[1] Electric vehicles: a 2% or a 20% solution?

While the share of renewable power generation has grown tenfold since 2004, the world still uses fossil fuels for 85% of its primary energy. Without displacement of direct fossil fuel use in transportation and industry, climate goals may not be reached within desired timeframes. Since road transportation accounts for 50% of global oil consumption, a key component of decarbonization is the speed of electric vehicle (EV) adoption. Forecasters are now jockeying for position with geometric projections. However, the transition to EVs is likely to be gradual, once again confounding the expectations of futurists.

Let’s start with public policy and manufacturer goals. The table on the left shows countries that have announced dates by which internal combustion engine (ICE) sales are banned, and countries with less binding EV sales targets. Automakers have announced EV sales targets as well.
How fast? Governmental agencies, economists, research analysts and futurists have all chimed in with EV projections. As shown below, there’s a very wide range of projections for the global EV fleet size by the year 2030\(^5\). Assuming a global fleet of 1.4 billion cars in 2030 (up from ~1 billion today), the projections range from 2% to 20% of the future projected fleet\(^6\). In most cases, these projections continue growing at a rapid pace to 2040 and beyond.

When looking at these projections, it’s worth recalling the overly optimistic EV projections made by some of the same forecasters a decade ago (see below). Yes, these forecasts took place before the decline in lithium ion battery prices, before subsidies for EV buyers and before government targets were established. However, they’re still useful as a reminder that many forecasters vote with their hearts instead of their minds, and often don’t incorporate real-life barriers to product displacement. Cars are not smartphones: they have higher upfront and ongoing maintenance costs, complex supply chains, refueling requirements and higher standards for performance and safety. The EV revolution is now upon us, but the important question for investors is the pace. The median forecast is ~125 million EVs by 2030; I’m taking the “under” rather than the “over”.

Prior generation of electric car projections out of sync with reality

---

\(^5\) The World Economic Forum forecast is derived differently: by electrifying fleets, taxis and other public transport rather than personal vehicles (which are on the road less than 5% of the time), 35% of US vehicle miles travelled could be electrified by 2030, even though the vehicle stock might remain 85% internal combustion engine cars.

\(^6\) We assumed a lower growth rate (2.8%) for light vehicles to 2030 compared to the historical 2005-2015 growth rate (3.8%) given the potential impact of more efficiently used autonomous cars.
Why might the EV revolution occur at slower speeds rather than faster ones? First, related infrastructure needs are not just charging stations and production factories. Large power generation and transmission investments would be needed as well. According to one analysis we have seen, India, China and Europe would face a combined $1.7 trillion in required capital investment. These are imprecise estimates, but could be quite large and require tough decisions in aging societies with growing unfunded pension and healthcare costs.

Another challenge: how far can lithium ion battery costs fall? There has been a sharp decline in the capital cost of lithium ion battery packs over the last decade to around $200 per kWh. The US Department of Energy has a stated goal of $100 per kWh on a cell basis (around $130 for the pack) in the next few years, a level often cited as the point at which mass-marketed EVs could reach parity with some ICE vehicles. However, in a January 2018 paper, ARPA researchers concluded that the DoE target could be hard to reach using current battery design. While they outline manufacturing processes and materials that might reduce costs, these approaches do not yet meet required performance standards. This DoE table compares current and future possible technologies:

Vehicle energy storage technology overview

<table>
<thead>
<tr>
<th>Current technology: lithium ion battery (graphite/NMC)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Current cost</strong></td>
</tr>
<tr>
<td><strong>Potential cost</strong></td>
</tr>
<tr>
<td><strong>Current cycle life</strong></td>
</tr>
<tr>
<td><strong>R&amp;D needs</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Next generation technology: lithium ion battery based on silicon composite/high voltage NMC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Current cost</strong></td>
</tr>
<tr>
<td><strong>Potential cost</strong></td>
</tr>
<tr>
<td><strong>Current cycle life</strong></td>
</tr>
<tr>
<td><strong>R&amp;D needs</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Longer term: lithium metal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Current cost</strong></td>
</tr>
<tr>
<td><strong>Potential cost</strong></td>
</tr>
<tr>
<td><strong>Current cycle life</strong></td>
</tr>
<tr>
<td><strong>R&amp;D needs</strong></td>
</tr>
</tbody>
</table>

