# The United States and China: The Race to Disruptive Transport Technologies

## Implications of a changing fuel mix on country competitiveness

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# 1

# Study overview and key findings

In late 2009, Accenture published the report, *Betting on Science: Disruptive Technologies in Transport Fuels*, in which we examined 12 transport technologies and 25 companies bringing them to market. In that report, we also looked at the activity of these technologies in 10 countries, namely, Brazil, Canada, China, France, Germany, Japan, Netherlands, South Korea, United Kingdom and United States. (In a sidebar that follows on page 7, **Betting on Science: Disruptive Technologies in Transport Fuels**, we explain the scope of *Betting on Science* and its relevance to this report, *The United States and China: The Race to Disruptive Transport Technologies*.) Figure 1 (from *Betting on Science*) illustrates how we think three key technologies will evolve over the course of the next 15 years.

**Figure 1. How will some of the key technologies continue to evolve?**

| | Less than 5 years | 5 – 10 years | 10 – 15 years |
|---|---|---|---|
| Next-generation internal combustion engine | OEM developments | New gasoline technologies enter market | 100 mpg test car<br>Very efficient gasoline engines |
| Biofuels | First and second generation<br>Waste-to-fuel<br>Butanol<br>Sugar-to-diesel | New energy crops<br>Biocrude<br>Biorefineries<br>Advanced enzymes and deconstruction | Algae<br>Combined pretreatment, deconstruction and possibly even conversion steps |
| Electrification | PEVs become commercially available | Batteries improve<br>Charging piloted and tested | Scale-up starts |

Note: OEM—original equipment manufacturers; PHEV—plug-in hybrid electric vehicles; mpg—miles per gallon.
Source: Adapted from Accenture analysis in "Betting on Science: Disruptive Technologies in Transport Fuels," Accenture 2009, www.accenture.com/Global/Services/By_Industry/Energy/R_and_I/Betting-on-Science.htm.

In our *Betting on Science* findings, we found that both the United States and China had specific similarities, including:

- Significant activity led by the government and private enterprise across a number of disruptive technologies.
- An understanding of the importance of supporting continued research and development (R&D) and long-term policy.
- An awareness of the significance that new technologies and a diverse fuel mix could have on the country's competitiveness.

In this report, we make the assumption that the future will see increased levels of transport fuel diversity, and we explore the implications of this assumption both in the United States and China, the world's two largest economies. To achieve this aim, we have leveraged the expertise of our local Accenture teams in the United States and China, as well as other members throughout Accenture's global network. The China perspective is of particular interest, as current estimates predict that, by 2020, China will have approximately 200 million cars on the road, and will require the infrastructure to support this level of growth.[1] In comparison, the United States already has a large legacy infrastructure in place and the number of cars on the road is expected to remain fairly constant, with the suggestion that the actual number of miles travelled could even decrease.[2] In addition, the general approach to market and industry development comes through in the "US perspectives" and "China perspectives" sections (see table of contents). The United States analysis emphasizes the impact of new alternative fuels on current infrastructure and trade without explicitly "picking a winner," while the China team makes very specific recommendations on the alternative fuel technologies that make the most sense for China based on the country's needs and goals.

# Betting on Science: Disruptive Technologies in Transport Fuels

In late 2009, Accenture released a study titled *Betting on Science: Disruptive Technologies in Transport Fuels*. The study examined transport technologies that have the potential to become cost-competitive to hydrocarbons because of higher yields per unit of energy input or new energy sources. We defined "disruptive" to mean how big an impact a new technology may have on either the future of energy supply and demand, or greenhouse gas (GHG) emissions. For a technology to be considered disruptive, it needed to have the potential to meet the following criteria:

- Scaleable: Greater than 20 percent potential impact on hydrocarbon fuel demand by 2030.
- GHG impact: Savings greater than 30 percent relative to the hydrocarbon it is replacing.
- Cost: Competitive at an oil price of $45 to $65 per barrel, at commercial date.
- Time to market: Commercialization date in less than five years.

These four criteria were used to select the technologies featured in the report. The 12 technologies examined were: next-generation combustion engine; next-generation agriculture; waste-to-fuel; marine scrubbers; synthetic biology: sugar cane-to-diesel; butanol; biocrude; algae; airline drop-ins; plug-in hybrid electric vehicle (PHEV)/electric vehicle (EV) electrification engines; charging; and vehicle-to-grid (V2G). In addition, we featured case studies of 25 companies that are attempting to bring these technologies to market. We also profiled the relevance of these technologies in 10 different markets. The markets included: Brazil, Canada, China, France, Germany, Japan, Netherlands, South Korea, United Kingdom and United States. One technology we did not explore was natural gas. This was because although it is "disruptive to the current fuels landscape," it also is a hydrocarbon.

A considerable source of the study's data came from primary sources, including interviews with companies, scientists and government departments. In *Betting on Science*, Accenture attempted to demystify these technologies—by providing data on when and what the trajectory might be for commercial viability—and to highlight the key challenges in economically bringing these technologies to market. The report was more than 300 pages long. We did not attempt to replicate the data and conclusions of that report in this current report, but we do reference key points in this report that enhance the reader's understanding of the United States' and China's evolving transport markets. A useful supplement to *Betting on Science* is the 2010 Accenture report, *Real-time S-curves: Valuing technology uncertainty in disruptive transport fuel technologies*,[3] which explains the methodology we have developed and patented to assess technology evolution.

In addition to *Betting on Science*, Accenture also completed two detailed reports that focused on global biofuels supply and demand considerations. These included *Irrational Exuberance?: An Assessment of How the Burgeoning Biofuels Market Can Enable High Performance—A Supply Perspective*[4] and *Biofuels Time of Transition: Achieving High Performance in a World of Increasing Fuel Diversity*,[5] respectively. There also is a supplement to the *Time of Transition* report that focuses specifically on Blending Biofuels in the European Union.[6]

Many of those reports are referenced in this report and can be found on Accenture's website at www.accenture.com.

The governments of both the United States and China are aggressively pursuing the development of alternatives to gasoline and diesel. This pursuit of alternatives is what we refer to as the "race." Unlike in the past, transportation technologies are no longer limited to advances in gasoline or diesel; and it is not only government policy, but the markets and private investment that also will determine the future transportation fuels landscape. There are multiple technology options and science is now a key determining factor. There is a recognition that technology breakthroughs could lead to new industries, increased country competitiveness, energy security and reduction in GHG. In the United States, we are seeing significant government commitment to R&D and matching private investment. For example, the Advanced Research Projects Agency-Energy (ARPA-E) focuses on the funding of high-risk projects with the aim of:

- Finding transformational technologies that will reduce US dependence on foreign energy imports.
- Enhancing US economic security by identifying technologies with the potential to cut energy-related GHG emissions and improve efficiency.
- Ensuring the United States maintains its position as a technological and economic leader in emerging transport technologies.[7]

And in China, we see significant financial support and policy to the scale-up of electrification.

As previously mentioned, of the 10 countries analyzed in *Betting on Science*, the United States and China were the most aggressive in investing and developing new technologies and, respectively, represent the greatest current and future demand markets. Although there are some similarities, what is most interesting are the diverse energy characteristics of both countries, the fundamentally different approaches the countries are taking in driving technology development and the varied implications that success could have in replacing a dependence on gasoline and diesel.

# 1.1. Similarities between the United States and China

## 1.1.1. Approximately 15 to 30 percent of gasoline or diesel miles replacement desired in the next 10 to 15 years

In the scenario we present for the United States, the implementation of a fuel-efficiency standard to 40 miles per gallon (mpg) by 2030 and the blending of 30 billion gallons of biofuels (less than the 36 billion gallons suggested by the RFS2) will replace more than 30 percent of gasoline and diesel demand by 2030 relative to 2010.

In China, the goal is to replace 15 percent of hydrocarbon fuels with alternative energy by 2020 and, also by 2020, to have alternative energy make up 30 percent of transport fuels.[8]

## 1.1.2. Objective to reduce crude imports

In the US scenario, crude imports are reduced by approximately 1 billion barrels of oil per year. A balanced gasoline scenario represents a reduction of 34 percent from the 3.3 billion barrels imported in 2009.[9]

As the third-largest petroleum import country in the world, China imports more than 50 percent of the country's total petroleum consumption.[10] As the domestic oilfield production declines and the demand for hydrocarbon fuel continues to increase, the dependence on oil imports is getting stronger. According to Accenture's analysis, the alternative energy industry could provide substitutions to traditional transport fuels to save oil imports by 21 percent (92 million tons or 676 million barrels) by 2020.

## 1.1.3. Connection between agriculture and jobs

Some view the United States as seeing the development of its domestic ethanol industry in large part as a support mechanism for rural America. It is estimated that the ethanol industry is responsible for 500,000 jobs nationwide.[11] In recent legislative moves, a bipartisan bill was proposed called the Grow Renewable Energy from Ethanol Naturally (GREEN) Jobs Act of 2010. The bill would extend ethanol tax subsidies as well as the ethanol tariff until 2016. While the main thrust of the legislation is largely focused on tax and tariffs, it is clear from its title that, for many in the United States, the use of biofuels is synonymous with the support of the domestic agricultural sector and, hence, American jobs.

In China, by 2020, the cellulosic industry will create six million jobs in rural areas, bringing close to $4.7 billion in annual revenue to farmers and increasing China's gross domestic product by 3.5 percent.[12] Although they did mention the abundant straw resources, the creation of jobs was the primary argument used by our China team in their rationale for cellulosic ethanol in China.

### 1.1.4. Key technologies

Three technologies that will play an important role in replacing gasoline and diesel miles in both markets are:

- Next-generation internal combustion engine (NGE) and hybrid electric vehicles (HEVs)—technology already being deployed in the United States and China. We expect the largest cut in gasoline demand to come from advances in this area, and more new cars sales to increasingly include these enhancements.

- Cellulosic ethanol—featuring in both markets. In the United States, this will complement corn with an initial focus on cobs, but is expected to expand into other feedstocks. In China, the focus is on its vast straw resources.

- Electrification—significant investment is going into electrification in both markets, as exemplified by the fact that every major automaker has planned or plans to launch an electric vehicle (EV) or HEV model. By 2010, in China, five auto manufacturers will have launched plug-in electric vehicles (PEVs) into the market. The key challenges are high battery costs as well as the cost and availability of charging infrastructure.

# 1.2. Differences between the United States and China

The United States and China are pursuing a similar share of alternative transport fuels in their fuel mix, driven by energy security and jobs and a focus on some of the same key technologies—but that is where the similarity ends. This section highlights how each country is running this "race"—the context, culture and resultant approaches are different.

## 1.2.1. Scale and fuel mix

As illustrated in Figure 2, the scale and fuel mix in both countries are quite distinct. The United States is the largest fuel market in the world, with a strong bias toward gasoline and a significant proportion of demand satisfied through biofuels. China is the second-largest fuel market globally, but demand is significantly lower than in the United States. China uses minimal amounts of biofuels and is oriented more toward the use of diesel, although the use of biodiesel is lower than ethanol.

While the US alternative energy story is one of displacement, in China it is about meeting new demand with alternative energy.

## 1.2.2. Growth versus mature and legacy infrastructure

In the United States, vehicle ownership per head of population has reached a plateau. Coupled with a leveling of vehicle-miles traveled (VMT) or moderate growth of VMT, this means that the increased share of non-hydrocarbon fuels or increased fuel efficiency will come at the cost of gasoline and, to a lesser extent, diesel demand. A key question for the United States will be around how to most effectively transition its existing infrastructure; for example, how to best manage the impact on the US refining industry, which is configured to gasoline production.

The stagnation in vehicle ownership and VMT in the United States is in contrast to China which, by 2020, will have approximately 200 million cars on the road, a drastic increase from the current number.[13] In contrast to the United States, Chinese refineries also are configured to maximize diesel production. In China, infrastructure investment is critical to growth, and there is the opportunity to build an infrastructure that will match the future fuels landscape. The incumbents are not necessarily losers, as the absolute volumes of gasoline and diesel continue to increase, even with an increasing percentage share of new fuels.

This is a significant difference for the players in the markets—in the United States, there will be clear winners and losers; in China, in the context of high growth, there are only winners and bigger winners.

## 1.2.3. Picking winners—the detail behind China's 10-year plan versus free market

In the absence of a strong US national energy policy, energy regulation in the United States looks set to continue as a patchwork of rules at the state level. There is a question of how much can be achieved and at what pace, given the lack of a federal energy policy. In addition, it should be noted that the US energy policies cover the development of all potential fuels. While overall energy R&D spending from the US Department of Energy has

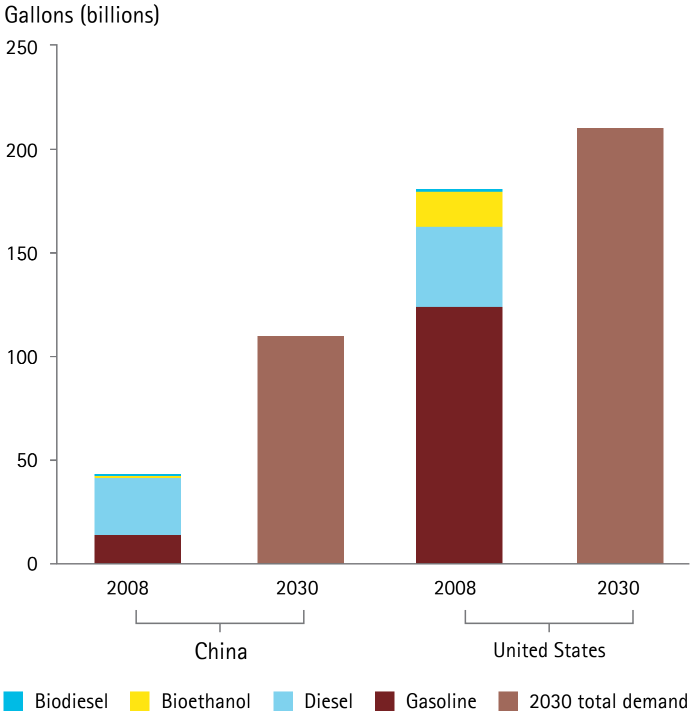


**Figure 2. Fuel split by country and projection of total transport energy demand in 2030.**

Sources: Accenture analysis; Renewable Fuels Association, Renewable Fuels Standard, www.ethanolrfa.org/pages/renewable-fuels-standard; "Short-Term Energy Outlook Supplement: Biodiesel Supply and Consumption in the Short-Term Energy Outlook," Energy Information Administration, April 2009, www.eia.doe.gov/emeu/steo/pub/special/2009_sp_01.pdf; "For the first time, China becomes the largest investor in clean energy in the world," China New Energy, March 2010, www.newenergy.org.cn/html/0103/3271031980.html.

increased to around $4 billion per year, it covers virtually the entire landscape of potential fuels highlighted in *Betting on Science* (e.g., biofuels, electrification, advanced internal combustion engines [ICEs]) as well as hydrogen, natural gas and coal fuels.

This is in contrast to China's 10-year plan and approximately $15-billion commitment over the next 10 years to support electric vehicle development and deployment.[14]

China is currently undergoing rapid economic development, but is faced with a large population, comparatively poor hydrocarbon and agricultural resources, and a weak economic foundation. Consequently, the introduction of alternative transportation fuel technologies needs to be managed in such a way as to minimize negative impacts, enhance all positive attributes, and balance China's short-term and long-term development goals. Within this context, it is more beneficial to manage the competition and the development of the alternatives. This is based on our analysis, where we see China focusing on the development of NGE, cellulosic ethanol and the electrification of transportation.

## 1.2.4. Industry opportunities

As we have stated in our previous research reports, countries tend to naturally optimize around their own domestic agendas, local resources and local economic development opportunities. For the United States, an obvious advantage is around the use of biotechnology and its application to bioenergy. For China, the advantage is on its vast reserves of lithium—the "feedstock" of electrification.

- Biotechnology in the United States: Biotechnology will deliver significant improvements in biomass and biofuels. The United States is a world leader in biotechnology and there is significant opportunity to export this expertise in the form of licenses or international expansion of US companies. In addition, international investment is likely to flow into the United States from foreign companies.

- Batteries in China: China supplies 20 percent of batteries to the global market, and its battery production is set to increase.[15] In the lithium battery production industry, China possesses a comparative advantage in its local supply, cost and industry scale over the other main players in this field; for example, Japan.

## 1.2.5. Advantaged supply

For both the United States and China, energy policy also will reflect natural supply advantages. For example:

- Natural gas in the United States: The potential volume of recoverable domestic natural gas in the United States was not on the horizon even three to four years ago. Although the bulk of this natural gas will probably be used for generation, the feasibility of using it as a transport fuel, particularly for heavy- and medium-duty vehicles, should not be ignored.

- Corn in the United States: The United States is the largest corn producer in the world, with the highest yields (twice the world average) and a significant domestic surplus. Furthermore, as will be detailed in the US section of this report, yield improvements are expected to continue. Ethanol production already represents 30 percent of corn supply, and with yields continuing to increase and the use of the cob in production, there will continue to be an excess of corn supply.

- Lithium in China: China has one of the largest sources of lithium, and is the only country with both the lithium natural resources and the battery production technology. With more than 5 million tons of saline lithium storage, China has the second-largest lithium reserve in the world.[16] These lithium resources could support China's power battery needs for 450 million electric vehicles. The abundant lithium resources give China a strong position in the PEV industry.

## 1.2.6. Fungible fuels

In the United States, research in the areas of fungible fuels aims to find ways to leverage the existing infrastructure. These technologies would remove the constraint on the speed and scale of the penetration of biomass-based fuel and avoid the infrastructure constraints faced by the ethanol-based technologies, which primarily rely on new cars and/or are limited by the ethanol-blending walls (the maximum percentage of alternative fuel that is permitted to blend with conventional, petroleum-based fuel).

Many scientists argue that ethanol is not the ideal fuel, that corn is not the ideal crop and that hydrocarbons are much more efficient than biomass. But what if you could produce gasoline or diesel equivalents with biomass? This is the promise of these fungible fuel technologies: fuels with the same or better energy content as today's hydrocarbons that can be "dropped" into the existing distribution infrastructure, and also dramatically reduce GHG emissions.

We profiled fungible fuel development in *Betting on Science*, in which we highlighted a number of technologies and included 10 case studies of companies across these technologies, although there are many others. This demonstrated just how much activity is going on in the area of fungible fuels. Some of the technologies include butanol and sugar-to-diesel. We have also seen recent announcements of these technology companies conducting initial public offerings (for example, Amyris[17]) or hitting other major milestones that indicate business progress.

In contrast, China's policies are focused on cellulosic ethanol as a solution for gasoline replacement and have yet to decide on a diesel solution.

## 1.2.7. Incumbents versus start-ups and new operating models

In the United States over the past five years, we have seen increasing numbers of start-up companies moving into the fuels market as they attempt to develop, grow and operationalize new fuel offerings across a number of different technologies. For example, in *Betting on Science*, we included case studies of 25 companies and with the exception of two of them, those companies are not traditional providers of fuels or fuel/vehicle technologies.

These companies, backed with venture capital and private equity funding, are looking to have a significant impact on the existing market. While some are keen to go it alone, most also have relationships with large, established players to capitalize on their experience, market reach and access to capital.

In China, the creation of the biofuels industry—due to its close relationship with overall food security—comes more from the clear direction given by the government than through the design of a free market structure to drive investment. With clear incentive plans, state-owned companies are working on the future development of the industry with government-funded support. Currently, the bioethanol industry is dominated by state-owned enterprises in China. At present, China National Cereals, Oils and Foodstuffs Corporation (COFCO), China National Petroleum Corporation (CNPC), China Petroleum & Chemical Corporation (Sinopec) and China National Offshore Oil Corporation (CNOOC) have all invested heavily into the market of cellulosic ethanol. These companies will play an important role in the future industrialization and commercialization of cellulosic ethanol.

In the EV industry, although government encourages private enterprises to join in the field, state-owned enterprises also play an important role in the development of EV. For example, China has established a national PEV research and production collaboration, to include automakers, battery and engine manufacturers, and charging infrastructure providers. This group also includes CNOOC, Sinopec and Petrochina.

# 1.3. Summary of findings

Who will win the race? The oversimplified short answer is that, assuming continued long-term government support for alternative energy and allocation of funds to R&D and deployment, our expectation is that China will be able to achieve its targets faster, but in a narrower field of technologies. While the United States may be slower in its development, its openness to new and disruptive technologies is more likely to generate a breakthrough (e.g., conversion technology that will produce bio-gasoline, higher yielding and more resilient microbes and new battery chemistries with much higher energy densities) solution.

The assumption of continued government support (however fragmented, in the case of the United States) is critical. The scale of funding needed to deliver the capital projects that will deliver these new fuels and infrastructure is enormous. Some $26 trillion in investment will be required to meet projected energy demand through to 2030. More than half of that investment will be needed in developing economies. In addition, the world's energy systems will need an extra $10.5 trillion in investment between now and 2030 to reduce dependence on fossil fuels, according to the International Energy Agency (IEA).[18] However, investment will only come if policy signals are clear and long-term. But assuming this policy stability, the current activity in the United States and China will fundamentally change the future of transportation fuels.

## 1.3.1. Completely new technologies will more likely come from the United States

Since Steven Chu became the US Secretary of Energy, there has been a renewed interest in R&D funding and an emphasis on technology as a key element of the energy solution. There are many areas of basic research funding in which the United States is investing. For example:

- Batteries for Electrical Energy Storage in Transportation (BEEST): ARPA-E's BEEST program seeks to create a portfolio of high-risk, high-reward R&D projects focused on developing ultra-high energy density, low-cost battery technologies that are complementary to the US Department of Energy, Office of Vehicle Technologies' existing R&D portfolio in state-of-the-art lithium-ion batteries.
- Electrofuels: ARPA-E is seeking new ways of making liquid transportation fuels—without using petroleum or biomass—by using microorganisms to harness chemical or electrical energy to convert carbon dioxide ($CO_2$) into liquid fuels.
- Joint Center for Artificial Photosynthesis (JCAP): As part of a broad effort to achieve breakthrough innovations in energy production, the US Department of Energy is bringing together a multidisciplinary team of scientists to establish an Energy Innovation Hub aimed at developing revolutionary methods to generate fuels directly from sunlight.

These are some of the examples in which the United States is looking to support revolutionary approaches to developing alternatives to gasoline and diesel. At this stage, we are not seeing support for similar approaches from the Chinese government.

## 1.3.2. China's decisiveness puts it in a stronger position to scale faster

In contrast to this strategy of broad support across a number of different technologies, China has taken a very deliberate approach in defining a limited number of technologies that are supportive of its short-term and long-term development goals. China is not looking for bench-scale R&D—it wants technology that is mature enough for commercialization, economically competitive in the market, has high energy efficiency and can bring about significant emission reductions. This decisiveness means that it is likely China will be able to scale faster in its chosen areas, where it is highly probable that we will see China achieving their set targets and goals. We have seen this in other areas. China's target of having 30 gigawatts (GW) of installed renewable capacity in place by 2020[19] will soon be exceeded through wind alone, and new targets are in the process of being set.

## 1.3.3. GHG reduction, although important, is not the key driver in either country

As we discussed in our *Irrational Exuberance* study, what is important for governments is the domestic agenda and setting policy that balances three key objectives: energy security, improving economics and climate change.

By 2020, transport will account for 20 percent of China's emissions and alternative transport fuels could mitigate about 10 percent of this.[20] But the focus of its policy is more about energy security, jobs and the economy. As the third-largest petroleum import country in the world, China imports more than 50 percent of the country's total petroleum consumption. As the domestic oilfields' production declines and the demand for hydrocarbon fuel continues to increase, the dependence on oil imports is getting stronger, potentially resulting in risks to national energy security. Adopting alternative energy could potentially mitigate this energy supply deficiency. The development of a cellulosic ethanol market could help China reverse the lack of economic development in its rural areas, by providing jobs and bringing investment. By 2020, the cellulosic ethanol industry is expected to create 6 million job positions in rural areas.[21]

In the United States, the story also is more about energy security and jobs than climate change. The relatively flat growth profile and the expected demand destruction that will come from improvements in the fuel economy and the substitution of fossil fuels for biofuels will inevitably result in reduced GHG emissions. The reduction in imports by around 1 billion barrels of oil per year will improve energy security and the increased use of biofuels will mean more jobs for rural America, with more dollars staying in the country. While both countries experience benefits in each of the three objectives, it is likely that the main focus for both countries is focused on energy security and economic benefit, rather than climate change and GHG emission savings.

