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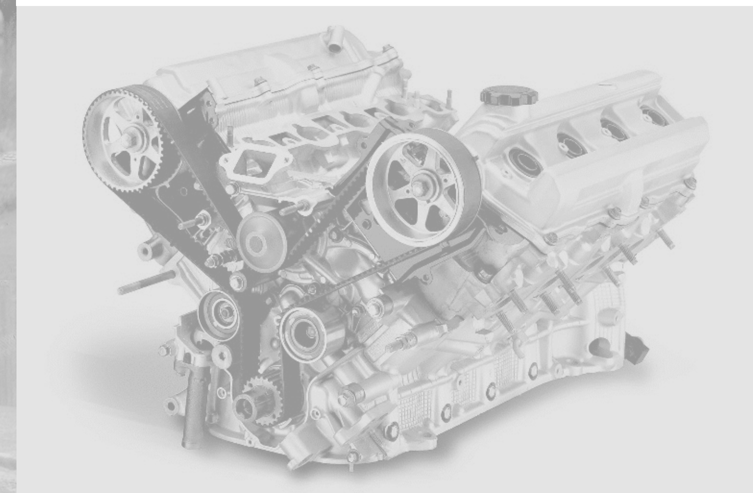
Cycles happen. Invest accordingly.



From Gasoline to the Grid

For the electric vehicle (EV) to reach cost parity vs. the internal combustion engine (ICE), it must contend with mineral shortages, inflexible grids, and increased cost competitiveness from fossil fuels. History suggests it only gets harder from here

Our detailed study integrates all aspects of the EV: availability of battery materials, scalability of electricity as a fuel, detailed cost comparisons between EV and ICE. All work is based on Recurrent Investment Advisors' proprietary economic model.

Recurrent Investment Advisors – Research Material Disclaimer

This material is for informational purposes only and is an overview of the future for Electric Vehicles and the potential impact on the energy market, and is intended for educational and illustrative purposes only. It is not designed to cover every aspect of the relevant markets, and is not intended to be used as a general guide to investing or as a source of any specific investment recommendation. It is not intended as an offer or solicitation for the purchase or sale of any financial instrument, investment product or service. This material does not constitute investment advice, nor is it a substitute for such professional advice or services, nor should it be used as a basis for any decision or action that may affect your business. Before making any decision or taking any action that may affect your business, you should consult a qualified professional adviser. In preparing this material we have relied upon data supplied to us by third parties. The information has been compiled from sources believed to be reliable, but no representation or warranty, express or implied, is made by Recurrent Investment Advisors, LLC as to its accuracy, completeness or correctness. Recurrent Investment Advisors, LLC does not guarantee that the information supplied is accurate, complete, or timely, or make any warranties with regard to the results obtained from its use. Recurrent Investment Advisors, LLC has no obligations to update any such information.

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About Recurrent Investment Advisors and our report

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WE ARE LONG-ONLY INVESTORS IN COMPANIES THAT produce, consume**,** transport, or otherwise meaningfully depend on energy and natural resources. We are keenly interested in the future of the electric vehicle because of its wide-reaching ramifications for the economy, for our investments, and for the way humanity consumes energy.

To say we have no dog in the fight would be untrue – we primarily invest in companies that are dependent on the commercial production of oil and gas, although it is worth noting that we purposely chose a mandate that allows for investment in natural resources as well as energy consuming industries, giving us the ability to invest in electric vehicle (EVs) manufacturers or producers of EV-intensive minerals like lithium or cobalt.

Given the prominence of the EV in the press, and investor and societal interest in the topic, we were surprised at how few thoughtful, economically-based studies of electric vehicles were in circulation.

There are plenty of triumphalist Silicon Valley reports, proclaiming that the combustion engine will only be found in museums just a decade from now, while (in classic technologist style) ignoring the massive practical challenges that accompany the EV transition.

There are also consultant reports, offering polling data, marketing jargon and predictions about the future of the EV so heavily caveated as to be useless to an investor.

Finding the available reports to be lacking in rigorous, historically-grounded or economically-grounded analysis, we started doing our own research, which we're excited to share with you.

Importantly, before we kick off the report, we'd like to note an observation that we developed and carried with us as we developed our economic model of the EV and wrote the following report based on that model.

There are not many innovations we use today that failed to achieve meaningful cost advantages vs. competitors within a decade of introduction. Take the iPhone, for example: back in 2009, it was easy to dismiss it as a fancy phone that only "techies" would buy. But really, Steve Jobs allowed you to throw out $600-700 of devices and replace them for $399. That's why my Dad owns one.

Similarly, Henry Ford didn't rely on futurists or hipsters to sell his Model T: it was cheaper for rural families using a horse for "last mile" transportation. These innovations just made economic sense for their users.

So, as we "hit print" on this report (and build our portfolios), we keep this economic observation in mind, while using our research to find out what makes economic sense, based on lower costs vs. competitors.

Finally, we want to thank Ileana Martinez and Nick Ravanbakhsh, our research interns whose enthusiasm helped bring this report into being.

Happy reading!

Brad Olsen **Mark Laskin**
Co-Founders of Recurrent Investment Advisors

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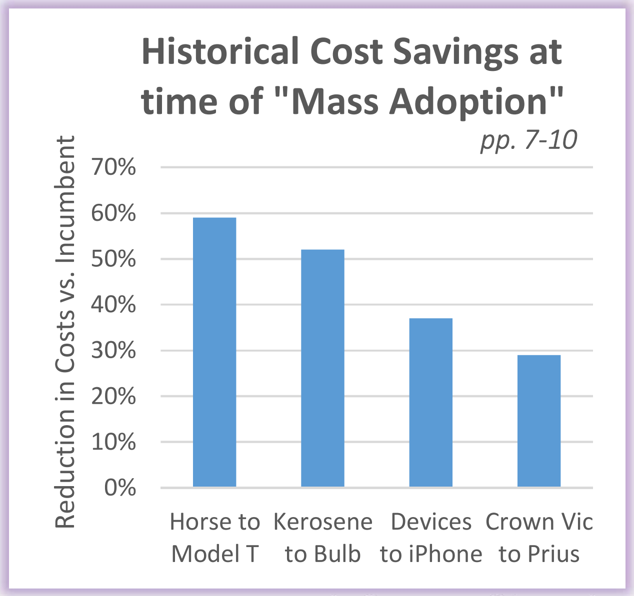
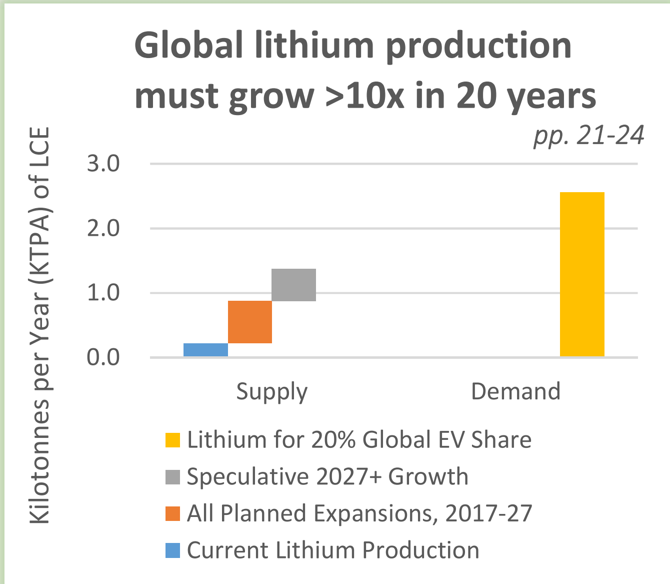
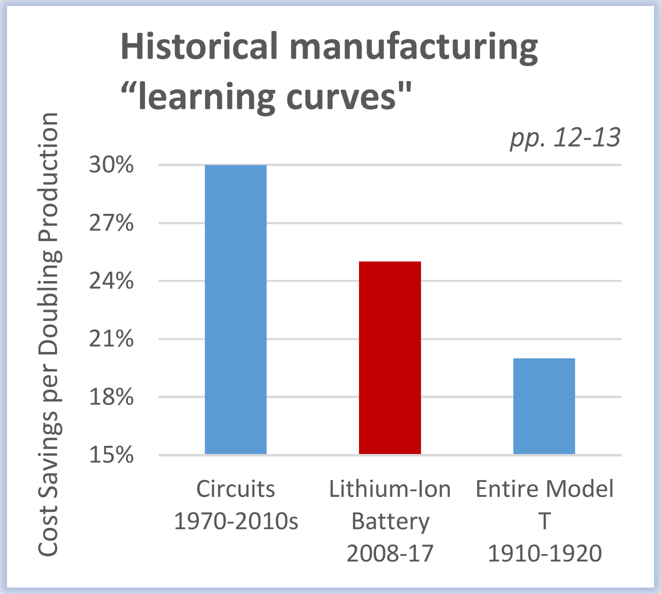


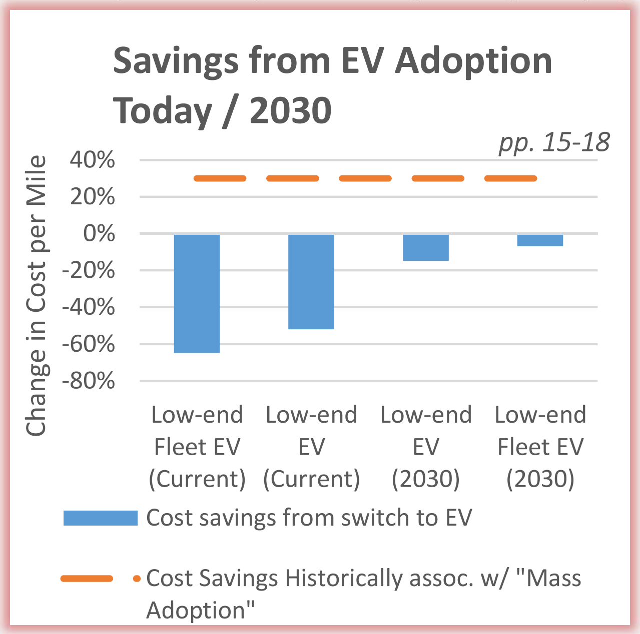
Historic innovations we take for granted (even the iPhone) didn't win without being notably cheaper



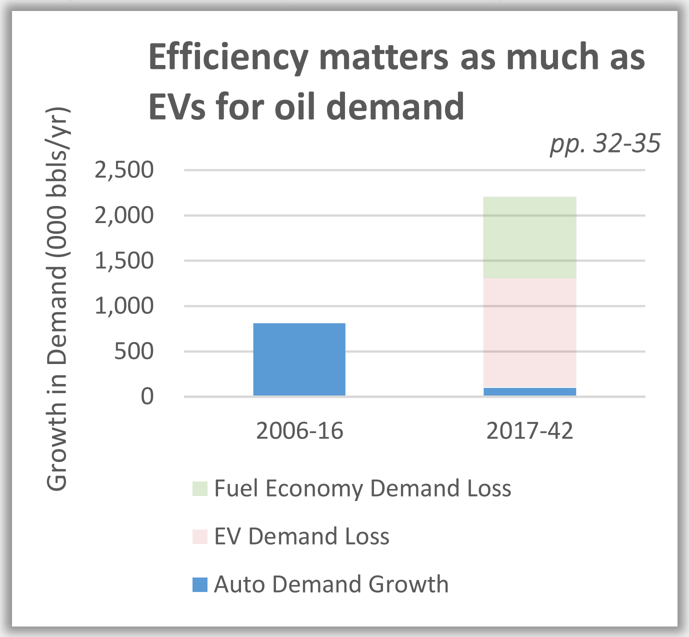
Even assuming meaningful efficiencies, lithium use grows more in 20 years than oil has grown in 70



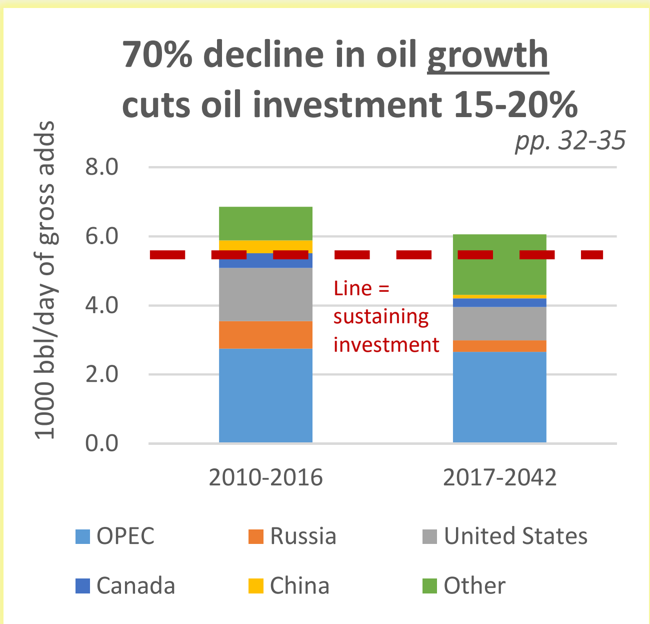
Battery cost savings have been impressive, but comparable to history and only 1 (big) part of the EV



Low-end EVs do not and will not deliver the savings historically required for "mass adoption"



Demand growth from vehicles drops dramatically in 2020s, reducing total demand growth by 2/3



2/3 decline in growth over next 25 years does not impact 80% of the capital needed to keep oil flat

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Topics addressed in our EV report

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Introduction – the transition from gasoline to the grid

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LET'S BEGIN OUR DISCUSSION OF A CONTROVERSIAL TOPIC WITH an uncontroversial premise: The rise of the electric vehicle (EV) will transfer a meaningful part of the world's energy consumption from oil to electricity, backed by mineral-intensive power storage.

