PPHB
ENERGY INVESTMENT BANKING

MUSINGS FROM THE OIL PATCH

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Allen Brooks
Managing Director

Note: *Musings from the Oil Patch reflects an eclectic collection of stories and analyses dealing with issues and developments within the energy industry that I feel have potentially significant implications for executives operating and planning for the future. The newsletter is published every two weeks, but periodically events and travel may alter that schedule. As always, I welcome your comments and observations.* Allen Brooks

The OPEC Bazaar Offers Something For Everyone

It wasn't the Roman Forum, but rather the OPEC Secretariat in Vienna. The media and analyst reports of the terms of the agreement hammered out at the 173rd Meeting of the OPEC Conference made us think of the lyrics of the song, "Comedy Tonight," from the show, *A Funny Thing Happened on the Way to the Forum*.

It wasn't the Roman Forum, but rather the OPEC Secretariat in Vienna

Old situations,
New complications,
Nothing portentous or polite;
Tragedy tomorrow,
Comedy tonight!

Something convulsive,
Something repulsive,
Something for everyone:
A comedy tonight!

Something aesthetic,
Something frenetic,
Something for everyone:
A comedy tonight!

Nothing with gods, nothing with fate;
Weighty affairs will just have to wait!

For Saudi Arabia, there is a new OPEC agreement cutting the organization's production by 1.2 million barrels a day, and which will last from January 2018 to December 2018. The new agreement replaces the current similar-sized production cut agreement that was due to expire at the end of March 2018. This move eliminated the

All long-term contracts have a 30-day cancellation clause

haggling over extending the current agreement for three, six or nine months. In reality, this new agreement reflects a nine-month extension. Keep in mind, however, that in the oilfield all long-term contracts have a 30-day cancellation clause, meaning they are all short-term agreements.

Saudi Arabia has been vocal this year about OPEC's need to very closely monitor member production compliance

Saudi Arabia also gets to chair the Joint Ministerial Monitoring Committee (JMMC), in conjunction with Russia, which oversees compliance by the various parties to the production cut agreement. During 2017, Saudi Arabia was a member of the JMMC, which was chaired by Kuwait, who remains a member of the committee. Saudi Arabia has been vocal this year about OPEC's need to very closely monitor member production compliance, but, more importantly, its need to monitor their oil export volumes better.

Russia has been outwardly concerned about rapidly escalating oil prices

Russia, the primary non-OPEC oil exporter who has supported the production cut agreement since its commencement in late 2016, secured the commitment for a formal review next June of oil market conditions and the progress the group is making in re-balancing the global market. That review will occur prior to the 174th Meeting of the Conference in June 2018. Russia has been outwardly concerned about rapidly escalating oil prices, which would incentivize American shale producers to drill and produce more oil. Also, Russia's economy has improved within the past year, reducing its need for sharply higher oil prices.

Nigeria and Libya, who were previously exempt from production restrictions under the prior agreement, will now be subject to a cap equal to their 2017 production level. They are now restricted, but in a significantly higher oil-price environment, meaning they will earn more money - their primary focus.

Venezuela's output continues to slide

Important for all OPEC producers is the fact that Venezuela's output continues to slide as the political and economic problems besetting that country have prevented PDVSA, its national oil company, from maintaining its output. That opens up the scenario of OPEC members cheating on their production caps, but finding that the additional oil only offsets the growing Venezuela supply deficit. That would help support higher oil prices in 2018.

They get a reprieve with higher oil prices enabling them to generate more income and to pay down debt

For U.S. shale oil producers, higher oil prices mean more income. For those explorers who have low-cost wells and prospects, they can drill more and earn even greater profits. For those exploration and production companies with substantial debt loads, they get a reprieve with higher oil prices enabling them to generate more income and to pay down debt, possibly ensuring their survival.

As the song's lyrics suggest: "Weighty affairs will just have to wait!" So, for those who were holding their breath until the bazaar closed last Thursday night, they can breathe easier now. However, the drama in the oil market will continue. We won't know for a while

whether this agreement will mean a "tragedy tomorrow, or comedy tonight!"

For EVs: Projections Automatically Become A Fact, Until Not

Blindly accepting statements as facts often leads to embarrassing retractions down the road

It seems that with any article covering the surging electric vehicle (EV) industry, the author embraces every utterance by a manufacturer as a fact rather than a projection, an estimate or possibly only a goal. Blindly accepting statements as facts often leads to embarrassing retractions down the road. Think about the numerous production claims issued by Tesla's (TSLA-Nasdaq) CEO Elon Musk, only to later acknowledge that manufacturing issues were delaying the output ramp-up. Or consider that the new Model 3 units are only being sold to employees who will then help iron out manufacturing defects.

It is always a better feeling to be issuing a positive view, unless you make your living selling fear protection

Many times, auto manufacturer statements assume aspects about the real world that they shouldn't, or at least should be spelled out to enable the public to properly assess the projection's validity. Forecasters are always subject to this criticism. It is often associated with what we refer to as "over the horizon" forecasts. Those are forecasts that have projections suddenly changing, or dramatically accelerating from current trends with little or no explanation as to why, and well beyond the near-term visibility of industry conditions. In most cases, it is because few forecasters see value in producing a projection that isn't optimistic, especially if the current environment is not positive. Think about BP plc's (BP-NYSE) CEO Robert Dudley when he offered the view in early January 2015 that oil companies should be planning for oil prices to be "lower for longer." His view was in sharp contrast with the many analysts who were assuming about how quickly oil prices would rebound in early 2015, such as they had in 2009 following the price drop associated with the 2008 financial crisis. It is always a better feeling to be issuing a positive view, unless you make your living selling fear protection.

When assessing shifts underway in the global vehicle sector, the assumption is that current EV acceptance trends will continue growing at their recent pace, but then experience runaway acceleration beginning at some future date. Will that prove to be the case in the real world? We'll see.

The key factors influencing these optimistic EV sales forecasts are the shifts in vehicle use, especially among young people, and how vehicles are powered

The key factors influencing these optimistic EV sales forecasts are the shifts in vehicle use, especially among young people, and how vehicles are powered. Chris Tomlinson, *The Houston Chronicle* business writer, recently wrote that self-driving taxis will become an accepted technology in the very near future. His conclusion was based on the announcement by car manufacturer Volvo that it will be delivering 24,000 self-driving vehicles to taxi start-up Uber, beginning in 2019. Mr. Tomlinson states, "That puts the company

[Uber] one step closer to eliminating drivers." The last we knew, there were tests of self-driving cars and self-driving taxis underway, but no one has commercialized a self-driving, non-driver taxi service. There are still many local laws that need to be addressed, as well as mapping roads and determining the liability in the event of an accident. In Pittsburgh, Pennsylvania, where a self-driving taxi test is underway, the vehicles are restricted to a portion of downtown, as well as requiring a human be in the front seat.