## 1.3.4. Trading relationships and trade flows will change

The ramifications of these technologies scaling could lead to potential shifts in power around the globe and a changed picture of trade with and between the United States and China. Several potential implications include the following:

### Increased energy security, but straining of current trading relationships

The increase in US and China energy security will provide the countries with a greater range of trading choices and result in less resource dependency on their respective trading partners. While on the whole, this is considered to be a welcome development, it is important to note that it could potentially strain the existing trading relationships of both countries. For example, exports to the United States are a prominent feature of current Canadian growth plans. Therefore, should the United States require fewer imports from Canada, there could be potential strains on relations between the two countries. While the relationship may not suffer if the United States maintains a preferential approach to buying from Canada, if federal or state legislation moves in the opposite direction by seeking to restrict imports of Canada's energy-intensive oil sands crude or products, then the relationship could be adversely affected. One example is already occurring in California, where legislation to restrict imports of crude from oil sands is being assessed.[22]

China is expected to be a significant importer of oil. If this were to change, China may have less of a reliance on oil from the Middle East, allowing a reduction in China's level of involvement in the region and the supply routes between the region and China through the Indian Ocean.

### Increased dependence on Asia for batteries

While energy security is likely to increase, should electrification scale heavily beyond 2030, it is likely that the United States will develop an increased import dependence on Asia. Despite US industry developments, Asia is likely to continue to be the number-one market for rechargeable batteries, indicating a growing number of battery imports to supply the US market for plug-in electric vehicles. For China, this is an opportunity. As the holder of one of the largest reserves of lithium and a significant battery production capacity, China can grow in its role as a battery exporter.

### Growth in South American importance and increased US imports from the region

As the US fuel mix becomes increasingly diversified through biofuels and electrification in particular, South America will grow in importance as a region and become a larger exporter to the United States. This growth is due to the region's supplies of lithium and biofuels, of which the United States will be increasingly reliant upon to maintain the diversity of its fuel mix. The diversification in crude sources could also see heavier crudes being sourced from Brazil.

### Peak refining in the United States and Europe

As crude imports decline, so too will the demand for refined petroleum products. This decline will result in peak refining, adversely impacting the refining industries of both the United States and Europe. Marginal refiners could close and refining margins across the markets in general could become suppressed.

### Increased OPEC dependence on China and India for demand

A total reduction of around 1 billion barrels of crude imports per year will result in some decline in the US imports from the Organization of the Petroleum Exporting Countries (OPEC) countries. To make up for this loss in demand, OPEC countries will turn to other growing markets, such as China and India.

## 1.3.5. Opportunity for US and China collaboration

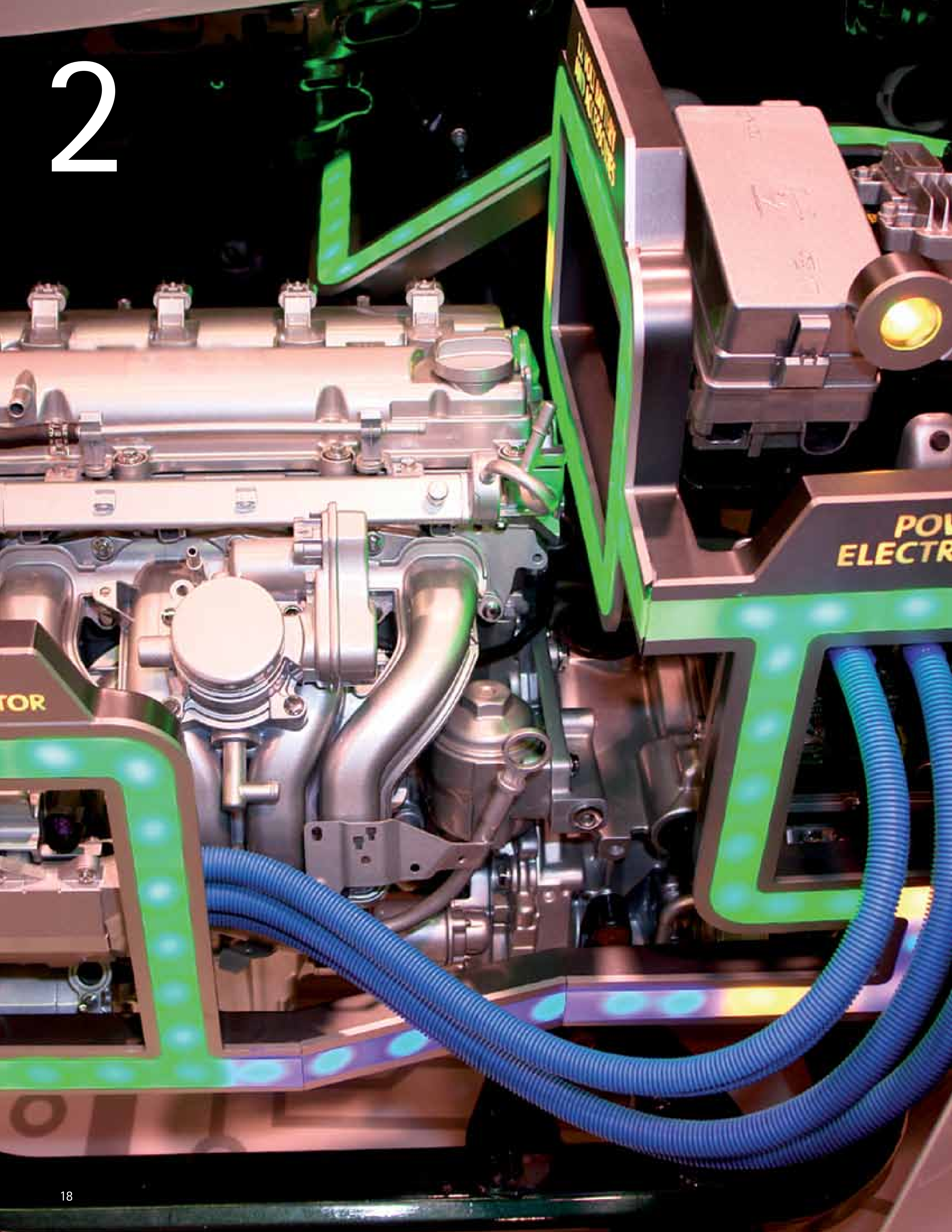
We have already seen that there is considerable overlap between the United States and China in areas in which they are interested. Increased collaboration could strengthen relations and/or create increased mutual codependence between the two countries. The Joint US-China Collaboration on Clean Energy (JUCCCE) is one example.[23]

This relationship development could be developed further to include other countries with advanced capabilities; in particular, areas including Brazil (biofuels), Germany and France (NGE improvements and electrification) and Japan and South Korea (batteries). In light of these potential benefits, it is our view that this level of cooperation would be beneficial to the evolution of the fuels landscape in both countries over the next 20 years.

So what does all of this mean to oil and utilities companies that are currently seeking to understand this changing landscape? There are new players entering the transport fuels market. There is increasing fuel diversity. And there will be changing roles for industry incumbents. We invite you to read more about how the future may evolve in the two countries currently ranked No. 1 and No. 2 in energy demand. The decisions they make and the positions they take will influence how the overall industry structure shifts and changes.

Whether the United States or China wins the race to disruptive transport technologies, one thing is certain: the future energy system will look different. Oil companies and utilities are now faced with important decisions on where and how they want to participate in the changing transport fuels market.

# 2



# US perspective

In our review of the 10 markets in *Betting on Science*, we concluded that the United States was the most active in the R&D of new transportation fuel technologies, with the highest levels of government support and private investment. To further illustrate this point, of the 25 companies profiled in *Betting on Science*, 12 are based in the United States. Since Steven Chu became the US Secretary of Energy, there has been a renewed interest in R&D funding and an emphasis on technology as a key element of the energy solution. The US Department of Energy's Energy Efficiency and Renewable Energy program has significant activities in the areas of vehicle technologies (which includes advanced combustion engines, energy storage and hybrid technologies), biomass and hydrogen/fuel cells.

Our research demonstrates that the US support for alternative transport fuels is driven by three factors:

- Energy security
- Domestic economic development and competitiveness
- Greenhouse gas (GHG) reduction

For our analysis of the United States, we have chosen to focus on the implications of a changing fuel mix on US energy security, domestic economic development and competitiveness. This focus is because much has been written about reducing GHG and about its implications, but even conservative assumptions of how the fuel mix will change (i.e., the trajectory of development today if policy remains constant and technology improves as expected) will have a significant impact on legacy infrastructure, the volume of US crude imports and the competitiveness of the United States.

# 2.1 US transportation energy characteristics

The US transportation sector is predominantly a gasoline market, consuming roughly 129 billion gallons of gasoline, 44 billion gallons of diesel, almost 11 billion gallons of ethanol[24] and just less than 700 million gallons of biodiesel per year.[25] Approximately 60 percent of the oil consumption in the United States is for transport and there are approximately 250 million vehicles.[26] The vehicle fuel-efficiency standards for passenger cars are currently set at 27.5 miles per gallon (mpg), and due to rise to 37.8 mpg by 2016. There is a 2016 fuel-efficiency target for the overall vehicle fleet (i.e., passenger cars and light-duty trucks) of 34.1 mpg.[27] Figure 3 illustrates varying countries' (including the United States and China) differing test cycles standardized to the New European Driving Cycle in $gCO_2$/km to enable a like-for-like comparison. For a closer look at the United States, Figure 4 provides the current energy breakdown in that country.

US demand is characterized by low growth and dependence on crude imports. The level of change in the future fuel mix is influenced by private investment and supporting government policy. Together, these four factors will have significant implications for the US energy mix and competitiveness. These four factors are explored in the next sections.

## 2.1.1 Low growth demand

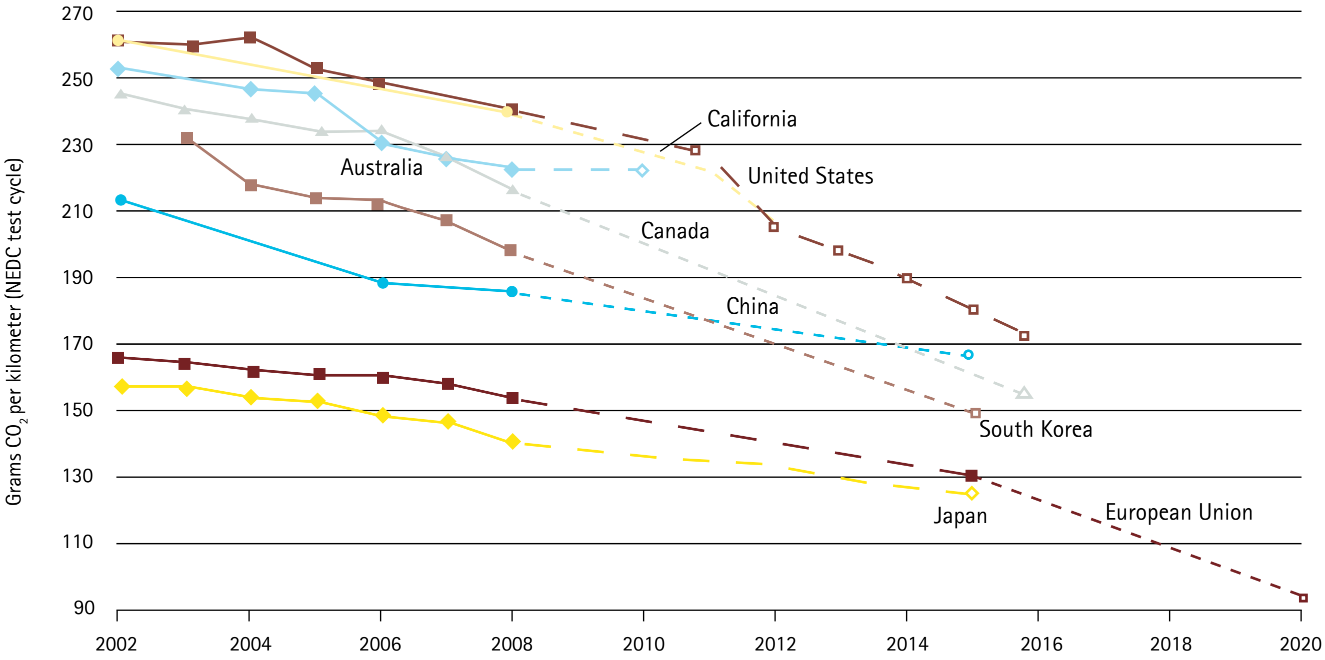
As the US economy matures, vehicle ownership per head of population has reached a plateau. This reduction in uptake, coupled with a recent trend toward a reduced demand for driving—spurred in part by the oil price increase in 2008 and sustained by the subsequent economic downturn—has seen overall vehicle-miles traveled (VMT) stabilize. This leveling-off of VMT is the first period without growth since 1979-1980. Correspondingly, domestic gasoline demand has begun to stagnate, a situation that will only be exacerbated by continued tightening of corporate average fuel economy (CAFE) standards and the increasing displacement of gasoline by ethanol. The Renewable Fuels Standard 2 (RFS2) calls for 36 billion gallons of biofuel to be blended into the nation's fuel supply by 2022.[28] With domestic supply of biodiesel small, the RFS2 will result in more ethanol leading to further erosion of gasoline demand—36 billion gallons of ethanol equates to around 24 billion gallons of gasoline (due to the lower energy content of ethanol); the equivalent of 1.5 million barrels per day of lost gasoline demand. Thus, demand in the United States is a story of displacement rather than growth.

## 2.1.2 Oil trade with few large partners

The United States is the world's largest oil importer, as illustrated by the fact that during 2008, 57 percent of all US oil was imported at a cost of about $380 billion, accounting for nearly 60 percent of the total trade deficit.[29] In 2009, the United States imported 4.2 billion barrels of crude and finished products, of which the vast majority (70 percent) was crude, totaling 3.3 billion barrels. That same year, the United States exported 740 million barrels of fuels, with finished petroleum products accounting for 88 percent (650 million barrels) and the bulk of this being distillate oil, residual fuel oil and petroleum coke.[30]

OPEC accounts for approximately 40 percent of all imports but only 5 percent of exports; the United States' primary OPEC trading partners are Algeria, Angola, Iraq, Nigeria, Saudi Arabia and Venezuela. Non-OPEC countries account for the remaining 60 percent of imports and approximately 95 percent of non-OPEC exports come from Canada and Mexico.[31] Figure 5 highlights the concentration of US imports; 86 percent of all crude and finished product imports come from 15 countries. Thus, US oil trade is dominated by a few large trading partners.

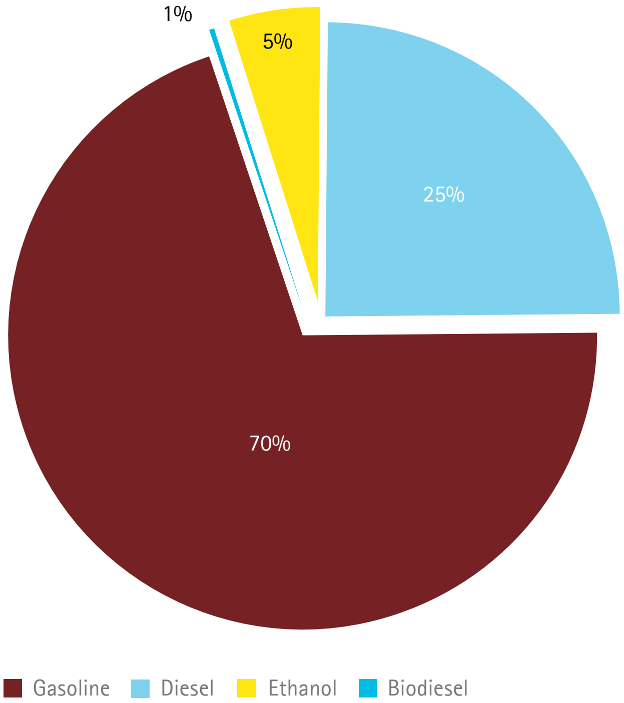
Figure 3. Passenger vehicle greenhouse gas (GHG) emissions fleet average performance and standards by region.



Solid dots and lines: actual data; hollow dots and dashed lines: nearest targets enacted;
smaller hollow dots and dotted lines: proposed targets

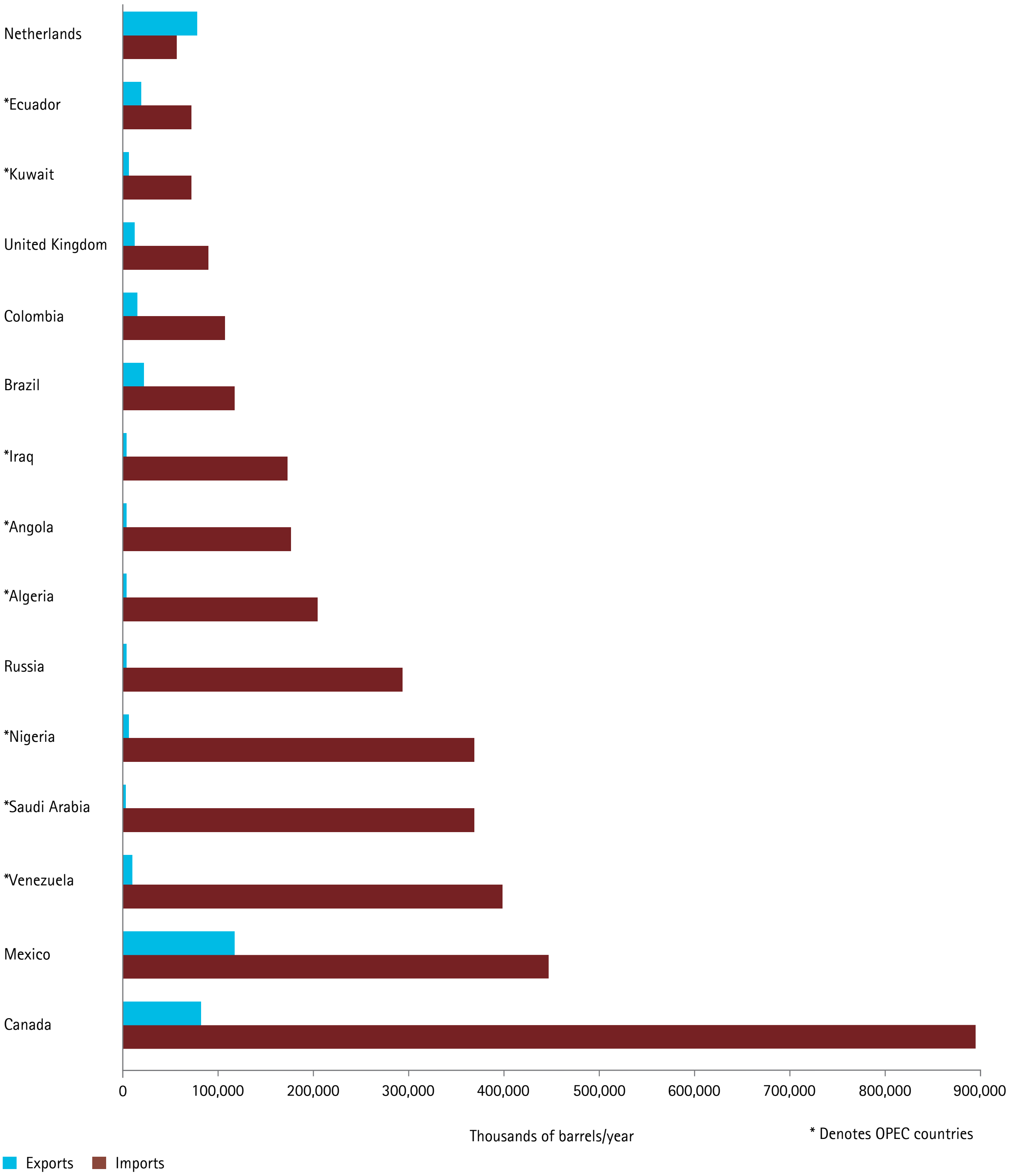
Note: NEDC – New European Driving Cycle.
Source: International Council on Clean Transportation, Global Passenger Car Fuel Economy and/or Greenhouse Gas Emissions Standards, April 2010, www.theicct.org/info/documents/PVstds_update_apr2010.pdf.

Figure 4. The current energy breakdown in the United States (2009).



Note: Due to rounding, total may not equal 100 percent.
Sources: Renewable Energy Consumption and Electricity Preliminary Statistics, Energy Information Administration, U.S. Department of Energy, August 2010, www.eia.doe.gov/cneaf/alternate/page/renew_energy_consump/table2.pdf.; Prime Supplier Sales Volumes, Petroleum Navigator, Energy Information Administration, U.S. Department of Energy, www.eia.gov/dnav/pet/pet_cons_prim_dcu_nus_a.htm.

**Figure 5. US oil imports and exports from top 15 trading partners, 2009.**



Sources: U.S. Imports by Country of Origin and Exports by Destination, Petroleum Navigator, Energy Information Administration, U.S. Department of Energy, http://tonto.eia.doe.gov/dnav/pet/pet_move_impcus_a2_nus_ep00_im0_mbbl_a.htm and http://tonto.eia.doe.gov/dnav/pet/pet_move_expc_a_EP00_EEX_mbbl_a.htm.

### 2.1.3 Key drivers of demand for new transport technologies

In a free-market environment, outcomes are determined by a combination of private sector investment and consumer demand. These two factors interact in a kind of symbiosis—customer wants are assessed by the private sector, which deploys capital in the pursuit of technological advancement. Customers themselves respond by selecting the technologies that most adequately meet their needs, thereby initiating the next round of research and development.

Looking at early venture capital funding is a good proxy for the direction technology is taking. Venture capital funding will enable identification of those technologies receiving the most support and, therefore, those that are likely to more rapidly reach scale and mass commercialization.

However, simply looking at venture capital funding will limit the story to early investments made. History is littered with examples of technologies that receive the requisite capital backing, only to be undermined by a lack of buyer interest. The absence of passenger diesel vehicles in the United States is a good example of customers acting as a barrier to technology uptake. Performance and efficiency have been accessible to gasoline engines for some time, yet several factors have held US customers back. While a lack of infrastructure is clearly one factor, a misperception of high cost and the previous failed experiment with diesel in the wake of the oil price shocks of the 1970s have certainly turned customers—and thus manufacturers—off diesel. Consumer demand will therefore be the “kingmaker” of market winners.

However, consumer preferences for one technology over another, or indeed any of these technologies, remain largely unknown. This is particularly true for those technologies that require substantial changes in behavior; for example, PEVs. Given that private sector investment is largely making technology bets, investment to date has been limited to a sample market size to test the viability and market perception of these technologies. Within PEVs, this is particularly evident. While most original equipment manufacturers (OEMs) have announced production of a PEV of some kind, there is a large divide between those betting on PHEVs and those betting on full EVs. The divide is most apparent in the market debate between Nissan’s EV, the LEAF, and GM’s PHEV, the Chevrolet Volt, both due to be released to the mass market in late 2010. While Nissan is targeting initial production of 50,000 vehicles in the first year of production, Chevrolet has limited production to 10,000 vehicles in the first year. Both production targets are conservative compared to the millions of ICEs produced each year, but indicate the uncertainty of consumer demand. Following the early bets placed by Nissan and Chevrolet, initial

**Figure 6. Key energy and environmental security policies.**

There are key policy elements in both energy security and environmental security policies that transcend politics and will be implemented:

A policy orientation to energy security will seek to reduce imports of energy feedstock and fuel

- Oil and gas (O&G) exploration and production: onshore and offshore
- Increasing the strategic petroleum reserve
- Infrastructure support for O&G and utilities
- Nuclear generation
- O&G subsidies and tax credits
- Ethanol subsidy and blending wall

**Resulting cross-cutting policy elements**

- Alternative fuels R&D
- CAFE standards
- Renewable Fuel Standard
- Smart grid development
- Energy efficiency

A policy orientation to environmental action will seek to reduce emissions of carbon and other pollutants

- Carbon capture and sequestration (CCS)
- Renewable portfolio standard
- Cutting tax incentives for O&G sector
- Cap and trade: emission targets and loose price controls
- International climate treaty
- International collaboration on fuels R&D

Source: Accenture analysis.

consumer response will ultimately drive the private sector going forward and determine the market winners.