To assume this will be rapid or seamless is to misunderstand the challenges involved. The oil industry is mature and highly efficient, operating a supply chain that delivers product anywhere in the world at nearly-uniform prices. Electricity is highly fragmented, with global disparities in cost and reliability. Yes, powering a car with electricity in the US today is cheaper than petroleum, but that's the tip of the iceberg: fuel is only a fraction of a car's total operating cost, and oil-powered cars outnumber EVs by 1000:1.

For more context: the world produces 4,700 mm tonnes per annum (mmtpa) of oil while the world produces 0.4 mmtpa of lithium and cobalt combined. To transition 20% of the global auto fleet to EVs by 2040 (aligned with our model), these minerals' production must increase >10x in <20 years. That sort of growth is literally unprecedented in the history of extractive industry. Oil, humanity's largest extractive endeavor, offers context: production has grown 10x in the past 70+ years.

The EV itself is an iterative equation. Demand for EVs is largely determined by cost competitiveness vs. an internal combustion engine (ICE). Increased EV production will drive efficiencies but also increase material input costs. Any credible forecast must assume that EV production efficiencies increase, while also anticipating the challenging of meeting demand for raw materials, not to mention the wave of demand for battery replacements a decade from now.

As we move from EVs representing 1% of global sales to a more meaningful share of new car sales, the transition will not be straightforward. Our research leaves us highly skeptical that there will be a "breakthrough" moment for the EV, but rather a long, slow grind to gain a minority market share v. the ICE, complicated by rising material costs and the ICE's resilient cost structure.

Even the lightbulb and automobile, which were followed by rapid infrastructure development and enjoyed greater cost advantages over their competition than the EV does today, still took 30-40 years to achieve dominance. For the mass EV, dependent on relatively scarce resources and competing against a mature and highly-efficient technology, the path to dominance will be much tougher than it was for the world-changing innovations over a century ago.

WE OFFER 3 POINTS FROM OUR STUDY OF THE EV'S FUTURE:

1. We have examined a variety of historical technological breakthroughs in search of a "recipe" for innovation. We find that a 30% cost advantage seems to be a driver of mass behavioral shifts. There is scant evidence that moral or ethical drivers, absent economic incentives, change mass behavior.
2. ICEs will remain mainstays of transportation for decades. Silicon Valley forecasts are hard to square with empirical analysis. EVs generate negative margin, receive subsidies, yet all-in operating costs for low- and mid-level EVs remain (and will remain) above ICE costs. The EV's flaw is its overlap with the ICE: battery and electronics (40% of costs) fall rapidly, but the rest is "just a car". A cost breakthrough that phases out ICEs is out of reach.
3. Today is, ironically, already the "golden age" of the EV. Subsidies abound, minerals are plentiful (although costs have spiked in the past year), and grid demands remain small. EV production, in the context of the global economy, is a laboratory experiment that investors are happy to fund for now.

There have been reports offering superficial analogies comparing the EV to past great inventions without economic context, while other reports predict an EV-dominated future without a discussion of how we transition 25% of all energy to a fragmented grid.

We hope this report offers a holistic perspective not found in other reports, and makes for more successful energy investing, for both us and our readers.

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Understanding what it takes to change our behavior

We take for granted the inventions of 100+ years ago that transformed our civilization – but what made our ancestors embrace new technology?

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History puts a high price on changing human behavior

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"We wanted flying cars, instead we got 140 characters" – Peter Thiel, Tech Entrepreneur

UNDER THE OPTIMISM THAT PULSES THROUGH SILICON VALLEY, THERE IS DISAPPOINTMENT THAT RECENT TECHNOLOGICAL ADVANCES – mainly information transfer and wireless technologies – have failed to transform our existence or increase lifespans. Even the Internet looks trivial in comparison to life-changing and life-saving inventions of the last 150 years: antibiotics, electric light, A/C, cars, aviation.

In many ways, the EV wears the mantle of the "great hope" of Silicon Valley – something that could transform our daily physical lives. And we believe (as detailed in this report) that the EV's impact will be significant. But great hopes alone do not make for great innovations.

As energy investors, it's our job to understand the magnitude of this shift and to identify winners and losers. We want to thoroughly deconstruct drivers of EV economics to understand the potential impacts on humanity's energy consumption. This goes far beyond tax credits and battery costs – **it forces us to ask why civilizations change their behaviors *en masse***.

To better understand why humanity's behavior undergoes massive shifts, we examine 2 innovations that appeared over a century ago and actually did change our lives forever: **Edison's light bulb** and the **Ford Model T**. These 2 are of particular interest because:

1) These inventions unseated incumbent technologies that had been dominant for millennia; and

2) These inventions required (but also economically justified) new and costly infrastructure

TO DISPLACE COMPETITIORS, COST DOMINANCE, NOT PARITY, IS REQUIRED

We find that these two technologies arrived near cost parity and achieved 30-60% savings vs. incumbents within several years. Still, it took 30-40 years to completely phase out competitors. Despite frequent comparisons (in Silicon Valley) between EVs and the "Great Inventions" of the late 19th and early 20th centuries (a comparison hinted at by Tesla's name), the EV's learning curve does not approach the dramatic efficiency gains achieved by the light bulb or the Model T.

These immediately life-enhancing inventions admittedly set a high bar, so we also evaluated 2 "lesser innovations" with lower stakes for humanity. They still rapidly replaced entrenched incumbents and drove widespread behavioral shifts. We examine hybrid cabs and iPhone:

1) These lesser innovations lowered costs and increased convenience but with minimal health/lifespan benefits

2) These lesser innovations did not require meaningful new infrastructure or a fundamental change to our lifestyles

SPREAD OF TECHNOLOGICAL BREAKTHROUGHS - MORE DEPENDENT ON ECONOMICS THAN HUMAN WELFARE

Despite lower stakes and lower impacts on human welfare, we see a similar paradigm with "lesser inventions": a 30% lower ownership cost vs. incumbent drove rapid adoption. Why the need for a commanding lead? Quite simply, it's hard to kill technology because costs drop in response to competition. If EVs are to replace even 20% of global fleet, the EV must achieve more than just cost parity.

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Edison's Lightbulb: saving money, lives and property

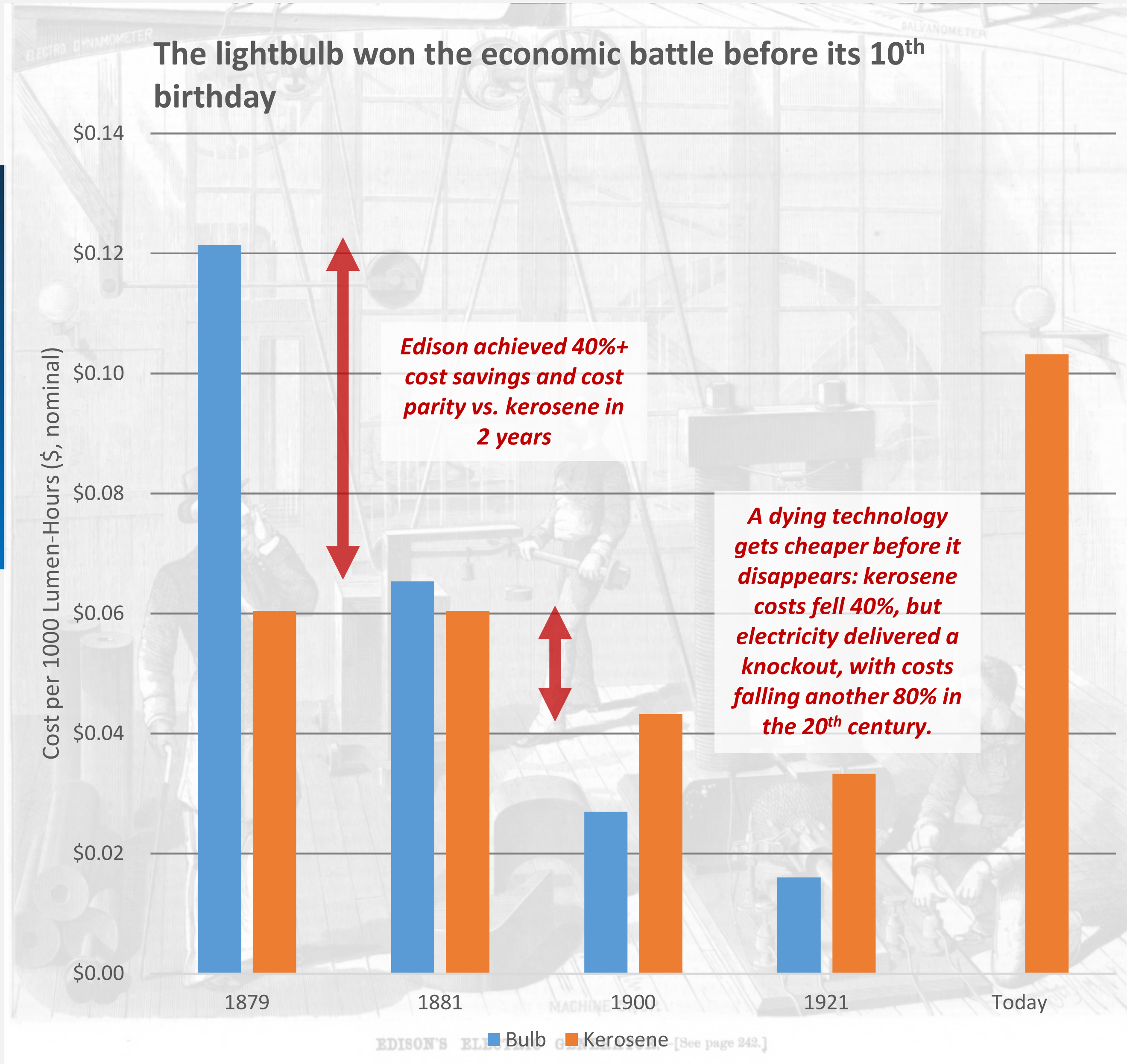
The Age of Invention (1870-1940)[2] shifted human expectations from technological stagnation (the rule for much of human history) to an expectation of continuous innovation.

TWO KEY POINTS EMERGE FROM AN ECONOMIC STUDY OF THE LIGHT BULB:

- *New technologies offering cost savings of 30% or greater pose an existential threat to incumbent technologies.*
- *Incumbent costs will fall in response to fierce competition. Therefore, "blank slate" innovations – brand new concepts, rather than improvements on existing technology – have the greatest potential for cost breakthroughs.*

What the adoption of the lightbulb tells us about the nature of innovation:

- ***Health and wellbeing concerns*** exerted little impact on mass consumption. During the 1800s, children, the elderly and the city of Chicago fell victim to flame-based lighting. Still, efforts to reduce the presence of open flames made little headway until the lightbulb offered a low-cost alternative.
- ***Infrastructure investment raced ahead*** of the nascent electric light industry. JP Morgan, the Vanderbilt family and others saw that power plants would be profitable by virtue of the bulb's dominant cost structure.



2. For an engrossing read on American economic history and the Age of Invention in particular, read Robert Gordon's "The Rise and Fall of American Growth."
For more on the history of light innovation, see Bill Nordhaus's paper, which is much more interesting than its title, "Do Real-Output and Real-Wage Measures Capture Reality?"