China's aim is to further the development of its own manufacturing industries

Volvo is owned by China's Zhejiang Geely Holding Group, having been purchased from Ford Motor Company (F-NYSE) in 2010. China is making a major push to lead the global EV industry as part of its "Made in China 2025" program, which it unveiled in 2015. China's aim is to further the development of its own manufacturing industries, and especially their level of domestic technology and material content. This is part of the government's effort to shift the country from a manufacturing export-driven economy to one that builds and sells domestically. The Made in China 2025 program is targeting ten industries where China wants to establish a global leadership position. Those ten industries include:

1. Information technology
2. Numerical control tools and robotics
3. Aerospace equipment
4. Ocean engineering equipment and high-tech ships
5. Railway equipment
6. Energy saving and new energy vehicles
7. Power equipment
8. New materials
9. Medicine and medical devices
10. Agricultural machinery

The push by China to excel in "new energy vehicles" (NEVs) is not surprising given the country's air quality issue. In furtherance of this effort, we expect the government will continue to take steps to push global auto manufacturers to invest in building NEVs in China. Since it is virtually impossible for a western car manufacturer to enter the Chinese market without a local partner, China is insured of benefitting from technology transfers through the many joint ventures being established.

Subsidies for EV purchases have been in place for a while, but they are now being reduced and replaced by mandates and other restrictions

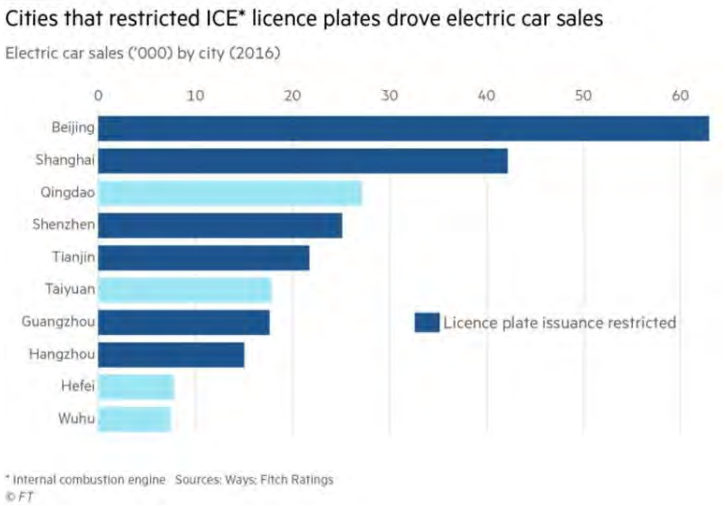
The push behind EVs is being engineered through mandates on the percentage of new car sales accounted for by EVs. Additionally, the government is requiring companies to buy EV "credits" from other producers for every conventional auto they make. Subsidies for EV purchases have been in place for a while, but they are now being reduced and replaced by mandates and other restrictions. These shifts have not gone unnoticed by American and European car

manufacturers, almost all of whom have established ventures with local Chinese auto manufacturers to design and build NEVs for the local market. These joint ventures may also wind up exporting some of their domestic output to international markets such as Europe and the United States.

The government, through its municipal officials, restricted the issuance of license plates for internal combustion engine cars

The Chinese economy is governed by a central planning mechanism, which requires a high level of regulation, driven by government edicts and financial support. For example, in an effort to improve urban air quality, a noted global criticism of China's major cities, the government, through its municipal officials, restricted the issuance of license plates for internal combustion engine (ICE) cars. Articles in local Chinese newspapers highlight how many recent EV buyers purchased their vehicles in order to secure a license plate much sooner than they would otherwise have been able to had they purchased an ICE car. Many of these same people talked about their disappointment with the performance of their EVs, especially during last year's harsh winter in Beijing.

Exhibit 1. Where EV Mandates Are Key In China



Source: ***Financial Times***

The Chinese government has stated it is considering instituting a ban on the sale of ICE vehicles, but they have yet to announce the date

China already is the world's largest EV market, having sales of 507,000 EVs last year and is on track for selling something in the order of 700,000 units this year, according to the China Association of Automobile Manufacturers. China has a goal of selling seven million EVs and hybrid vehicles by 2025. There are reports that China may copy European countries who have announced bans on the sale of ICE vehicles in the 2030 timeframe. The Chinese government has stated it is considering instituting a ban on the sale of ICE vehicles, but they have yet to announce the date. What China does have in place are aggressive mandates for EV sales in the near-term. China announced that any automaker producing or importing more than 30,000 cars must ensure 10% are all-electric, plug-in hybrid, or hydrogen-powered by 2019. That share rises to

12% in 2020. Because the government has given automakers some leniency in meeting the initial target, the 12% target in 2020 is the first enforceable number. It is this reality that is driving western auto manufacturers to form joint ventures with local carmakers, and to plan new EV models for the Chinese market.

Most car manufacturers have announced many new EV models at this year's auto shows

As governments around the world announce their desire for more EVs on their roads, we are just now beginning to learn of auto company plans. Most car manufacturers have announced many new EV models at this year's auto shows. The new models are targeted for sale over the next one to five years. Some of the new models are likely sister cars that will be manufactured on the same platform, thereby reducing research and development costs, plus the expense of retooling their assembly operations.

Mr. Hackett's plans included the creation of Team Edison to build a business case for EVs

This September, new Ford CEO Jim Hackett, who took over from former CEO Mark Fields in May, announced that the company would begin an accelerated EV effort. He had been a Ford director before stepping down in 2016 to run Ford's "mobility services" unit. Ford had long trailed its cross-town rival General Motors (GM-NYSE), which was clear when GM announced plans for 20 new battery-powered models by 2023. Mr. Hackett's plans included the creation of Team Edison to build a business case for EVs, and that the company will introduce its first long-range EV in 2020.

A few weeks ago, Mary Barra, CEO of GM, presented at an institutional investor conference. Her presentation dealt with the new dimensions of the company. One slide presented GM's electrification strategy, which stated that it wanted EVs that were: "DESIRABLE, OBTAINABLE, AND PROFITABLE VEHICLES DELIVERING OVER 300 MILES OF RANGE."

In the presentation, Ms. Barra discussed the company's EV history and its successes to date. Importantly, she highlighted plans for the future, which involve reducing the cost of its EV batteries from the $145/kWh it is paying LG Chemical now to $100/kWh by 2022. That may require GM to begin manufacturing its own batteries, but that possibility was not acknowledged.

Exhibit 2. How GM Sees Lowering EV Battery Costs

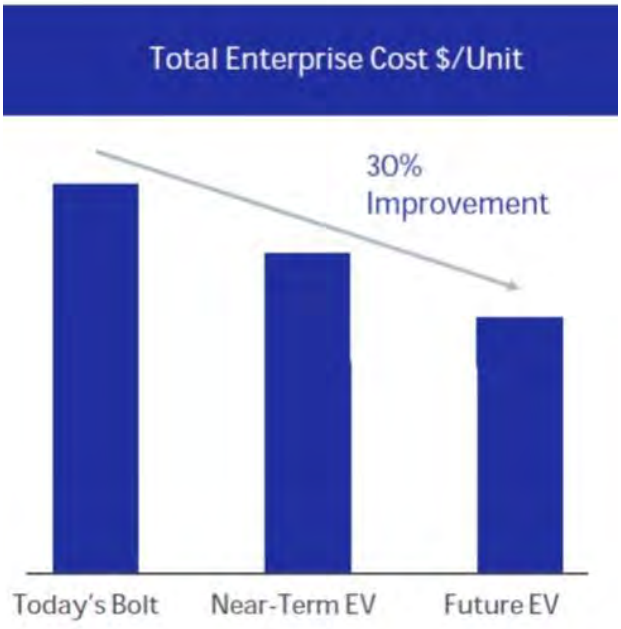
Source: GM

GM executives have acknowledged it loses about $9,000 per EV sold

She also highlighted the need to reduce the manufacturing cost of GM's EVs by 30%. As we expected, there were neither dollar figures or dates associated with the cost improvement goal. Since GM executives have acknowledged it loses about $9,000 per EV sold, there is a strong incentive to reduce the manufacturing cost. In fact, it is a necessity to figure out how to make a profit since California and nine other states, including New York and New Jersey, require EV sales in order to sell conventional cars in their states. Those ten states represent 30% of the U.S. auto market.