## 2.1.4 Uncertain policy environment

US government policy has the potential to influence alternative transportation fuel markets through regulations, R&D funding and subsidies. The potential of these three policy drivers to affect alternative transportation fuels must be considered individually. Federal and state regulations can either require the use of alternative transportation fuels or increase the costs of traditional fuels. Government R&D funding can bridge the crucial gap between the laboratory and the market. Subsidies can lower the cost of alternative fuel production or of purchasing an alternative fuel vehicle—encouraging consumer adoption of alternative transportation fuel technology and buying time for the technology to mature and achieve scale efficiencies. The following research findings around each policy driver support our overall conclusion on the impact of US energy policy:

- The strength of existing state energy policies in the United States will be a primary driver for alternative fuel development.
- US government R&D for alternative transportation fuel is spread thinly across a number of technologies.
- Subsidies suffer from political instability.

These findings emerged from a close examination of current US policies, legislation before Congress (at the time of writing this report) and numerous conversations with experts and professionals involved in US energy policy. While increased regulation of fuel producers seems certain, the details of regulation are uncertain. These findings cannot predict specific outcomes.

### 2.1.4.1 The strength of existing state energy policies in the United States will be a primary driver for alternative fuel development

An analysis of federal and state energy legislation and regulation, and conversations with US energy policy specialists indicates that while the emergence of a strong US national energy policy does not seem likely in the short term, a set of politically durable policies will likely be enacted. These individually enacted federal policies and a patchwork of strong state policies will provide an impetus to alternative transportation fuel development.

A set of cross-cutting policies emerged from a close reading of major bills before Congress.[32] Many of the policy elements contained in these bills naturally aligned to either energy security or environmental action policy orientations. But several of these policy elements cut across these policy orientations (see Figure 6). This indicates a group of energy policy elements that could be considered durable regardless of the policy orientation guiding legislation.

Several of these cross-cutting policies, such as Corporate Average Fuel Economy (CAFE) standards, alternative fuels R&D and a Renewable Fuel Standard (RFS), would directly affect transport fuel use. A strong RFS could change the game for alternative fuel producers, though it would likely boost corn ethanol alongside other alternative transportation fuels. Support for smart grid and energy-efficiency initiatives would directly affect energy feedstock use and influence the development of electric vehicles. While the enactment of these policies—much less their final form—is uncertain, these policy elements seem likely to remain on the table regardless of shifts in the political landscape.

The strength of existing state energy policies in the United States will be a primary driver for alternative fuel development. Regulations in states such as California, which has enacted strict tailpipe emissions standards and a renewable portfolio standard of 33 percent by 2020,[33] will support companies seeking to bring alternative transportation fuels to market. Regional cap-and-trade initiatives such as the Western Climate Initiative also plan to address transportation, further boosting opportunities for low-carbon alternative fuels.

But individually enacted federal policies and a patchwork of state policies seem unlikely to provide as strong an impetus to investment and commercialization as a federally enacted, comprehensive energy policy.

### 2.1.4.2 US government R&D funding is spread thinly across a number of technologies

Overall energy R&D spending from the US Department of Energy has increased to around $4 billion per year, with a spike around 2009's stimulus funding, but it covers a wide breadth of generation and transport technologies which thinly spreads individual technology funding. When compared to Chinese government guarantees of approximately $15 billion over 10 years to support electric vehicle development and deployment,[34] US government R&D funding for alternative transportation fuels seems insufficient to generate a competitive advantage.

This dilution of US funding reflects a lack of strong policy focus on a single "national champion" fuel, as is seen with China's 10-year investment commitment to EV R&D. While the US approach could prove superior by supporting multiple fuels, US government-funded R&D alone will likely not produce a competitive alternative transportation fuel industry.

### 2.1.4.3 Subsidies suffer from political instability

Alternative fuel vehicles in the United States currently benefit from significant subsidies and tax incentives, which reduce the cost of these vehicles to consumers and encourage alternative fuel adoption. However, these subsidies, coupled with global competition, may not "last forever" and examples from other industries have shown that a dependence on a source of funding that is susceptible to political instability is unsustainable. This was the case with biofuels in Germany and solar energy in Spain, whereby a withdrawal of subsidies led to a detrimental impact on the development of the respective industries.

The US federal government currently offers tax incentives that reduce the purchase price of all alternative transportation fuel vehicles.[35] These tax incentives will expire at certain dates, or after a certain number of alternative transportation fuel vehicles are produced. At that point, the tax incentive will require reauthorization in both houses of Congress. Whatever the political support for alternative fuel vehicles, these renewals could be blocked by budgetary concerns. The cost to fund tax incentives up to current production limits is estimated at $3.4 billion, or $6,553 per vehicle.[36]

The main aim of subsidization is to provide this new technology enough time to mature to allow for the scaling that will enable the fuel-vehicle combination to become a viable long-term competitive option, as was the case with corn and sugar cane ethanol in Brazil.

The wind production tax credit (PTC) is a prime example of how short-term commitments can create uncertainty in the market. The economics of the US wind industry depend on the PTC, which must be approved by both houses of Congress. The PTC was allowed to expire and then renewed in 1999, 2001, 2003 and 2005.[37] Each renewal was accompanied by intense lobbying efforts from the wind industry. The wind PTC was most recently renewed in 2008, and will require renewal in 2012.[38] This uncertainty deepens risk for investors and entrepreneurs and further weakens the United States' competitive position relative to a country like China, which had made longer-term commitments to support emerging technologies.

In this section, we have reviewed what we feel to be four of the key characteristics of the US energy market, namely:

- Low growth demand
- Oil trade with few large partners
- Private investment favoring energy efficiency and electric vehicles
- Uncertain policy environment

Based on our research, we feel these four characteristics will have a significant impact on how the future fuel mix will evolve as well as having future implications for US competitiveness. In the next section, we explore these implications in more detail using a scenario to examine potential implications of a changing fuels mix.

# 2.2 Modeling of alternative transport fuel demand

Many transport fuel technologies are in play today and will continue to develop. It is a race to commercialization, and breakthroughs in one technology will impact the space left for the others.

In the United States, we are not comfortable “picking a winner” for the future transport fuel technology because, as can be seen by the technologies reviewed in *Betting on Science* and the policy and private investment analysis, there is no obvious consensus. However, we can develop a plausible scenario by which many implications can be fleshed out.

Figure 7 illustrates the key assumptions derived from our findings in *Betting on Science*, as well as the desire for energy security, low growth demand, private investment and policy. Based on these assumptions, we present a scenario (as a basis for discussion of the implications in this section) that fuel-efficiency improvements and alternative transport fuels could constitute more than 30 percent of the US gasoline and diesel miles by 2030, compared to 2010 (see Figure 8). For further comparison, Figure 9 illustrates (via scenario) the share of displacement of alternatives in 2030.

**Figure 7. 2030 US fuel mix scenario assumptions.**

| Area | Assumption |
|---|---|
| Vehicle fleet | • The number of vehicles remains constant. |
| | • 15-year turnover cycles are assumed. |
| Demand | • Baseline demand from gasoline-type vehicles grows by an average of 1 percent per year; baseline demand from diesel-type vehicles grows by an average of 1.7 percent per year. |
| | • With the number of vehicles remaining constant, the increase in miles driven is in line with baseline demand growth. |
| | • There is no reduction in road demand as a result of shifting to other transportation modes. |
| PEV | • Vehicle sales distribution depends on income segments. |
| | • $25,000 to $50,000 (28 percent of population) account for 30 percent of new vehicle sales. |
| | • $50,000 to $75,000 (13 percent of population) account for 25 percent of new vehicle sales. |
| | • $75,000 to $100,000 (5 percent of population) account for 15 percent of new vehicle sales. |
| | • More than $100,000 (6 percent of population) account for 25 percent of new vehicle sales. |
| | • Assumed suburban population 25 percent below average vehicle purchase rates. |
| | • Assumed city population 50 percent below average vehicle purchase rates. |
| | • Total PHEV market size depends on population numbers living in cities and suburban areas. |
| | • Total EV market size depends on city population. |
| | • Proportion of population living in cities increases 5 percent by 2030. |
| | • Proportion of population living in suburbs increases 5 percent by 2030. |
| | • Early adoption (2010-15) PHEV sales following projection from Sentech/Pike. |
| | • Early adoption EV sales follow projection by JD Power. |
| | • After 2015, the adoption follows below assumptions around income segments and urban/suburban population. |
| | • Adoption rates remain 0 for the less than $50,000 income segment; increase to 7.5 percent in the $50,000 to $75,000 income segment and 10 percent in the more than $75,000 segment in 2020. |
| | • Assumed are further increases up to 9 percent and 13 percent, respectively, in 2030. |
| | • The concentration of PEVs in cities indicates that the majority of miles driven could be electric. |
| | • Average PEV gasoline consumption is 20 percent of internal combustion engine (ICE) consumption based on expected proportion of PHEV engine utilization. |
| | • Battery target cost is $500/kilowatt-hour (kWh) in 2020. |
| ICE/HEV | • Fuel-efficiency standards for ICEs rise to 34.1 mpg in 2016. |
| | • Further improvements up to 40 mpg in 2030 are assumed. |
| | • No additional efficiency improvements assumed for diesel vehicles. |
| | • Hybrid electric vehicle (HEV) fuel efficiency is capped at 63.1 mpg. |
| | • Number of HEVs follows a 7 percent growth trajectory to 2019 and 5 percent thereafter. |
| | • ICE new vehicle sales equal total new vehicle sales net PEV, HEV, natural gas new vehicle sales. |

**Biofuels**

- E15 will become the blending wall for ethanol in 2012.
- The blending wall for butanol is set at 25 percent in 2012.
- Total biofuels blending amounts to 30 billion gallons in 2030.
- Corn ethanol stays at 15 million gallons per year (mgpy); cellulosic increases to 5 mgpy.
- Assume tariff on Brazil ethanol remains, so that there is no increase in Brazil sugar cane imports.
- Cellulosic is primarily the cobs and small volumes of other waste or grasses.
- Biobutanol could be produced from corn (assumes 50 percent reduction in GHG, compared to gasoline).
- Biomass-based diesel follows the RFS, i.e., 1 billion gallons blended in 2030.
- Undifferentiated advanced biofuel (various clean-diesel technologies, e.g., hydrotreated renewable diesel, sugar-to-diesel) follows the RFS. Five billion gallons blended in 2030.
- Flexfuel vehicles using E85 grow to 2 percent of total in 2030.
- Drop-in biofuels (e.g., algae) are only starting to be commercialized, we assume zero volume.
- Standard energy content conversions to gasoline or diesel:

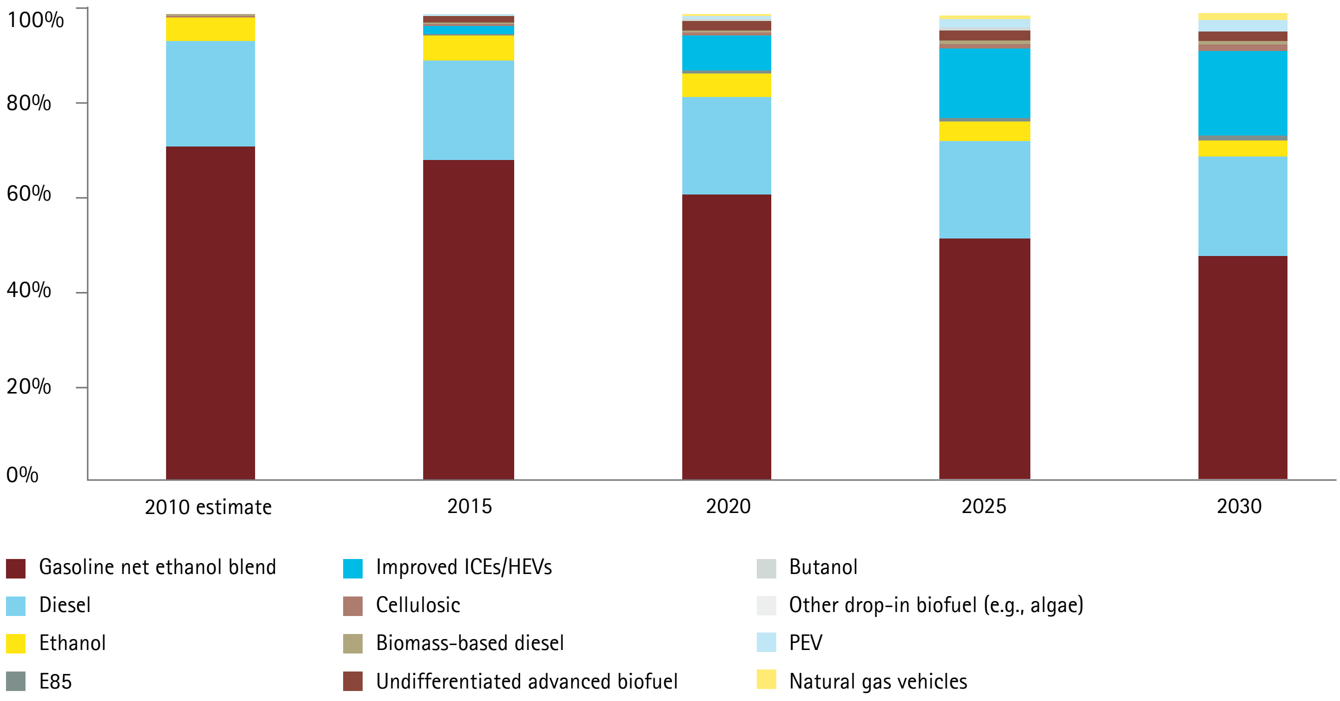
| Biofuel | Energy conversion to gasoline (diesel for biodiesel) |
|---|---|
| Ethanol | 0.66 |
| Cellulosic ethanol | 0.66 |
| Butanol | 0.83 |
| Biodiesel | 0.91 |

**Natural gas**

- Natural gas is predominantly used in the grid, but there is increasing demand from natural gas vehicles in medium and heavy duty, replacing conventional diesel (becomes approximately 15 percent of heavy-duty vehicles sales in 2030).

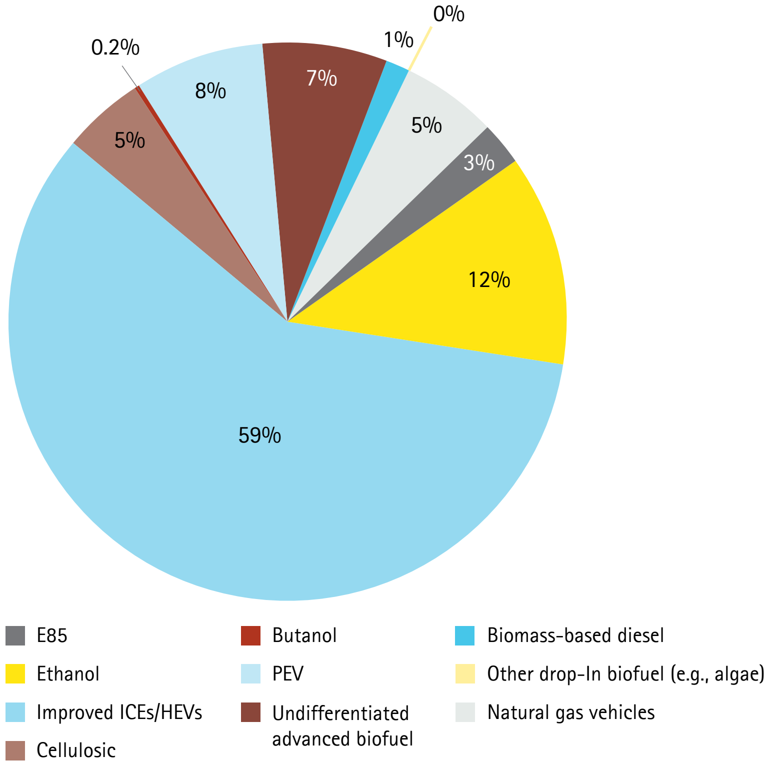
Source: Accenture analysis.

Figure 8. Scenario—Hydrocarbon miles displaced.



Source: Accenture analysis.

Figure 9. Scenario—Share of displacement of alternatives in 2030.



Note: Due to rounding, total may not equal 100 percent
Source: Accenture analysis.

Key uncertain elements in our scenario include:

- Moving of the blending wall to E15.
- Successful commercialization of biobutanol for fuel, and the ability to deliver a 50-percent reduction in GHG relative to gasoline using corn as a feedstock.
- Scale-up of PHEV/EV, and in the case of PHEV, the percent of gasoline versus electric miles.

But this is offset by other elements, which we believe to be conservative. For example:

- Fuel efficiency (mpg) for ICE could improve beyond 2016 to European levels.
- Fleet replacement could be sooner than 15 years.
- The fuel efficiency of ethanol could be better than the 0.66 we assume and/or the share of E85 greater than 2 percent. For example, the BEST (Bioethanol for Sustainable Transport) project looked at 10 E85 sites across Europe and found the fuel efficiency of ethanol in the best case to be 1.14 (0.88) versus the theoretically assumed 1.41 (0.70), or the even more conservative 0.66 we used.[39]
- There could be more cellulosic volumes, driven by further breakthroughs in enzymes and deconstruction technologies that dramatically reduce costs (current estimates focus on cobs and other waste streams).
- There could be breakthroughs in the development of photosynthetic algae or other drop-in fuel technologies, or even hydrogen.
- Higher volumes of PEVs driven by US policies and incentives.
- Higher volumes of natural gas vehicles driven by US policy that supports the development of a natural gas vehicle infrastructure.

But we also expect the scale-up of new technologies to be more challenging than currently expected. Implementation rarely goes as planned, particularly given the sheer number of the first commercial and new plants that have a multiyear development cycle. We also assume that RFS2 will be the dominant legislation, rather than anything more severe.

But the scenario also assumes that there are technology breakthroughs that enable the commercialization and scaling of new technologies.

It is important to reiterate the significance of continued R&D and to note that our fuel-mix scenario is reliant on these developments and investment continuing at current levels. Only with continued investment will these technologies manage to scale as rapidly as in the scenario and result in a diversification of the current fuels landscape, providing greater energy security and strengthening the United States' global energy positioning.

This scenario will be the basis of discussion of the implications in the next section.

# 2.3 Implications for US competitiveness

What are the potential implications for different industries in the United States if the fuel mix changes away from gasoline and diesel? In our view, the implications are cross-industry and widespread.

## 2.3.1 Restructuring of US refining industry

The fall in gasoline demand and the resulting reduction in crude imports will have a significant impact on the refining industry. Our estimate is that the reduction in gasoline demand in 2030 is approximately 22 billion gallons per year. This reduction in gasoline demand will likely drive a structural change in the refining industry, impacting US refineries in two dimensions: reduction in volume or output and a change in product mix. Both dimensions will result in the most marginally profitable refineries shutting down capacity.

This structural change in fuel demand would tend to favor larger, more complex refineries with lower marginal costs and the production flexibility to make different product slates, including "fuel switching" or the ability to incrementally increase diesel production (or gasoline) if demand dictates. Smaller, less complex refineries would likely shut down as they were built to maximize gasoline production, have less upgrading capacity and flexibility for fuel switching and—as such—would require significant capital investments to reposition their production profile.

If we expect only the most efficient refineries with production flexibility to remain in operation (and marginal refineries shut down), this phenomenon, coupled with expected capacity creep and/or performance improvements in hydrocrackers and fluid catalytic cracking (FCC) units, would allow the United States to adjust to the new fuel-demand mix and move to a long or balanced fuel supply position. Because there is some flexibility within highly upgraded refineries for fuel switching, there is a long/short fuel scenario which is immaterial and could be balanced with existing refining capacity. Additionally, global demand for transportation fuels will drive how the US refining fleet rationalizes excess volume. As long as fuel standards/specifications remain relatively globally consistent, then fuel will continue to be a global commodity that can be easily imported and exported to offset short-term US supply/demand imbalances.

Under the previously described demand scenario, we calculate that demand for crude imports could decline by approximately 1 billion barrels per year, allowing a corresponding rationalization of refinery capacity. Assuming that natural gas becomes a significant part of the supply mix by 2030, refineries can be rationalized to balance gasoline demand with diesel short of approximately 200 million barrels per day, assuming no investment in cracking capacity. Figure 10 shows the assumptions of the refinery model.

As a result of the reduction in demand in our scenario, the competitiveness of the US refining industry decreases. Note that we only modeled the implications of a reduction in demand and assumed no other regulation that would impact the competitiveness of

Figure 10. Assumptions of the refinery model.

| Area | Assumption |
|---|---|
| Capacity | Annual increased capacity of 0.75 percent, based on historical performance. |
| Improvements | No additional capital investment in FCC or hydrocracking capacity. |
| Market context | US refineries are not disadvantaged by carbon regulations or costs relative to the rest of the world. |

Source: Accenture analysis.

US refineries. We did not assume the US refineries are further disadvantaged by additional carbon regulation that increases the cost of operations or products. However, additional carbon regulation would further decrease the competitiveness of US refining (particularly if their international competitors are not faced with the same carbon legislation). One key area of research is how to fully leverage existing assets; for example, how existing assets can be modified to process biocrude.

## 2.3.2 Reduced fuel imports

US crude imports were 3.3 billion barrels in 2009.[40] Our refinery analysis showed that this could be reduced by approximately 1 billion barrels per year by 2030. Although there are some restrictions on the type of crudes that can be processed, there is an opportunity to diversify sources, so the United States is not dependent on a key group of trading partners. Rationalization of less-complex, lower-margin refineries will decrease refinery demand for lighter crude types (e.g., those from the Middle East and Nigeria) and may give the United States more flexibility in crude supply.

## 2.3.3 Use of natural gas for road transport

The combined effects of a potential short diesel position and the rapid increase in forecasted US natural gas supply has led to renewed interest in natural gas vehicles as a method of reducing emissions and dependence on foreign oil. This interest is particularly focused on heavy-duty vehicles, which are traditionally powered by diesel. Heavy-duty vehicles are more challenging to transition to electrification and biofuels than light-duty vehicles, as the greater power output needed for these heavier, load-carrying vehicles requires considerably greater battery storage capacity for electric vehicles; and biodiesel productivity is not yet advanced enough to significantly displace diesel volumes.

Natural gas vehicle technology is considerably more mature than other alternative transport fuels, and compressed natural gas (CNG) light-duty infrastructures are widespread in other parts of the world with a global fleet exceeding several million. Widespread uptake of natural gas in heavy-duty vehicles still requires improvement in overall engine efficiency and performance to provide range, engine power and consistent fuel cost savings. Focus on liquefied natural gas (LNG) also is of particular importance as the increased energy density of LNG compared to CNG is vital to providing a strong alternative to diesel for long-haul heavy-duty vehicles. Required LNG fuel investment includes improving cryogenic pump technology to make it safer for widespread use and enhancing onboard storage tanks which are currently unable to stop the "venting" of methane as liquefied gas escapes from tanks, particularly in infrequently used vehicles.

In addition to these technological obstacles, the key challenge is triggering the widespread rollout of a natural gas vehicle economy. Vehicle manufacturers are reluctant to invest in developing natural gas vehicles for the open market until there is sufficient refueling infrastructure, while refueling infrastructure is slow to develop, as poor economies of scale and weak demand mean the economics do not support their operation. This leads current growth to be focused on enclosed fleets, such as buses, waste collection and port vehicles, which can install their own refueling stations at their bases. Widespread, cross-country heavy-duty vehicle use will require government support to ensure a nationwide network of refueling stations and a broad range of engines and integrated natural gas vehicles providing competitive performance at comparable cost to diesel.