What about rare earth metals and other critical materials? Most research we’ve seen projects that there will be enough lithium, graphite and other minerals to meet growing demand. It’s a bit dated, but in 2011, the US Department of Energy published a report on critical materials supply and found that with the exception of dysprosium, neodymium and terbium, most did not present a medium term supply risk. In 2017, researchers from the University of Science and Technology in Beijing looked at the same question, perhaps since China is the world’s largest EV market. Here’s what they found:

- Demand from electric vehicles is expected to reach 68% of all rare earth demand in 2030 (compared to 50% today)
- While current rare earth elements are mined primarily by China and Australia, there are 478 megatons of rare earth oxides widely distributed around the world which could sustain current global rare earth production for over 100 years
- However, the largest increases in demand are expected to be for neodymium and dysprosium (as in the 2011 DoE study), whose shortages could become an issue for supply chains


A brief comment on autonomous car energy use

Researchers from the University of Michigan Center for Sustainable Systems looked at autonomous car energy use vs passenger-controlled EVs and ICE cars. For some vehicles, energy benefits from autonomous driving more than offset its incremental energy drag due to computing power needs, additional weight and vehicle drag. But for larger applications (e.g., Waymo installed in a minivan), autonomous car tests showed higher net energy use. We will keep an eye on this.

Source: Bloomberg, February 2018.

---

Note: “Global Potential of Rare Earth Resources and Rare Earth Demand from Clean Technologies”, Zhou, Li, and Chen, University of Science and Technology in Beijing, Minerals magazine, October 2017.
**Bottom line:** the EV revolution is here, and some manufacturers claim that break-even costs vs ICE vehicles are closing fast (see next page). But some EV forecasts seem too aggressive to us, given the challenges. As a result, we’re inclined towards the lower half of the forecasts on page 10, and are dubious that EV demand will exert a material impact on oil prices in the next few years. The concept of “peak oil extraction due to falling demand” might exist, but (a) closer to 2030 rather than during this decade, and (b) be more likely if most of the world enacts an outright ban on the sale of ICE cars. As shown earlier, that’s not happening, at least not yet. Changes in GDP growth, improvements in the efficiency of the internal combustion engine and the cost/ regulation of hydraulic fracturing of shale oil are all likely to have a larger impact on oil prices than EVs for the foreseeable future.

**EV Appendix I: How green are electric cars?**

Most lifecycle analyses agree that EVs reduce global warming risks. Electric motors using natural gas and renewable energy as indirect fuel are more carbon-efficient than ICE cars, reducing emissions by 25%-50%. [Note: in our 2016 energy paper, we showed this chart on the renewable percentage of the electricity grid by country and by US state].

However, environmental impacts are not limited to CO₂ emissions. The chart above from Arthur Little estimates the lifecycle environmental impact of ICEs vs EVs, measured as “days of life lost to toxicity”. In this analysis, EV environmental impacts are 3x higher. The primary reason: freshwater and terrestrial exposure to copper, cobalt, nickel and graphite during the mining process. Even if the grid were fully renewable and EV “in-use” toxicity were zero, Arthur Little still estimates a higher environmental impact for EV cars. I doubt this will be a roadblock in the EV revolution, since such risks are borne mostly by countries which have less ability/ interest to aggressively control them: the Philippines, Russia, the Congo, China, India, Brazil, Vietnam and Turkey. Arthur Little’s analysis on EV toxicity draws from a widely cited 2013 paper in the *Journal of Industrial Ecology* from Anders Stromman at the Norwegian University of Science and Technology on EV supply chain eco-toxicity and eutrophication.

I’m not 100% sold on the relative aspect of Arthur Little’s analysis, since it seems to underestimate toxicity risks from oil production and exploration, as well as from gasoline refining and distribution. One example: a 2016 paper from the Johns Hopkins School of Public Health measured hydrocarbon spills at gas stations, and found that regulations typically do not address subsurface contaminations from chronic gasoline spills, even though they could result in non-negligible exposure to toxic and carcinogenic compounds. Every lifecycle analysis has its own biases, and the Arthur Little version is no exception.