We are not quite sure how that per unit loss figure is determined. Does it include costs such as the destination charge and the holdback from a dealer that facilitates his MSRP sales promotions? In the case of the Chevy Bolt, those two figures amount to about $2,000 per unit, which means the actual cost reduction target is only $7,000.

Exhibit 3. What GM Needs To Do For EV Success



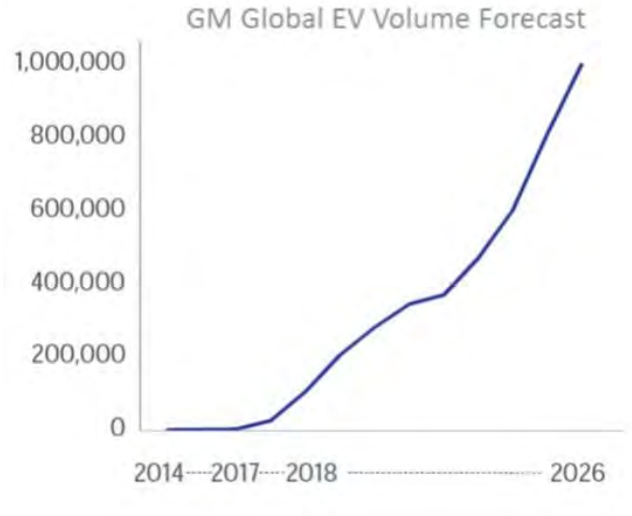
Source: GM

GM then expects sales to accelerate to one million EVs by 2026

An important take-away from the analyst presentation was a chart showing GM's projected global EV sales. While there is no date associated with the projected totals, we estimate that GM plans to double its estimate 2018 EV sales of 200,000 units by 2021. GM then expects sales to accelerate to one million EVs by 2026. The acceleration would come with the availability of those 20 new EV models by 2023. Based on the monthly EV sales data compiled by *InsideEVs.com*, through October, GM has sold nearly 34,000 EVs, comprised almost equally by Chevy Bolts and Chevy Volts. GM has also sold 175 EVs comprised from the two Cadillac and another

Chevy EV model it manufactures. If GM is selling roughly 200,000 EVs globally, then a substantial number are being sold in Europe and China.

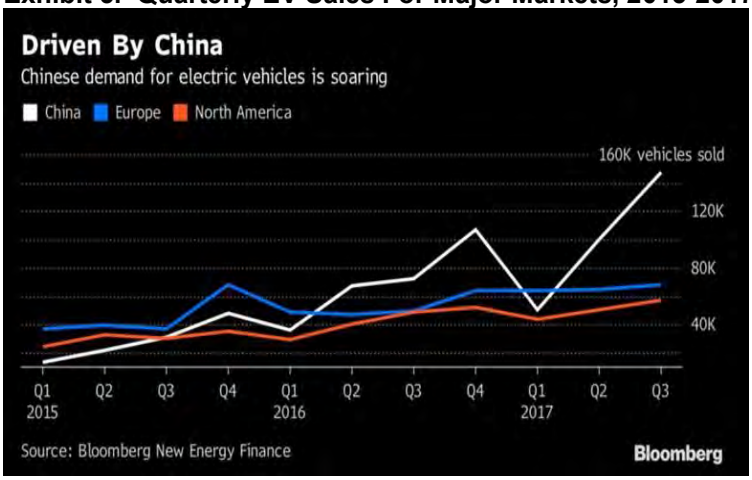
Exhibit 4. GM's Forecast For Its Global EV Sales



Source: GM

That regional sales breakdown has validity given the 2017 quarterly total EV sales data for North America, Europe and China.

Exhibit 5. Quarterly EV Sales For Major Markets, 2015-2017

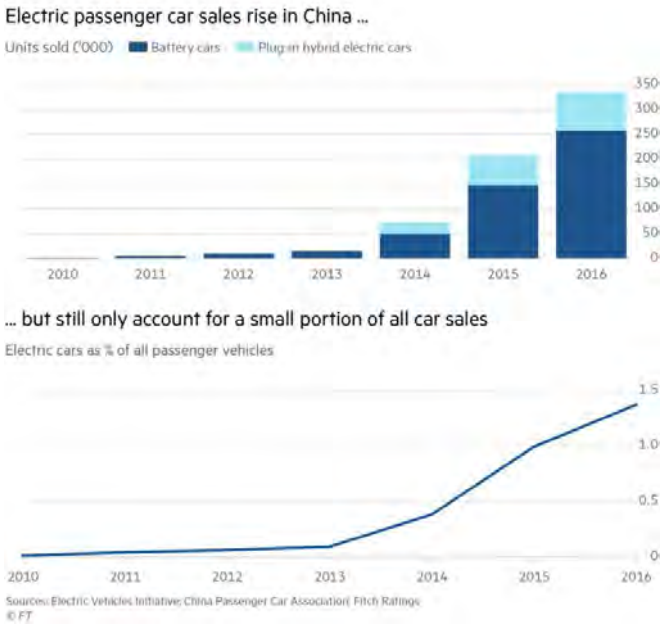


Source: Bloomberg

The other trend of note is the rapid increase in the number of plug-in hybrid electric vehicle sales in China

While China's current EV sales is outpacing Europe, which in turn is leading North America, it still reflects a tiny market - under 1.5% of new car sales in 2016. The other trend of note is the rapid increase in the number of plug-in hybrid electric vehicle sales in China.

Exhibit 6. China Is Global Driver For EV Sales



Source: ***Financial Times***

With all these optimistic forecasts and government financial support and mandates, should we accept every statement as a fact? That is an important question for those involved or invested in the automobile and oil and gas industries, the two sectors being disrupted by the changes underway in the transportation market. We would urge some caution in blindly accepting the latest statements as facts about the future.

This would result in the displacement of eight million barrels of oil per day, a devastating hit to the oil industry's business model

Bloomberg New Energy Finance (BNEF) suggested in a 2017 study that EVs will account for a third of the global automobile fleet by 2040, after reaching 54% of new car sales that year. This would result in the displacement of eight million barrels of oil per day, a devastating hit to the oil industry's business model. While the 2017 BNEF EV outlook is higher than its 2016 forecast, it was after the earlier forecast that people contemplated how the oil and gas industry would fare in this dire scenario given the damage done by the two-million-barrels a day supply glut in 2014.