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The Ford Model T: a standout even among great inventions

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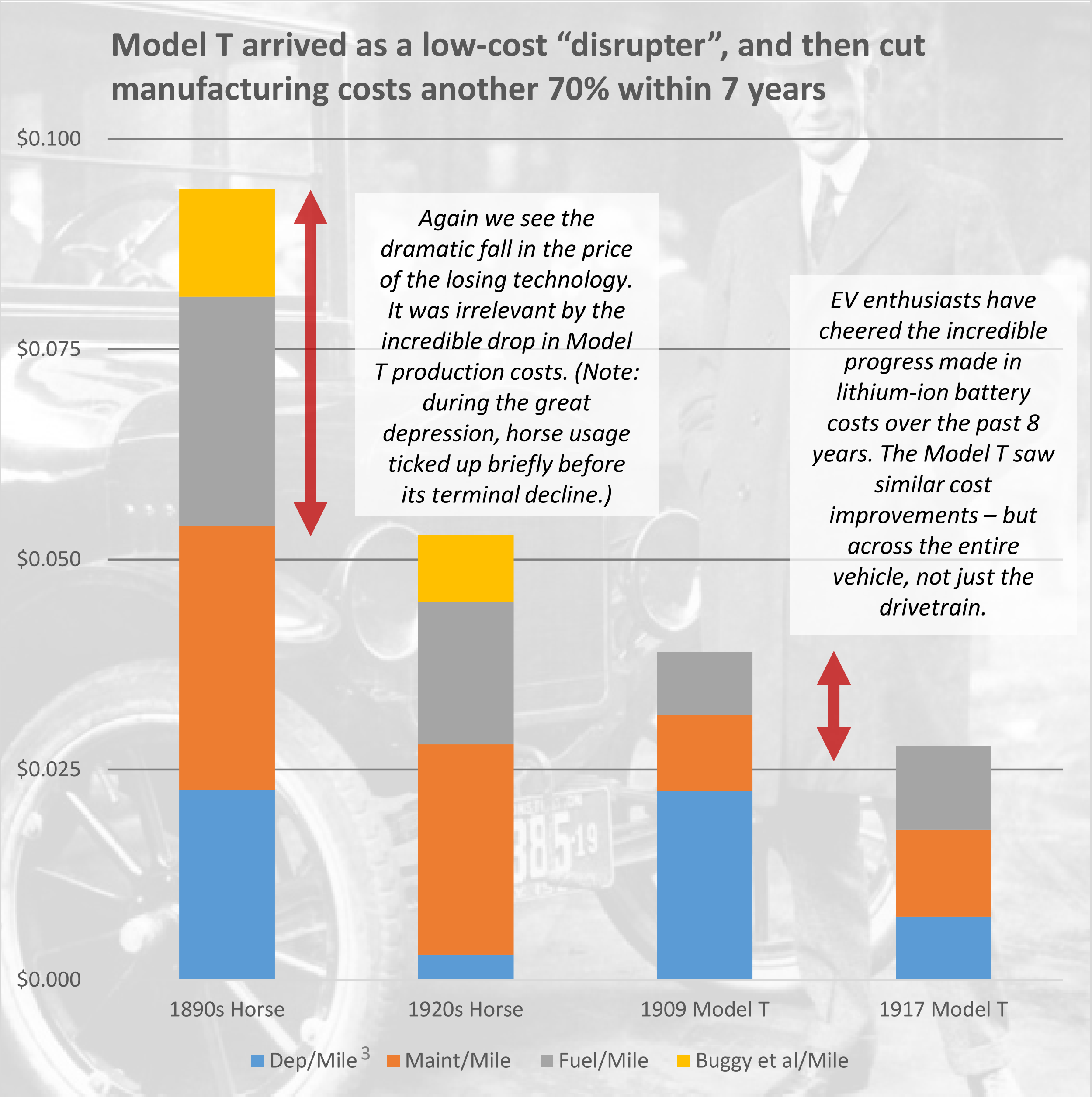
The disruptive, innovative potential of today's EV is commonly likened to the most renowned transportation innovation, the Ford Model T. The Model T offered 50%+ cost savings upon its introduction, and eliminated the urban horse population, the primary menace to public health in the late 19th century.

MODEL T FURTHER INFORMS OUR VIEW OF CONSUMER RESPONSE TO INNOVATION:

- *We again see the importance of 30%+ cost savings vs. existing technologies. Equally important are continued efficiencies, as even the Model T had to continue innovating to "outrun" the falling cost of the horse and feed.*
- *Infrastructure does not inhibit explosive growth for dominant cost innovations. Auto sales grew from 0.2mm to 2.2mm in 7 years after the Model T. Entrepreneurs opened gas stations and dealerships, creating "network effects". Cars flourished even before Federal infrastructure spending in the 1920s.*
- *Humanity does not stop engaging in behavior detrimental to its health until a low-cost alternative appears. The urban horse population, like the kerosene lamp, was directly (hooves) and indirectly (disease) responsible for thousands of fatalities per year. But horse populations quadrupled in the 50 years prior to the introduction of the car.*



3. For the horse, depreciation is cost of purchase over 5 year useful life. Maintenance consists of urban boarding and care, while fuel consists of feed. A detailed breakdown of pre-automobile horse ownership (and lease) costs can be found here, "The Horse World of London, by W. J. Gordon, 1893 - The Carriage Horse": http://www.victorianlondon.org/publications6/horse-08.htm

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Innovation can spread like wildfire from saving costs, if not lives

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SCANT EVIDENCE OF NON-ECONOMIC DRIVERS

To some, the omission of global warming from our discussion must seem like we're dancing around the elephant in the room. We would answer that whether changing the world or changing accessories, humanity (in aggregate) reacts to lower costs, not moral imperatives.

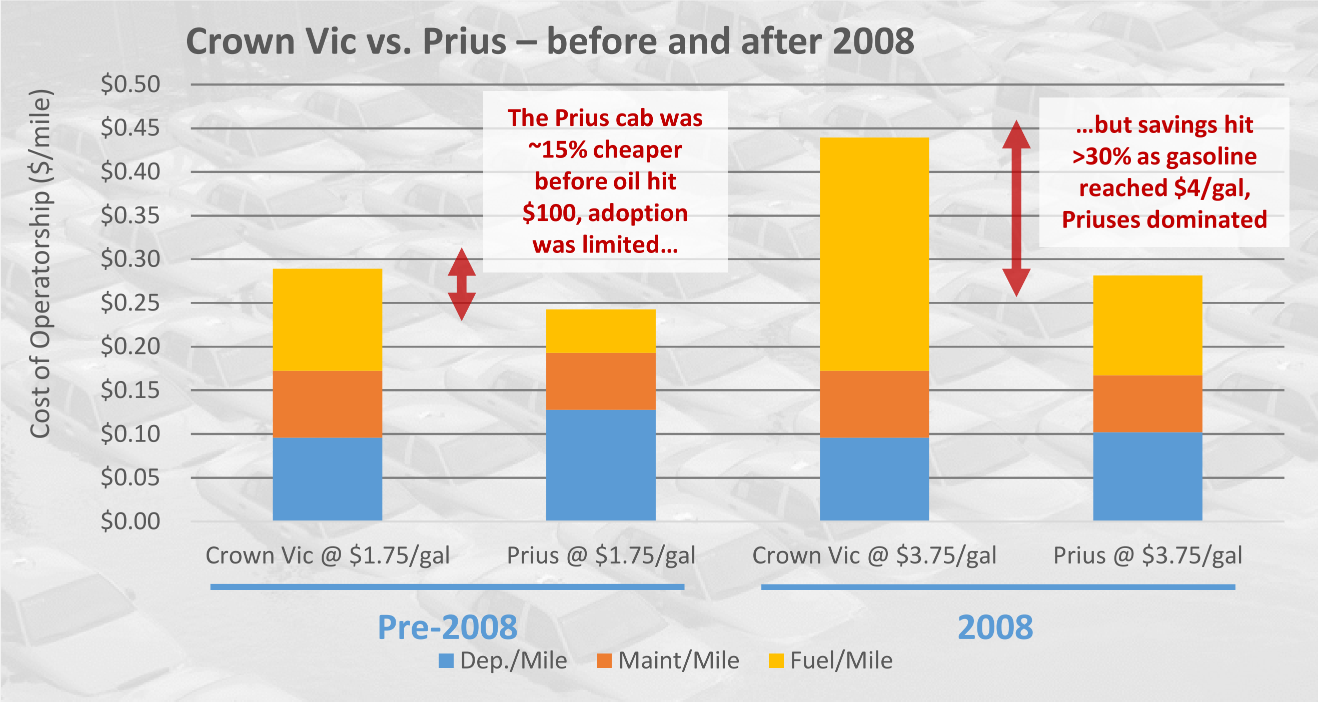
Prior to the 2008 spike in oil prices, taxi cab regulators and management companies were encouraging owner-operators to switch to hybrids. In October 2004, NYC officials auctioned discounted medallions to cabbies who chose hybrid cars for – you guessed it – a **30% discount** to encourage cabbies to switch.

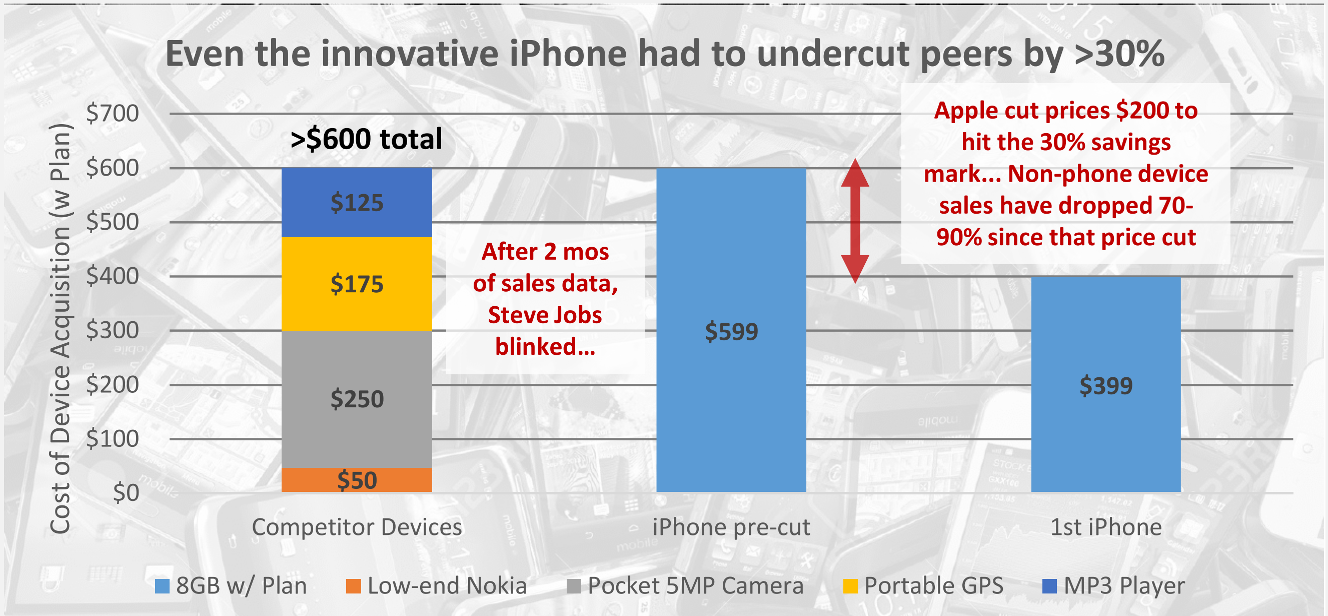
The NYC Taxi Commission fought hybrids, claiming they offered insufficient legroom for passengers, and yet within 5 years, as economics shifted, they had became the workhorses of the NYC cab fleet.

DOMINANT IN 10 YEARS, ALONE IN 30 YEARS

By offering a safer, cleaner life for millions of people, the lightbulb and automobile achieved dominance within 10 years (Tesla's 10th birthday as a bona fide manufacturing company will be in 2018) and drove competitors out of the market within 30 years. But other economically advantaged innovations, like the fleet hybrid and the iPhone, required limited new infrastructure, and transformed their markets even more rapidly.

Today, we're almost spot on the iPhone's 10th birthday. It's (former) competitors don't exist anymore (does anyone own a TomTom?) and it's created a category of product that we couldn't imagine life without. As we argue, **paths to disruption begin with +/-30% lower costs.**





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Measuring innovative potential of the Electric Vehicle (EV)

It seems a consensus is forming that human transportation is on the cusp of significant change. Is the EV a catalyst or a limiting factor for that change?

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From innovations of the past to the electric vehicle of the future

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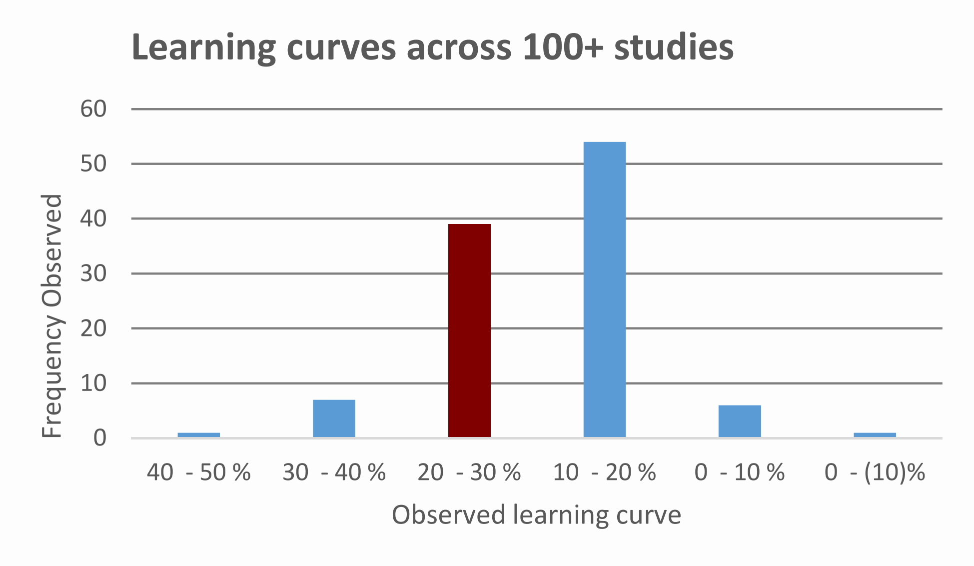
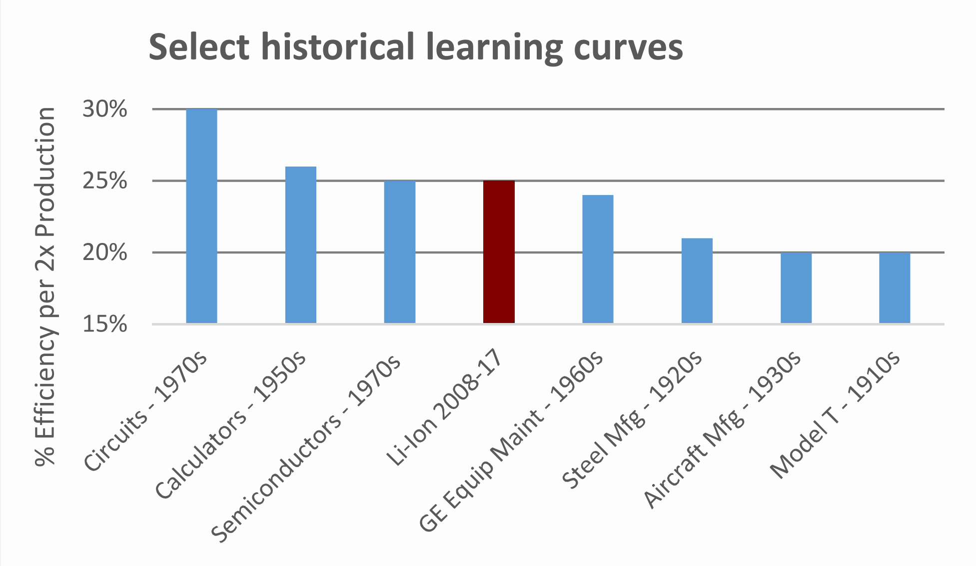
"This I call the miracle of Musk… why wouldn't all [second vehicles] go electric in the next decade?" - Bloomberg

