese and Chinese manufacturers are already bringing plug-in hybrids and full-electric vehicles to market. However, a longer-term recession is likely to discourage the bold, forward-looking product decisions that would accelerate the move to alternative powertrains.

Companies that are moving forward to develop alternative technologies are those that will profit substantially from the shift. Electric car makers BYD, Tesla and Reva have already realized the potential of electric vehicles and are gaining a foothold in the market. The vehicles they have unveiled, and the partnerships they have forged with established OEMs, vouch for the market potential.

Technological maturity and infrastructure. Technological maturity and infrastructure are especially important for manufacturers of electric and fuel-cell vehicles.

The maturation of battery technology is particularly crucial. Innovations in active chemical components and control electronics will significantly improve range, durability and weight of lithium-ion batteries. By 2020 these batteries will allow travel from 200 to 300 kilometers over the battery’s life cycle, depending on the battery’s size and the vehicle. Range-extender generators for plug-in hybrids will increase this range to that of conventional engines. In contrast, fuel cells have several technical problems that seem insurmountable, such as storing hydrogen and operating in cold temperatures.

Natural-gas engines, plug-in hybrids, electric and fuel-cell vehicles all require new or enlarged infrastructures. Natural-gas infrastructure expansion is off to a good start. In Europe, compressed natural gas is already available at 4 to 8 percent of all gas stations and liquefied petroleum gas at 15 to 25 percent of stations. Electric vehicles will be recharged mostly at home, but a network of quick-charging stations will still be needed. These stations will allow recharging up to 50 percent faster than a normal fuel stop. They have relatively low costs to set up, and utilities are set to go, so this infrastructure could be built quickly. In contrast, interchangeable batteries won’t be broadly available by 2020, mainly due to logistical complexity and lack of battery standardization.

**FIGURE 2: Alternative powertrains are gaining popularity**

<table>
<thead>
<tr>
<th>Top manufacturers</th>
<th>Natural gas</th>
<th>Fuel hybrid</th>
<th>Plug-in electric</th>
<th>Fuel cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>• VW</td>
<td>• Toyota</td>
<td>• Mitsubishi</td>
<td>• Daimler</td>
<td></td>
</tr>
<tr>
<td>• GM</td>
<td>• GM</td>
<td>• BYD Auto</td>
<td>• GM</td>
<td></td>
</tr>
<tr>
<td>• Fiat</td>
<td>• Ford</td>
<td>• Tesla</td>
<td>• Honda</td>
<td></td>
</tr>
<tr>
<td>• Ford</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Daimler</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vehicles available (select)</th>
<th>Natural gas</th>
<th>Fuel hybrid</th>
<th>Plug-in electric</th>
<th>Fuel cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>• VW Touran</td>
<td>• Toyota Prius</td>
<td>• Mitsubishi</td>
<td>• None</td>
<td></td>
</tr>
<tr>
<td>• Opel Zafira</td>
<td>• Lexus RX 400h</td>
<td>• BYD MEV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Fiat Panda</td>
<td>• Chevrolet Tahoe</td>
<td>• BYD F3DM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Ford C-Max</td>
<td>• Ford Mariner</td>
<td>• Tesla Roadster</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Mercedes B-Class</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Broad market availability (year)</th>
<th>2012</th>
<th>2010 to 2014</th>
<th>2015 to 2020</th>
<th>Not foreseeable</th>
</tr>
</thead>
</table>

Source: A.T. Kearney analysis

The introduction of a CO₂ limit by 2020 is probable in China, India and Russia. These thresholds will accelerate the shift to green technology.
Fuel-cell infrastructure is costly. Equipping 20 percent of gas stations in Europe with hydrogen would cost more than $15 billion. The cost, combined with extremely low demand, means a comprehensive fuel-cell infrastructure is unlikely by 2020.

In Europe, compressed natural gas is already available at 4 to 8 percent of all gas stations and liquefied petroleum gas at 15 to 25 percent of stations.

Tougher regulations. Global emissions regulations will continue to toughen for both conventional emissions, such as particulate matter and nitrogen oxide, and CO₂ (carbon dioxide). In 2020, a strict 95 g/km CO₂ limit will likely apply in Europe, while a comparatively lenient threshold of 164 g/km is under discussion in the United States. The introduction of a CO₂ limit by 2020 also is probable in China, India and Russia. These thresholds will accelerate the shift to green technology. In the long term, market demand for these technologies will ensure that the limits are achieved without government intervention. Nonetheless, it will be essential for alternative-engine technologies to be supported by fiscal assistance, purchase-price subsidies and favorable tax laws, particularly in times of economic stress.

An Electric Future
The analysis of these four dimensions paints a clear, comprehensive picture of the future. Although gasoline-powered cars define the market today (with gasoline’s share at about 80 percent and diesel’s at 20 percent), the future will be electric. Internal-combustion engines will dominate until 2020 with about 60 percent share, but they will steadily be replaced by alternative engines (see figure 3).

Thanks to favorable operating costs and improved infrastructure, natural-gas engines are grabbing market share, and in some regions already comprise 14 percent of newly produced vehicles. By 2020, full hybrids will have long since come of age due to more-efficient and lower-cost batteries. These vehicles will be more attractive in terms of operating costs and purchase price. Even today, they account for close to 20 percent of newly produced vehicles in certain regions.

Also by 2020, electric vehicles and plug-in hybrids will comprise 10 percent of new vehicles worldwide. In contrast, there will be no notable proliferation of fuel-cell vehicles due to high unit costs and the infrastructure investments required. For all green technologies, the shift will occur more slowly in countries such as Brazil, Russia, China and India than it will in developed markets.