It is important to remember that the two-million-barrel a day glut did not develop overnight

It is important to remember that the two-million-barrel a day glut did not develop overnight. In fact, the glut emerged at the start of 2014 and grew steadily throughout the year. That explains why oil prices began 2014 at over $100 a barrel, but were down to $100 by late June. They continued falling from then, reaching about $80 a barrel

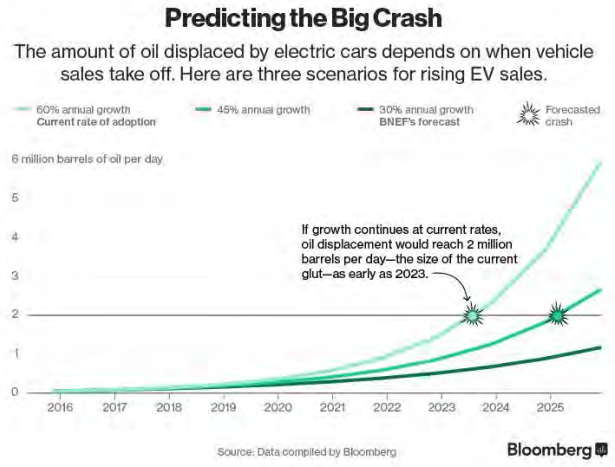
in November, OPEC convened in Vienna and announced the ending of Saudi Arabia's support for oil prices, coupled with a planned surge in its output. That announcement sent oil prices plummeting. This history is important since an eight-million-barrel a day glut will not

happen overnight. We expect that as a one-million-barrel a day glut grows toward an eight-million-barrel a day glut, producers will stop drilling wells, and instead elect to let well decline-rates offset any growing production glut.

The oil glut scenario discussed after the 2016 BNEF forecast was based on projecting a continuation of the 60% EV sales growth experienced in 2015. That rate would lead to the two million barrels a day glut by 2023. *Bloomberg* analyst Tom Randall opined that it was not realistic to assume a continuation of such a high rate of EV sales. So, he reduced the EV growth rate to 45%, which shifts the glut's arrival to 2025. A third projected EV sales growth projection assumes a 30% penetration rate. According to Mr. Randall, "BNEF has taken a more methodical approach in its analysis today, breaking down electric vehicles to their component costs to forecast when prices will drop enough to lure the average car buyer. Using BNEF's model, we'll cross the oil-crash benchmark of 2 million barrels a few years later—in 2028."

"Using BNEF's model, we'll cross the oil-crash benchmark of 2 million barrels a few years later—in 2028"

Exhibit 7. Oil Glut Forecast Gets Pushed Out By EV Costs



Source: Bloomberg

Implicit in that five-year shift in the arrival of the oil glut is a closer examination of the real-world costs of building EVs. It also implies that EV sales prices and performance will not attract buyers as quickly as their basic forecast model assumes. A five-year difference in glut-arrival dates is a little more that "a few years later" for purposes of planning business strategies. Understanding the analytical mindset of the BNEF study's author is critical. Salim Morsy said, "If you look at reports like what OPEC puts out, what Exxon puts out, they put adoption at like 2 percent. Whether the end number by 2040 is 25 percent or 50 percent, it frankly doesn't matter as much as making the binary call that there will be mass adoption." This is a critical point. Will it be "mass adoption," or possibly "mass incarceration?"

A five-year difference in glut-arrival dates is a little more that "a few years later"

Batteries account for a third of the cost of an EV

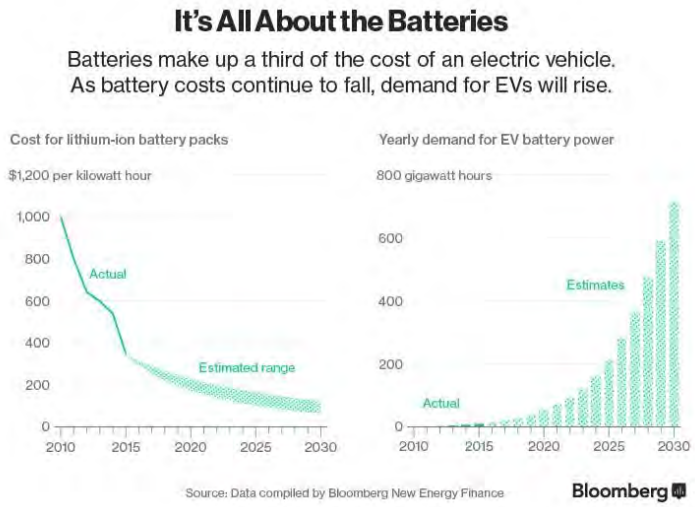
BNEF's approach to forecasting EV penetration is based on examining the total cost of ownership of EVs, with the critical element being the cost of batteries. Batteries account for a third of the cost of an EV. According to BNEF, for EVs to achieve widespread adoption, one of four things must happen:

1. Governments must offer incentives to lower the costs.
2. Manufacturers must accept extremely low profit margins.
3. Customers must be willing to pay more to drive electric.
4. The cost of batteries must come down.

For BNEF, and in almost every EV forecast, the assumption is that the cost of the battery will continue to fall, lowering the cost of EVs to, and eventually below, that of conventionally-powered cars

BNEF states that the first three things are happening now in the early-adopter days of EVs. Importantly, they recognized that those factors can't be sustained, which shifts the focus to what is happening to the cost of batteries. For BNEF, and in almost every EV forecast, the assumption is that the cost of the battery will continue to fall, lowering the cost of EVs to, and eventually below, that of conventionally-powered cars. That is the inflection point for the acceleration in EV sales. We suspect this assumption may overlook other key issues such as EV range and the ease of recharging. It also doesn't address issues with battery procurement.

Exhibit 8. Battery Cost Is Key To EV Forecast Accuracy



Source: Bloomberg

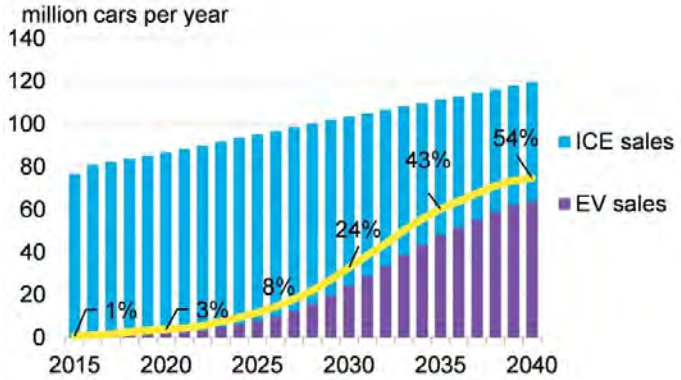
BNEF cites that battery costs have fallen by 73% since 2010, and sees them falling by another 70% by 2030

The 2017 BNEF forecast calls for a much higher EV sales rate in 2040 – 54% of new car sales versus 33% - based on much lower battery costs. BNEF cites that battery costs have fallen by 73% since 2010, and sees them falling by another 70% by 2030. That is key to their forecast of an EV inflection point being reached at the end of the 2020s. According to Colin McKerracher, lead advanced transport analyst at BNEF, "We see a momentous inflection point for the global auto industry in the second half of the 2020s. Consumers will find that upfront selling prices for EVs are comparable or lower

BNEF sees EV sales growing slowly, but steadily, through most of the 2020s, but then exploding

than those for average ICE vehicles in almost all big markets by 2029." In other words, BNEF sees EV sales growing slowly, but steadily, through most of the 2020s, but then exploding due to EVs gaining a comparative advantage over internal combustion engine cars. This leads to their forecast for EVs eventually exceeding ICE cars, as shown in Exhibit 9.

Exhibit 9. 2017 Forecast Is For Robust EV Sales



Source: Bloomberg New Energy Finance

It is interesting how the 2017 forecast has become much more aggressive based on critical assumptions tilting the scales in favor of EV pricing. What does it mean for EV prices to be equal or below ICE cars in "almost all big markets by 2029"? Which markets don't reach that threshold? What about the rapidly growing developing economy markets that are tiny vehicle markets now? How does that contrast with the mature European and North American markets?

Will EV buyers be willing to pay much higher costs if we experience another commodity super-cycle as in the 2000s?