---

1 In its forecasts for 2040, BP estimates that oil displaced by ICE fuel efficiency gains will be 7x larger than oil displaced by electric vehicles.
EV Appendix II: could Tesla produce an EV truck with a fast payback period?

Taxis, garbage trucks and semi trucks could be good candidates for conversion to electricity or natural gas if fuel savings offset higher upfront costs in a short period of time. Tesla claims that its new semi truck will do just this. However, our estimate of its payback period is longer than some recent forecasts.

The average short haul diesel truck costs $120k, travels ~90,000 miles per year (~300 per working day and capable of traveling 1,000+), and lasts for around one million miles. Tesla announced two possible substitutes: an EV semi capable of travelling 500 miles per charge at a cost of $180k, and a 300 mile version at $150k. Tesla claims that its EV fuel efficiency will offset higher upfront costs in a short period of time. Some analysts agree, and we have seen estimates as low as a 2 year payback period.

There’s a lot that isn’t known yet about Tesla’s hypothetical truck; the table shows our estimates of factors that affect payback periods, and the chart shows our simulated results. **Our Tesla payback period estimates are higher than 2 years, and are similar for 300 mile and 500 mile versions.**

One decision we had to make: what about Tesla’s electricity price guarantee of 7 cents per kWh? This guarantee is available to drivers using Tesla’s proprietary mega-charging stations (a network that doesn’t exist yet), and relies on Tesla remaining a going concern. In any case, we modeled it both ways.

### Assumptions

<table>
<thead>
<tr>
<th>Factors</th>
<th>Fixed</th>
<th>Min</th>
<th>Mean</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery replacement</td>
<td>$115</td>
<td>$125</td>
<td>$135</td>
<td>$/kWh</td>
<td></td>
</tr>
<tr>
<td>Tesla fuel efficiency</td>
<td>1.80</td>
<td>2.00</td>
<td>2.40</td>
<td>kWh/miles</td>
<td></td>
</tr>
<tr>
<td>Diesel fuel efficiency</td>
<td>6.00</td>
<td>7.50</td>
<td>8.50</td>
<td>miles/gal</td>
<td></td>
</tr>
<tr>
<td>Annual miles driven</td>
<td>80,000</td>
<td>85,000</td>
<td>90,000</td>
<td>miles</td>
<td></td>
</tr>
<tr>
<td>Battery cycles (lifetime)</td>
<td>1,500</td>
<td>1,750</td>
<td>2,000</td>
<td>cycles</td>
<td></td>
</tr>
<tr>
<td>Diesel price</td>
<td>$2.50</td>
<td>$3.50</td>
<td>$4.25</td>
<td>$/gal</td>
<td></td>
</tr>
<tr>
<td>Electricity prices</td>
<td>$0.09</td>
<td>$0.10</td>
<td>$0.13</td>
<td>$/kWh</td>
<td></td>
</tr>
<tr>
<td>Incremental diesel repair</td>
<td>$0.06</td>
<td>$0.10</td>
<td>$0.12</td>
<td>$/mile</td>
<td></td>
</tr>
<tr>
<td>Depth of discharge</td>
<td>80%</td>
<td></td>
<td></td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Discount rate</td>
<td>3%</td>
<td></td>
<td></td>
<td>%</td>
<td></td>
</tr>
</tbody>
</table>


### Payback periods for Tesla EV trucks vs diesel

- At Tesla guarantee of 7 cents per kWh
- At commercial prices for electricity

<table>
<thead>
<tr>
<th>Payback periods for Tesla EV trucks vs diesel</th>
<th>Percentage of observations, n=10,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 mile version</td>
<td>25%</td>
</tr>
<tr>
<td>500 mile version</td>
<td>20%</td>
</tr>
</tbody>
</table>

Source: JPMAM, 2018.