WITHIN THE EV, THE CORE INNOVATION IS THE LITHIUM-ION BATTERY (LIB), WHICH HAS SEEN COSTS DROP FROM >$1,000/KWH IN 2009, approaching $200/kwh today. Costs ($/kwh) have fallen exponentially, leading analysts to extrapolate this forward.

In reality, LIBs sit well within the range of historical learning curves. The "learning curve" is defined as the fall in cost per doubling in production. From 2009 to 2017, automotive LIB production increased 40x – the 80% cumulative drop reflects a 25% learning curve *(LIBs shown in red below)*. The next 40x (and cost drop) will take 2-3 decades (optimistically), fighting against rising mineral costs.





RAW MATERIALS AND THEIR IMPACT ON FUTURE EFFICIENCIES

The most daunting challenge for middle- and lower-market EVs comes not from battery chemistries or lack of charging stations, but from simple math: as LIB costs fall, raw materials account for a greater share of LIB (and EV) costs *(see illustration on page 21)*. Raw materials are not subject to the same efficiency gains as manufactured products. This fact will be further exacerbated by increasing mineral prices – cobalt prices increased 2x and lithium 3x in the last year – *and that was as EV sales approached <**1%** of global sales.*

The $700/kwh of battery savings over the last decade equates to $42,000 of savings per mid-sized EV with a 60 kwh battery. Future cost declines – say, from $200 to $100/kwh – equates to $6,000 of per-EV savings. A decade ago, a battery might have cost $50,000+. Of that $50,000, "battery sensitive" commodities comprised 10-15%. Efficiencies since then have reduced mineral consumption per kwh, but mineral prices have increased by more than consumption has declined. As a result, cutting-edge batteries now cost ~$12,000 – and EV-sensitive commodities, which do not obey the rules of industrial efficiencies, are roughly 50% of that battery cost.

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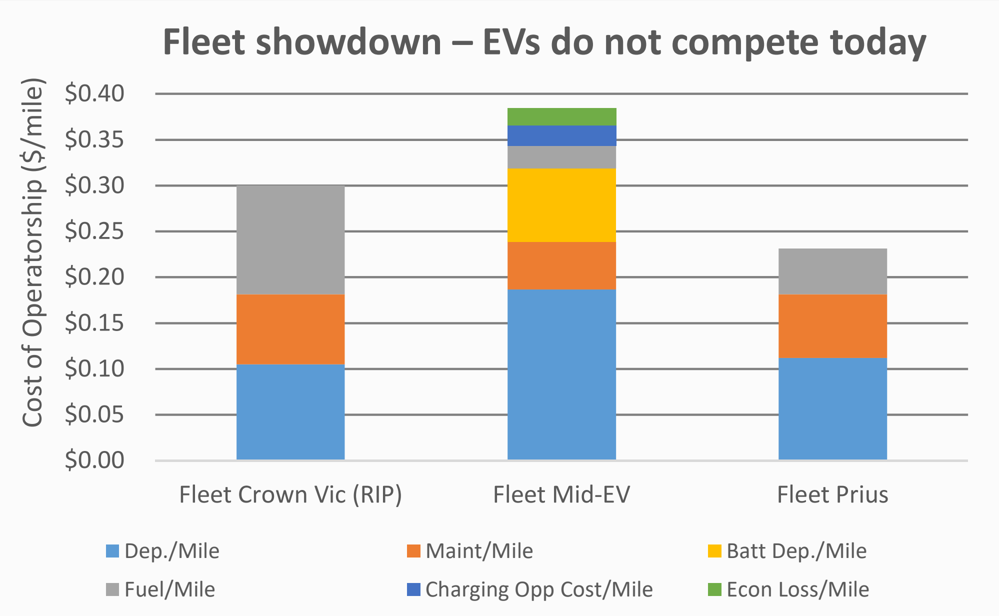
UNPACKING ANALYSIS FROM SILICON VALLEY'S BEST EV REPORT

Autonomous vehicles (AVs), employed by ride-sharing fleets, will bring about the rapid collapse of the fossil fuel auto industry. That is the conclusion of a recently published, and compelling report by *ReThink* – a think tank run by technology investors.

We reference *ReThink* because their report is the most thoroughly articulated, economically-based account of Silicon Valley's vision for the future of transport. Per their report, once human drivers are phased out, fleets will address vehicle operating costs.

The logic follows that fleets and ride sharing companies will rapidly switch to lower-cost, longer-life, lower-maintenance EVs, and ICEs will be museum exhibits by 2035.[4]

There's one (small) catch: lower-end EVs are significantly more expensive today and will remain so for years. An AV fleet operator would be incentivized to use ICEs.



"Almost all new vehicles will be autonomous within 10 years" *- Elon Musk*

"By 2030… 95% of US passenger miles traveled will be served by on-demand EVs." - ReThink

ADDITIONAL PESKY ECONOMIC DATAPOINTS:

1) the operating cost of today's unsubsidized EV is significantly higher (60-70% higher per mile) than that of ICEs and will remain so (we analyze future fleet costs on the next slide). Today's subsidized, loss-making mid-level EVs need more than just LIB savings to hit true cost parity vs. profit-making ICEs.

2) A vehicle's "uptime" – % time available to operate – is crucially important to fleets. Charging a 150-200 mile battery to 80% of capacity takes 40 minutes on a supercharger. A NYC cab runs >200 brutal miles/day, typically 24/7. An AV would run even more. An EV would require 80-100 minutes per day, *assuming 100% supercharger availability*, to work 24-hour fleet service. Cars competing for 40 minute charging slots would introduce additional logistical headaches.

For decades into the future, fleets will favor fast-fueling, low-cost, hybrid ICEs – just as cabs do today. Accordingly, we do not believe the AV will create a "breakthrough" for the EV.

4. If you haven't done so already, listen to "Red Barchetta" by Rush, Canadian prog-rock heroes – the greatest (and only?) song written about the end of the ICE.

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Ride-sharing is the future of transport… if it doesn't go bust next year

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"Autonomous vehicle fleets… will account for the majority of [ridesharing] within 5 years"
- John Zimmer, CEO and Founder, Lyft

If you think the average American will use an autonomous ridesharing vehicle for their primary means of transport in the next decade, we may need to pump the *(regenerative)* brakes.

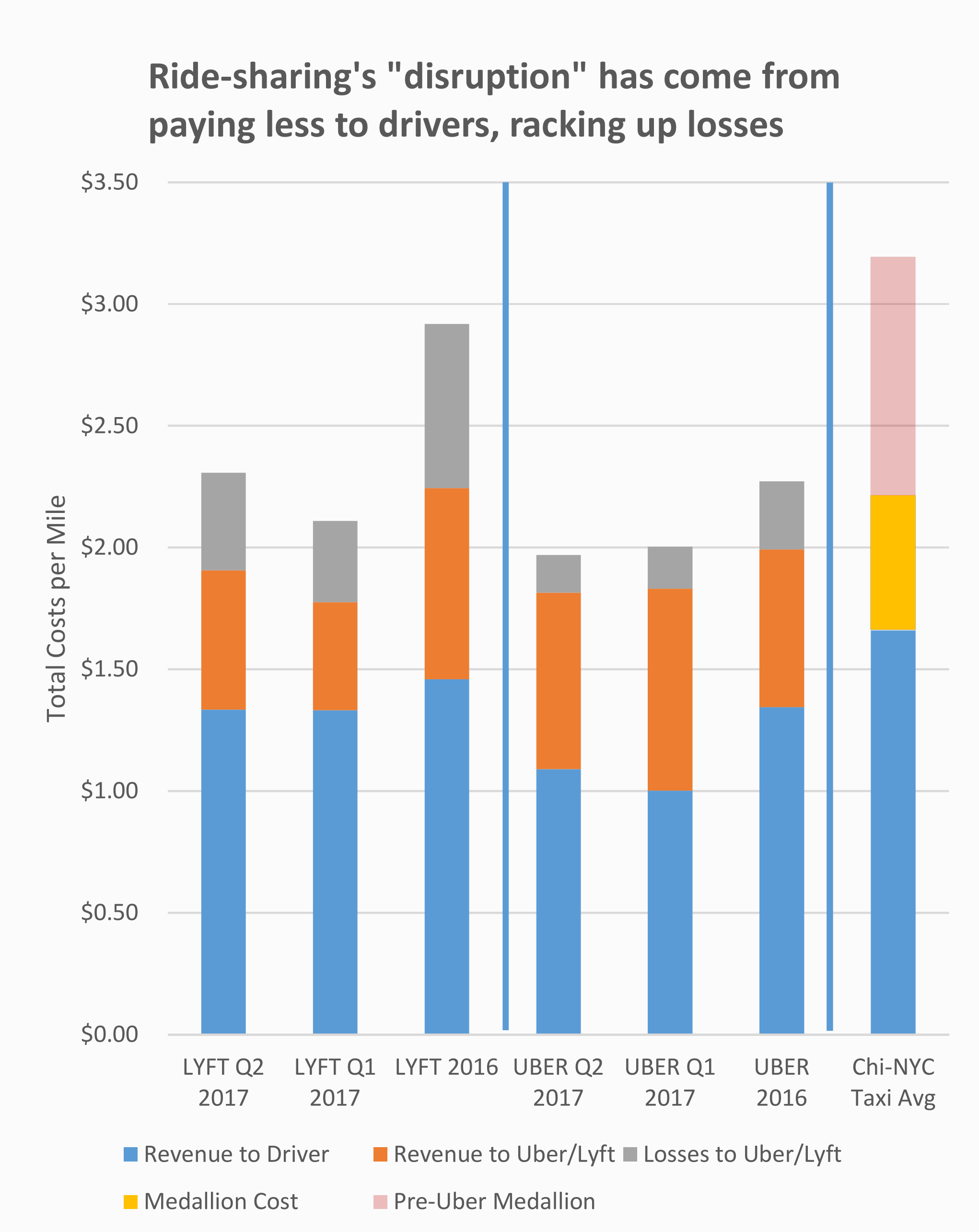
It all sounds great – Uber and Lyft help re-imagine travel and drive down costs by making transportation a robot-service-based, rather than an car-ownership-based, experience.

By hyping the potential for autonomous vehicles, ridesharing CEOs are simply assuming away their largest cost – the human driver. Doing so allows these CEOs to explain away the 9- and 10-figure losses currently subsidizing their costs of operation.

While ridesharing CEOs and investors *may* believe in the future of autonomous vehicles, the economics show that they *need* to believe in them, because otherwise, ridesharing cost structures really don't look much different from your plain yellow cab.

UBER AND LYFT – WAITING ON AN (AUTONOMOUS) MIRACLE

- Uber and Lyft expanded ride-hailing beyond the borders of densely populated metropolitan areas (nice work)
- Overpriced Medallions (taxi permits) made cabs less cost competitive, and Uber/Lyft delivered meaningful savings in 2013-15. As always, disrupted incumbents got cheaper.
- Medallion prices came crashing down, and Uber/Lyft reached cost parity with traditional cab services *(see right)*
- As a result, Uber/Lyft have been obliged to force down driver pay, accept large losses, with no clear path to delivering lower prices and profitability to investors
- If Uber and Lyft passed losses onto customers, they would be at cost parity with Prius cabs.