We remain skeptical after reviewing BNEF's shift in its EV growth projection last year when they did a detailed cost analysis of the cars. We still have little knowledge about future availability or cost of the various rare minerals needed for EV batteries in 10-20 years. Will EV buyers be willing to pay much higher costs if we experience another commodity super-cycle as in the 2000s? Or, are the forecasters merely assuming that increased volumes will lower per unit costs, or maybe that a new battery chemistry will evolve that will be much cheaper? We fully understand and appreciate the challenges of preparing forecasts, something we have done for most of our working career. Maybe it is just us, but we always presented forecasts as estimates subject to our assumptions proving correct. Accepting statements about plans and/or goals as facts sets one up for issuing mea culpas down the road. Of course, the key to success in forecasting is to forecast often so people forget the all the wrong prior forecasts.

Electric Cars Have Long History Of Failing To Meet The Hype

The history of EVs dates from the early 1800s

Many people believe the history of electric vehicles (EV) began only a few years ago. That is far from reality as a review of EV history shows the history of EVs dates from the early 1800s and that the hype over EVs has gone through several eras in the interim.

The sadder event was that it was destroyed by railway workers who saw the EV as a threat to their jobs, even though the EV was nowhere near being an economical form of transportation

The first known electric car was created as a model car in 1828 by Hungarian inventor Ányos Jedlik, who had developed an early electric motor. In 1834, Vermont blacksmith Thomas Davenport and his wife, Emily, built a small, model electric car that ran on a circular, electrified-track wired with silk threads from a scarf. That was followed in 1835 by the building of a small electric car powered by non-rechargeable batteries. The Davenports and a colleague received the first American patent for an electric machine/motor in 1837. Starting then, and over the next four years, an Aberdeen chemist, Robert Davidson, built the first full-sized EV. It can pull six tons of weight at four miles per hour for about 1.5 miles. Sadly, it weighed seven tons. The sadder event was that it was destroyed by railway workers who saw the EV as a threat to their jobs, even though the EV was nowhere near being an economical form of transportation. Another case of Luddites striking out at technology. What is true today about EVs was true then: batteries cost more than traditional power sources. In this case, it was the cost of using zinc in a battery being about 40 times greater than the cost of burning coal to power steam locomotives.

The next era of EV popularity happened in the late 1890s and early 1900s. The first American EV was unveiled in 1890. It was built by William Morrison of Des Moines, Iowa, a transplanted Scotsman. The EV was a 6-passenger wagon that could travel at up to 14 miles per hour, and it may have been the first land vehicle with a steering wheel. It was shown at the World's Colombian Exposition in Chicago in 1893, and likely influenced the early development of EVs. In France at this time, regenerative braking was developed that allowed the storage of power in the battery.

The first car with power steering was introduced, and it was an EV

During the last years of the 1890s, the first American electric car company was formed, and soon after electric taxis appeared on the streets of New York City. A battery swapping company was founded in Hartford, Connecticut, which fascilitated the development of taxi services. Battery-powered street cars soon arrived in New York City and other cities in the eastern part of the U.S. The first car with power steering was introduced, and it was an EV. Road races and speed records were being won by EVs, as these vehicles began dominating the American fleet.

At the turn of the century, nearly 34,000 EVs, 38% of all U.S. automobiles, were on the roads

At the turn of the century, nearly 34,000 EVs, 38% of all U.S. automobiles, were on the roads. The rest of the fleet was composed of vehicles powered by steam (40%) or gasoline (22%). In 1901, Thomas Edison patented the nickel-iron battery, and a year later, in Germany, Dr. Ferdinand Porsche built his second car, a hybrid with an electric range of 40 miles.

Henry Ford began mass producing his Model T at prices half to a third of the cost of EVs

By 1912, another 5,000 EVs were on America's roads, but key developments in conventionally-powered vehicles began to undercut the success of EVs. That year, the electric starter was invented, which eliminated the hand crank for starting gasoline-powered cars. At the same time, Henry Ford began mass producing his Model T at prices half to a third of the cost of EVs. Moreover, cheap Texas oil was discovered, the nation's road system improved, and people's ability/desire to travel longer distances than EVs were capable of achieving and at faster speeds began to impact the transportation market. The image of EVs being only for women further harmed EVs' marketablity, although it was interesting that Henry Ford purchased EVs for his wife and son.

As the environmental movement rallied behind California's ZEV effort, government subsidies and mandates for these vehicles increased spurring the growth of the EV business

The next era of EV interest occurred in the 1970s following the 1973 Arab Oil Embargo that spurred interest in reducing U.S. reliance on imported oil and greater use of domestic energy sources. In 1976, the US Congress passed the Electric and Hybrid Vehicle Research, Development, and Demonstration Act, which increased research and development of electric motors, batteries, and other components of electric and hybrid vehicles. But it wasn't until 1990 when the California Air Resources Board began pushing automakers to produce more-fuel-efficient, low-emissions vehicles and eventually transition to zero emissions vehicles (ZEV) that the development of EVs and hybrid cars was truly kicked off. As the environmental movement rallied behind California's ZEV effort, government subsidies and mandates for these vehicles increased spurring the growth of the EV business, not only in the U.S., but worldwide, too.

We were fascinated to stumble on a 1966 article from *Popular Science* magazine, which reported on the auto industry's efforts at developing EVs based on new battery technology. The motivation of the carmakers was to address growing concerns about urban air pollution. Both Ford (F-NYSE) and General Motors (GM-NYSE) were actively involved in developing ZEVs. In fact, the head of Ford's research pointed

out that the company had been working on this technology since 1958.

Exhibit 10. The Vision Of An Electric Car In 1966

Source: *Popular Science* via Phil-are-go.blogspot.com

The challenge was that the sodium-sulfur battery needed to operate at around 500 degrees Fahrenheit in order to keep the sodium and sulfur molten

The article discussed the current state of battery technology at that time, indicating that Ford had found a new battery chemistry that would yield more energy than the traditional lead-acid battery. The technology focused on sodium-sulfur battery packs with 15 times the power stored in a standard lead-acid battery. These new batteries were being successfully tested in small sizes, but Ford engineers were predicting it would only take two years to be able to scale them up in size and output sufficient to power a car. The challenge was that the sodium-sulfur battery needed to operate at around 500 degrees Farhenheit in order to keep the sodium and sulfur molten. Whenever the vehicle was operating, it was not a problem. Parked, however, created a challenge for keeping the vehicle's battery hot. The solution the engineers foresaw was for parking lots to have plug-in facilities that would keep the battery hot, much like Canadians do when they plug in their engines during the winter.

A conclusion offered in the article by Ford's research director was: "We'll need a whole new approach to vehicle engineering." His vision was for a car about six feet long, with enough room to hold two adults and two children. The car

would have a range of 40 miles and a top speed of 40 miles per hour. These EVs were envisioned primarily for city and suburban use, where range restrictions were considered to be unimportant. Ford saw the eventual development of EVs that could travel 200 miles at highway speeds, and then be recharged in an hour while the driver had lunch.

These EVs were envisioned primarily for city and suburban use

The 1966 article set forth a vision of the world for developing EVs that is curiously similar to today's world view for EVs. It's funny that the future outlook for EVs, as expressed in the article, was similarly discussed during each of the EV eras. If the most optimistic current forecasts for EV penetration are examined, they project the electric share of the fleet in 2040 rising to where it was back in 1900.