### Important notes on our analysis

- **Some analysts assume that Tesla’s one million mile warranty includes battery replacement.** There has been no clear messaging from Tesla on this issue. We assume the driver replaces the battery once its cycle lifetime has run its course. The driver could opt instead to relegate the truck to other uses at this point since it would still function, albeit with depleted battery capacity. However, in this case the EV truck is no longer an economic substitute for the diesel, and entails revenue losses that would have to be factored in. **Payback analyses that do not assume that the battery is replaced (either by Tesla or the driver) and do not account for utility loss make little sense to me.**

- **We did not include possible losses associated with reduced Tesla payloads.** Tesla battery packs have energy densities of 160-200 Wh/kg, which include the weight of housing, cooling systems, mechanical support structures, electronics and cell connectors. For the 500 mile version, the weight of the battery could result in a 15%-20% lower max payload than the comparable diesel truck. However, many trucks max out on volume rather than weight, in which case this would be less of an issue.

- **Why are payback periods similar for 300 & 500 mile versions?** While the former’s upfront cost is lower, it requires 2 battery replacements over its million mile life rather than 1, as per our assumptions.

- **Tesla’s electricity subsidy for truck buyers appears substantial, since the company recently increased its Supercharger electricity prices for new model S/X/3 buyers to 24-26¢/kWh in Oregon, California and NY.**
Let’s keep some things in mind about **Tesla and its hypothetical truck**:

- Tesla’s truck doesn’t exist yet, and neither does its production facility
- Tesla truck prices are indicative and non-binding, and could change
- Our analysis doesn’t incorporate possible impacts of constant driving and fast-charging on battery capacity, safety and useful life
- Payback periods do not incorporate how truck buyers might feel about a company that usually does not allow anyone else to work on their vehicles, and does not sell service manuals or parts either
- Tesla has a history of missing its production targets, just suffered the worst quarterly financial loss in its history as well as an outflow of senior executives, has a high level of junk debt and has a high level of CEO compensation for a loss-generating enterprise.

Consider us skeptical, at least until more details emerge. Here are some charts assessing Tesla as a going concern with long term warranty and electricity price guarantees. For the complete set of our Tesla charts on these and other related topics, please click [here](#).

---

**Tesla Model 3 production: targets vs reality**

Weekly # of Model 3s manufactured

- **Tesla’s initial production target Aug ’17**
- **Target revised Nov ’17**
- **Target revised Jan ’18**
- **Est. actual production**
- **Apr 3, after shutting down higher-margin Model S/X production**


**Tesla’s cash burn**

Free cash flow, US$ millions

- **Reported free cash flow**
- **…less customer deposits & SolarCity capex**
- **…less zero emission vehicle credits**

Source: Bloomberg. 4Q 2017.

**Carmaker credit spreads**

Basis points over Treasuries

- **Tesla - maturing 2025**
- **Ford - benchmark 10 yr**
- **GM - benchmark 10 yr**


**Tesla’s Altman Z-score**

Lower score indicates higher likelihood of bankruptcy

- **Distressed**

Purpose of This Material: This material is for information purposes only. The views, opinions, estimates and strategies expressed herein constitutes Michael Cremnalest's judgment based on current market conditions and are subject to change without notice, and may differ from those expressed by other areas of J.P. Morgan. This information is in no way constitutes J.P. Morgan Research and should not be treated as such.

Non-Reliance: We believe the information contained in this material to be reliable and have sought to take reasonable care in its preparation; however, we do not represent or warrant its accuracy, reliability or completeness, or accept any liability for any loss or damage (whether direct or indirect) arising out of the use of all or any part of this material. We do not make any representation or warranty with regard to any computations, graphs, tables, diagrams or commentary in this material which are provided for illustration/reference purposes only. We assume no duty to update any information in this material in the event that such information changes. Any projected results and risks are based solely on hypothetical examples cited, and actual results and risks will vary depending upon specific circumstances. Forward looking statements should not be considered as guarantees or predictions of future events. Investors may get back less than they invested, and past performance is not a reliable indicator of future results.