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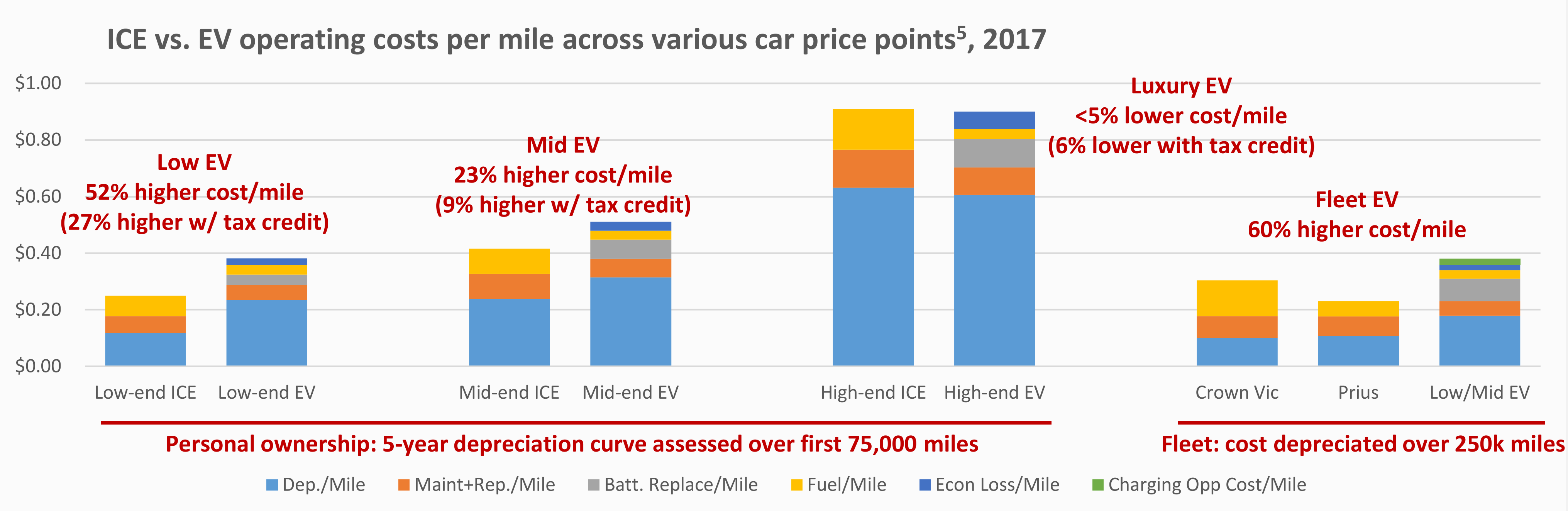
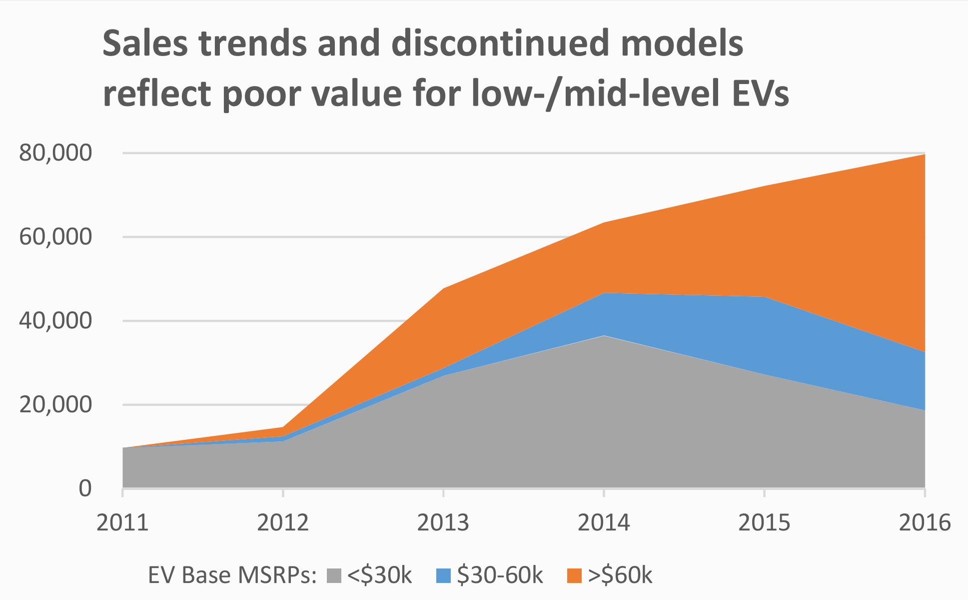
Where comparative operating costs per mile stand today





The comparative economics (and sales data) of the EV serve as a reminder of the difficulty of hiding a $10,000+ lithium-ion battery (LIB) in the average car ($33,000 in the US, median price sub-$30k).

- Directly comparable lower-end car pairs (i.e. Focus / Focus EV) reflect $2k-$4k higher costs for the EV, which reflects a cost difference subsidized by automakers' losses on EVs
- Tesla's genius in pursuing the high-end car market is made plain in the above chart – luxury cars have high fuel costs, a weakness Tesla can exploit, while batteries remain a manageably small part of a luxury car's cost. Luxury is the only growing EV segment.
- In our comparison, we assume Tesla must eventually claw back 10% operating margins from customers. Contrast with Porsche, a comparable high-end carmaker, which generates >25% margins.

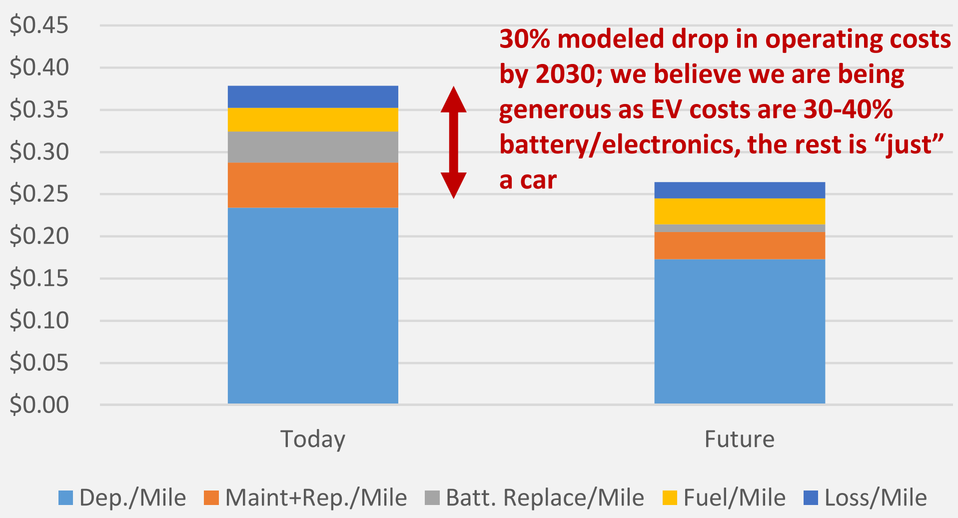
5. EVs: (LOW) Nissan Leaf, Ford Focus EV, Chevy Spark EV, (MID) Chevy Bolt, BMW i3, Tesla 3, (HIGH) Tesla S 75, Tesla X 75. ICEs: (LOW) Honda Civic, Focus, Spark, (MID) VW Golf, BMW 320i, Acura TLX, (HIGH) Lexus LS 460, Lexus LX 570

Key drivers of lower EV costs per mile in our EV-ICE showdown

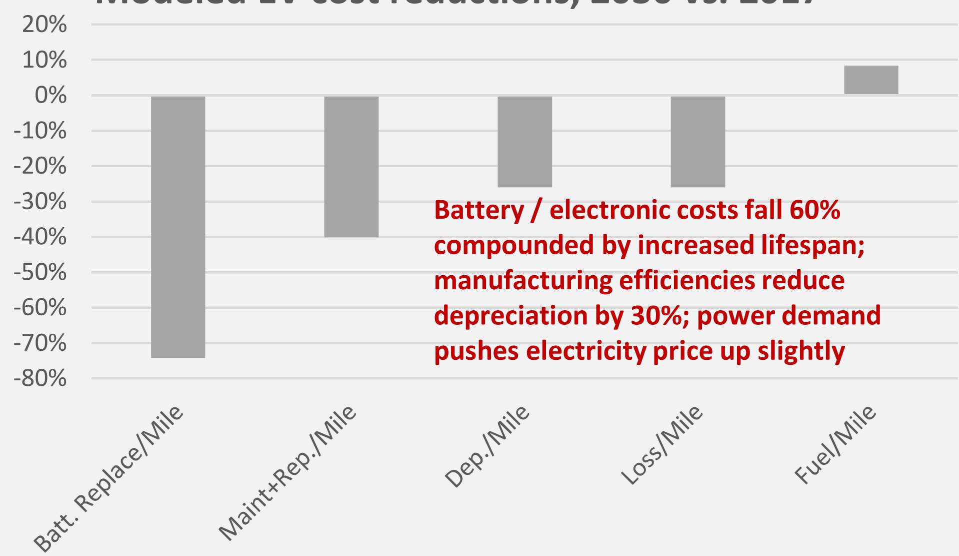
As noted above, the lithium-ion battery (LIB) is the key driver of lower costs for the EV. Below we review the key cost components in our study, as well as how we expect EV costs to decline:

- **depreciation per mile** – rates vary by car but fall within a well-defined range. ICE depreciation is well-understood; EVs vary more widely. Tesla's rate is low due to limited production and strong demand; the Leaf's depreciation is high due to limited range. We assume low-end EVs see lower depreciation as batteries get bigger. We assume high-end EVs hold firm even as availability increases.
- ***NOTE:*** *we exclude all consumer subsidies from car prices. The $7500 US tax credit winds down upon the delivery of each EV-maker's 200,000th EV. Big dogs Tesla and Chevy will enter 1-year sunset period as early as late 2017, all EVs likely outgrow Fed subsidy by 2022.*
- **maintenance and repair expense per mile -** maintenance will be dramatically lower – we estimate 60% less for an EV vs. an ICE. EV repair expense/mile is significantly higher than ICE today. This is evidenced in Tesla warranty expense and costs of EV extended warranties vs. ICEs'. We expect EV repair costs to decline but to remain slightly more expensive vs. ICEs in the future.
- **battery replacement per mile** – LIBs have a shorter lifespan than a car. We generously model 60% depletion over 10 years (to reach sub-100 mile range), then we assume replacement. We model $200/kwh costs today; by 2030 we see 14 year lives and $90/kwh costs.
- **fuel per mile** – 1 kwh (11c in the US today) moves a car 3.5 miles; a gallon of gas ($2.40) moves a car 20 miles. Going forward, we see MPG improve 25% in the next 13 years (vs. 20% in the past 10 years) while battery range per kwh improves 15%.
- **economic loss per mile –** today's high-end EVs generate breakeven operating profits (vs. industry average 15-20%). Low- and mid-level EVs generate losses. A negative margin car won't be mass produced - automakers must eventually "claw back" losses from consumers.

EV operating cost efficiencies, 2017-2030



Modeled EV cost reductions, 2030 vs. 2017



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Looking to 2030, EVs dominate high-end, secure <20% overall share

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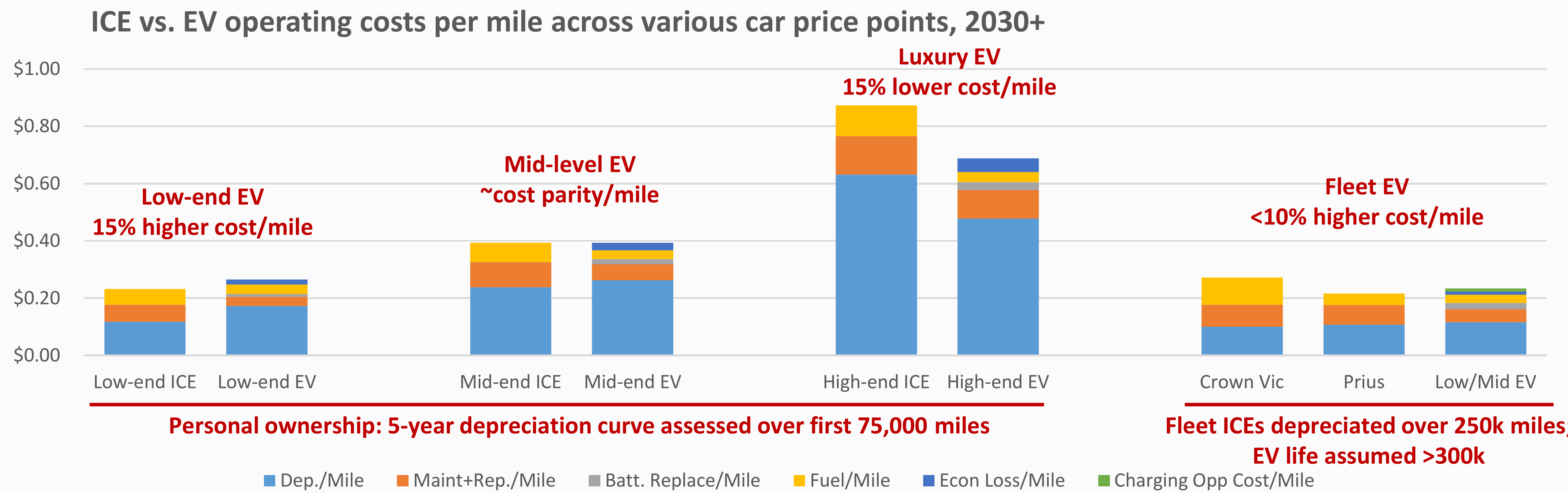

BY 2030, THE MASS-PRODUCED EV HAS FAILED TO CLEAR THE COST SAVINGS THRESHOLD REQUIRED FOR MARKET DOMINANCE

HIGH END CARS: EV is victorious, lower cost and helped by the fact that high-end EV buyers may be commute-only drivers, rarely "road-trip", certainly have 2 cars and may have a 3rd car for more practical use. Car purchases >$60,000 are 5-6% of US car sales, less worldwide.