## 2.3.4 Exporting biotechnology

Biotechnology will deliver significant improvements in biomass and biofuels. The United States is a world leader in biotechnology and there is significant opportunity to export this expertise in the form of licenses or international expansion of US companies. In addition, international investment is likely to flow into the United States from foreign companies. Figure 11, from our *Betting on Science* report, provides examples of how biotechnology/genetic engineering is being applied across biofuels production.

## 2.3.5 Leading the global agriculture revolution

Biofuels production in the United States has grown approximately 248 percent between 2005 and 2008, delivering significant benefits to the agriculture sector.[41] Government policy has largely provided the impetus for this growth; however, this should not detract from the year-on-year enhancements in yield and cost due to the improved technologies, continued innovation and successful collaborations of the players in this market. It is not a single type of technology that has underpinned growth. Instead, it is an evolution of business models, land and feedstock approaches and the leverage of deep agriculture experience in applying new technologies to today's current first-generation biofuels footprint that enables the sustainable and scalable "growing" of energy. This is just a continuation of the development of the agricultural sector in the United States, as Figure 12 illustrates.

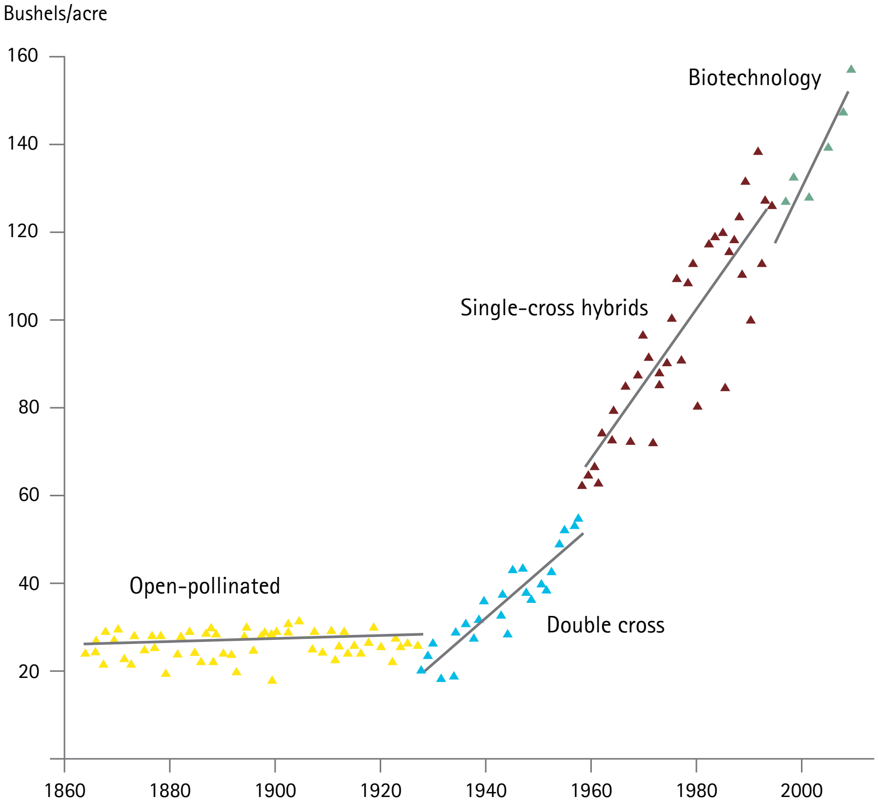
The demand for biofuels could drive a renaissance in agriculture—a sector that has suffered globally from lack of investment. US companies could potentially lead this new agricultural revolution—at least as an interim solution to the adoption of a coherent long-term policy. If this is the case, the goal will not be to increase the amount of land being farmed but to increase

Figure 11. Application of biotechnology across biofuels production chain.

| | Application | Examples of players |
|---|---|---|
| By/co-product upgrading and other products | • Engineered organisms produce desired chemicals, with increased yield and productivity<br>• Upgrading of by-products of biofuel production (e.g., glycerin) process using modified organisms for the fermentation process (cheaper than traditional petrochemical route) | • GlycosBio |
| Conversion | • Biofermentation/biocatalytic conversion: microbe-based conversion of either sugar-to-fuel (diesel, gasoline) or syngas-to-ethanol<br>• Microbes are cheaper than conventional catalysts, continually regenerate, can be engineered to be tolerant to more impurities and operate at a broader range of temperatures/pressures/pH. Engineer microbe to selectively produce desired end product | • Mascoma<br>• QTEROS<br>• Amyris<br>• LS9, Inc.<br>• Gevo<br>• Solazyme |
| Enzyme | • Genetically enhanced microbial enzymes that are:<br>More efficient: achieve higher sugar yields<br>More cost effective: requires lower dosage, lower temperatures<br>More resilient to range of inhibitors produced upstream<br>• Crop-produced enzymes (hydrolytic enzymes to reduce subsequent pre-treatment) | • Genencor<br>• Novozymes<br>• Edenspace<br>• Zymetis |
| Feedstock | • Genetically modified crops, with improved characteristics:<br>Drought/disease resistance<br>Faster, improved yield, more uniform growth<br>Decreased nutrient requirement; "single harvest only" growth | • Mendel<br>• Ceres<br>• Monsanto<br>• Syngenta |

Source: Accenture "Betting on Science: Disruptive Technologies in Transport Fuels," 2009, www.accenture.com/Global/Services/By_Industry/Energy/R_and_I?Betting-on-Science.htm.

Figure 12. Improvements in average US corn yields.



Source: National Agricultural Statistics Service database, US Department of Agriculture (USDA), www.nass.usda.gov/Data_and_Statistics/index.asp.

Figure 13. Corn yield trends around the world.

Corn yield trends (Bushel per acre)

| | 1990 | 2000 | 2005 |
|---|---|---|---|
| World average | 59 | 70 | 75 |
| United States | 113 | 137 | 149 |
| Argentina | 60 | 93 | 109 |
| China | 74 | 78 | 80 |
| Brazil | 33 | 47 | 54 |
| India | 23 | 29 | 31 |
| Sub-Saharan Africa | 22 | 24 | 25 |

Source: Accenture interview; "Growing Energy" presentation:
http://www1.eere.energy.gov/biomass/pdfs/Biomass_2009_3-17_Plenary_Hamilton.pdf.

yields, reduce costs and improve productivity while managing resources such as water and energy. Hybrid genetics and biotechnology have driven a five-fold increase in average US corn yields since 1940. As illustrated in Figure 13, there is a significant difference in crop yields around the world, and there is still huge potential to implement similar yield increases in other parts of the world, relatively quickly.

Next-generation agriculture is in its infancy. There is significant potential for improvement, particularly given the historic advances made with genetic modification of crops to obtain desired characteristics, increase yield and reduce harvesting and processing costs. It is likely we will see these improvements in a much shorter period than we currently witness. Advances in breeding and biotechnology have been able to produce enhanced crops with desired characteristics (such as seedless varieties, greater resistance to disease, easier to harvest, reduced water and nutrient requirements) while increasing yields. These techniques are now being applied to crops to develop characteristics desirable for fuel production, and there are a number of US companies leading this market. Most importantly, improvements also are aimed at reducing water use and energy use. In *Betting on Science*, we include a case study on POET that shows water use declining by 80 percent in the past 20 years and energy use declining by 33 percent in the past 12 years.[42]

If the United States is able to develop into a global leader within the agriculture space, there will be benefits within and beyond purely the development of biofuels. Firstly, an increased emphasis on agriculture is vital to meet the food needs of the world's growing population. Secondly, from a biofuels perspective, the United States will have greater international research leverage, enabling a greater contribution to collaborative research programs as well as enabling the potential exchange of agriculture intellect for other research insights in which the country may not be as strong.

### 2.3.6 Risks and opportunities from electric vehicle growth

Although our estimates for electrification of transport are relatively modest to 2030, we do expect the electrification share to grow at a faster rate post-2030. This scale-up provides the United States with a number of potential market opportunities in terms of resources and market development, but also indicates several challenges which will need to be carefully mitigated.

On the one hand, electrification scale-up provides new opportunities for natural gas. New electricity demand, combined with the retiring of the current, ageing US power generation fleet, will require a new wave of power generation facilities. As developments in shale gas continue to transform the US natural gas supply position, we expect natural gas to play a major role in the new generation mix. Natural gas has been the largest contributor of new generation capacity for more than a decade, accounting for 40 percent of new capacity in 2009.[43] In addition, access to US natural gas reserves (and technological advancements that reduce the cost and increase the yield of natural gas) increases the attractiveness of natural gas as an alternative fuel.

Natural gas also is viewed as an important part of the new generation mix, as it can be ramped up and down more easily compared to coal-fired generation. If the same R&D effort being applied to new fuels is applied to the engineering of natural gas plants—e.g., with the aim of complementing the volatility of solar and wind generation, we believe the efficiencies of natural gas plants can be increased. Natural gas could support the increased use of less predictable renewable generation, such as wind and solar. The level to which natural gas becomes part of the generating baseload is dependent on a number of factors, namely the success of US coal and nuclear lobbies as well as the long-term price forecasts for natural gas. Ultimately, the overall use of domestic natural gas (or coal or nuclear) to power electric vehicles will have a direct impact on reducing demand for imported crude.

Secondly, electrification of transport further provides opportunities for growing US industry players across the electrification value chain. Many of the top electrification contenders in the market today (for example, Better Place, Coulomb Technologies and A123 Systems) are based in the United States, providing the country with the ability to be a leading global player in the electrification space. However, while government and industry together are currently driving the market forward (for example, as part of the American Recovery and Reinvestment Act, the US government earmarked $2 billion for the manufacturing of advanced batteries, resulting in, among other developments, more than 10 grants for new plant builds), continued support is essential to ensure the required improvement trajectories for significant scale beyond 2030 are reached.[44]

These market opportunities are not without challenges, and the United States' competitiveness will be constrained by the competitiveness of other markets and the availability of natural resources. First, the importance of continued funding is particularly true in light of electrification developments in China. With the country announcing its target to be the largest electric vehicle producer in the world, China is rapidly ramping up manufacturing capability—particularly with regard to batteries. Asia, including South Korea, Japan and China, accounts for approximately 60 percent of total US rechargeable battery imports, with trends indicating that China's contribution to this total is growing. A recent study by the Argonne National Laboratory estimated that 400 organizations in China are currently dedicated to battery development or manufacturing, with government providing incentives to strengthen this focus.[45]

**Figure 14. Implications of future fuel mix scenario on US competitiveness.**

| # | Implication | US competitiveness |
|---|---|---|
| 1 | Restructuring of US refining industry | ▼ |
| 2 | Reduced fuel imports | ▲ |
| 3 | Use of natural gas for transport | ▲ |
| 4 | Exporting biotechnology | ▲ |
| 5 | Leading the global agriculture revolution | ▲ |
| 6 | Risks and opportunities from electric vehicle growth | ▬ |

▲ Increased ▼ Decreased ▬ No change

Source: Accenture analysis.

The latter points to a second challenge to US competitiveness in the market—the supply of lithium, which is the primary contender for PEV batteries. Although there is significant research looking at a range of materials, lithium remains the dominant material for PEV batteries. Currently, lithium reserves are concentrated in Bolivia, Chile and China and are predominantly mined from salt ponds, as this is the easiest and lowest-cost method. Due to the relative scarcity of salt ponds, there is a short-term dependence on the aforementioned trio. Further supporting this is the fact that other technologies which exist to extract lithium; for example, geothermal hotspots, are currently prohibitively expensive.

Continued R&D and support for electrification will help mitigate the challenges associated with obtaining raw materials and enable more rapid scaling of the technology associated with lithium extraction and greater competitiveness for the United States.

The announcement of the US-China Electric Vehicles Initiative in November 2009[46] is a good step in the right direction with joint standards, joint demonstrations, a joint technical roadmap and combined efforts with regard to public awareness and engagement, but efforts need to be made to ensure this collaboration continues.

As electrification scales and battery manufacturing capability in the United States increases, trade with Bolivia, Chile and China for lithium will be on the rise. In addition to lithium imports, the likelihood is that the United States will need to import the majority of the batteries required for electric vehicles, and it will likely look to Asia to do so.

## 2.3.7 Summary

The diversification of the US fuels landscape will result in a number of game-changing developments, impacting the supply/demand mix and trading partners. Figure 14 summarizes our views.

While the next 20 years could see all of the previously mentioned technologies beginning to scale, post-2030 will be a different story as some of the technologies will increase in importance, while others decline. Our view is that ICE improvements, HEVs and biofuels will account for the majority of the fuel substitution prior to 2030, but that electrification will continue to scale beyond that date, supporting the continued US displacement of gasoline demand.

The ramifications of these scaling technologies could lead to potential shifts in power across the globe and a change in the picture of US trading partners.


ELECTRIC
VEHICLE
CHARGING
STATION

# 3


大光明钟表商店
茂昌眼镜公司
鸿翔时装公司
恒源祥商厦
上海市第一食品商店
宝大祥服装批发城
培罗蒙公司
百事可乐
SEIKO
67420

# China perspective

Recognizing the tremendous opportunities in the global alternative energy industry, China has proactively joined the race to obtain leadership within this area. In recent years, investment by the Chinese government on alternative energy has been rapidly increasing. By 2009, China's investment in alternative energy had reached RMB 240 billion (US$35 billion), more than any other nation.[47] To achieve its goal of replacing 15 percent of all hydrocarbon fuels with alternative energy by 2020 and reducing carbon emission by 40 percent (based on the emission level of 2005), the Chinese government plans to invest another RMB 5 trillion (US$740 billion) over the course of the next 10 years.[48]

In Accenture's view, the Chinese government could benefit from not only selecting the alternative energy solutions within the transportation sector that are most appropriate to the country's specific needs, but also by targeting the right sectors of the industrial chain to effectively facilitate the development of these new industries. In addition, to build long-term sustainable growth, there must be a focus on technological advancement. By positioning itself as a world leader within alternative transport energy R&D, China will place itself in the best possible position to maximize the benefit brought by technological advancement in terms of energy strategy and emission reduction. Currently, China's economy is predominantly based around manufacturing, which adds less value than high technology; therefore, a move toward the latter has the potential to reap greater economic benefit.

# 3.1 China transportation energy characteristics

China's transportation sector is predominantly a diesel market, consuming 39 million tons (14 billion gallons) of gasoline, 91 million tons (28 billion gallons) of diesel, 1.5 million tons (500 million gallons) of ethanol and 600,000 tons (200 million gallons) of biodiesel.[49] In China, traditional energy such as diesel and gasoline are still the main resources of transport energy, accounting for more than 96 percent of total energy consumption. In contrast, CNG and other alternative energy, such as biofuels, contribute to less than 4 percent of the total transportation energy. The breakdown of the current transportation composition energy in China is illustrated in Figure 15.

## 3.1.1 Growth in energy consumption of transport

According to our research, we predict that transportation energy consumption will keep increasing along with the rapidly growing vehicle population. For our analysis, we make the assumption that in 2009, vehicles sales stood at 11.3 million. Assuming an average annual growth rate of 8 percent, we predict that the annual sales of automobiles will be approximately 24 million by 2019 (see Figure 16). As we previously stated, the total number of automobiles on the road is estimated to reach approximately 200 million by 2020, up from 76 million.[50] This calculation takes into account a 10-year scrappage cycle.

Consequently, by 2020, the energy consumption of the transportation sector will be equivalent to 80 million tons (29 billion gallons) of gasoline and 180 million tons (55 billion gallons) of diesel, almost twice as much as current transportation energy consumption.[51] By that time, the transportation sector will account for more than 45 percent (250 million tons) of China's total oil consumption, an increase of 12 percent from the current figure of 33 percent (130 million tons).[52]

Note: Chinese refineries are configured to maximize diesel production—one ton of crude oil can produce 0.2 tons of gasoline and 0.4 tons of diesel. This is opposite to the US situation, in which refiners maximize gasoline.

## 3.1.2 Outlook for alternative energy

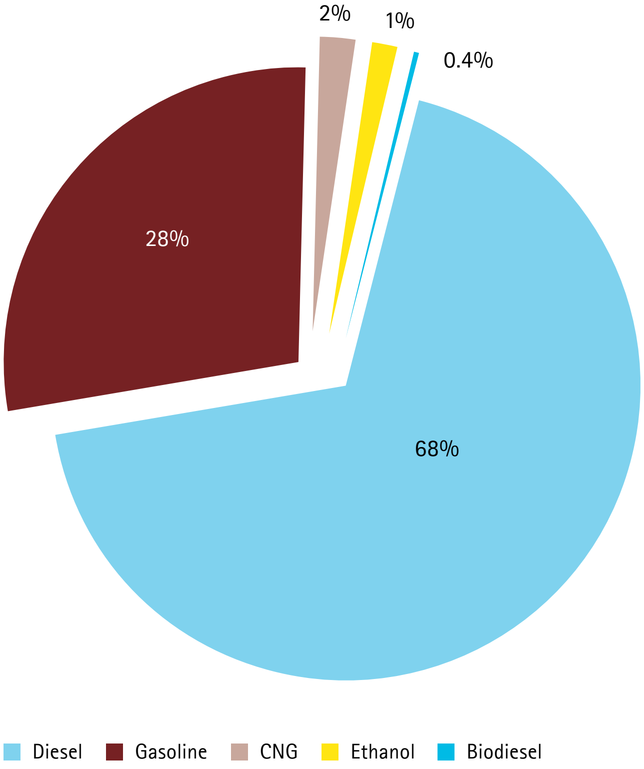
The structure of the transportation energy sector in China is expected to change significantly over the course of the next 10 years (see Figure 17). The proportion of alternative energy is expected to increase, gradually eroding the share currently occupied by traditional energy sources. Our projection for the future energy structure in China is based on a key assumption that all of the alternative energy technologies in play today will continue to advance but, due to internal and external reasons, the development of different technologies might vary. By 2020, up to 30 percent of the transport fuels will be replaced by alternative energy. As a result of uncertainty of the market change and policy adjustment, the energy savings contributed by alternative energy could fluctuate from 27 to 32 percent.

The development of alternative energy in the Chinese transportation sector could benefit the nation in a number of ways:

### Fulfilling China's emission commitment

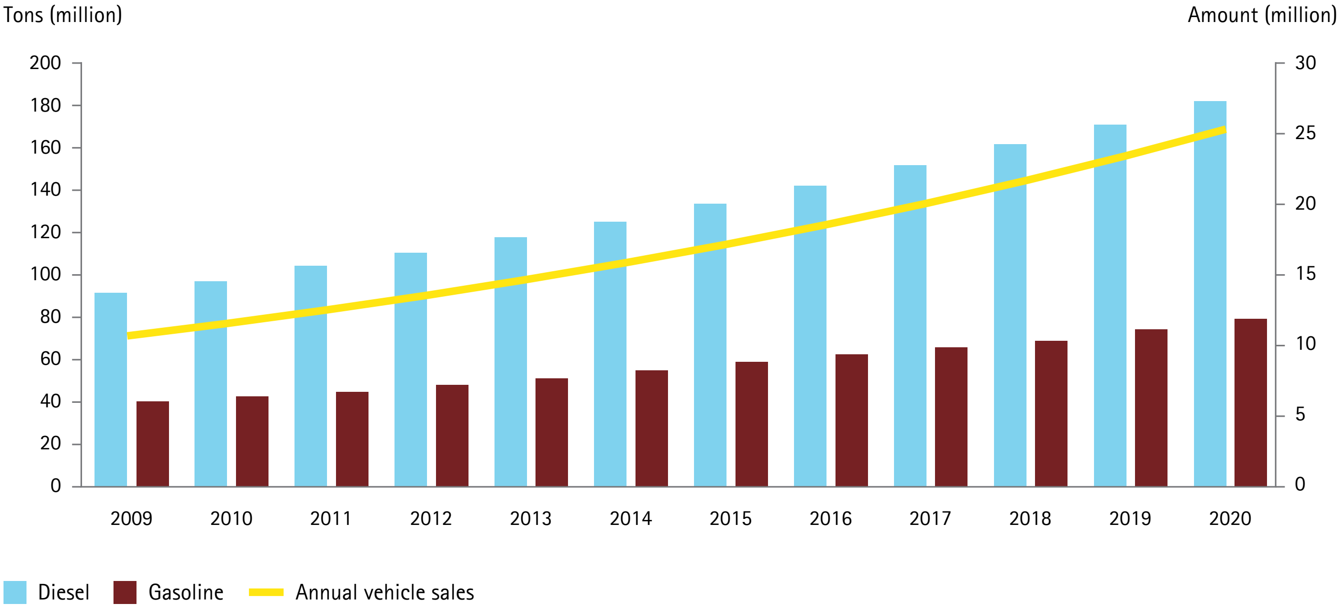
To achieve its goal of environmental protection and sustainable development, China will be forced to change from traditional energy to clean alternative energy. By 2020, transportation emissions will account for more than 20 percent of China's total emissions.[53] China's own ambitions are echoed by the December 2009 United Nations Climate Change Conference in Copenhagen, which

Figure 15. China's energy structure in transportation sector (2009).



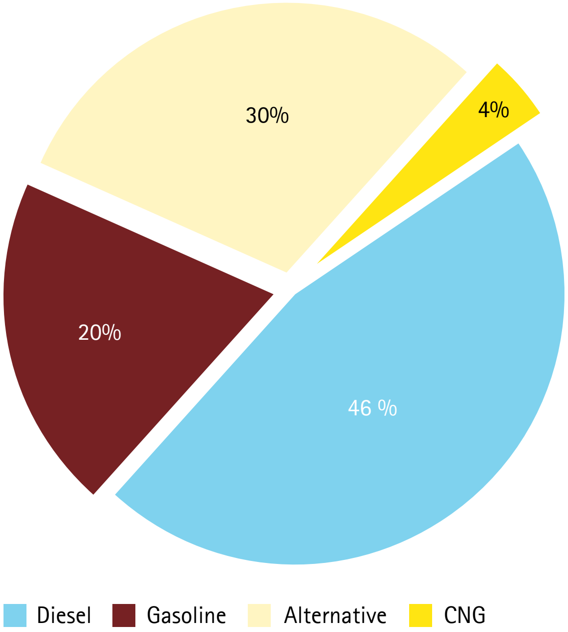
Note: Due to rounding, total may not equal 100 percent.
Source: "For the first time, China becomes the largest investor in clean energy in the world,"
China New Energy, Date, http://www.newenergy.org.cn/html/0103/3271031980.html.

Figure 16. Projections on vehicle sales and transportation energy consumption in China.



Sources: Accenture analysis: Automotive industry expert interviews: Dean of Department of Automotive Engineering at Tsinghua University, Ouyang,Minggao; Accenture traffic forecasting model of the energy market.