However, if the current crisis becomes a years-long slowdown in the automotive industry, there will be a similar slowdown in the development of alternative engines. Even in this scenario the shift to electric powertrains will come about eventually.

Implications for Manufacturers
While there is no doubt that alternative powertrains are the future, the new technology does not necessarily represent automatic success for carmakers. In fact, there are definite risks and pitfalls. With this in mind, A.T. Kearney designed a strategic

FIGURE 3: Alternative engines will be cost competitive by 2020

Notes: Europe refers to the EU-27, Asia consists of China, India and Japan; the percentages, which may deviate due to rounding, reflect vehicles produced in 2020.

Source: A.T. Kearney analysis
Strategy: Continuing Competence

Traditionally, the powertrain forms a core component of manufacturers’ value-add, essential parts of engines and transmissions that are developed and produced in-house.\(^2\) To date, about half the value-add in this area has been achieved internally. The share has been decreasing over the past few years for modern combustion engines, as innovations such as turbochargers and direct injection all come from suppliers. How will alternative technologies affect the equation? The component with the greatest value-add—the battery—is in the hands of suppliers, and manufacturers hold no notable shares in electric engines and control electronics. With the current distribution, this diminishes by one-third manufacturers’ share of value-add for full hybrids. This figure plummets to zero for plug-in hybrids and electric vehicles (see figure 5).

To retain control of the powertrain value chain and related jobs and revenues, manufacturers are exploring ways to boost their share of value-add without straying too far from their traditional fields. This is no easy task. With batteries, for example, half of the value is added in the stages from raw material to the single cell, which is virtually unknown territory for auto manufacturers. In contrast, the value derived from packaging design, cooling, electronics and overall integration could be obtained through acquisitions. Daimler’s stake in battery producer

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\(^2\) Value-add refers to the additional value of a commodity over the cost of commodities used in the previous stage of production.
Li-Tec probably marks the beginning of such a trend. The same is true for electric engines. Some manufacturers are already considering opportunities for in-house production. Whether or not such a vertical integration can be set up profitably must be considered in detail. In this context, partnerships will be key to attaining in-house value-add.

If the current crisis becomes a years-long slowdown in the automotive industry, there will be a similar slowdown in the development of alternative engines.

R&D: Increasing Complexity

The alternative engine technology winner probably won’t be determined before 2030. Until then, complexity along the entire value chain will increase enormously. In the conventional powertrain market today, there are 15 to 25 different variations of engine type, performance and transmission format. Adding natural-gas engines, gasoline or diesel hybrids, plug-in hybrids and pure electrical variants could easily triple that figure. This will increase complexity not only of engine components, but also of vehicles as installation calls for various space requirements.

Companies can minimize this complexity by reducing the existing diversity of variants for conventional engines. Complexity management for new engines should be conducted along the following three dimensions.

Portfolio. Which vehicle should be offered with which engine for which market? When is it beneficial to develop a tailored vehicle? For example, should the company offer a lightweight construction vehicle with an electric engine only? When should this vehicle be available with a choice of engines?

Platforms and modules. Adapt platforms and modules to be capable of integrating additional components for alternative engines.

Components. Standardize components and the integration of electrical engines and batteries to help reduce complexity.

Purchasing: Largely Unknown Territory

As the industry shifts to alternative engines, purchasing departments will have to identify the best suppliers for new components and implement new cost objectives. In doing so, purchasers will be moving into largely unknown territory for some components. Relationships with battery manufacturers such as Sanyo, Saft and Hitachi are at an early stage, and knowledge about the battery-components markets is generally insufficient. Supplier knowledge—transparency over value chains and their players—will become a critical factor in choosing components partners. This is all the more important because the relevant providers are usually armed with tremendous market power. For example, the top three suppliers for batteries and components for hybrids and electric vehicles hold more than 60 percent market share. Innovative sourcing that responds to the supply-and-demand situation is key to successful transactions in these component groups.3

Operations: Capacities and Footprint

Regional manufacturers will be influenced by the trend toward alternative powertrains, too. Demand for conventional combustion engines is stagnating in Europe, the United States and Japan. Assuming an upturn in productivity, this would unlock capacities of about 10 million units in this triad of markets. In return, demand for hybrid systems and full-electric engines is growing the fastest in these regions. In China and Russia, in contrast, demand for conventional engines is doubling. Along with depth of value-add, manufacturers must also consider impact on development and production capacities.

Marketing and Sales: Selling “Green”

When it comes to green technologies, manufacturers face a dilemma. While legislators are forcing carmakers to introduce new gas-saving technologies, few consumers are willing to pay a higher price for these technologies. As a result, many manufacturers sell their innovations at a loss. In this context, discounts are not usually part of a market-penetration strategy, rather

3 For more information about this concept, see “The Purchasing Chessboard” at www.atkearney.com.
a statement that higher prices cannot be passed on to the customer—at least not yet.

To avoid this situation, some companies are pursuing innovative pricing and marketing approaches. They are emphasizing both the financial benefit of reduced gas consumption and the emotional appeal of the sustainability theme. For example, a micro-hybrid in the upper middle-class segment with a price of $425 pays for itself in just two years, and even sooner for frequent drivers. When the technology’s green image is enhanced further by vehicle design, it creates rational and emotional value for consumers. Due to less-price-sensitive clientele and a high percentage of fleet customers, premium manufacturers in particular stand a good chance of implementing these strategies successfully.4

The Race Is On
The automotive industry is facing one of the most revolutionary changes in its history as it moves toward sustainable mobility. This trend will unleash both opportunity and risk for every manufacturer. In the not-so-distant future, successful manufacturers will not only embrace the powertrain of the future but also firmly anchor it in their firmwide strategies.

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4 For more information about value-based pricing, see “Pricing: An Eternity of Frustration” at www.atkearney.com.