Risks, Considerations and Additional information: There may be different or additional factors which are not reflected in this material, but which may impact on a client’s portfolio or investment decision. The information contained in this material is intended as general market commentary and should not be relied upon in isolation for the purpose of making an investment decision. Nothing in this document shall be construed as giving rise to any duty of care owed to, or advisory relationship with, you or any third party. Nothing in this document is intended to constitute a representation that any investment strategy or product is suitable for you. You should consider carefully whether any products and strategies discussed are suitable for your needs, and to obtain additional information prior to making an investment decision. Nothing in this document shall be regarded as an offer, solicitation, recommendation or advice (whether financial, accounting, legal, tax or other) given by J.P. Morgan and/or its officers or employees, irrespective of whether or not such communication was given at your request. J.P. Morgan and its affiliates and employees do not provide tax, legal or accounting advice. You should consult your own tax, legal and accounting advisors before engaging in any financial transactions.

Contact your J.P. Morgan representative for additional information concerning your personal investment goals. You should be aware of the general and specific risks relevant to the matters discussed in the material. You will independently, without any reliance on J.P. Morgan, make your own judgment and decision with respect to any investment referenced in this material.

J.P. Morgan may hold a position for itself or our other clients which may not be consistent with the information, opinions, estimates, investment strategies or views expressed in this document. JPMorgan Chase & Co. or its affiliates may hold a position or act as market maker in the financial instruments of any issuer discussed herein or act as an underwriter, placement agent, advisor or lender to such issuer.

References in this report to “J.P. Morgan” are to JPMorgan Chase & Co., its subsidiaries and affiliates worldwide.

Legal Entities and Regulatory Information: In the United States, Bank deposit accounts, such as checking, savings and bank lending, may be subject to approval. Deposit products and related services are offered by JPMorgan Chase Bank, N.A. Member FDIC.

JPMorgan Chase Bank, N.A. and its affiliates (collectively “JPMCB”) offer investment products, which may include bank managed accounts and custody, as part of its trust and fiduciary services. Other investment products and services, such as brokerage and advisory accounts, are offered through J.P. Morgan Securities LLC (“JPMS”), a member of FINRA and SIPC. JPMCB and JPMS are affiliated companies under the common control of JPMorgan Chase & Co. Products not available in all states.

In the United Kingdom, this material is issued by J.P. Morgan International Bank Limited (JPMIB) with the registered office located at 25 Bank Street, Canary Wharf, London E14 5JP, registered in England No. 03838766. JPMIB is authorised by the Prudential Regulation Authority and regulated by the Financial Conduct Authority and the Prudential Regulation Authority. In addition, this material may be distributed by JPMorgan Chase Bank, N.A. (“JPMCB”), Paris branch, which is regulated by the French banking authorities Autorité de Contrôle Prudentiel et de Résolution and Autorité des Marchés Financiers or by J.P. Morgan (Suisse) SA, which is regulated in Switzerland by the Swiss Financial Market Supervisory Authority (FINMA).

In Hong Kong, this material is distributed by JPMCB, Hong Kong branch. JPMCB, Hong Kong branch is regulated by the Hong Kong Monetary Authority and the Securities and Futures Commission of Hong Kong. In Hong Kong, we will cease to use your personal data for our marketing purposes without charge if you so request. In Singapore, this material is distributed by JPMCB, Singapore branch. JPMCB, Singapore branch is regulated by the Monetary Authority of Singapore. Dealing and advisory services and discretionary investment management services are provided to you by JPMCB, Hong Kong/Singapore branch (as notified to you). Banking and custody services are provided to you by JPMIB and/or JPMCB Singapore Branch. The contents of this document have not been reviewed by any regulatory authority in Hong Kong, Singapore or any other jurisdictions. You are advised to exercise caution in relation to this document. If you are in any doubt about any of the contents of this document, you should obtain independent professional advice.

With respect to countries in Latin America, the distribution of this material may be restricted in certain jurisdictions. Receipt of this material does not constitute an offer or solicitation to any person in any jurisdiction in which such offer or solicitation is not authorized or to any person to whom it would be unlawful to make such offer or solicitation. To the extent this content makes reference to a fund, the Fund may not be publicly offered in any Latin American country, without previous registration of such fund’s securities in compliance with the laws of the corresponding jurisdiction. Public Offering of any security, including the shares of the Fund, without previous registration at Brazilian Securities and Exchange Commission – CVM is completely prohibited. Some products or services contained in the materials might not be currently provided by the Brazilian and Mexican platforms.This material should not be duplicated or redistributed without our permission.

© 2018 JPMorgan Chase & Co. All rights reserved.