**Figure 17. Energy structure projection in China's transportation sector by 2020.**



Sources: Accenture analysis: Automotive industry expert interviews: Dean of Department of Automotive Engineering at Tsinghua University, Ouyang, Minggao; Accenture traffic forecasting model of energy market; Accenture analysis: expert interview—new generation of internal combustion engine technology; Zhang, YangJian, Xiang, Weida, China's fuel ethanol development status and trend analysis, China Energy, January 31, 2009; Automotive Technology Day: Winter 2010, http://techon.nikkeibp.co.jp/article/SEMINAR/20100105/178950; U.S. Department of Agriculture, Foreign Agricultural Service, Global Agricultural Information Network, China Biofuels Annual Report 2009, http://gain.fas.usda.gov/Recent%20GAIN%20Publications/BIOFUELS%20ANNUAL_Beijing_China%20-%20Peoples%20Republic%20of_2009-7-17.doc.pdf.

expects developing countries to reduce their emissions. The development of alternative energy could help to mitigate at least 10 percent of transportation emission if developed properly.[54]

## Ensuring China's energy security

Developing alternative energy will help protect China's energy security. The gap between supply and demand for traditional energy in China is growing; internal resources alone cannot meet the market demand and support the country's economic development. As a result, energy imports are expected to rise to fill the gap. As the third-largest petroleum import country in the world, China imports more than 50 percent of the country's total petroleum consumption.[55] As the domestic oilfields' production declines and the demand for hydrocarbon fuel continues to increase, the dependence on oil imports is getting stronger, potentially resulting in risks to national energy security. Adopting alternative energy could potentially mitigate this energy supply deficiency. According to Accenture's analysis, the alternative energy industry could provide substitutions to traditional transport fuels to save oil imports by 21 percent (92 million tons or 676 million barrels) by 2020.[56]

## Benefiting China's economic development

Alternative energy and new technologies play an important role in China's future economic growth; namely, the development of alternative energy could provide broader benefits to the domestic economy. The majority of development in China has occurred in urban areas, but less in rural areas. A major challenge for China is how to redress the balance of overall economic growth. The development of a cellulosic ethanol market could help China to solve these issues by providing jobs and bringing investment into agricultural and rural areas. By 2020, the cellulosic ethanol industry is expected to create 6 million job positions in rural areas.[57]

# 3.2 Alternative transport fuels in China

In *Betting on Science*, we looked at technologies in transport fuels that have the potential to "disrupt" the current views of supply, demand and GHG emissions over the next 10 years. Accenture identified 12 technologies and classified them into three categories: Evolutionary, Revolutionary and the Game Changer. It is important to note that *Betting on Science* did not aim to pick winning technologies. There will be technologies that we missed, and not all technologies highlighted in the report will be successful. The goal was to raise awareness of the technologies that could change the fuels landscape and the companies commercializing these technologies. This section explores which of these technologies have the most potential for China.

China is a developing country with a large population and a comparatively weak economic foundation. This is due to the disparity between the fast economic development occurring in urban areas, as opposed to the slower development witnessed in rural areas (due to a poor economic foundation in these areas). However, this development is littered with hidden pitfalls, such as environmental degradation and food shortages, which are of concern to both the government and the public. Considering our assessment of 12 technologies in China (see Figure 18), not all of them possess the potential to develop prosperously in the next 10 years. Some technologies are not in practice in China (marine scrubbers and airline drop-ins), some have technology disadvantages or uncertainty (waste-to-fuel, butanol and algae), and some will threaten food security (technologies that rely on corn, sugar cane or other food feedstock).

Based on our research, the technologies on which we think China will focus development are: next-generation internal combustion engine (NGE), next-generation agriculture (represented by cellulosic ethanol) and electrification (PEV).[58] The recommendation is based on China's geographic location, and we believe it will balance China's short-term and long-term development goals. Furthermore, the right strategy and investment in alternative energy will enable China to move ahead of the competition in the global economic arena.

Figure 18. Accenture's assessment of the 12 technologies in China, from *Betting on Science*.

| | Technology | Economic competitiveness | Market (supply and key players) | Social responsibility (emission commitment, job creation and other concerns) | Resources (materials, investment and facilities) | Government regulations |
|---|---|---|---|---|---|---|
| **Evolutionary** | | | | | | |
| Next-generation internal combustion engine (NGE) | ○<br>Multiple technologies exist in this field, most of which are mature enough for large-scale manufacture. NGE will be one of the easier technologies to implement. | ○<br>Comparatively low cost. The extra cost of NGE could be covered by energy savings soon enough. | ○<br>China has the largest vehicle market in the world. Due to the rapidly increasing oil price, the demand for a high-efficiency engine also is growing. | ○<br>Current technology could save energy use by 5 percent and reduce emission. The energy-saving efficiency will keep increasing with technology development. | N/A | ○<br>Government is working on new energy-efficiency standards for vehicle engines. |
| Next-generation agriculture (cellulosic) | ○<br>International cooperation in R&D; technology breakthrough in five years that could increase energy conversion efficiency and reduce cost by 50 percent. | ○<br>Unit cost of cellulosic ethanol is RMB 8,000/ton; the cost will be lower with technology development. | ○<br>The demand for biofuels is large; cellulosic ethanol will be the major biofuels in China. State-owned enterprises (SOEs) take the lead in cellulosic ethanol industry. | ○<br>E10 gasoline could reduce CO emission by 30 percent, hydrocarbon by 40 percent, $CO_2$ by 90 percent and also reduce NOx emission. | ○<br>China is rich in straw resources (feedstock), the annual production amount of which is as high as 650 million tons. | ○<br>China views biofuels, especially cellulosic ethanol, as essential and strategic components of a secure economy and has taken an active role in regulating the supply and demand side of the biofuels market. |
| Waste-to-fuel | ?<br>High theoretical feedstock ability; currently the major resource is extra vegetable oil. New technology is in R&D. | ○<br>Feedstock costs represent a considerable portion of biofuel production costs; with less than zero or even negative feedstock costs, the economics of waste-to-fuel processes appear favorable. | ○<br>China has great potential in the waste-to-fuel market. 50 plants have been completed, with another 25 under construction. | ○<br>Some incineration processes are fairly GHG-intensive. More advanced techniques offer better emissions reduction performance. It could create millions of job and huge profits in China. | ○<br>Asian Development Bank invested $200 million to build waste-to-fuel factories in China. | ?<br>No clear standard in this field causes a slow development. |
| Marine scrubbers | N/A | N/A | N/A | N/A | N/A | N/A |
| **Revolutionary** | | | | | | |
| Synthetic biology: Sugar cane-to-diesel | X<br>China does not have any experience in this technology. | X<br>Assuming this uses food feedstock to obtain the sugar (e.g., sugar cane or corn), this will not be allowed. | N/A | N/A | X<br>Threatens food security. | ?<br>China might support this technology since it does not hold strong opposition against genetic engineering. |
| Biobutanol | X<br>A fungible fuel with a wide range of applications, but China does not have technological proprietary intellectual property rights in this field. | X<br>Assuming this uses food feedstock to obtain the sugar (e.g., sugar cane or corn), this will not be allowed | ○<br>Huge market demand; five major manufacturers in the industry; large annual production. | N/A | X<br>Threatens food security. | ?<br>Government has initiated multiple plans to encourage development of the butanol industry. |

| | Technology | Economic competitiveness | Market (supply and key players) | Social responsibility (emission commitment, job creation and other concerns) | Resources (materials, investment and facilities) | Government regulations |
|---|---|---|---|---|---|---|
| **Revolutionary** | | | | | | |
| Biocrude | ?<br>Technology is still in the beginning phase; currently not mature enough. | ?<br>If the scaling and technology development could be accomplished, biocrude is expected to be competitive within this range. | ○<br>Meets the demand of fast-growing diesel and aviation fuel demand. | N/A | N/A<br>The first generation of biocrude will use corn straw as feedstock. Feedstock logistics will be a challenge. | N/A |
| Algae | X<br>Only a few research institutions (e.g., Tsinghua University) are engaging in the research of algae technology. | N/A | ○<br>If developed properly, could meet the huge market demand for new and clean energy substitution. | ○<br>Not only reduces emissions, but also sequesters $CO_2$ from power plants. Algae does not take up farmland. | X<br>Currently, the engineering, infrastructure and water required is still significant. | N/A |
| Airline drop-ins | N/A | N/A | N/A | N/A | N/A | N/A |
| **The Game Changer: Electrification** | | | | | | |
| PHEV/PEV/ electrification engines | ○<br>Independently designed PEV; EV/ PHEV/HEV are all evolving rapidly. | ?<br>PEV is much more expensive than traditional vehicles, but the savings on energy consumption could compensate the extra expense. | ○<br>China has the largest vehicle market; the demand for alternative energy also is huge. PEV is the future of transport fuels. | ○<br>HEV could save 40 percent energy consumption; PHEV 60 percent and EV 100 percent. | ○<br>Huge amount of capital is flowing into PEV industry from government and private investment. | ○<br>Government sets national developing goals of PEV industry; offers subsidies to PEV costumers. |
| Batteries | ○<br>China has one of the world's top battery companies; leadership in battery manufacture. | ?<br>Currently, battery price is high, but electricity price is much lower than gasoline as power source. | ○<br>Large market for battery. | N/A | ○<br>Rich in lithium resources; abundance investment. | ○<br>Encourage the development of battery industry and best leverage China's comparative advantages. |
| Vehicle-to-grid (V2G) | N/A<br>Technology not mature enough to assess. | ○<br>If V2G is realized, the cost of PEV will be reduced significantly. | ?<br>Relies on public facilities and government support; market has great uncertainty. | ○<br>V2G has the potential to have significant savings over the traditional energy. | N/A | ○<br>Build public charging stations; view PEV as strategic developing goal. |

**Assessment marks:**

○ : the technology has potential or advantages under given criteria
? : uncertainty in future development
X : disadvantages or bottleneck exist
N/A : no information

Notes: (1) Overall judgment of technologies is based on assessments from different criteria.
(2) Some of the technologies, such as marine scrubbers and airline drop-ins, do not exist in China or are not currently in practice, so the information is not available.
Sources: Sources for this figure can be found in the Endnotes section at the end of the document.

Figure 19. Energy-saving efficiency and emission reduction of NGE, cellulosic ethanol and PEV.

| Technology | Energy-saving potential | Emission reduction |
|---|---|---|
| NGE | 20 to 40 percent | 20 to 40 percent |
| Cellulosic ethanol | 80 percent | Reduce CO by 30 percent, $CO_2$ by 10 percent and, hydrocarbon by 40 percent |
| PEV | 100 percent | Zero emission |

Source: Accenture analysis.

The criteria we used to select the recommended technologies and the rationale for this recommendation is described below and in Figure 18.

- Technology that is mature enough for commercialization: The technologies in NGE, cellulosic ethanol and PEV are mature enough for commercialization. For NGE, there are already technologies that are either available or soon to be applied in China. The technology for large-scale cellulosic ethanol production is already a reality and will continue to improve over the course of the next five years. In contrast, some technologies, such as biobutanol and algae, are not currently available in China and therefore there is little scope for their development over the course of the next five years.
- Economically competitive in the market: As the price of oil increases, the economics of NGE and PEV are becoming increasingly more attractive in the vehicle market. The unit cost of cellulosic ethanol will be lower than the average oil price in three to five years.
- High energy efficiency and significant emission reduction: The three recommended technologies (NGE, cellulosic ethanol and PEV) possess great potential in energy savings and emission reduction (see Figure 19). These three technologies are expected to ease gasoline use by 46 million tons, which is as much as 17.7 percent of total transportation energy consumption in 2009.
- Strong regulatory support and direct investment from the government: The Chinese government has taken various steps to encourage the development of the three aforementioned technologies, namely, via the introduction of regulatory support, financial incentives and direct investment (see Figure 20).

By 2020, the three major alternative technologies mentioned will have very different energy-saving contributions (as illustrated by the scenarios in Figure 21). In Accenture's view, in the short term (next five to 10 years), NGE and bioethanol will continue to develop at a steady pace, while in the long term, the energy structure will become more diversified with various new technologies entering the market. Of the three technologies on which we focused, NGE will be the main contributor to energy savings. In relation to the development of bioethanol, we predict that it will gradually transition into the stage where cellulosic materials are used as feedstock. The technology which has the highest level of uncertainty is PEV. The range of transport fuel replacement is mainly caused by the number of PEVs on the road.

Figure 20. Current policies concerning alternative energy in China.

| | NGE | Cellulosic ethanol | PEV |
|---|---|---|---|
| General view | Main force of energy savings and emission reduction in the next five to 10 years. | Strategic component of energy security, significant job creation and sustainable economy. | Game changer in transportation sector, future of new energy industry. |
| Guidelines | Encourage engine technology development; encourage low emission vehicles with high energy efficiency. | Biofuel development should not compete with crops intended for human consumption. Policy inclines to cellulosic ethanol. | Want to own the largest amount of PEV and HEV in the world. |
| Developing goal | By 2020, NGE vehicles will account for 36 percent of total vehicle amount, and save 8.9 percent fuel consumption. (Does not include HEV) | By 2020, non-grain-based fuel ethanol annual production ability will reach 10 million tons. (3.6 billion gallons) | By 2020, PEV account for 10 percent of China's total vehicle population. |
| Tax deduction | Vehicles with 1.6 L engine (or smaller): In 2009, 50-percent purchase tax deduction; in 2010, 25-percent purchase tax deduction. | – | – |
| Subsidies | – | – | Provide RMB 60,000 (US$8,800) subsidies to PEV customers; compensate the extra cost for hybrid bus. |
| Investment | – | – | Invest more than RMB 100 billion (US$15 billion) to facilitate the commercialization of PEV in the next 10 years. |

Sources: Zhang, YangJian, Xiang, Weida, China's fuel ethanol development status and trend analysis, China Energy, January 31, 2009; U.S. Department of Agriculture, Foreign Agricultural Service, Global Agricultural Information Network, China Biofuels Annual Report 2009, http://gain.fas.usda.gov/Recent%20GAIN%20Publications/BIOFUELS%20ANNUAL_Beijing_China%20- %20Peoples%20Republic%20of_2009-7-17.doc.pdf; National development and reform commission, "Mid/long-term development plan for renewable energy," August 31, 2007, www.ndrc.gov.cn/zcfb/zcfbtz/2007tongzhi/t20070904_157352.htm; Automotive industry restructuring and revitalization plan, document from the State Council, www.gov.cn/zwgk/2009-03/20/content_1264324.htm; "New paradigm for new energy vehicles," Industry Updates, August 31, 2010, via Factiva, © China Daily Information Company;"Ten City, Thousand Cars," the policy of Ministry of Science and Technology, Xiong jinchao, January 6, 2009, Xinhuanet; http://news.xinhuanet.com/auto/2009-01/07/content_10615121.htm; The 11th Five Year Plan, Chinese Government's Official Web Portal, www.gov.cn/english/special/115y_index.htm.

Figure 21. The future development of NGE, cellulosic ethanol and PEV in China.

| Next-generation engine (NGE) | Cellulosic ethanol | PEV (PHEV and EV) |
|---|---|---|
| • Potential for technology improvement<br>• Comparatively easy to implement<br>• Economically desirable in the market | • Significant job creation<br>• Significant emission reduction<br>• China possesses resources advantages | • Game changer in transportation sector<br>• Government's policy and financial support<br>• Transition from hybrid to pure EV |
| By 2020 | By 2020 | By 2020 |
| • 40 percent of vehicle population<br>• Save about 12 percent of traditional energy | • 10 million tons per year<br>• Substitute about 4 percent of transport fuels | • 5 percent of total vehicle population<br>• Substitute about 4 percent of traditional energy |

Source: Accenture.

**Figure 22. Current NGE technologies in China (cost comparison and energy saving efficiency).**

| NGE technology | Extra cost | Energy-efficiency saving |
|---|---|---|
| Variable valve timing (VVT) | 2 to 3 percent higher; about RMB 800 | 1 to 3 percent |
| Entire aluminum engine (EAE) | 5 to 10 percent higher; about RMB 4,000 | 2 to 3 percent (weight reduction) |
| Turbocharger (T) | RMB 2,000-3,000 higher | 3 to 5 percent (dynamic strength improvement) |
| Downsized gasoline direct injection (GDI) | RMB 3,000-5,000 higher | Approximately 5 percent |

NOTE: Extra cost and energy-saving efficiency of NGE is compared with traditional engine of similar performance.
Sources: Accenture analysis: Interviews with market experts on internal combustion engines; Interviews with car sales agents; Accenture analysis, car price and energy consumption data from Autohome, www.autohome.com.cn.

From our analysis, we predict that by 2020, NGE (together with HEV) will save transportation gasoline consumption by 31 million tons (11.3 billion gallons) and cellulosic ethanol will act as a substitute for 10 million tons (3.6 billion gallons). The energy-saving contribution of PEV may vary in accordance with our range of potential fuel scenarios from 5 million tons of gasoline (1.8 billion gallons) to 17.7 million tons (6.4 billion gallons). In our conservative scenario (mix: 60 percent NGE, 20 percent biofuel, 20 percent PEV) we estimate an energy-saving contribution of 15 percent or 40 million tons of gasoline. Our primary optimistic scenario (50 percent NGE, 17 percent biofuel, 33 percent PEV) would yield a gasoline savings of 18 percent or 48 million tons, with our secondary optimistic scenario (45 percent NGE, 15 percent biofuel, 40 percent PEV) producing a gasoline savings of approximately 20 percent of 54 million tons.

Our projections on the emission-reduction contributions from the three major technologies by 2020 suggests a potential reduction in transportation emissions of about 45 percent and of China's total emissions by approximately 9 percent.

It is important to enlarge the proportion of PEV in alternative transportation, which will maximize energy savings and lead to a reduction in emissions in the long run.

## 3.2.1 Next-generation internal combustion engine

### Opportunity

Given the mature technologies and market, NGE is the most effective way to realize energy savings in a relatively short period of time. NGE is an evolution based upon existing technologies, thus it is comparatively easy and cheap to implement. NGE technology is already being widely used in China, with NGE vehicles currently accounting for 5 percent of total vehicles on the road, and 20 percent of new vehicle sales.[59]

Multiple advanced engine technologies already exist in the market (see Figure 22). Currently, existing NGE technology in China can save energy use by an average of 5 percent, compared with traditional vehicles.

Furthermore, future technological advancements could potentially lead to the energy-saving efficiency of NGE increasing to around 20 to 30 percent by 2020.

Major automobile companies all actively engage in R&D and commercialization of NGE. NGE vehicles are becoming increasingly more economically desirable in the market, due to the green concept and increasing fuel price. As a result, most automobile companies in China now play an active role in the R&D of NGE and have brought energy-saving vehicles to the market (see Figure 23). In the future, we expect this trend to continue as these companies continue to increase their investments in NGE industry.

Figure 23. Chinese automobile companies and their NGE technologies (after 2008).

| Company | Next-generation engine technology | Vehicle type | Time to market | Proportion of total sales |
|---|---|---|---|---|
| FAW-VW | T/GDI | Magotan, Sagotan | 2009 | 33% |
| Changan Ford | VVT | Focus, Ford Mondeo | 2008 | 70% |
| | EAE | Focus, S-MAX, Ford Mondeo, New Fiesta | 2008 | 100% |
| FAW Toyota | VVT | Toyota RAV4, Corolla, Landcruiser, Reiz, Vios | 2008 | 80% |
| | EAE | Toyota RAV4, Corolla, Crown, Reiz, Vios | 2008 | 87% |
| Honda | VVT | Honda CR-V, Civic, Fit-Saloon, new Odyssey, Accord | 2008 | 93% |
| | EAE | Honda CR-V, Civic, Fit-Saloon, new Odyssey, Accord, Spirior | 2008 | 100% |
| Suzuki | VVT | Liana, Tianyu SX4, Swift | 2008 | 45% |
| | EAE | Langdi, Alto, Liana, Tianyu SX4, Swift | 2008 | 100% |
| Dongfeng Nissan | VVT | Tiida, Teana, Qashqai, Sylphy, Tiida NB | 2008 | 65% |
| | EAE | Geniss, Livina, X-Trail, Tiida, Teana, Qashqai, Sylphy, Tiida NB | 2008 | 100% |
| Changcheng Auto | VVT | GWPeri, Harvard M1, Coolbear, Florid, Lingao | 2008 | 63% |
| | EAE | GWPeri, Harvard M1, Coolbear, Florid, Lingao | 2008 | 63% |
| Geely Auto | VVT | Vision | 2009 | 13% |
| | EAE | Vision | 2009 | 13% |
| Chery Auto | T/GDI | Ruiqi G5 | 2010 | 4% |
| | EAE | Chery A5 | 2009 | 4% |

Note: T: Turbocharger; GDI: Gasoline direct injection; VVT: Variable valve timing; EAE: Entire aluminum engine.
Sources: Company websites, press releases and annual reports.

Based on the cost-benefit analysis on NGE vehicle consumption, energy-saving efficiency and gasoline price, energy savings could compensate for the extra vehicle expense in three to four years (see Figure 24). The NGE energy-saving efficiency will keep increasing as technology develops, which in turn will make the NGE industry more competitive, giving cause for optimism in the future.

To encourage the development of NGE, in 2009, the Chinese government provided a 5-percent tax rate reduction on vehicles with 1.6 L engines or smaller (from the original 10-percent tax rate) as an incentive for customers to purchase NGE vehicles. In 2010, the tax rate was 7.5 percent (a reduction of 2.5 percent from the original tax rate).[60]

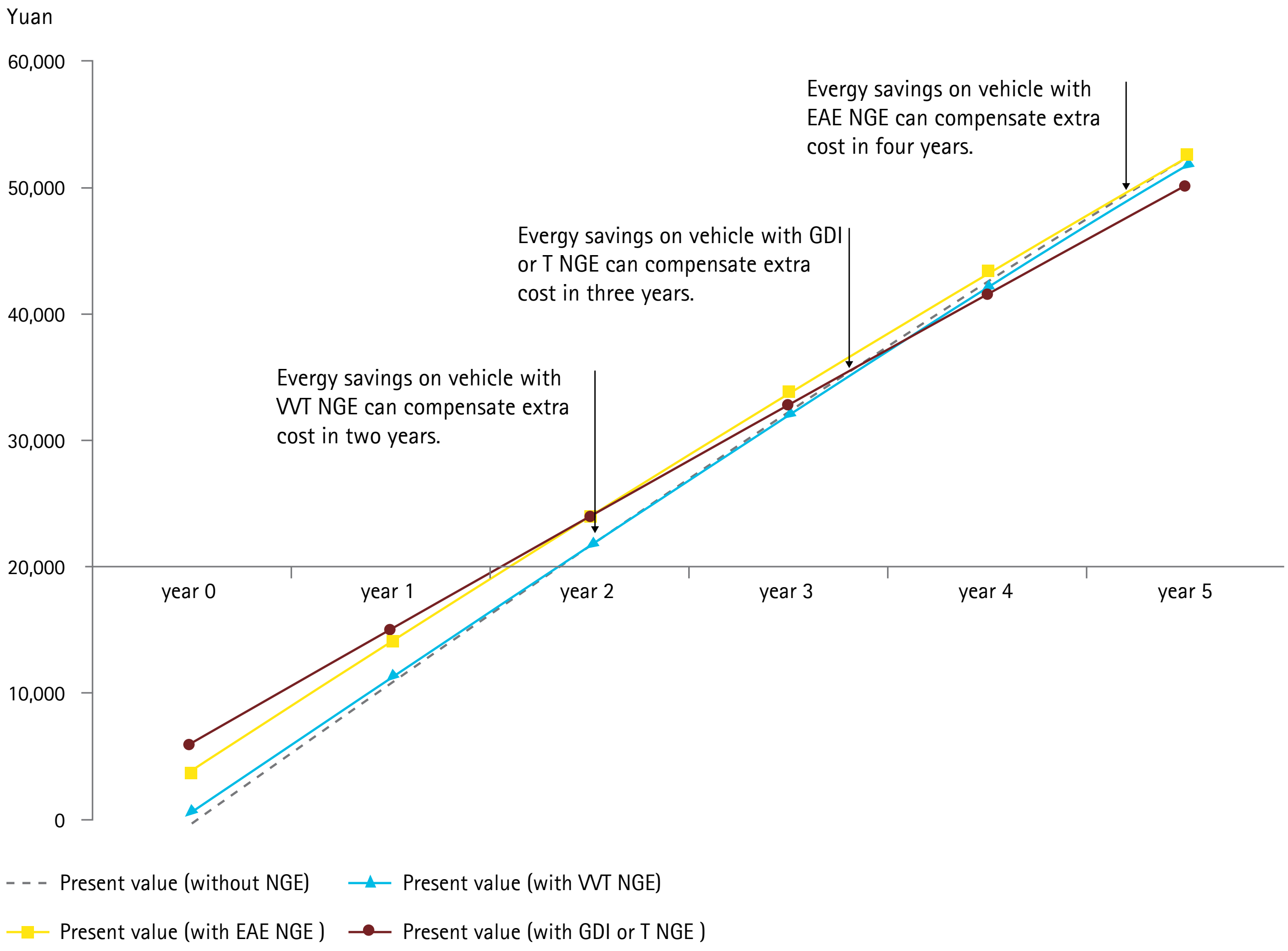
HEV opens a new arena of advanced engine technologies. A number of Chinese automobile companies are actively engaged in the HEV market. HEVs combine a conventional ICE with an electric propulsion system. By utilizing an electric power-train during start up and acceleration, HEVs are capable of achieving better fuel economy as well as better performance. The energy-saving efficiency of HEV can be as high as 40 percent, compared with traditional ICE vehicles.