The 1966 article set forth a vision of the world for developing EVs that is curiously similar to today's world view for EVs

The *Popular Science* article concluded with the author relating a story about him following two "grizzled, cynical reporters" from an EV technical demonstration in Dearborn hosted by Ford. He wrote: "'When do you think you'll be parking an electric in your garage?' one asked the other. 'I'll tell you,' he continued, answering his own question. 'Never.'" For a battery-electric car, 'never' seems to have meant 35 years.

The article's concluding paragraph summed up the author's view of the future for EVs. After stating that the two reporters' views he quoted were wrong, he then wrote, "When a development is needed badly enough, it comes." He went on writing: "The electric automobile can stop the trend toward poisoned air. Its details are yet to be decided. But it will come. And it won't be long." That was in 1966!

"When a development is needed badly enough, it comes"

The Electric Semi Truck Is On The Horizon – Good News?

How many electric vehicles (EVs) will be on the world's roads in 2040? It seems as though every consulting firm and participant in the vehicle industry has an estimate (guess?). The range of estimates is wide, and, depending on where you are on that spectrum, likely signals your view of how significantly the EV fleet will impact the oil and gas industry's future. From 'little impact' to 'devastating' seems to be the damage range.

From 'little impact' to 'devastating' seems to be the damage range

While most of the focus is on EV cars, few people have addressed how many electric trucks we might see on the roads. This is becoming a timelier question, as major truck builders are now introducing electric models, including that latest upstart truck manufacturer, Tesla Motors (TSLA-Nasdaq). In the United States, semi-trucks account for about 1% of all vehicles on the roads, so why should we be concerned? Those trucks produce 16% of U.S.

vehicle emissions, which is why we should care. As traditional internal combustion engine (ICE) cars become cleaner and cleaner, and EV cars begin entering the domestic vehicle fleet in greater numbers, addressing truck emissions is becoming a more pressing issue.

These big trucks are expensive to operate and maintain, but these are areas where an electric version will sharply reduce the outlays

Recently, *The Houston Chronicle's* business columnist, Chris Tomlinson, wrote about his personal experience with EVs. In a column the morning after Thanksgiving Day, he wrote about the electric truck introduced by Elon Musk, the CEO of Tesla, during a spectacular media event a few days earlier. Mr. Tomlinson discussed how the over-the-road truck business was potentially a more lucrative market for EV manufacturers. These big trucks are costly to purchase, meaning the high price of EVs will be less of a sticker shock for buyers. These big trucks are expensive to operate and maintain, but these are areas where an electric version will sharply reduce the outlays. In other words, in the long-run the life-time ownership cost will make the electric version of the semi-truck cheaper.

The market for these big trucks is only a few thousand per year, making it much easier for Tesla to be successful

Mr. Tomlinson also pointed out that the market for these big trucks is only a few thousand per year, making it much easier for Tesla to be successful as opposed to working to overcome the challenges of mass manufacturing cars. Given Tesla's problems in manufacturing its Model 3, the mass-market version of Tesla's EVs, conquering the smaller big truck market might be considerably easier, and commercially more successful. Remember, Tesla has yet to earn a profit from any of the EVs it has sold so far, and prospects for profits in the near-term appear remote.

Exhibit 11. The New Tesla Semi Electric Truck

Source: Tesla

Mr. Tomlinson further lionized the new Tesla Semi, as the truck is being called, by noting that orders had been placed by Wal-Mart (WM-NYSE) and J.B. Hunt (JBHT-Nasdaq), two very large shipping companies, as well as others. Of course, all the companies had to

Wal-Mart ordered 15 trucks – five for its U.S. operations and ten for Canada – out of a fleet of over 6,000 trucks

do was put down a $5,000 deposit for each truck ordered, quickly that was upped to $20,000. Deliveries are promised to start in late 2019, and presumably buyers would test the trucks before deciding whether to order more. Interestingly, Wal-Mart ordered 15 trucks – five for its U.S. operations and ten for Canada – out of a fleet of over 6,000 trucks that the company operates in North America. We were surprised at the distribution of test trucks between Canada and the U.S., given the larger shipping infrastructure in the latter market. In early 2017, Wal-Mart had more than 11-times the number of U.S. stores (~4,700) compared to those is operates in Canada (~410).

At the Semi introduction, Mr. Musk made a number of significant performance claims for the truck, some of which are questionable, beginning with his highlighting the design of it hi-tech cabin. The cabin is high enough for the driver to stand up in it, while the driver's seat is centered. There is only one seat, which raises the question of where a second person would sit.

The truck would be able to accelerate from zero to 60 miles per hour in five seconds without a trailer, and in 20 seconds with a trailer's full 80,000-pound load

In the performance category, the truck will be able to travel 500 miles before having to be re-charged. Mr. Musk claimed this was about the average driver's daily distance given the federally mandated work restrictions. To enable the trucks to go further, Tesla plans to establish a network of Megacharger re-charging stations where a truck could add 400 miles of range in a 30-minute charging session. The truck will have four electric motors – one for each wheel on each of the two rear axles – and they would utilize technology from the Model 3 battery pack. The truck would be able to accelerate from zero to 60 miles per hour in five seconds without a trailer, and in 20 seconds with a trailer's full 80,000-pound load. Jackknifing the truck will be impossible due to its drive train and motors. The truck's drivetrain is guaranteed to last for one million miles without breaking down. Lastly, the windshield would be made from a material that would withstand a nuclear explosion, meaning it would resist highway rocks from cracking it, necessitating lost time and expense associated with replacing it, which happens often for many trucks. The most important item, but one Tesla did not announce, was the truck's initial cost. However, Mr. Musk implied it would be expensive when he said, "Tesla stuff is expensive," to the approval of the crowd.

The truck will be equipped with radar sensors, cameras and processors to enable drivers to use a version of Tesla's Autopilot self-driving system for lane-keeping and collision avoidance

Mr. Musk highlighted the new cab design, which was reported as being designed for the driver. Instead of locating the driver position on the left side, Tesla has centered the seat for "better driver visibility all around the vehicle." There are also touchscreen displays on each side of the driver's seat, providing navigation and blind spot monitoring systems. The truck will be equipped with radar sensors, cameras and processors to enable drivers to use a version of Tesla's Autopilot self-driving system for lane-keeping and collision avoidance. Tesla also points out that the computer system in the truck could be linked to its home office and navigation systems for ease of scheduling.

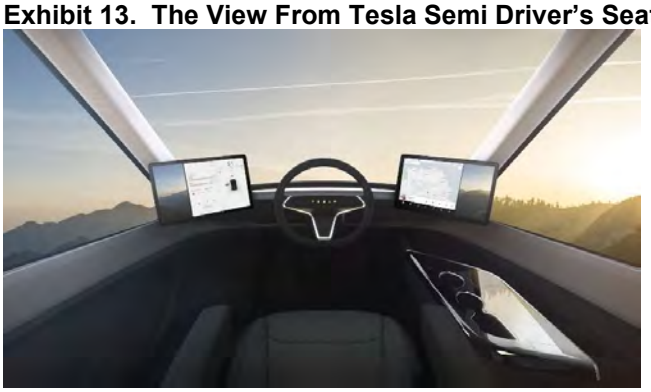
Exhibit 12. Tesla Semi Cabin Interior

Source: Tesla

The commentary from over-the-road truck drivers was not complementary about the new cabin design

Supposedly, a reason for locating the driver seat in the center of the truck's cabin is to eliminate the need to reconfigure the truck for right-hand driving countries. The commentary from over-the-road truck drivers was not complementary about the new cabin design. It is possible that the hi-tech design and video displays might be attractive for Millennials who could be coaxed into becoming drivers.