MID-LEVEL: With cost parity, mid-level EVs ($30-40k) achieve 40% market share in the middle 45% of sales, based on lifestyle preferences.

LOW-END CARS: the wave of discontinued low-end EVs we've already seen sets an accurate trajectory for the ~50% of the market below $30k. Even at reduced lithium-ion battery (LIB) prices, low-end EVs remain largely unprofitable, and undesirable for cost-conscious buyers.

REVIEWING KEY 2030 MODELING ASSUMPTIONS

- **VEHICLE COST/DEPRECIATION:** By 2030, we assume 15-25% savings on purchase, driven by $90/kwh batteries, while non-battery electronics fall by 50%. Some cost savings are offset by automakers generating higher margins on EVs. For fleet vehicles, we assume EVs run 25% longer, although this is totally speculative.
- **BATTERIES:** Battery savings also reduce replacement costs. Replacement cycles increase 40% to 14 years, and credits from battery recycling offset 15% of the cost of a new battery (assuming that old LIBs are used for less-strenuous grid storage applications).
- **FUEL:** By 2030, the high cost of widespread renewable installation and costly battery storage backstopped by fossil fuel power, compounded by increased demand from EV charging, drives prices to 13c/kwh, reflective of Californian power costs today. Range per kwh increases 15%, offsetting some of this increase.
- **REPAIRS AND MAINTENANCE:** We assume maintenance remains 60% cheaper than comparable ICE costs, while repairs move from 50% higher vs. ICEs to 30% higher as battery repairs become more commonplace.

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Further discussion of our operating cost drivers

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Cost Component/Definition	Qualitative background	How we model it into the future
Depreciation. Theoretically, it's price/useful life. In reality, depreciation is based on supply/demand, unless you buy a car and drive it until it dies.	Depreciation rates for ICEs are well-established. For EVs, not so much: the Nissan Leaf's is sky-high due to poor battery range; Tesla S's is low due to high demand and limited production. EV-optimists forecast radically lower depreciation from better, cheaper LIBs (certainly) and also from longer lives (debatable).	For fleet cars, we use price/total life. For personal vehicles, we look at *Edmund's* depreciation rates, and lower EV depreciation rates in anticipation of bigger batteries and longer ranges. **PRICE:** There is no debate that EV costs will fall more than ICEs in the next decade, due to cheaper batteries and electronics. We factor 50-60% savings on batteries and drivetrain components for our 2030 forecast. This is mitigated somewhat as EV-makers must increase price to improve margins. Costs further flatten as chronic mineral shortages take hold by the late 2020s, even assuming significant new discoveries of world-scale lithium deposits. **USEFUL LIFE:** We don't buy optimistic predictions of 500k-mile EVs, and we don't know that they even matter. Economically-driven ICEs (like taxis) routinely last 300,000+ miles. Consumers replace cars because they want to, or because cost of maintaining (engine and non-engine parts) is too high vs. a used car cost. Drivetrain failures are responsible for a minority share of auto replacements.
Maintenance. Oil changes, brake pad replacements, tires, rotations and alignments.	EVs, with no oil changes, fewer moving engine parts, and regenerative brakes, should have lower maintenance.	Our part-by-part maintenance buildup suggests 40% lower maintenance costs per mile for EVs; we use 60% to be generous to the EV. Savings are derived from fewer/no: oil changes, air and fuel filter changes, coolant flushes, spark plug replacements, belt replacements. Brake maintenance is reduced meaningfully by regenerative braking on EVs. Maintenance of interior comforts, tires, and shocks and struts is largely unchanged.
Repairs. Typically mechanical failures covered by warranty in first 3-4 years.	The jury is still out here. Tesla's 10-K implies warranty expense/vehicle that is 30-50% more than costly-to-repair Benzes and BMWs.	We assume that EVs, unless specifically detailed by the manufacturer (as Tesla does in their warranty guides), cost 30% more than comparable ICEs to repair. Interestingly, Tesla's extended warranties anticipate significantly higher repair expenses vs. high-end ICEs. This makes sense, as there's nothing inside an ICE as expensive as Tesla's $12,000-$20,000 battery (at $200/kwh pricing) and costly associated electronics.
Fuel costs. Gallons of gasoline or diesel, or kilowatt-hours of electricity	One area where the EV's dominance is clear, at least at current prices.	At $2.40/gal, the average US-based ICE costs 13c for every mile (including MPG for trucks and buses). The average mid-level EV sedan costs 3-4c to move 1 mile at 10c/KWH (US retail average). As EV competition increases, we expect ICE MPG improves by 25% through 2030. This compares to the 20% improvement in fuel economy on new car sales in the US in the last 10 years. EV fuel economy (mi/kwh) improves by 10% over this time. In our 2030 case, gasoline prices average $2.25/gal while electricity is 13c/KWH.
Lossmaking "subsidies". How much did creditors and investors in carmakers subsidize you for your new EV?	In 2016, Tesla posted 0% margin before R&D costs vs. $80k revenue/car. Also-pricey Porsche posted >25% pre-R&D operating margin. If we normalize Tesla G&A, margins reach 8%.	Tesla generates roughly 8% "adjusted" margin on sales of high-end cars. Other EV manufacturers are generating operating losses on EV manufacturing, vs. industry-wide profits clustered between 10% and 20%. Additionally, no EV maker is servicing a fleet of EVs the way legacy ICE makers must do. In other words, today's EV buyer is being subsidized from 5% to 20% as a result of automakers generating no profits from EV manufacturing. Limited production runs allow automakers to eat losses, but as EVs become widespread, operating margins must normalize to justify increased production.
Charging opportunity cost. For fleet vehicles only - revenue-generating time lost due to time spent charging.	As described on the prev slide, fleet EVs lose >1 hr/day from 40 minute supercharging sessions, each adding 150 miles of range. (*Note: today, superchargers only exist for Tesla cars*)	We assume 80 minutes of lost uptime for fleet vehicles, effectively burdening the cost of the remaining 22 hours and 40 minutes per day with the cost of zero-revenue charging time. We model that superchargers are available into the future and have no wait times. In reality, there is no large-scale fast-charging available for the world's EVs. Today, superchargers are a subsidized amenity for Tesla owners, for which Tesla pays $300k to build and then subsidizes electricity.

info@recurrentadvisors.com

Is the world (and its minerals) ready for the EV?

At 20% of the global fleet, the EV will put unprecedented stress on the world's lithium and cobalt supplies

info@recurrentadvisors.com

Lithium – a once-sleepy commodity is the linchpin of the EV's future

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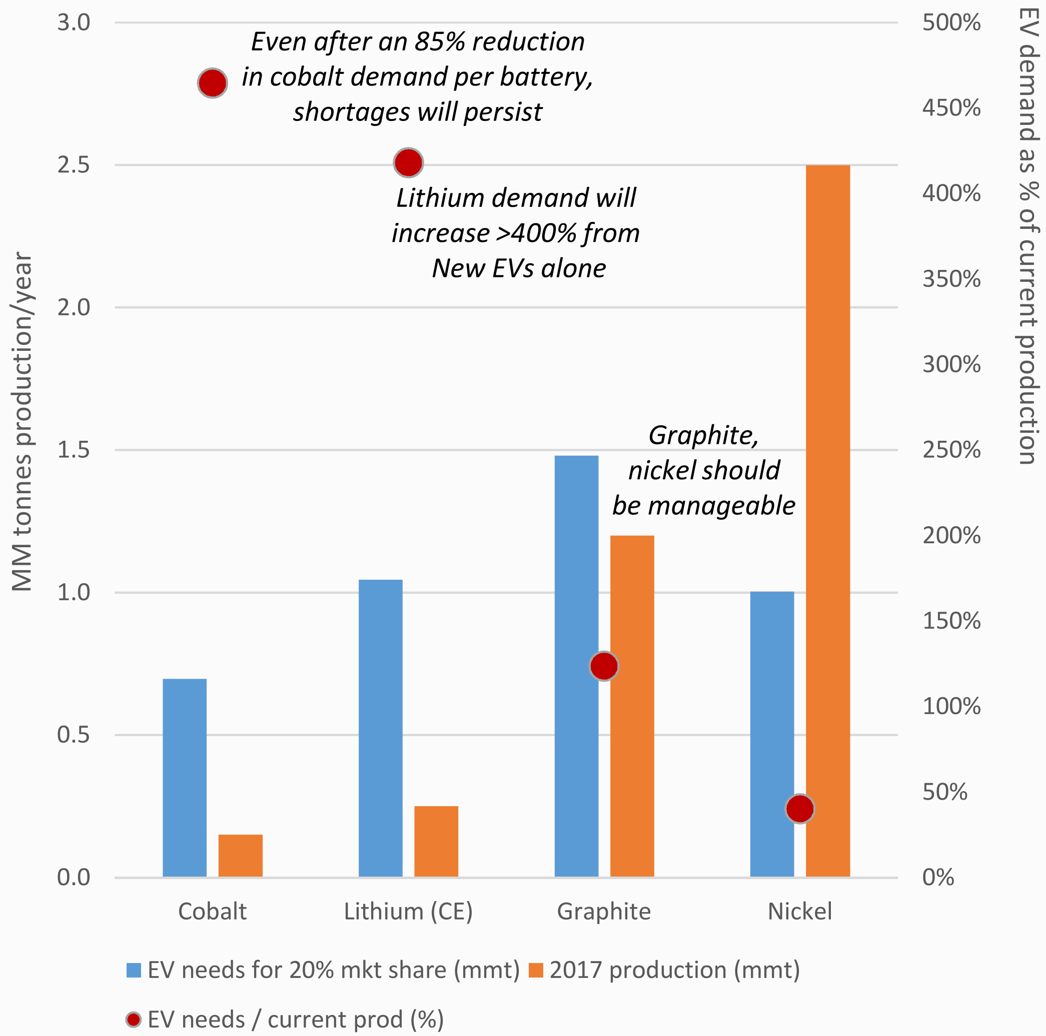
"Our cells should be called Nickel-Graphite... [There's] a little bit of lithium in there, but it's like the salt on the salad" – Elon Musk, June 2016... the next 12 months saw a 100% rise in lithium and cobalt prices driven by EV battery demand

20% EV market share will seriously tax mineral markets, even with advanced LIB chemistries



WITH EV SALES <1% OF GLOBAL AUTO SALES, LITHIUM demand has just begun to increase. We have seen over 100% increases in lithium (and cobalt) prices in the past 12 months.

There are different lithium-ion battery (LIB) chemistries for EVs - lithium and cobalt are two key cathode components. LIB-makers are moving to reduce/eliminate dependence on cobalt, while lithium remains an essential ingredient.

SHORTAGES LIKELY, EVEN WITH FALLING MINERAL INTENSITY

We assume an >80% reduction in cobalt usage in future LIB chemistries. Cobalt demand still skyrockets, *see graph at left.*

We assume lithium intensity of LIBs falls meaningfully - from 1.2-1.5 kg of LCE/kwh today to 0.75 kg/kwh in the 2030s. Assuming 20% EV market share, new cars consume 1 mmtpa, before demand for replacements, grid or gadget batteries.