We predict that the NGE industry will develop prosperously in China and over the course of the next five years, and automobile manufacturers will devote more effort to the development of NGE vehicles. NGE vehicles (including HEV) will account for 41 percent of China's entire vehicle population, and save gasoline consumption by more than 30 million tons (approximately 12 percent) by 2020 (see Figure 25).[61]

## Challenges

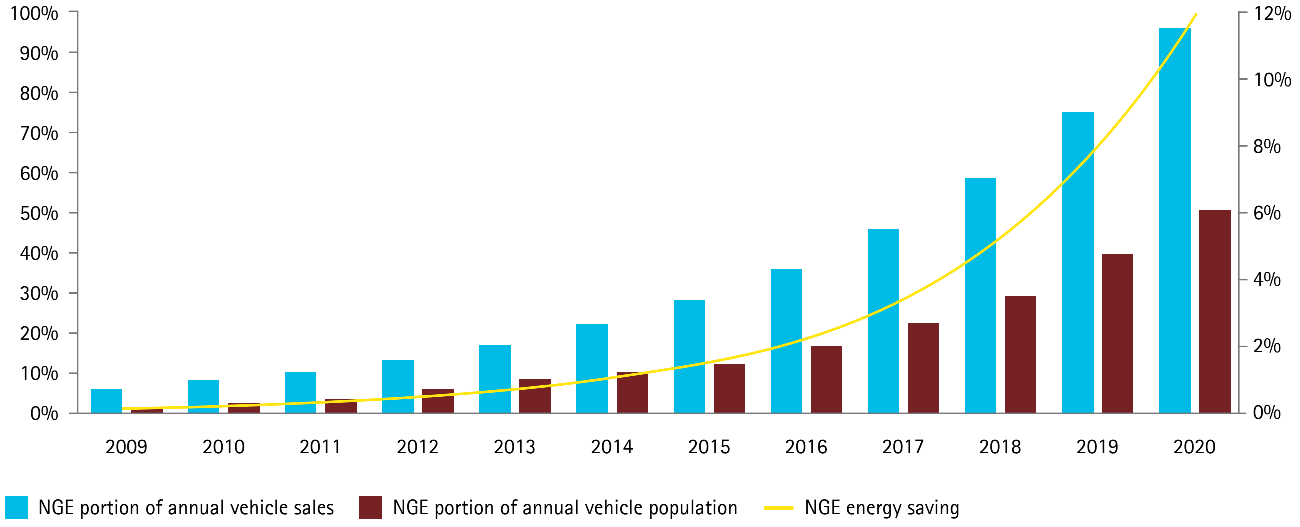
The competition between manufacturers within the NGE industry is centered on the development of technology. With advanced NGE technologies, countries could maximize the benefits of energy savings and emission reduction. However, at present, China does not possess the world's most advanced NGE technologies. Instead, developed countries such as Japan, Germany and the United States are leading the way in the revolution of the ICE. Currently, the energy efficiency of ICEs in China's vehicle market is more than 10 percent lower than that in the aforementioned developed countries. Furthermore, China's vehicle engine technology is at least 10 years behind that of Japan.[62] This deficit in the development of engine technologies compromises the energy-savings and emission-reduction contribution of NGE to China's future energy demand and presents the country's biggest challenge.

Figure 24. Cost-benefit analysis of existing NGE technologies in China.



Note: NGE – Next-generation engine; VVT – Variable valve timing; GDI – Gasoline direct injection; T – Turbocharger; EAE – Entire aluminum engine.
Sources: Accenture analysis; expert interview - new generation of internal combustion engine technology; Interviews with market experts on internal combustion engines; Interviews with car sales agents; Accenture analysis, car price and energy consumption data from Autohome, www.autohome.com.cn.

Figure 25. Projection of the NGE developing trend in China.



Sources: Accenture analysis: Accenture traffic forecasting model of energy market; Expert interview - new generation of internal combustion engine technology.

## 3.2.2 Cellulosic ethanol

### Opportunity

China's demand in the transportation area is dominated by diesel. Theoretically speaking, biodiesel should have higher market opportunity compared with ethanol. However, biodiesel suffers from low quality and limited feedstock, and the lack of a commercialized channel and clear government incentives.

The future of the biofuels industry in China is cellulosic ethanol, as it could provide a steady source of transportation energy substitution in the future. China views biofuels, in particular bioethanol, as an essential component of its future energy security strategy and economic development, and has taken an active role in regulating both the supply and demand of the biofuels market. Figure 26 illustrates the industrial value chain of the cellulosic ethanol industry. In the past, the Chinese government supported the corn-based bioethanol industry; however, as a result of food scarcity, government policies have turned to support non-grain-based fuel ethanol production. The Chinese government has mandated that biofuel development (including fuel ethanol and biodiesel) must not compete with crops intended for human consumption.[63]

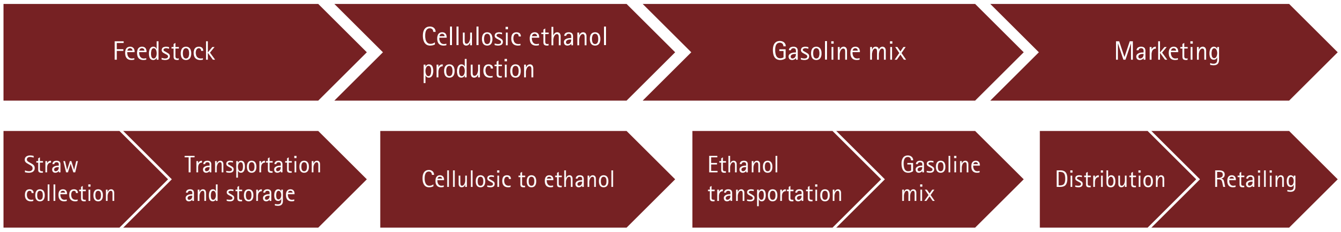
According to China's development plan for alternative energy, in 2010, the use of non-grain-based bioethanol was 3 million tons (1.1 billion gallons) and by 2020, the annual production ability will reach 10 million tons (3.6 billion gallons).[64]

State-owned enterprises dominate the market with huge investments. Due to the lack of government incentives, private companies are not as actively involved in the market of bioethanol in comparison with other alternative energy sources. Currently, the bioethanol industry is dominated by state-owned enterprises in China. At present, China National Cereals, Oils and Foodstuffs Corporation (COFCO), China National Petroleum Corporation (CNPC), China Petroleum & Chemical Corporation (Sinopec) and China National Offshore Oil Corporation (CNOOC) have all invested heavily into the market of cellulosic ethanol (see Figure 27). These companies will play an important role in the future industrialization and commercialization of cellulosic ethanol.

Furthermore, Chinese companies also are seeking international cooperation within technology R&D. For example, COFCO and Sinopec are collaborating with Novozymes on R&D for cellulosic ethanol production.[65] With expected technological breakthroughs in the next three to five years—including better enzymes, efficient yeast strains to convert both C5 and C6 sugars, integrated and optimized engineering processes, and comprehensive utilization of side products like lignin—the unit cost of ethanol production will be reduced dramatically and may be competitive against corn-based ethanol.[66]

China has a resource advantage in cellulosic ethanol with an annual straw production of 650 million

Figure 26. Industrial value chain of the cellulosic ethanol industry.



Source: Accenture.

Figure 27. Major players in cellulosic ethanol industry and their investment plans.

| Plant | Company | Feedstock | Investment plan | Capacity |
|---|---|---|---|---|
| Heilongjiang Huarun ethanol | COFCO | Cellulosic | RMB 10 billion (US$1.5 billion) in five years.<br>Cellulosic will account for 66 percent of feedstock. | 3 million tons (1.1 billion gallons) ethanol production by 2010. |
| Anhui Fengyuang bioethanol | | Cellulosic | | |
| COFCO Guangxi cassava program | | Cellulosic | | |
| Jilin bioethanol | CNPC | Cellulosic | RMB 10 billion (US$1.5 billion) by 2010.<br>Build another 100 bioethanol plants by 2020. | 2 million tons (0.7 billion gallons) ethanol production by 2010. |
| Hennan Tianguan bioethanol | Sinopec | Cellulosic | | |
| CNOOC | CNOOC | Cellulosic | Invest RMB 370 billion (US$5.5 billion) in the ethanol program with Indonesia. | |

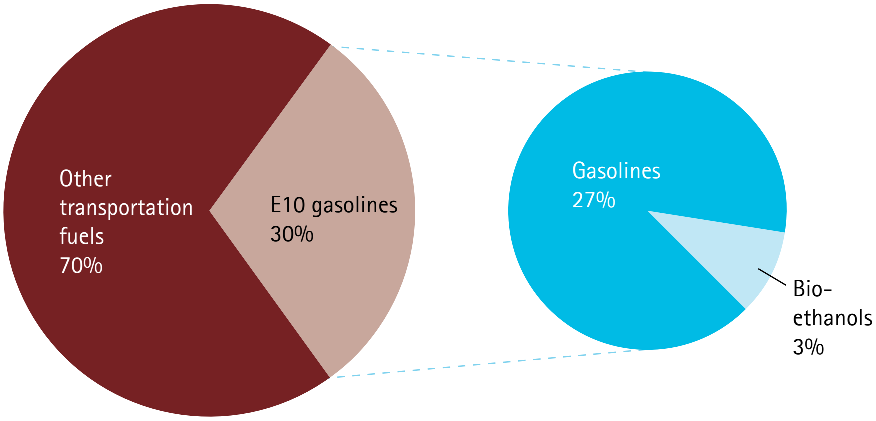
Sources: "The development of world cellulosic ethanol industry," SinopecNews, January 8, 2008, www.sinopecnews.com.cn/shzz/content/2008-01/08/content_468198.htm; 2009 annual reports of Sinopec, CNPC and COFCO.

Figure 28. China's straw resources and cellulosic ethanol production.

**650 million tons straw = 139 million tons bioethanol = 2.7 Daqing oilfields = 100 percent of 2009 transportation energy = 40 percent transportation energy in 2020**

Source: Accenture.

Figure 29. Contribution of cellulosic ethanol to transportation energy savings in China (2020).



Sources: U.S. Department of Agriculture, Foreign Agricultural Service, Global Agricultural Information Network, China Biofuels Annual Report 2009, http://gain.fas.usda.gov/Recent%20GAIN%20Publications/BIOFUELS%20ANNUAL_Beijing_China%20-%20Peoples%20Republic%20of_2009-7-17.doc.pdf; Clean energy industry research report 2009, China Investment Corporation.

tons.[67] China's cellulosic ethanol production capability (theoretically) is as much as 139 million tons (50 billion gallons). This potential capability could meet the energy need of the entire transportation sector (2009) and account for more than 40 percent of transport fuels by 2020 (see Figure 28).

It is predicted that China's annual cellulosic ethanol production will reach 10 million tons (3.6 billion gallons) by 2020, saving 3 percent of the total transportation fuel (in the form of E10 gasoline) which will, in turn, account for 30 percent of transport fuels[68] (see Figure 29).

## Challenges

Feedstock accessibility and unit cost are the major challenges for profitable growth that will constrain the development of the cellulosic ethanol industry.

The lack of efficient business models in collection and transportation constrains the scaling of the cellulosic ethanol industry. While the abundance of straw is a resource advantage for bioethanol development in China, only one-third of the straw resources can be collected for ethanol production (one-third of the straw is used to nourish fields and the other third of straw production is used for feeding). Furthermore, the dispersed agriculture structure makes feedstock collection difficult and expensive.[69]

In addition, the storage of straw creates difficulties. The moisture of straw is still very high after collection; therefore, it must be dehydrated to save storage space and cost. This process is time consuming and requires significant farmland to dry the straw.

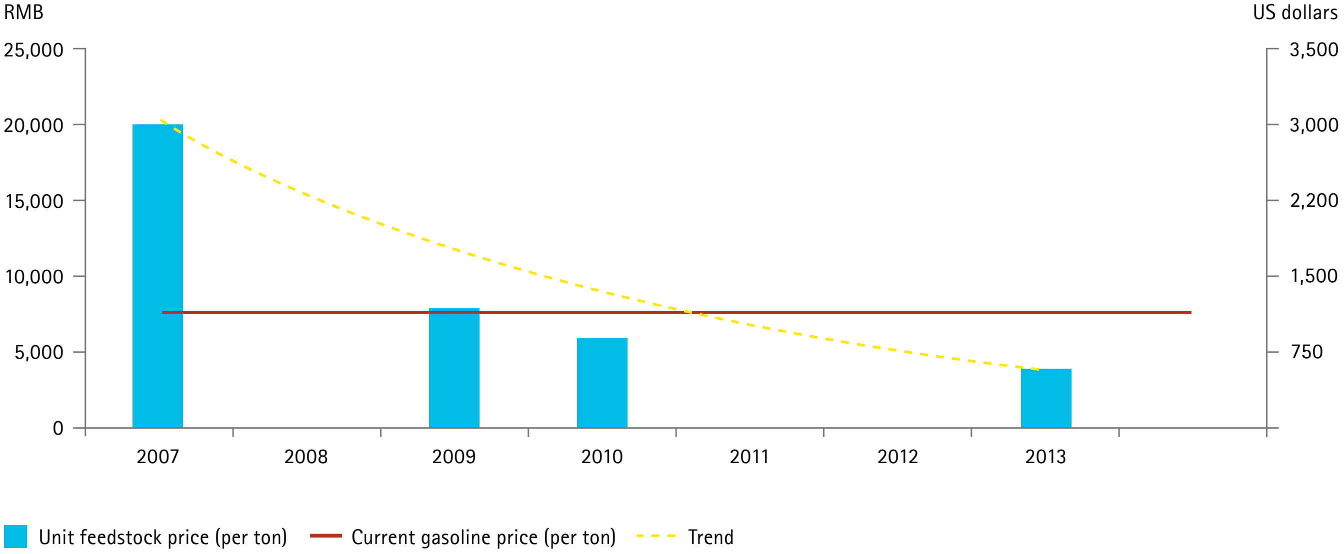
Straw collection and transportation also compromise the accessibility of feedstock. Currently, there is not an efficient and effective business model to guide feedstock collection and transportation in China. Therefore, the difficulty of feedstock collection and transportation will be the bottleneck that constrains the scaling of the cellulosic ethanol industry.

Unit cost determines the economic competitiveness of cellulosic ethanol, and also determines the commercialization of cellulosic ethanol. Currently in China, some ethanol producers such as Tianguan Group have been talking about unit cost of cellulosic ethanol under RMB 8,000/ton (US$3.2/gallon). Given the current gasoline (93#) price of RMB 5.44/L (US$3.1/gallon) at the time of the writing of this report, the cost of cellulosic ethanol must be reduced to RMB 7,600/ton (US$3.1/gallon) for it to be economically competitive.[70]

Feedstock and deconstruction are the two key components of the cellulosic ethanol industrial chain, which constitutes 75 percent of its total cost, with the remaining 25 percent coming from processing. These two sectors also are the crucial links on which to focus in order to reduce the unit cost of cellulosic production.

For cellulosic ethanol, the feedstock cost is about RMB 100 to RMB 300/ton (US$15 to US$45/ton). However,

**Figure 30. Unit feedstock cost of cellulosic ethanol in China.**



Source: Accenture analysis: Novozymes interview.

the actual cost of straw is very low, approximately RMB 20 to RMB 50/ton (US$3 to US$7.4/ton). The major portion of feedstock cost is straw collection and transportation, accounting for more than 80 percent of feedstock cost. The dispersed agriculture structure in China, together with increasing oil price, makes it difficult and expensive for feedstock collection.

However, as we previously mentioned, there is currently no efficient and effective business model for feedstock collection and transportation. Furthermore, the Chinese government provides no clear financial incentives, such as subsidies for feedstock production. Therefore, the rather uneconomically viable picture for investors remains a huge challenge that currently limits potential future investment.

Another potential way of reducing feedstock cost (unit cost) is to reduce feedstock consumption by increasing energy conversion efficiency. Following the expected technological breakthroughs over the next three to five years described earlier in this section (i.e., better enzymes, among others), energy conversion efficiency is anticipated to increase significantly, with the unit cost for feedstock consumption seeing a concurrent significant reduction[71] (see Figure 30). Additionally, ethanol production contributes to 55 percent of the total cost of cellulosic ethanol production, a major part of which is the cost of cellulase (25 percent of total cost). Technology improvement could lower the cost of cellulase and reduce the cost of ethanol production.

In Accenture's view, there is a huge potential market demand for cellulosic ethanol in China. The feedstock for ethanol production (straw resources) is abundant and the expected technological advancements should result in a significant decrease in the unit cost of cellulosic ethanol. As a result, cellulosic ethanol will become economically desirable in the market and the target of producing 10 million tons (3.6 billion gallons) of cellulosic ethanol by 2020 appears feasible. Nevertheless, the lack of an efficient and effective business model in feedstock collection and transportation compromises the industrialization of the cellulosic ethanol industry in China.

## 3.2.3 Electrification of transport

### Opportunities

An increasing number of players are entering the electrification market with huge investments. Figure 31 illustrates the extensive industrial value chain of the PEV industry. China's PEV market is developing prosperously, with increasingly more players entering the market. Since 2007, major automobile companies have started to invest in PEV R&D. By 2010, five national automobile companies had launched or announced the launching of a PEV in the market, compared to only BYD launching a PEV to market two years ago.

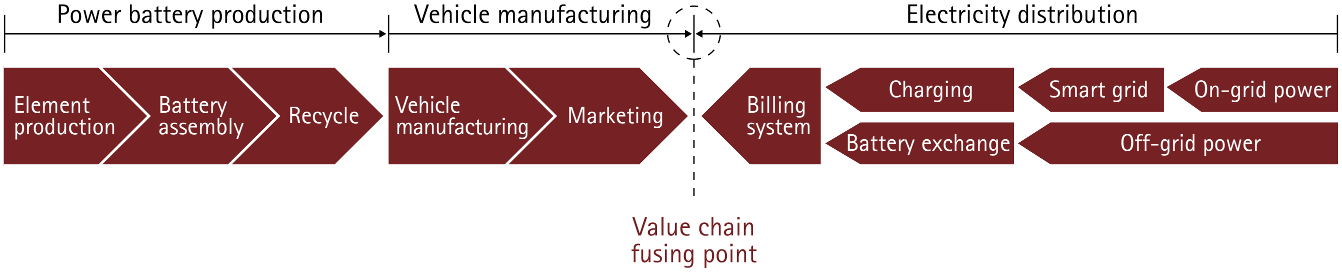
Seeing PEVs as a promising field for new business growth, these automobile companies have been investing a huge amount of capital into this new industry (see Figure 32). Therefore, even if the current annual production of PEVs is considerably small, the future development of the PEV industry looks optimistic.

Currently, the government provides appealing financial incentives to PEV consumers. These consumers could receive RMB 50,000 (US$7,400) subsidies, while the subsidies for EV consumers could be as high as RMB 60,000 (US$8,900).[72]

In addition, to boost the commercialization of PEVs, the Chinese government has devoted significant amounts of investment into this new industry. According to the latest official figures, the government will invest more than RMB 100 billion (US$15 billion) in the next 10 years, to facilitate the development of the entire PEV industrial chain[73] (see Figure 33).

In China, the cost of PEVs is much higher than vehicles with traditional ICEs. Nevertheless, the extra cost could be offset by low energy-consumption expense. Under current oil prices, the energy consumption savings of PEVs could compensate for the extra vehicle expense in five years. In addition, government subsidies could compensate 50 to 80 percent of the total purchasing cost of PEVs. In China, this makes PEVs already desirable in the market, from an economic perspective.

Figure 31. Industrial value chain of the PEV industry.



Source: Accenture.

Figure 32. Automobile companies' investments in PEVs in China.

| Company | Investment on R&D |
|---|---|
| BYD | RMB 2 billion (US$300 million) on the R&D of PEV |
| SAIC | RMB 6 billion (US$900 million) on R&D of EV (RMB 2 billion on new power system; RMB 2 billion on vehicle design; RMB 2 billion on key component) |
| DFAC | RMB 33 billion (US$4.9 billion) on R&D of EV in the next 10 years. |

Sources: "Electric vehicles drive closer to reality," Auto China, September 17, 2008, via Factiva, © China Daily Information Company; "China invests heavily in fertile green auto ground," Reuters News, April 21, 2010, via Factiva, © 2010 Reuters Limited. "Dongfeng Motor to invest RMB 33 billion in green vehicles," ET Net News, August 28, 2008, via Factiva, © ET Net Limited.

Figure 33. The Chinese government investment plans in the PEV industry (2011-2020).

| Sector | Investment |
|---|---|
| Technology R&D in EV industry | RMB 50 billion (US$7.4 billion) |
| Commercialization of EV | RMB 30 billion (US$4.4 billion) |
| Commercialization of HEV and PHEV | RMB 20 billion (US$3 billion) |
| Key components of EV | RMB 10 billion (US$1.5 billion) |
| Utilities construction | RMB 5 billion (US$800 million) |

Source: "Government to implement standards for charging up EV infrastructure," Auto China, August 24, 2010, via Factiva, © China Daily Information Company.

**Figure 34. Criteria assessment of power batteries.**

| Battery type | Cost (RMB) | Energy density | Battery endurance | Energy efficiency | | Battery life (charging) | Charging time |
|---|---|---|---|---|---|---|---|
| | | | | km/kWh | RMB/km | | |
| Lead battery | 2.4/WH | 70 WH/L 40 WH/kg | 80-160 km | 4.83 km | 0.17 | 500 times | 10 hours |
| NI-MH battery | 3/WH | 90 WH/L 50 WH/kg | – | – | – | 500-700 times | Slow: 16 hours<br>Fast: 3-4 hours |
| Zinc air battery | – | 270 WH/L | 400 km | – | 0.09 | – | – |
| Aluminum air battery | – | 79 WH/L | 1600 km | – | – | – | – |
| Lithium-ion battery | 3.4/WH | 220 WH/L<br>150 WH/kg | 380 km | 8.05 km | 0.06 | 1000-2000 times | 2.5 hours (40 min 85 percent) |

Sources: Nanjing Holy Capital Ltd "China Li-ion battery market research report, 2008; Battery Industry Investment Analysis and Forecast Report 2009-2012 (China Investment Corporation).

**Figure 35. Lithium resources and PEV production capability in China.**

**5.2 million tons lithium = 9,000 million kilowatt-hour battery = 450 million EV or 1.3 billion PHEV**

Source: Battery Industry Investment Analysis and Forecast Report, 2009-2012, China Investment Corporation.

China has advantages in the power battery industry: large industry scale and abundant resources. The power source (battery) is the key component of electric vehicles, accounting for 40 percent of the total production costs. The qualities of the battery such as endurance, lifespan, cost and charge time are all fundamental to the commercialization of PEVs. Of the five major types of battery currently on the market, the lithium battery is the most viable option due to its excellent performance (see Figure 34). Based on our research, lithium batteries will lead the revolution of transportation electrification.

In the lithium battery production industry, China possesses a comparative advantage in industry scale over the other main players in this field (namely Japan and Korea). At present, China supplies 20 percent of batteries to the global market.[74] Based on current estimates, China's lithium battery production capability is expected to continue increasing over the course of the next five years.

As a result of the large industry scale, the average production cost of power batteries in China is less than the industry average (of about US$10,000).[75]

Lithium-ion is the key material for lithium power battery production. With more than 5 million tons of saline lithium storage, China has the second-largest lithium reserve in the world.[76] These lithium resources could support China's power battery needs for 450 million electric vehicles[77] (see Figure 35). The abundant lithium resources give China a comparative advantage in the PEV industry.