Exhibit 13. The View From Tesla Semi Driver's Seat



Source: Tesla

Truck drivers commented that the seat location prevents them from being able to exchange paperwork with terminal gate guards or police officers while seated

Truck drivers commented that the seat location prevents them from being able to exchange paperwork with terminal gate guards or police officers while seated. It also means that the blind spots – in particular the one next to the driver's door – will now require the driver to rely on cameras rather than their eyes or mirrors. The seat position also eliminates the ability of a driver to see the corner of his truck, and he cannot lean out the window to see the back of his trailer when backing up. Another question drivers asked was which window rolled down to enable paperwork exchanges, as they could not determine that from the models and pictures shown. These are all serious issues for current truck drivers.

A much more important safety point about the center seat location is that the driver cannot see around a truck ahead of him without pulling nearly half-way into the next lane, risking an accident. Maybe that will bring back Citizens Band Radio communications.

Additionally, the cabin sets up a potential vision challenge for drivers. The screens depicted will significantly brighten up the cabin at night and risk potentially ruining the night vision of drivers, creating a possible unsafe condition.

The American Transportation Research Institute estimates that it costs $1.59 per mile to operate the average diesel truck, which includes about $0.37 for fuel and $0.26 for the cost of the truck and trailer

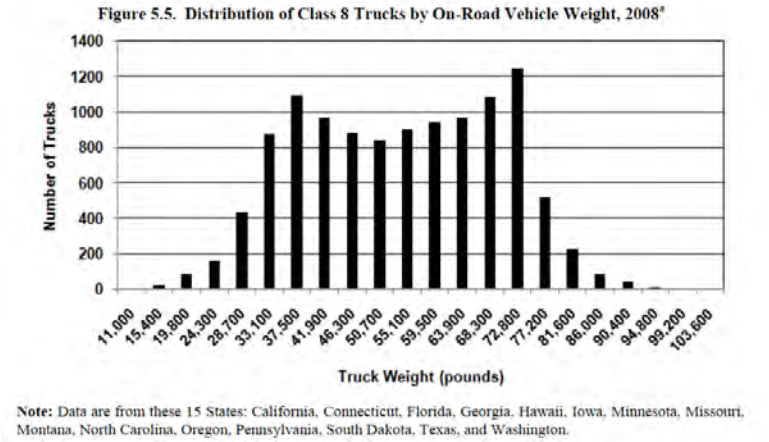
The real question for the electric truck's success is its economics. While the truck may cost more initially, will the elimination of diesel fuel and lower maintenance costs offset the higher purchase price? Mr. Musk claimed that the Tesla truck will cost about 25 cents per mile less to own and operate than for a comparable diesel truck. He quoted an operating cost of $1.26 per mile versus a comparable diesel truck at $1.51 per mile. The American Transportation Research Institute estimates that it costs $1.59 per mile to operate the average diesel truck, which includes about $0.37 for fuel and $0.26 for the cost of the truck and trailer. While the fuel cost would disappear with an electric truck, the purchase cost amortization would increase sharply, given the higher cost of the Tesla Semi. Truck maintenance costs account for about 10% of the operating cost for an average truck, so here is an area where cost savings will be evident.

The Semi would have a battery composed of 11 Model 3 battery packs, adding up to a weight of 11,638 pounds

The battery issue will become important, and it was something that Tesla hasn't said much about, other than it will use technology from the Model 3 battery. Tesla said that the truck's energy consumption is less than two kilowatt-hours (kWh) per mile. At 1.8 kWh per mile, and the 500-mile per charge range, the battery capacity will need to be about 900 kWh. The Model 3 Long Range version has an 80.5 kWh battery, which weighs 1,058 pounds. Using these numbers, the Semi would have a battery composed of 11 Model 3 battery packs, adding up to a weight of 11,638 pounds.

A diesel truck's engine, transmission and differentials come in at a weight of about 4,000-5,000 pounds. That means the additional battery weight would eat into the cargo capacity of the Semi, directly

Exhibit 14. Why Tesla Battery Weight Is Less Of A Concern



Source: Oak Ridge National Laboratory

impacting the truck's revenue generating capacity. A research firm that has a bullish take on electric trucks cites data from an Oak Ridge National Laboratory report for the Department of Energy showing that few trucks – 11% weighing 72,800 pounds and 10% at 68,300 pounds – are near the federal maximum tractor-trailer weight limit of 80,000 pounds. This suggests that more trucks are "cubing out" (running out of trailer space, before they "weigh out." That means the additional battery weight may not be as much of a hinderance as it appears, but the ultimate judge of that issue will be the truck buyers and their specific needs.

This suggests that more trucks are "cubing out" (running out of trailer space, before they "weigh out"

Another issue raised by truckers was what they saw in the Semi photos that showed special electric lines extending from the tractor to the trailer rather than the traditional air hoses for the trailer brakes. Will the Semi need an air compressor to power the brakes on existing trailers, or will truck buyers have to purchase Tesla trailers, too? That would add additional costs to the purchase decision. If an air compressor is designed in to the electric truck to enable the use of existing trailers, where would it go, what would it mean for additional weight and maintenance costs?

Will the Semi need an air compressor to power the brakes on existing trailers, or will truck buyers have to purchase Tesla trailers, too?

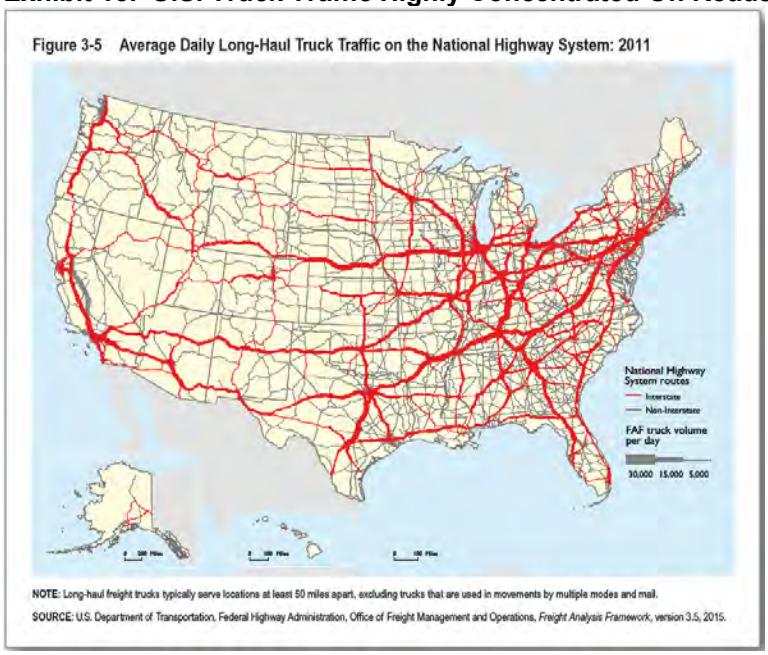
With respect to batteries and charging, it has been suggested that regenerative braking could be utilized, which would allow for some recharging of the battery whenever the truck was braking, such as occurs with hybrid vehicles. The major problem with this concept is that over-the-road trucks are designed to be run at highway speeds for long periods of time, and not braking much. Thus, the regenerative brakes would not provide much battery charge.