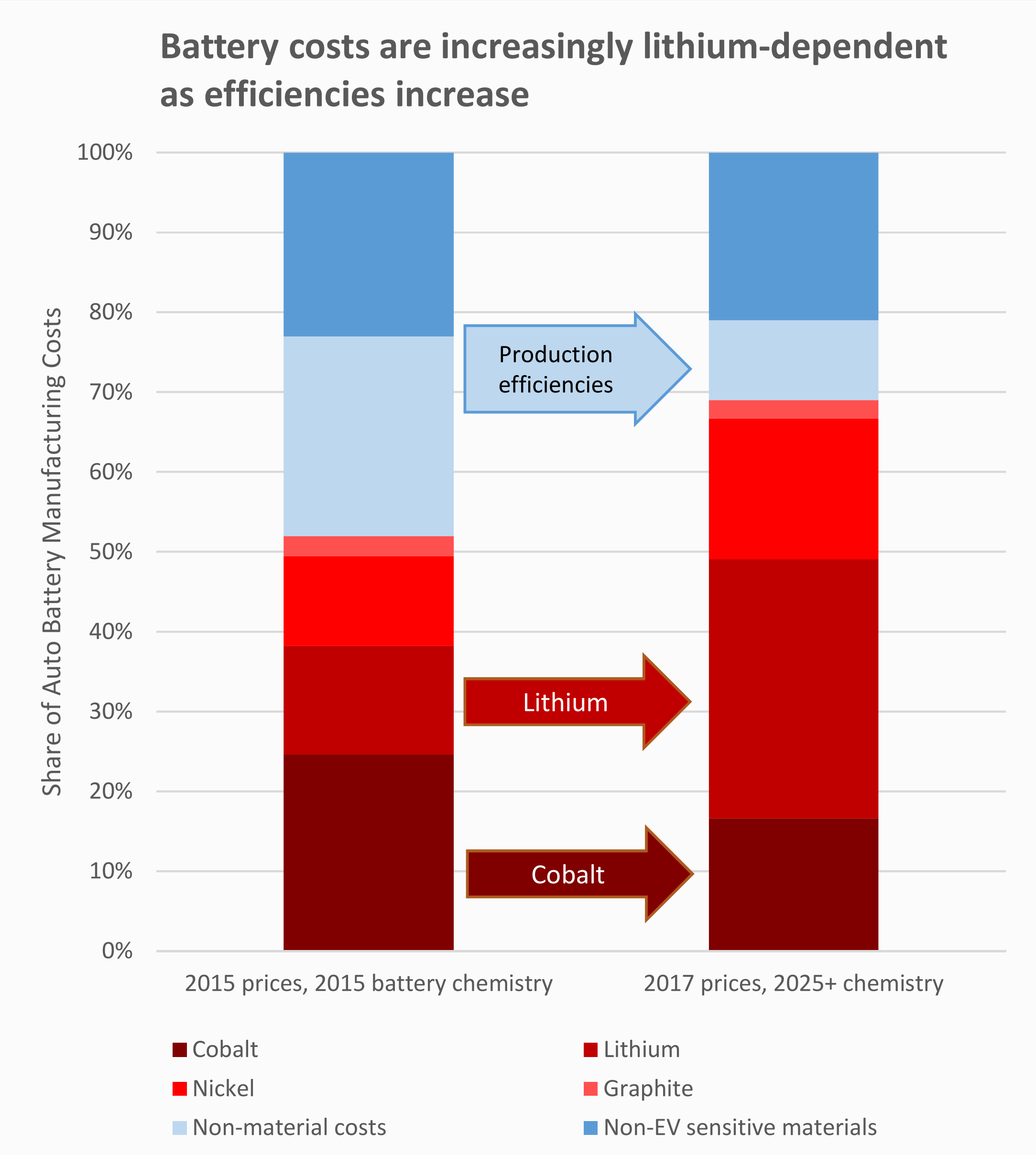
20-YEAR OUTLOOK FOR LITHIUM

- Investment in new production through the early 2020s has been considerable, with several mega projects (Australia and Lat Am) driving a supply surge through 2025.
- We see potential oversupply in 2018-2025, even with typical startup delays and production shortfalls.
- By late 2020s, automotive LIBs and grid battery demand exceeds supply. In 2030s, the world needs 1-2 world-scale lithium mines annually to keep pace with demand.
- Lithium recycling is too costly, and the quality of recycled lithium too inconsistent, for large scale LIB recycling today. Lithium costs would need to rise considerably to justify energy-intensive recycling, putting EV economics at risk.

info@recurrentadvisors.com

The quest to reduce batteries' costs, as well as mineral requirements

"Volkswagen told a lithium conference… lithium and cobalt, are of the greatest concern to the carmaker… BYD, the Chinese EV and bus company, said it was talking to producers in Chile about potential deals to secure lithium supply" – FT, June 2016



As mentioned on the previous slide, the high cost of cobalt (and more recently, the high cost of lithium) are driving innovations to reduce the consumption of these minerals.

In our model, we assume advanced battery chemistries reduce cobalt demand per kwh of capacity by 85%, and lithium demand by nearly 40% *(reflected at left)*.

PARADOX OF EFFICIENCY – LITHIUM WILL MATTER MORE

As new battery manufacturing capacity comes online and efficiencies increase, ironically, a greater share of battery economics will be dependent on raw material costs.

As shown at left, reduced overhead and investment costs, combined with reduced cobalt consumption, puts greater emphasis on lithium and nickel (Li, Co, Ni account for 70% of future battery costs vs. <50% today).

ALPHABET SOUP – A BRIEF NOTE ON CHEMISTRIES

- The next battery breakthrough is not going to be discovered in our report, but here is a brief backgrounder for those who want to Google further.
- Tesla's Nickel-Cobalt-Aluminum (NCA) batteries provide high specific energy, and were chosen (wisely) by Tesla due to their high power delivery and low cobalt content.
- With lower power delivery but also lower manufacturing cost, Nickel-Manganese-Cobalt (NMC) is used in most non-Tesla EVs, and is attractive due to the abundance of manganese (although it requires more cobalt vs. NCA).
- For EV fans who hate hearing "cobalt", Iron Phosphate (LFP) provides hope. But with lower energy density, it would require another thousand pounds for a car battery.

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Lithium – getting to know the rock itself, and its cost structure

Evaporation ponds associated with Orocobre's 18 ktpa Olaroz lithium salar (salt mine) in Argentina. The salar is located in the South American "Lithium Triangle," which holds ~50% of the world's lithium deposits

Pure lithium reserves are estimated by the US Geological Survey at 14 mm tonnes (30 years of production, assuming 20% EV fleet penetration), while other experts estimate that number will likely double or triple as prices, investment and exploration increase.

Identified reserves increase, but it is annual production, not reserves, that constrain LIB production. With prices between $10,000/t and $20,000/t today, many planned brine developments are highly profitable – the snag is the 10 year typical lead time.

New Lithium Deposits Online, 2017-2027

Reserves from planned projects	**LCE**	**Pure Lithium**
Total LCE Reserves (k tonnes)	19,051	3,582
Total Capacity/Longevity		
Production Capacity (ktpa)	646	121
Capacity growth vs. 2016	240%	240%
Avg. Capacity/Mine (ktpa)	29.4	5.5
Average Life (Years)	27.4	27.4
Years to Reach Full Production	1.4	1.4
Cost Structure (assuming 80% utilization)		
Capex/Annual Prodn ($/ktpa)	$12,531	$66,657
Capex/Tonne i.e. D&A ($/t)	$506	$2,690
Operating Cost/Tonne ($/t)	$3,449	$18,347

A QUICK PRIMER ON THE MINERAL ITSELF

- Lithium is typically produced from brine (saltwater), in a process where lithium-rich saltwater is pumped out of a salt mine and evaporated.
- Low-cost lithium comes from brine. Brine reserves can be produced, depending on the quality of the deposit, for $2 to $7 per kg (producers receiving net $10-20/kg today).
- Higher cost hard-rock deposits can cost multiples higher. Lithium recovery via recycling is still relatively small-scale and experimental, and the cost of recovering battery-quality lithium from discarded batteries is cost-prohibitive.
- Lithium is typically produced as part of a mineral compound – the most common being lithium carbonate (LC). As a result, lithium production is quoted in LC equivalent (LCE), of which 19% is "pure" lithium.
- Reserves typically take 8-12 years to identify and produce from announcement to commercial mining for new resources (shorter for expansions).
- The world's largest mines produce 50-60 ktpa of lithium vs. 2017 production of 190 ktpa.
- Almost all the world's production comes from South America (50% of reserves), Australia or China. US reserves are concentrated in Nevada (hence Tesla's gigafactory nearby).

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25-year Lithium Supply Outlook: The world needs way more lithium

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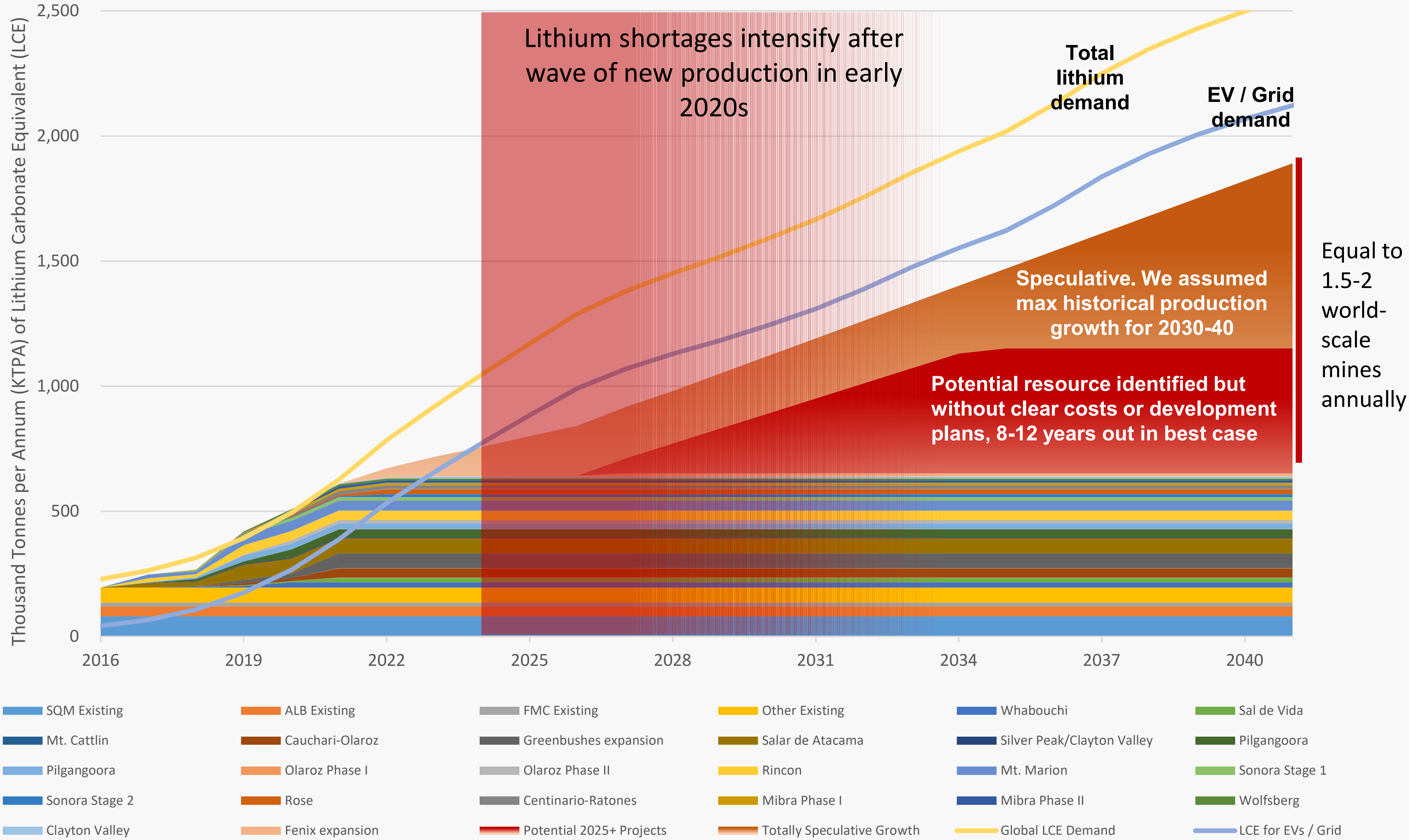
***Even with less lithium-intensive LIBs*, 20% EV penetration requires 2 world-scale lithium mines (equal to 60% of current world production) annually for 20 years**



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25-year Lithium Demand Outlook: EV batteries are the whole story

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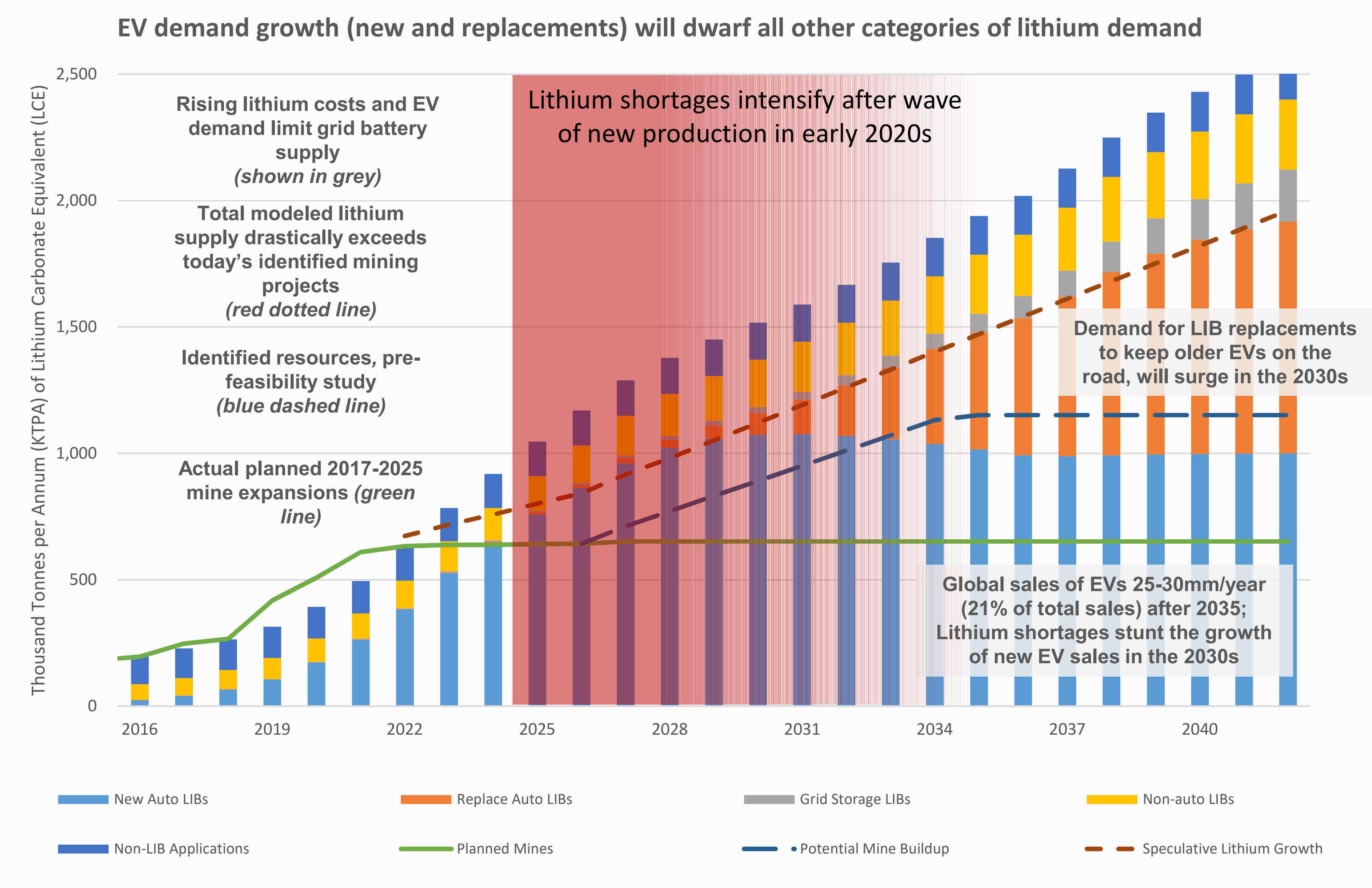