There are a number of factors that could potentially facilitate the development of PEVs in China, namely, an active market, large number of manufacturers, strong government support and comparative advantages in the power battery industry. According to the Ministry of Science and Technology, "fuel-efficient and new energy vehicles should account for 10 percent of the total industry in 2012."[78] There is an expectation that China will experience a transition from hybrid (PHEV) to pure EV.[79]

## Challenges

High production cost and facility deficiency are the major challenges that constrain the commercialization of PEVs in China.

However, high unit costs (i.e., the production cost) could be reduced as technology improves. The production cost of PEVs is on average 20 to 30 percent higher than traditional ICE vehicles. Currently, this extra cost of PEVs is compensated by the government. However, the industry must reduce unit costs to be competitive in the market once the government cancels its subsidies.

The high cost of power batteries is due to technological barriers; technology R&D could be the key to lowering the production cost. Using the lithium battery as an example, there are three reasons for the high cost of lithium batteries: expensive raw material, a

Figure 36. Types of charging in China–development and performance.

| Type | Availability/ feasibility | Cost ($US) | Capacity (kW) | Charging time (hours – approximate) | |
|---|---|---|---|---|---|
| | | | | PHEV-60 | BEV 200 |
| **For private space** | | | | | |
| Standard outlet (residential) | 🔴 | ≥0 | 1.6 | 8 | 20 |
| Power outlet (residential and commercial) | 🔴 | 500 | 7 | 2 | 4 |
| High ampere outlet with rapid charger (commercial) | 🔵 | >1,500 | 15 | 1 | 2 |
| **For public space** | | | | | |
| Rapid charger and two-way communication for control and billing | 🔵 | 3,000 | 15 | 1 | 2 |
| **Range extenders** | | | | | |
| Battery swap stations | ⚫ | 500,000 to 1 million | – | 5 min. | 5 min. |
| Industrial super chargers | 🔵 | >0.1M | 120 | 10 min. | 20 min. |

🔴 Currently available 🔵 Will be available in five to 10 years ⚫ Longer than 10 years to be feasible

Sources: Lu, JianGuang, China's fuel ethanol industry development policy research, ECONOMIC RESEARCH 2008.

complicated manufacturing process and low (almost zero) recycling rate. Technology improvement could solve the first two problems. For example, with technology R&D, the raw materials of lithium batteries have changed from expensive lithium cobalt oxide (RMB 600,000/ton or US$88,490/ton) to much cheaper lithium manganate (RMB 50,000/ton or US$7,375/ton). Moreover, with technology R&D, Chinese battery production companies could reduce the unit cost of lithium batteries by 30 percent in the next two years.[80] Technology R&D also will increase the performance and security of lithium batteries.

Lack of infrastructure to support charging is another key challenge constraining the commercialization of PEVs in China. Electricity distribution is another link in the PEV industrial chain that plays a crucial role in the development of PEV. In China, the lack of a supporting infrastructure, namely charging stations, has become a bottleneck that slows down the commercialization and adaptation of PEVs. Although the government provides extremely high subsidies, PEVs still have little market in China.

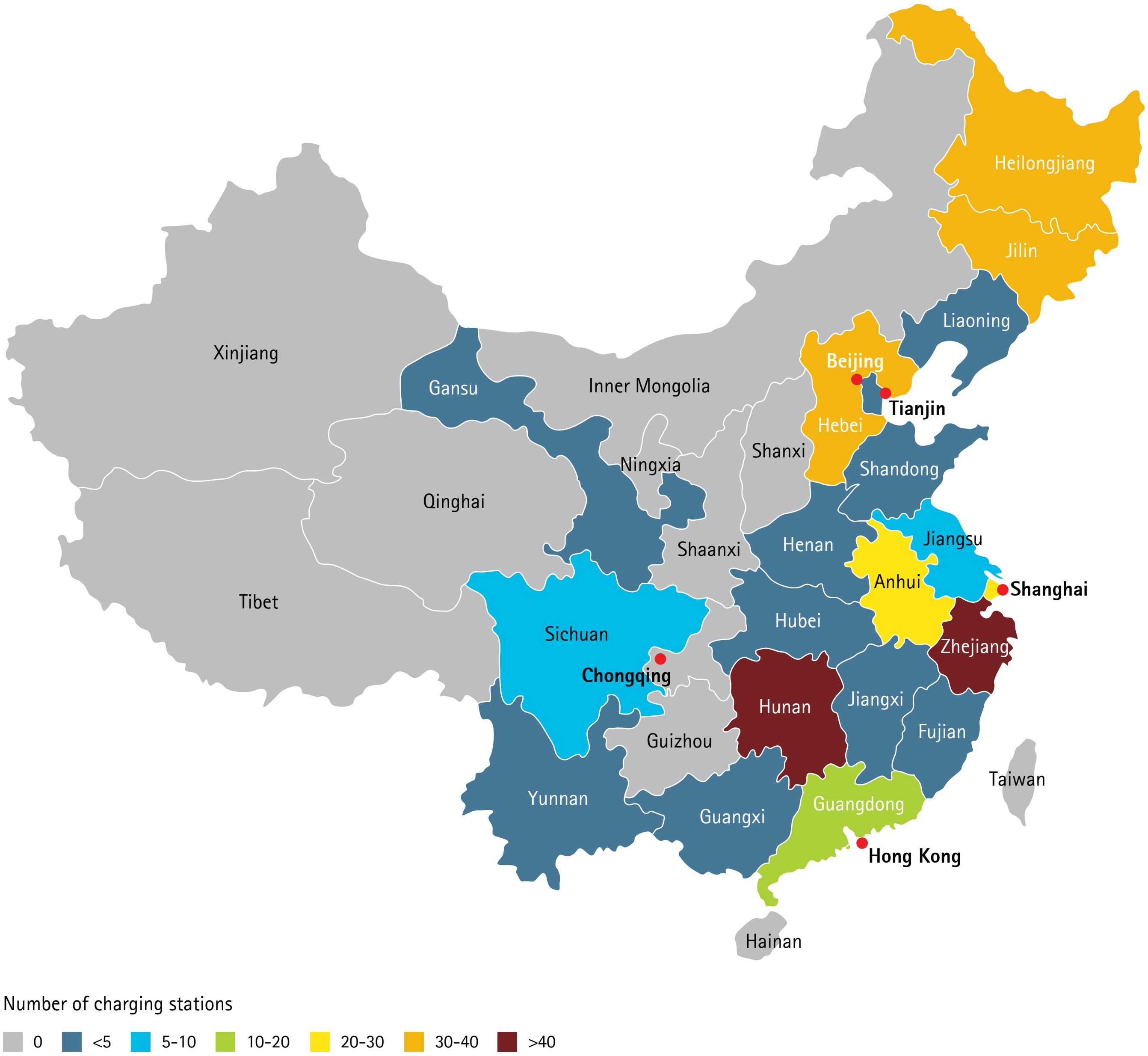
First, PEV charging is extremely inconvenient in China; by the end of 2009, there were only a handful of public charging stations located in a few cities, such as Shenzhen.[81]

Moreover, most people cannot bear the average waiting time of three to four hours for battery charging (see Figure 36).

The root cause for the charging infrastructure challenges in China is lack of a proper business model for PEV charging stations. The Chinese government has devoted great effort and investment to building public charging stations (see Figure 37). However, the current gasoline-station/charging model is not consumer-friendly, a rate-limiting factor in the potential uptake of PEVs. Adaptation to a charging-while-parking model would be of greater benefit to the promotion of electric vehicle usage.

Another problem centers on the ambiguity for potential investors around earning potential from a venture that currently does not have the appropriate infrastructure in place.

Figure 37. China's PEV charging station construction plan.



Source: Yulong, Zhu, "China's Plan of Electric Vehicle Charging Stations," http://forum.eet-cn.com/BLOG_ARTICLE_4682.HTM.

# 3.3 Implications for China's competitiveness

## 3.3.1 Government support for alternative energy

### Government plays a crucial role in accelerating the development of the new energy industry

The Chinese government plays an important role in the development of the new energy industry. So far, all promising alternative energies are either in the process of technology improvement or facing the uncertainty of return on investment. The government's new energy development strategy and associated policies will set clear direction and encourage more investment to ensure the fast pace of technology and market breakthrough.

### Develop a clear new energy strategy and selectively provide incentives and investments

The Chinese government has developed a long-term primary energy mix target for 2030. These targets are necessary for developing the strategies that will encourage the investment in the right sectors. Financial incentives, preferential policies and direct investments should be appropriately utilized to encourage the development of a new industry and to achieve the goals of energy security, emission reduction and economic development.

- Choose the most suitable technologies, which comprehensively take into consideration local resources, economic and societal desires (such as job creation), emission reduction and energy security.

- Incentives and direct investment need to be appropriately implemented in the right sectors of the entire industrial value chain to ensure effective development of the industry.

- Target core challenges and organize resources to achieve a breakthrough.

There are lessons to be learned from the Japanese government, which has developed a range of effective policies to accelerate the development of their new energy industry:

- Technology strategy: By envisioning the opportunities and strategic importance of PEV and its own advantages in the vehicle industry, Japan targets PEV as the highest priority in the new energy industry.

- Huge investment: The Japanese government has been devoting a huge effort to encourage the development of the PEV industry. As early as 1971, the government invested in the development of PEV in Japan. The Japanese government has since invested billions of dollars in the PEV industry.[82]

- Targeted investment: Japan's investment in the PEV industry is not aimless, but with a focus on the key sector, namely, power batteries. Japan has invested more than $1 billion in its battery companies.[83]

- Target critical bottlenecks: The high unit cost is the major challenge that impacted the commercialization of PEV in Japan. The government provides tax exemption as high as 50 percent for PEV consumers. Moreover, government subsidies to PEV (including PHEV) could compensate almost 50 percent of the purchasing expense.[84]

Strong and proper government support has been the key to Japan's success in the PEV industry.

### Establish unified national standards for the new energy industry

Implementing a unified national standard is another key component for the commercialization of new energy technologies. The lack of clear and unified industrial standards has constrained the development of new energy technologies in China. To rectify this, the Chinese government needs to be proactive in the defining and implementation of unified national standards for battery cells, charging facilities, biofuel blending and usage and in encouraging inter-industry collaboration, thus accelerating commercialization.

As the world leader in the PEV industry, Japan also was the first mover in industry standardization. In 2010, major Japanese automobile companies Toyota, Nissan, Mitsubishi and Subaru, together with Tokyo Electric Power Co., formed the first EV charging association[85]—"CHAdeMO."[86] The aim of this association is to devise unified standards on PEV charging, including charging pressure, charging time, charge plug-in type and battery size. This unified and detailed PEV standard will enhance Japan's leading position in PEV technology and commercialization, as well as effectively generating demand by providing user-convenient solutions, such as battery exchange.

## 3.3.2 Innovation and collaboration

### Companies to be more innovative and take the initiative in the development of new technologies

According to Accenture's *Understanding the Future Energy System* research, published earlier in 2010, the global energy industry is undergoing dramatic changes, which may occur faster than many expect.[87] Companies must attempt to predict potential changes and develop aligned strategies to seize new opportunities and avoid being eliminated by new competition. Companies must take a long-term view when selecting the right technology in which to invest, which could align with the nation's energy-saving and GHG targets, as well as cope with economic development obligations.

Given the uncertainty of technology and infrastructure development trends, companies need to develop flexible business models that integrate new technologies into their original advantages (for example, Sinopec leverages its retail network in a joint venture with COFCO and Novozymes in the cellulosic bioethanol business).

### Develop close collaboration and acquire new capabilities along the entire industrial chain

The new energy industry has exhibited an increase in momentum, and techniques with multi-industry know-how; for example, the PEV industry has consolidated techniques of car manufacture, battery cell production, telecommunication in billing, grid-supported charging and power generation. Different companies have different comparative advantages in the history of their development journeys. Given the fast-changing pace, companies must develop effective collaboration and new capability acquisition strategies to be in the leading edge of the new game. Shareholding swap, joint ventures, or strategic partnerships should be appropriately selected to align the same objective, achieve technology breakthroughs and maximize competitiveness through collaboration.

For example, as the second-largest power battery producer in the world, BYD leads the battery industry in China. In the face of emerging opportunities, BYD actively joined the new market by expanding its business into electric vehicle production. Positioned on the global leading edge in power batteries, BYD seeks different partners in different sectors of the PEV industrial chain. Recently, it announced the cooperation plan with Daimler AG in PEV production. BYD will provide power batteries utilizing its comparative advantage in the industry, while Daimler AG will mainly engage in vehicle production.[88] This new business model has put BYD into the leading position of the PEV industry in China, and positioned the company for global competitiveness.

## 3.3.3 Strengthening technology R&D

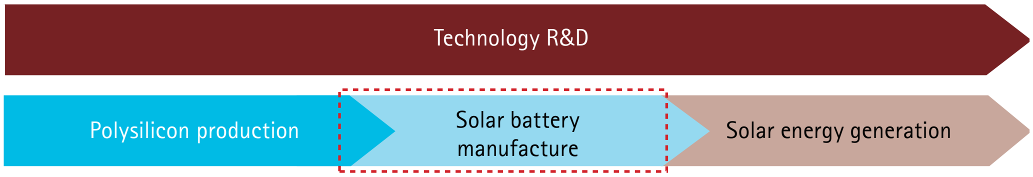
To build long-term sustainable growth within the alternative energy industry, China must emphasize technology R&D within this area. Only by obtaining an R&D leadership position will China be able to enjoy the benefit of technology in terms of energy security, emission reduction, and in transforming its economic structure to one of high value-add.

### Technology leadership is crucial for a country's sustainable development

Technology independence greatly influences economic development. Across the majority of industries, companies in possession of intellectual property (IP) tend to reap the greatest economic benefit. The same also is true for future transportation fuels, which is now a technology-intensive industry, and where IP is the key factor that determines economic benefit as well as the future development of the industry. If China fails to obtain technological leadership in future transportation fuels (such as NGE, cellulosic ethanol and PEVs), the nation will be limited in reaping the economic benefit of the scale-up of these new technologies.

Without technology independence, a huge amount of capital will flow out of China as a result of technology import. Consequently, economic benefits will be greatly compromised. Using power batteries, which is the key sector of the PEV industry, as an example: for two lithium battery manufacturers with the same production, same operating cost and same revenue, but different intellectual property rights, the economic benefits vary significantly.

Figure 38. Industrial value chain of the solar energy industry.



| R&D | | **Technology monopoly:** Technical patent monopolized by eight companies from Germany, Japan and United States | **Market competition:** Large number of manufacturers; little technology competition but severe market competition | **Developed countries:** Using solar energy for electricity generation is mostly used by developed countries; conversion efficiency 15-17% |
|---|---|---|---|---|
| Economic benefit | Capital investment | $44.5 million | $740 million | $444.5 million |
| | Annual cost | $186.7 million | $1 billion | $357 million |
| | Annual revenue | $311.1 million | $1.3 billion | $592.6 million |
| | Rate of return | 26% | 2% | 14% |
| Energy consumption | | 180 million kWh | 240 million kWh | |
| Emission | | Low emission, high toxicity | High emission | Zero emission |

⬚ Sector of the value chain in which China is currently engaged

NOTES: (1) The given data is for a company with 1,000 tons of annual polysilicon production, a manufacturer with 500-megawatt annual solar battery production and a plant with 100-megawatt annual electricity generation.
(2) Annual investment includes material, manufacturing, human resource and technology patent.
(3) Rate of return (ROR) is defined as: ROR = profit/asset × 100 percent = (revenue – annual investment – depreciation – tax) / (fixed asset + tangible asset) × 100 percent
(4) Circled area is the industry China currently is mainly engaged in.
Source: Clean energy industry research report 2009, China Investment Corporation.

If we use the average capital cost, production ability and market price for both scenarios, the only difference occurs when the company does not own the IP. In this situation, the company has to spend RMB 200 million (US$29.4 million) to purchase the production line—twice as much a company in possession of IP, and that in turn increases production cost. As well as purchasing the production line, a company that does not own the IP has to pay a licensing fee for every product brought to market. This is evident in the Chinese wind industry where, for each turbine sold, RMB 0.1 goes to the owners of the IP. By not owning the IP, Chinese companies are unable to compete in the high-end segments of the value chain for the high-value-added production.

## Technology independence determines energy security and emission commitment

Without a level of technology independence, China's energy security and emission commitment will rely heavily on countries with advanced IP. This reliance on technology importation from IP-owning countries would create new security issues for overall economic growth, and Chinese enterprises will need to pay high patent fees. This has happened before. Taking solar energy as an example (see Figure 38), most of the R&D patents are concentrated in the upstream polysilicon production area, with the United States, Japan and Germany controlling the key technology. As can be seen from the figure, this part of the value chain yields the highest rate of return. In contrast, due to a disadvantage in technology R&D, China is mainly engaged in the low-value-added solar battery manufacturing with huge polysilicon import and more than 95 percent solar battery export.[89]

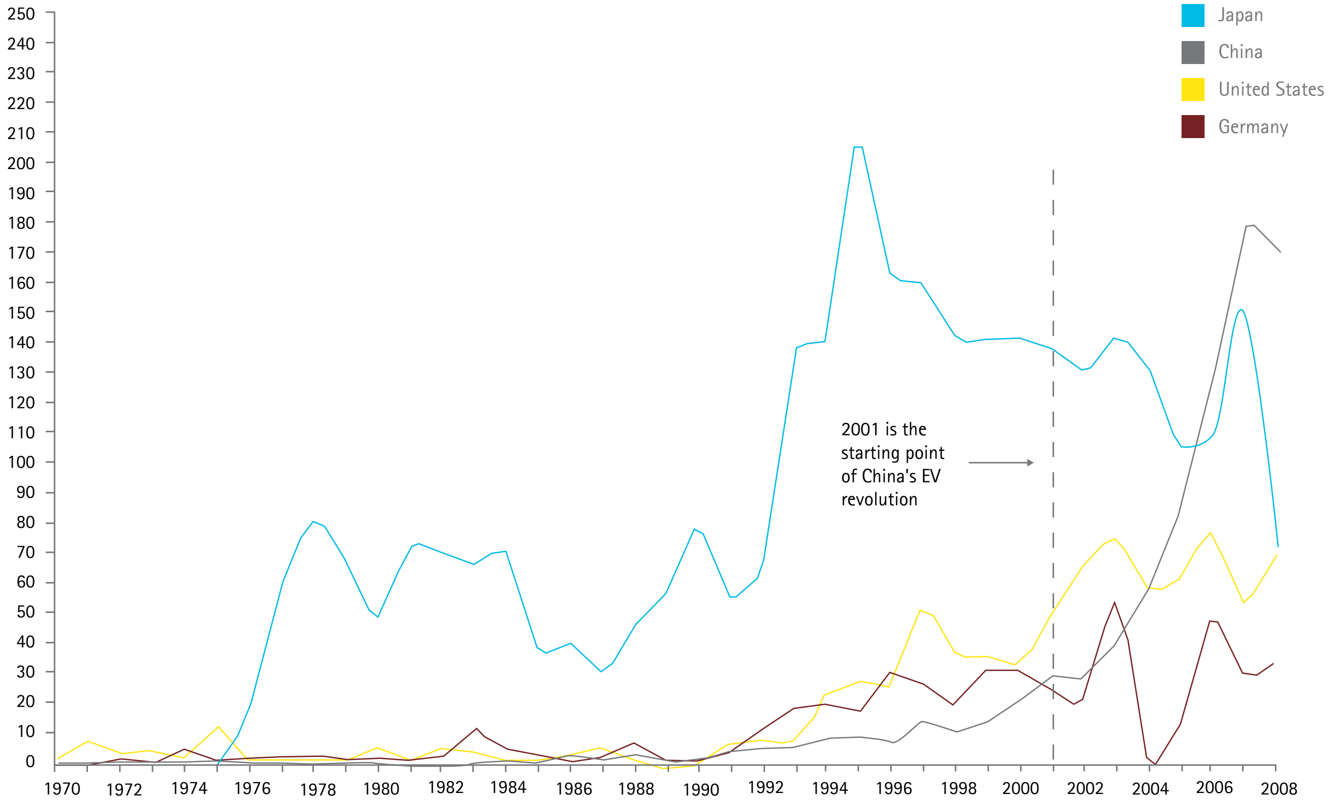
While developed countries such as Germany, Japan and the United States enjoy "zero-emission" solar energy, China, as the solar battery manufacturing foundation, is suffering from huge resource consumption and serious environment pollution.

Therefore, even with the huge investment and rapid growth in gross domestic product, China will still face the challenges of high resource consumption (energy and water), and risk achieving its emission-reduction target. The reliance on technology importation from IP-owning countries also will create new security issues for overall economic growth. Moreover, Chinese enterprises will pay high patent fees in every product market.

## Government investment, incentives and free market financing are crucial to strengthen technology development

The most effective way to support technology R&D and obtain technology leadership is in government investment and incentive policies. The development of the PEV industry in China best proves this assertion.

Figure 39. The developing trend of global PEV intellectual patents (2009).



Source: Review of the patent situation of pure electric vehicle technology, IPRTop, www.iprtop.com/pages/view/367.

Recognizing the significance of PEV in the future transportation energy structure, the Chinese government implemented its PEV development plan in 2001. With approximately RMB 1 billion direct investment on technology R&D,[90] the PEV industry started to boom in China in 2001. (For example, Figure 39 depicts the developing trend of intellectual patents.) Currently, in the PEV industry, China owns the second-highest number of patents in the world.[91] This growth in patent number is a direct result of government incentives provided to companies to encourage investment (in addition to government funding). In our view, an effective incentive plan will play a critical role in stimulating the fast growth of R&D in the future.

## 3.3.4 Summary

As a result of exploding transportation fuel demand, alternative energy use will increase. In the next 10 years, alternative energy will play an important role in energy security, emission control and economic development by replacing a considerable proportion of traditional energy. We expect NGE, cellulosic ethanol and PEVs to contribute up to 30 percent of the traditional energy savings by 2020.

The Chinese government needs to develop a clear new energy development strategy to cope with the nation's carbon emissions and local economic targets. These goals can be achieved by effectively leveraging the resources China has at its disposal. Ultimately, this should lead to the transformation of China's energy industry, resulting in a high-value-added economic structure, while also addressing the issues surrounding energy security. Government policy and direct investment will play a crucial role to imposing significant influence on commercialization of the aforementioned technology and accelerate the fast growth of China's new energy industry, helping to ensure China's competitiveness in the global economic arena.

The Chinese government should invest in and promote the relevant sectors of the entire industrial chain through incentive policies to obtain the goals of energy security and emission reduction. Above all, technology is expected to play a pivotal role in the new economic arena. Hence, China must recognize the importance of technology R&D and emphasize the investment flow into the right sector by providing direct investment and policies to guarantee the investment return.

Chinese enterprises need to envision the trend and landscape changes, take proactive initiatives in formulating strategy and creating innovative business models to ensure its competitiveness in the next wave of the energy industry arena.


500ml
APPROX.
400
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200
100

# 4

# Implications

Change is looming in the transport fuel sector and while this transformation and the advent of PEVs may herald new growth opportunities for utilities, the future for oil companies is more complicated. As we can see from this report, when we look at China and the United States—the world's two largest economies—and the implications the changes in these countries will have for oil companies, it is a tale of two markets.

The United States is the largest fuel market in the world, with a strong bias toward gasoline and a significant proportion of demand satisfied through biofuels. China is the second-largest fuel market globally, but the country's demand is significantly lower than that of the United States. China uses minimal amounts of biofuels and is oriented more toward the use of diesel, although the country's use of biodiesel is lower than ethanol. While the United States' alternative energy story is one of displacement, in China it is about partially meeting new demand with alternative energy.

A key question for the United States, in light of reduced fossil fuel demand, will be around how to most effectively transition its existing infrastructure, especially when considering the impact on the US refining industry. In China, where growth is the prevalent market manifestation, infrastructure investment is critical to growth, and it has the opportunity to build an infrastructure that will match the future fuels landscape. The incumbents in China are not necessarily losers, as the absolute volumes of gasoline and diesel continue to increase, even with an increasing percentage share of new fuels.