It is also thought that the Tesla Megacharging stations might be configured to charge multiple batteries at the same time. This would facilitate the design of multiple batteries powering each wheel's motor. A system of this design would reduce recharging time. As shown in the Department of Transportation map (next page) that shows the magnitude of average daily long-haul traffic on the national highway system, the concentration of truck traffic would enable the installation of these super-charging stations nationwide much faster than how long it will take to build out a nationwide car-charging system. The biggest issue is that these Megacharging stations will cost upwards of $500,000 a piece, meaning a nationwide system will be very expensive.

It is also thought that the Tesla Megacharging stations might be configured to charge multiple batteries at the same time

Another Tesla Megacharging issue pointed out by John Federsen, CEO of Aurora Energy Research, is that the unit would need 1,600 watts of power to recharge the truck in 30 minutes. That is the equivalent power for 4,000 homes for the same time period. This sparks a question about the performance and resiliency of the electric grid.

Exhibit 15. U.S. Truck Traffic Highly Concentrated On Roads



Source: Federal Highway Administration

Last year, Daimler sold 415,108 heavy duty trucks worldwide, earning revenues of $39 billion

The electric truck landscape is about to become more crowded. About a month ago, German automaker Daimler AG (DDAIF-Nasdaq) introduced its long-haul electric truck prototype, signaling that it will be available in a few years, but more importantly delivering a message that Daimler will be a fierce competitor. Daimler is the world's leading truck builder operating under the Daimler and Mercedes-Benz names, and in the U.S. owning the Freightliner, Western Star and Thomas Built Buses lines. Last year, Daimler sold 415,108 heavy duty trucks worldwide, earning revenues of $39 billion. Marc Llistosella, CEO of Daimler Trucks Asia, commented, "We know this business. Why should we hand it over to Tesla, which has no experience in trucks?"

"Basically every manufacturer is developing battery, fuel cell electric or hybrids. Peterbilt, Kenworth, Volvo"

China's BYD Co. Ltd. (BYDDF-Nasdaq), with a manufacturing plant in the United States, has already delivered its first semi-tractor for pulling containers around ports in Southern California, but with only about 100 miles of battery range. Toyota Motors (TM-NYSE) has a fuel-cell heavy duty truck working in the Port of Los Angeles hauling containers. Cummins, Inc. (CMI-NYSE), the diesel engine maker, debuted a prototype electric-drive semi, recently. The vice president for BYD Motors North America commented, "Basically every manufacturer is developing battery, fuel cell electric or hybrids. Peterbilt, Kenworth, Volvo." In addition, there are number of new companies planning to introduce electric semis, including Wrightspeed, Proterra, Chanje, and Nikola One. Mitsubishi Motors (MSBHY-Nasdaq) is delivering medium-duty electric trucks to United Parcel Service, Inc. (UPS-NYSE).

With all this competition, one wonders how well Tesla will do given everything already on its plate. According to Antti Lindstrom, truck industry specialist at *IHS Markit*, the penetration of the long-haul track market by electric trucks "isn't going to be very significant until after 2025 or 2030. And even then, it will be very limited compared to the total number of trucks being sold."

The focus on electric trucks in the U.S. has largely been driven by the push to lower diesel emissions, especially in California. At the same time, the high cost of diesel fuel has been an issue, but the oil industry downturn of the past nearly three years, has muted that motivation. When many of the ideas behind electric trucks were born, fuel was the most expensive marginal cost component of operating heavy-duty trucks, as shown in data from the American Transportation Research Institute. Between 2008 and 2014, fuel costs were the largest marginal cost per mile for long-haul trucks, exceeding the cost of driver wages. That relationship changed in 2015 and 2016 following the collapse in oil prices in late 2014. Now that oil prices are beginning to rise, so too are diesel costs, but they still likely trail the rise in driver wages, especially given the new limited work rules.

Between 2008 and 2014, fuel costs were the largest marginal cost per mile for long-haul trucks, exceeding the cost of driver wages

Exhibit 16. Low Oil Price Makes Fuel Cost Less Important

Table 8: Average Marginal Costs per Mile, 2008-2016

Motor Carrier Costs	2008	2009	2010	2011	2012	2013	2014	2015	2016
Vehicle-based									
Fuel Costs	$0.633	$0.405	$0.486	$0.590	$0.641	$0.645	$0.583	$0.403	$0.336
Truck/Trailer Lease or Purchase Payments	$0.213	$0.257	$0.184	$0.189	$0.174	$0.163	$0.215	$0.230	$0.255
Repair & Maintenance	$0.103	$0.123	$0.124	$0.152	$0.138	$0.148	$0.158	$0.156	$0.166
Truck Insurance Premiums	$0.055	$0.054	$0.059	$0.067	$0.063	$0.064	$0.071	$0.074	$0.075
Permits and Licenses	$0.016	$0.029	$0.040	$0.038	$0.022	$0.026	$0.019	$0.019	$0.022
Tires	$0.030	$0.029	$0.035	$0.042	$0.044	$0.041	$0.044	$0.043	$0.035
Tolls	$0.024	$0.024	$0.012	$0.017	$0.019	$0.019	$0.023	$0.020	$0.024
Driver-based									
Driver Wages	$0.435	$0.403	$0.446	$0.460	$0.417	$0.440	$0.462	$0.499	$0.523
Driver Benefits	$0.144	$0.128	$0.162	$0.151	$0.116	$0.129	$0.129	$0.131	$0.155
TOTAL	**$1.653**	**$1.451**	**$1.548**	**$1.706**	**$1.633**	**$1.676**	**$1.703**	**$1.575**	**$1.592**

Source: American Transportation Research Institute

Many people remark about the marketing genius of Mr. Musk and Tesla. For EV enthusiasts, that marketing may be enough to earn their loyalty and car purchases. Trucks may prove to be a different ballgame, where economics dictates. According to consultant Deloitte, a medium-duty electric truck costs about $70,000 more than the equivalent diesel truck. Deloitte estimates that a heavy-duty truck with a range of 300 miles or more, will cost upwards of $150,000 more than its diesel competitor, which is estimated to be in the range of $130,000-$150,000. These estimates are consistent with the costs of Tesla battery packs costing around $120/kWh to $160/kWh. For 900 kWh of battery capacity, the cost would range between $108,000 and $144,000. But one analyst simply calculated that if the Tesla Semi can go for one million miles without breaking down and deliver $0.25/mile in cost savings, then the electric truck owner would be saving $250,000, providing substantial room for a high-priced Tesla truck. Of course, this analysis doesn't take into

For 900 kWh of battery capacity, the cost would range between $108,000 and $144,000

account the money needed to replace the battery pack before the million-miles of driving occurs, cutting the estimated savings in half or more.

Using electric trucks where short distances and significant waiting (idling) times are involved makes perfect sense

Using electric trucks where short distances and significant waiting (idling) times are involved makes perfect sense. For long-haul trucking, in contrast, the economics must be studied by potential buyers, suggesting that the analyst's estimate of electric trucks not making significant penetration into this market segment until 2025 or 2030 may prove correct. The analyst touting the $250,000 cost savings, also highlighted that even if there wasn't such a magnitude of savings, the press coverage for buying a Tesla Semi would be worth substantial value. We wonder what business decisions this analyst has made lately.

Contact PPHB:
1900 St. James Place, Suite 125
Houston, Texas 77056
Main Tel: (713) 621-8100
Main Fax: (713) 621-8166
www.pphb.com

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