This is a significant difference for the players in the markets—in the United States, there will be clear winners and losers; in China, in the context of high growth, there will be only winners and bigger winners.

For the United States, even conservative assumptions of how the fuel mix will change will have a significant impact on legacy infrastructure, the volume of US crude imports and the country's competitiveness. With the rise in fuel-efficiency standards, substitution of fossil fuels for biofuels and the advent of other alternative transport fuels, demand destruction is almost assured.

In China, we predict that transportation energy consumption will keep increasing along with the rapidly growing vehicle population, up from 11 million in 2009 to 24 million by 2020, with the total number of automobiles on the road reaching approximately 200 million by 2020, up from 76 million in 2009.

For all the distinctions between the two marketplaces, there are a number of common elements:

- Energy security is key to the national energy plan and both countries are actively seeking to reduce crude imports. In the US scenario, crude imports are reduced by approximately 1 billion barrels of crude per year—a reduction of 34 percent from the 3.3 billion barrels imported in 2009. As the third-largest petroleum import country in the world, China imports more than 50 percent of the country's consumption and with domestic crude production declining and demand increasing, this percentage is set to rise.

- Biofuels support policies are driven more by support for rural, domestic economies and energy security than by GHG policies. What is important for governments is the domestic agenda and setting policy that balances three key objectives: ensuring energy security, improving economics and responding to climate change. While both countries experience benefits in each of the three objectives, it is likely the main focus for both countries is to concentrate on energy security and economic benefit, rather than climate change and GHG emission savings.

- Competition will be common across different markets—it is just the emphasis that will change. Disruptive transport fuel technologies are similar. Three technologies that will play an important role in replacing gasoline and diesel miles in both markets are next-generation internal combustion engine (NGE)—which includes hybrid electric vehicles (HEVs)—cellulosic ethanol and electrification.


PVC, CADM
220-240V

# 4.1 Implications for international and national oil companies

Both international oil companies (IOCs) and national oil companies (NOCs) face impingement upon their traditional sphere of influence and challenges to grow the alternative energy side of their businesses. Biofuels is the area that makes most sense for oil companies, as it aligns most easily to existing infrastructure and knowledge. However, biofuels growth in China will be carefully managed by government departments to ensure no impact is seen on the availability of food, although we are not seeing the level of government involvement that is afforded to electric vehicles. According to China's development plan for alternative energy, in 2010, the use of non-grain-based bioethanol was 3 million tons (1.1 billion gallons) and by 2020, the annual production ability will reach 10 million tons (3.6 billion gallons).[92] Feedstock accessibility and unit cost are the major challenges for profitable growth that will constrain the development of the cellulosic ethanol industry. However, the Chinese government provides no clear financial incentives, such as subsidies, for feedstock production. This situation is in contrast to that in the United States, where strong support for biofuels is provided through R&D funding, subsidies and production mandates. Irrespective of this imbalance in government support, IOCs face significant demand destruction in their traditional markets, while the markets in which the NOCs tend to operate are exposed to growth. How they react to these challenges and opportunities will determine what the future holds for these companies.

## 4.1.1 Challenges

As demand shifts and regulation drives greater fuel diversification, both IOCs and NOCs will face a number of pressures, some of which are relevant to both markets.

### Demand destruction and volume pressure

In many markets, there is already significant competition in the retail and commercial fuel markets and this is set to increase as biofuels, electrification and NGE technology become more prevalent. This impending shift is most readily apparent in the US market. In the scenario we present for the United States, the implementation of an increased fuel-efficiency standard and the blending of biofuels replace almost 40 percent of gasoline and diesel demand by 2030, relative to 2010. In China, the goal is to replace 15 percent of hydrocarbon fuels with alternative energy by 2020 and, also by 2020, to have alternative energy make up 30 percent of transport fuels, albeit within the context of rising demand.[93]

### Restructuring of the US refining industry

The fall in gasoline demand and the resulting reduction in crude imports will have a significant impact on the refining industry. This reduction in gasoline demand will likely drive a structural change in the refining industry, impacting US refineries in two dimensions: reduction in volume or output and a change in product mix. Both dimensions will result in the most marginally profitable refineries shutting down capacity. This structural change in fuel demand would tend to favor larger, more complex refineries with lower marginal costs and the production flexibility to make different product slates, including “fuel switching” or the ability to incrementally increase diesel production (or gasoline) if demand dictates. Smaller, less complex refineries would likely shut down as they were built to maximize gasoline production, have less upgrading capacity and flexibility for fuel switching, and—as such—would require significant capital investments to reposition their production profile. This impact will be exacerbated if refiners are further disadvantaged by additional carbon regulation that increases the cost of operations or products, particularly if their international competitors are not faced with the same carbon legislation.

### Increased risk and cost of supply

Oil companies will continue to be the biggest buyers, blenders and marketers of biofuels. Most integrated oil companies do not operate in agriculture or otherwise produce biofuel feedstocks, as this is clearly not a core capability. As we have seen in the biofuels market, vertical integration can pay dividends with such a complex value chain, and many oil companies are now looking to access a secure supply of feedstocks through joint ventures or outright ownership. This integration is not limited to IOCs. In Accenture’s *Time of Transition* report, we highlighted the partnerships between the Chinese state oil and state agriculture companies (e.g., COFCO, CNPC and Sinopec) giving them a distinct advantage in supply.

### More complex supply chain

We discussed the challenges of integrating the hydrocarbon and biofuel value chains in our *Time of Transition* report, and a huge challenge still remains in feedstock/biomass logistics and optimal blending.

### Changes to sites

There are the obvious challenges regarding how to integrate increasing volumes of biofuels on the forecourt and whether electric vehicles will be accommodated. In addition, there are a number of other products, such as heavy-duty diesel (HDD) and differentiated fuels, that will also need to be considered in light of local market considerations. How this flow of new products is managed from an infrastructure and marketing point of view will determine their success.

### Feedstock solution for biodiesel

Since Accenture’s first biofuels report, *Irrational Exuberance*?, we have often remarked that the feedstock options for diesel are limited, and biodiesel is in need of its own “sugar cane”—an abundant feedstock with attractive yields, economics and GHG savings. This situation remains the case, and the urgency is highlighted by China’s market (which is likely to remain very much a diesel market) and the expected growth in HDD.

## 4.1.2 Looking forward

Given these impacts, there are a number of actions that oil companies will need to take.

### Rationalize marginal assets

US oil companies will need to take a strategic review of their assets to understand their long-term economic viability in markets that face significant demand destruction. Are the assets of greater value to another party? Is it better to realize their value earlier rather than waiting for the point when they have to be shuttered? Are there alternative uses as supply depots or terminals? A number of researchers and companies are developing innovative processes (pyrolysis and thermochemical conversion) to turn a wide range of biomass into stable, concentrated bio-oil (biocrude) that is compatible with existing refinery technology and can be converted into biofuels. Is it possible that biocrude offers a potential, partial solution? Decommissioning these refineries creates significant cash and political costs as sites must be reclaimed and the job losses from putting a refinery out of service creates strained relationships with local communities. It is in everyone's interests to ensure impacts are assessed early and all possible mitigation attempted.

### Global expansion and portfolio planning

Faced with the complication of changes to the energy mix and the dynamics of the value chain, Chinese oil companies will need to closely watch future trends, and proactively restructure their business portfolio as required to take advantage of opportunities. New energy development will change the trade relationships between countries, and the relevance of assets and global portfolios within companies. Chinese oil companies will need to understand the potential changes in major markets, and plan accordingly to ensure long-term strategic goals and value creation continue to be supported. As Chinese companies expand internationally, it is important for the enterprises to have a clear business growth agenda, develop a value-based M&A strategy and strong execution across the entire life cycle of M&A, from candidate screening and comprehensive due diligence, to comprehensive approach, through to post-merger integration.

### Optimize through feedstock selection, blending and local marketing

As markets become increasingly different, the opportunities to develop products for specific markets will increase. Given the need to supply different products to different markets, oil companies will need to create additional value through greater integration along the supply chain. Focusing on key planning and optimization activities can drive incremental value from their assets, but requires significant changes in how refining, supply, trading and marketing organizations are organized and interact. Creating locally focused organizations with a single point of accountability for commercial optimization and performance can allow planning and operations decisions to be made across the asset portfolio. The integrated oil companies are the biggest blenders of biofuels, and meeting the blending mandates requires a significant amount of biofuels in their portfolio; this requirement will impact the production pattern of core refined fuel components in blending (in terms of yield and quality). Although we believe many oil companies have biofuels built into their refinery linear programming (LP) models, it is at a simplistic level. We believe there are solutions that will allow integrated oil companies to optimize the refinery, logistics and supply envelope simultaneously. Supply chain optimization can make a huge difference to the competitiveness of those that produce and/or buy and blend biofuels, and in the current "peak-refining" environment, this capability will become even more critical.

### Close collaboration and partnering along the entire industrial chain

Given the uncertainty of technology and infrastructure development trends, companies need to develop flexible business models that allow them to work with a range of partners and integrate new technologies and approaches. For example, Sinopec leverages its retail network in a joint venture with COFCO and Novozymes in the cellulosic bioethanol business.[94] Given the fast-changing pace of the global market, companies must develop effective collaboration and new capability acquisition strategies to be at the leading edge. Partnerships should be appropriately selected to align objectives, achieve technology breakthroughs and maximize competitiveness through collaboration. In this context, partnering with NOCs should be explored. IOCs must consider where growth in energy consumption will occur. While Chinese NOCs are positioning themselves to meet as much of their domestic gasoline demand as possible, IOCs should find ways to serve this market. Upstream technology plays that allow IOCs to complement or supplement existing NOC capabilities, particularly in accessing unconventional gas reserves and advanced biofuels, could support access to the Chinese transportation fuel market. A decision by the Chinese government to pursue cellulosic ethanol or other advanced biofuels could advantage oil companies with significant biofuels knowledge and production assets.

### Business model innovation

The diversity of new transport energies not only provides uncertainty, but also enables new entrants in the traditional transport market. Irrespective of the fuel or the business model, the pursuit of consumer satisfaction will continue to be paramount. The future landscape in the transport market could herald new entrants in both countries with higher customer satisfaction and loyalty, putting increased challenges on traditional oil companies that have operated with less focus on the consumer.

### Fungible fuels and advantaged molecules

For the US market, the race to find a fungible fuel that can leverage the existing infrastructure is critical. The company that can solve this issue and patent these molecules stands to command a premium in the marketplace. However, to achieve patentable molecules, extensive R&D is required and should remain part of the oil companies' strategy. It is unclear what new fuels will be demanded by advances in the ICE and the development of greater levels of hybridization, but it is clear that there is an increased opportunity for differentiated fuels within the fuel mix, and that continued R&D offers oil companies the opportunity to profit from having advantaged molecules. This could offer oil companies an alternative route to market through the licensing of their technology to others in markets where they are not currently operating, allowing others to sell their products and share the financial rewards.

### Use of natural gas for transport

Current trends indicate that natural gas demand will grow as an electricity source. Use of natural gas for power generation is highly attractive for use in a smart grid that experiences intermittent demand because, in addition to its lower carbon intensity, it is much easier to ramp up and down than coal production. But it is as a transport fuel where natural gas offers unique opportunities to oil companies. The combined effects of a potential short diesel position and the rapid increase in forecasted US natural gas supply has led to renewed interest in natural gas vehicles as a method of reducing emissions and dependence on foreign oil. This interest is particularly focused on heavy-duty vehicles, which are traditionally powered by diesel and are more challenging to transition to electrification and biofuels than light-duty vehicles.

Despite the headlines of reduced demand in many of their key markets, IOCs have a number of opportunities to explore. We would expect oil companies to expand their natural gas portfolios and promote natural gas consumption in electricity generation and in transportation. Margin uplift can be found by focusing on tightly managed supply chains, optimization of assets and a local marketing strategy. Oil companies will invest in disruptive technologies to determine which offer highest marginal value. The speed with which shifts in the markets will occur and their significance should not be understated. Industry leaders must begin to understand, invest and act now to address these opportunities for ongoing growth. China offers the opportunity of growth, but remains a difficult environment for many IOCs to operate in. Demand will increase, but some of this uplift will be taken by alternative fuels. An opportunity for IOCs to access this market in China may be through advantaged molecules and biofuels.

Ultimately, it is worthwhile to note that there remains uncertainty in how consumers will react to new transport technologies and new fuels, and how long regulators will continue to support new technologies. Therefore, it is imperative that companies keep a close eye on market developments and anticipate changes in how the industries will develop.

# 4.2 Implications for utilities

We are witnessing a period of significant investment from the Chinese and US governments. For example, the Chinese government has committed to investments of more than RMB 100 billion (US$15 billion) across manufacturing, supply chain and commercialization of plug-in electric vehicles (PEVs) over the next 10 years.[95] The US government has also made significant investments in PEVs (although alternative fuels investment in the United States is more broadly spread). For example, in 2009 alone, the US government released an estimated $8 billion in loans to Ford, Nissan and Tesla to propel the development of advanced vehicle technologies,[96] and $2 billion for the manufacturing of advanced batteries. This support and investment has only increased in 2010, with the US government supporting PEV pilots to demonstrate, test and improve the technology.

The heavy investments from the two governments have propelled the private sector forward and have already shown tangible results. For example, in the past two years in China, there have been four announced launches of PEVs, bringing the total to five vehicle models. These investments and results point to the potential for significant consumer demand for PEVs emerging over the next 20 years.

As the core power supplier, utilities are being handed a unique opportunity for rapid revenue growth in a century-old and very mature industry. Aside from the increase in electricity demand, utilities also are seeing new opportunities in distribution and retail as these new marketplaces develop and take shape. However, like all markets in their infancy, there are significant challenges and risks. It will be important for utilities to manage these challenges and risks, while moving quickly to capitalize on the opportunities at hand.

## 4.2.1 Opportunities

### 4.2.1.1 Generation and distribution

**Increased demand**

Regardless of who ultimately owns the electric vehicle supply equipment (EVSE)—i.e., the charging infrastructure—the introduction of PEVs will lead to increased electricity demand. This increased demand will not only result in increased revenue for utilities, but also result in an opportunity for utilities to bring greater amounts of renewable energy online through smart charging. Smart charging presents a great opportunity for renewable energy to be used during peak times as, on average, cars are only driven one hour per day,[97] and therefore, have great flexibility for charging at peak times. The key to accessing that flexibility will be ensuring there is adequate charging infrastructure available to consumers, and that consumers keep their vehicles plugged in while they are not being driven.

On the generation side, natural gas will further help to balance the volatility of renewable energy sources. In the United States, in particular, natural gas is likely to play an important role, as it is readily available and can be ramped up and down more easily compared to coal-fired generation. Natural gas has been the largest contributor of new generation capacity for more than a decade in the United States, accounting for 40 percent of new capacity in 2009.[98]

**Potential for battery storage**

As utilities look for ways to handle less predictable energy sources such as wind and solar, and grapple with the challenge of continued need to increase base load capacity, energy storage in the low-voltage space has the potential to play a significant role in utilities' future. The heavy investment in PEV technology has included large investments in battery research, providing utilities with additional opportunities to leverage the resulting advances for large-scale energy storage and peak-load leveling. Since grid storage batteries will remain stationary, and thus the size versus energy-density ratio is not a concern, the technology is not limited to lithium-ion batteries as the most viable solution, as in the case of PEVs. Continued developments in grid storage battery technology should allow utilities to bring significantly larger amounts of renewable energy sources online.

In the longer term, with implementation of vehicle-to-grid (V2G) technology, PEV batteries themselves also have the potential to act as energy storage for utilities. Combined with smart charging, PEVs present potential for base-load leveling for utilities when V2G becomes commercially viable. However, it is interesting to note that battery storage utilization rates of a distribution company alone are not likely to justify the business case, and investments would most likely need to be shared across other market actors. Utilities should begin to consider this investment share model to reap the benefits of battery storage technology.

**Government investment and reinforcement of distribution network**

To support expansion of the PEV market, governments are providing funding to support grid reinforcement. The Chinese government has allotted RMB 5 billion (US$800 million) for utilities construction over the next 10 years, which includes a significant portion for PEV infrastructure.[99] This provides a unique opportunity for utilities to reinforce ageing infrastructure in a highly regulated industry. Additionally, significant investment is currently being poured into the smart grid agenda globally. For example, in China, the government has committed RMB 50 to 60 billion (US$7.3 to $7.8 billion) over three to five years, starting in 2010, to build smart grids, and plans to invest more than RMB 4 trillion (US$585 billion) over the next 15 years into smart grid research and construction.[100] In 2009, the United States invested US$11 billion in smart grid stimulus, and investment is expected to increase in the coming years.[101] PEV initiatives can be incorporated into these larger smart grid trials and, therefore, funding to support smart grid developments can be leveraged for PEV initiatives.

### 4.2.1.2 Retail

**New revenue streams**

EVSE will be required to support PEVs, providing utilities with the opportunity to own and/or operate this infrastructure. With this equipment comes the opportunity for utilities to provide services and tariffs targeted at PEV vehicle users. This integration of EVSE into the utility value chain also will provide utilities with the opportunity for a closer consumer relationship. The ability to establish this relationship early will have significant implications for PEVs, and also for the home as smart grid technology becomes a reality. As consumers gain more ability to monitor and control their energy use, there will be an increasingly active relationship between the consumer and their service provider.

## 4.2.2 Challenges

### 4.2.2.1 Generation and distribution

**Demand is unpredictable**

Overall demand increase is difficult to forecast, as PEV adoption rates are likely difficult to estimate. Lack of strong national energy policy in the United States, paired with the infancy of the industry and consumer changes that PEVs imply, make it difficult to estimate the speed at which the market will adopt PEVs. China's clear support of PEVs should give more confidence to utilities; however, in both cases it will ultimately be the consumers who will decide how quickly, and to what degree, adoption will take place. Additionally, continued government support and funding of this nascent industry will be critical for wide-scale adoption to take place.

Another factor that could significantly affect PEV adoption is the supply of lithium. As noted in section 3.2.3 of this report, our research indicates lithium batteries will be the primary battery type for PEVs. With the majority of easily accessible lithium concentrated in Chile, Bolivia and China, the United States will rely entirely on foreign supplies of lithium to support its PEV industry. The price of lithium will be a key factor in battery prices and, subsequently, consumer demand. While this is a challenge for the United States, it presents a great opportunity for China. With the second highest lithium reserves in the world—enough to produce batteries for 450 million EVs—China will likely have no issue supporting its PEV industry's battery requirements.[102]

With so much uncertainty, utilities are reluctant to make the significant infrastructure upgrades required until they can be confident they will see a return on their money. However, if utilities do not keep pace with the rest of the players in the PEV industry, they will miss out on the opportunities at hand. As explained in *Betting on Science*, consumers currently have the ability to charge their PEVs at home by plugging them into a regular socket like any home appliance. While there is no difference from a consumer perspective, the increased demand on substations can be significant. An EPRI study found that even one PHEV charging at 240 volts at peak times overloaded 36 of 53 examined transformers.[103] Additionally, level-III charging, also known as "fast charging," which charges the vehicle in 10 to 15 minutes and is most likely to be the preferred charging method, has the most significant impact on the grid. If utilities do not begin to structurally plan for these changes, they are likely to be in continuous fire-fighting mode and will have to manage unexpected consequences; for example, transformer upgrades as a result of "fast charging." Utilities must actively manage these risks to ensure they are able to adequately control consumer charging habits and manage the impact on their infrastructure.

**Charging patterns are likely to be different in different markets**

Building on the grid impact, consumer charging habits will have a significant effect on requirements for and location of distribution network reinforcement. Recent pilots have provided important data on charging habits, but also have indicated that these habits are likely to vary from market to market. It will be important for utilities to understand consumer habits in the specific markets in which they operate, to understand the infrastructure requirements and new revenue opportunities in each area. Charging at home is likely to result in additional load at peak time, as consumers come home from work and plug in their cars. On the other hand, the availability of suitable at-home charging locations varies greatly from region to region. In the United States, there are five times as many cars as there are garages in which they may be charged.[104] This means that in many regions, consumers will rely on publicly available charging infrastructure along with private charging infrastructure in locations such as office parking lots and shopping centers. The variation from region to region will result in very different charging patterns, which the utilities must understand in order to make the required infrastructure reinforcements.

### 4.2.2.2 Retail

**Changes in utility support systems**

New retail opportunities will require updates to the utilities' business models, including significant upgrades to their support systems. Increased contact with the consumer will require more advanced customer-facing services that will all require significant investment if utilities want to compete with new players in the marketplace. Billing systems in particular will need to be adapted to more complex billing models as utilities look to tailor their offerings to different consumer segments, and allow for charging across multiple locations. Utilities will be able to build off their existing back-office structures, but will require significant upgrades to manage the increased volume and complexity of data.

**Threat of market competitors**

The new opportunities for utilities also are shared by new competitors that will aggressively pursue the EVSE market. The EVSE market requires technical expertise outside utilities' traditional scope. Additionally, utilities have not traditionally been strong in customer service, branding and marketing. Energy services companies and other new market entrants will be quick to move into this space and capitalize on this opportunity to be first to reach the consumer and secure real estate to install public EVSE. Moreover, competition between players that decide to enter the market is likely to be tough, as PEV propositions will only result in marginal returns. Utilities will need to proactively manage the competitor landscape (particularly within the home—as this is where they currently have competitive advantage and where customer propositions are likely to be the most attractive) to ensure they are key market players.

While these new market entrants will be competitors to utilities in capturing new market share, there also are opportunities for partnerships. As we demonstrated in our *Betting on Science* report, numerous utilities are participating in pilots across the globe. In the United States, Pepco Holdings Inc., Southern California Edison, Austin Energy, Xcel Energy, Duke Energy and Seattle City Light are all currently taking part in smart grid and PEV pilots.[105] Participation in these pilots not only will help them understand this emerging market and build the required capabilities, but it also will allow them to establish partnerships with the other industry players. These early partnerships will serve as a foundation for long-term partnerships as the industry evolves. It is likely that the companies investing early will ultimately dominate the PEV space, so it will be critical that utilities jump in the game to not miss the opportunities at hand.

## 4.2.3 Looking forward

Going forward, to address these opportunities and challenges, utilities' planning should include the following key areas:

**Technology and infrastructure:** Low- and medium-voltage grids will require continuous observation and testing to analyze the impact of PEV penetration and the requirements for grid upgrades. Generic infrastructure will be impacted based on where PEVs are concentrated, as existing infrastructure is not currently designed for such heavy loads.

**Standards and guidelines:** PEVs, as part of the wider implementation of smart technology, will have significant impact on the utility standards, guidelines, and engineering, design and construction practices. Standards and guidelines will need to be reevaluated as smart technology becomes more widespread and new standards developed.

**Rates and regulations:** Utilities will need to proactively plan for the required changes in infrastructure and consumer offerings so that they are able to effectively work with regulators to set a rate structure that fits with the new PEV market.

**Operating model and financials:** To fully capitalize on the emerging PEV market, utilities will require updates to their existing operating models. This effort will include back-office systems, staffing needs, resource allocation and infrastructure management. Utilities will need to plan accordingly to ensure they are prepared for the significant change to a traditionally very stable industry.

**Partnerships:** Partnerships with energy services companies, retail power providers and a multitude of new emerging players will be a significant part of the PEV landscape. Utilities will need to develop these new partnerships to ensure this opportunity does not pass them by.

As this new market unfolds, utilities will need to accept risk and uncertainty and, most importantly, be willing to play in an environment where consumer interactions and new, creative ways of creating touch points with consumers are requirements. As the traditional utility industry struggles to play catch-up with technology providers in the space, both power retail and energy service companies will be natural participants in PEV charging investments and ventures. These organizations have the flexibility to think quickly and secure their fair share of the limited amount of prime real estate for supporting PEV infrastructure. Utilities must be open to partnerships with such organizations and be willing to participate in the numerous pilot programs taking place. Those who are unwilling to participate, or are simply too slow to react, will likely miss out on the majority of the value created by this new industry. For those who do participate, their success will hinge on their ability to understand the consumer. By understanding the consumer, utilities will be able to understand the opportunity PEVs present, and the requirements to support them.

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