From petroleum to electricity

The expansion of EV usage structurally reduces oil demand growth, puts new pressure on our electrical grid

The EV and its impacts on energy consumption

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The EV will play a role in our society, but far short of Silicon Valley predictions:

- The revolutionary cost savings that allowed great inventions of the 19th century to become staples of our 20th century is likely out of reach for the lithium-ion EV.
- Since the EV is not a truly "disruptive" innovation, the ICE will remain dominant for most price categories of automobile. Still, EVs grow to 20% of the global auto fleet by 2030+ on peak 25% sales.
- This 20% EV penetration rate will put unprecedented pressure on mineral supply, notably on the world's lithium and cobalt production.
- New EVs are the biggest demand driver for lithium, but replacement batteries (necessary for EVs after 8-12 years) drive the 2nd largest source of demand in the 2030s.
- The ability to reduce costs in lithium-ion battery (LIB) technology will be limited starting in the late 2020s by a lack of raw material availability, even assuming significant advances in battery technology.

Electricity demand will increase (albeit mostly off-peak demand), oil demand will slow

- As a result of falling power prices over the past 3-5 years, coal and nuclear retirements are accelerating, replaced by solar and wind generation capacity – just in time for the EV's growth.
- Assuming flat non-EV demand, EV demand drives on-peak retail electricity prices back to 2005-2008 levels by the 2020s (based on growing utilization rates of fully-dispatchable fossil fuel plants).
- Grid LIBs play a role in 2035+, only if EV recycling rates are close to 100% (today, there is no large-scale LIB reuse program). US demand is 4,100 terawatt-hours/yr; a large grid LIB is 0.0001 TWH.
- Oil demand growth declines 70% over our 25-year forecast period. However, 20% of oil investment is driven by growth; 80% of investment is needed to sustain oil production. We expect that oil remains in a $30-70/bbl range through 2042 as a result of reduced automotive demand.

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20% EV penetration outpaces renewables, drives fossil fuel power

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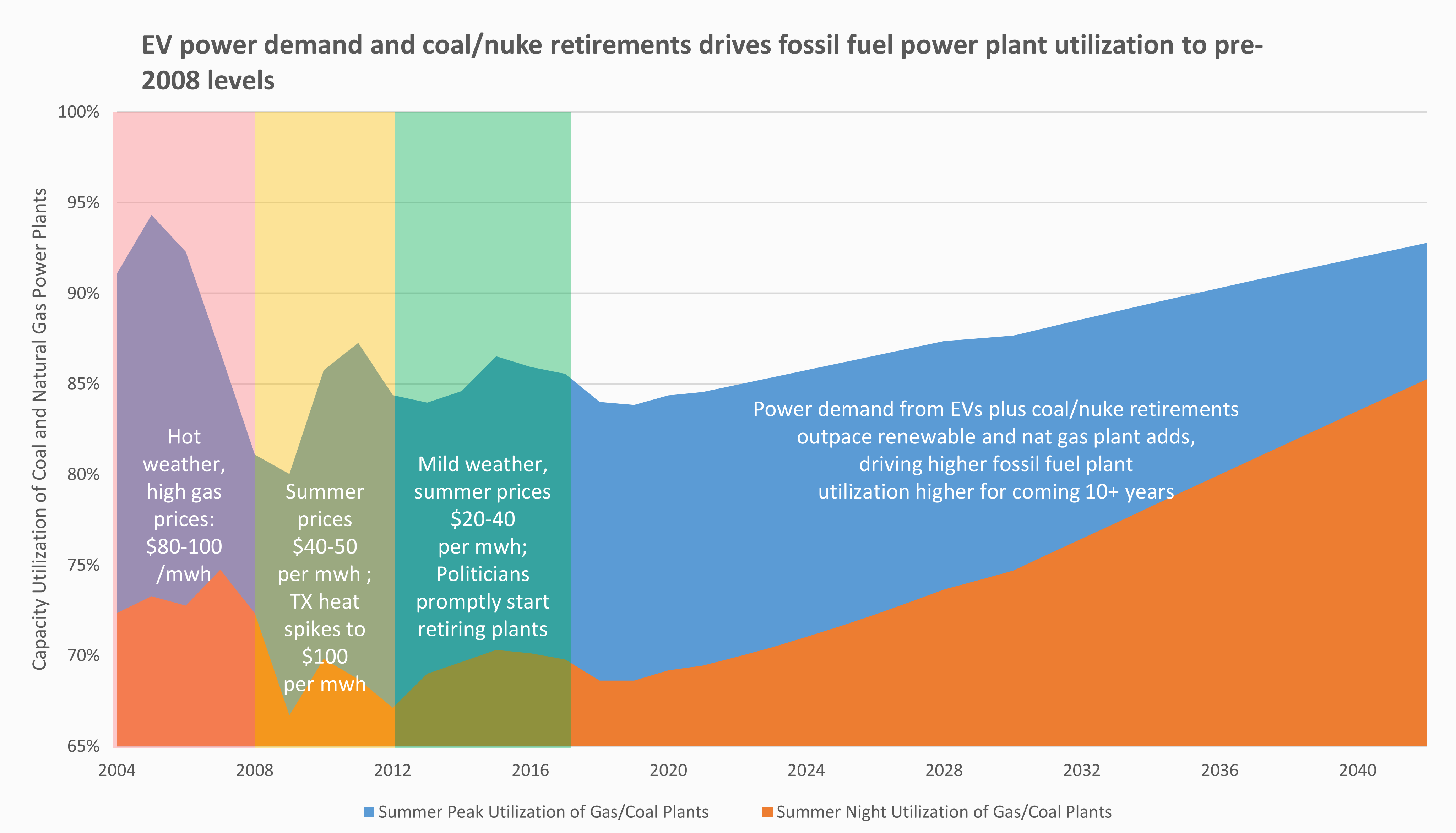

Source: Recurrent research.
Notes: Total generation capacity assumed flat between 2017 and 2042. Capacity through 2021 based on EIA projections; coal retirements continue at 3% annually, gas grows 1% annually, nuke and oil retire at 3% annually, wind grows 3% annually, solar grows 7% annually.
Base power demand grows 0.2%, EV demand modeled separately. Summer peaks are 170% of average, summer nights 115% of yearly average. To calculate need for fossil fuels, we assume solar runs 25%, wind 34%, nukes 95%, hydro 40%.

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Renewables reduce grid profits, increase costs just as EVs show up

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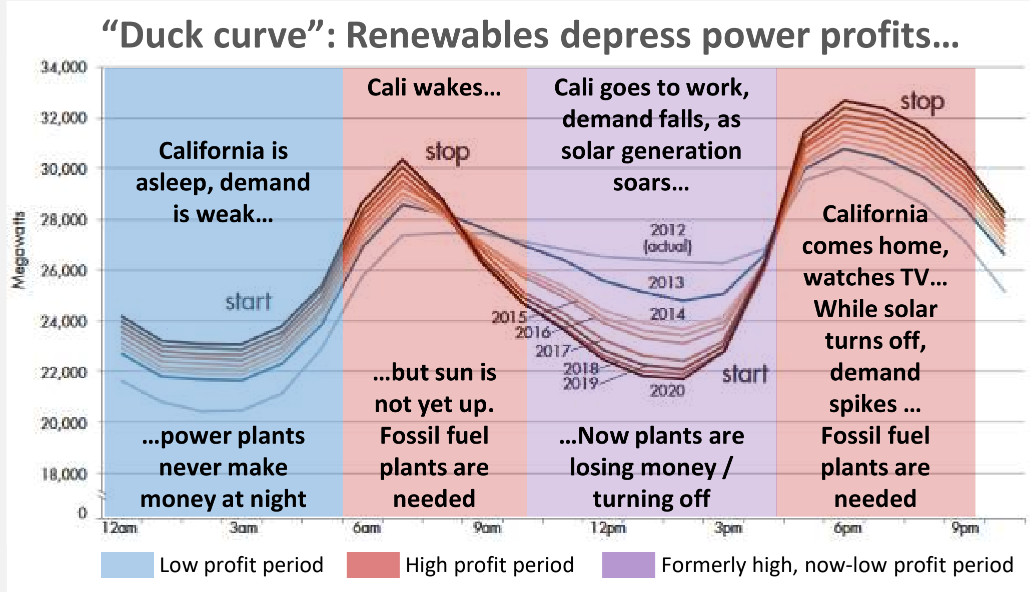
"Solar generation has driven [California] power to very low prices… California continues to pay retail electricity prices among the highest in the nation."
– US Energy Information Agency (EIA)

What? Did I read that right? Yes you did. How, you ask, do retail prices spike as wholesale prices drop – it sounds scandalous!

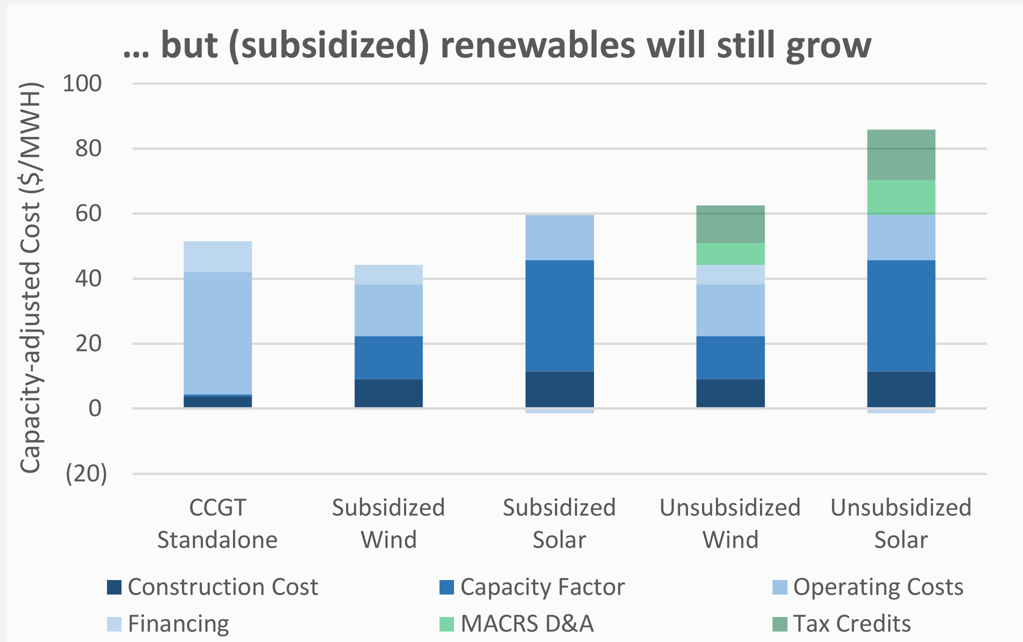
In disparate economies – like California and Germany – where renewables are ~30% of capacity, it is happening.

FALLING POWER PROFITS, RISING COSTS? HERE'S HOW:

- Power markets are managed for several objectives:
  - **Reliability:** Ensuring no blackouts / power failures
  - **Flexibility:** Efficiently turning plants on and off based on operating costs to balance supply and demand
  - **Economic Sustainability:** Providing conditions for efficient generators to profit (ensuring investment in power grid)
- Reliability, flexibility, economic sustainability are related. Investment is needed for sufficient, flexible capacity
- In the past decade, reducing CO2 emissions has become a fourth objective
- Capacity requirements are based on estimated **peak demand**; while profitability is influenced by **average utilization**
- Renewables pose 2 challenges: 1) intermittent generation *(solar ~6 hrs/day; wind ~10 hrs/day)*; 2) cannot turn on/off
- Therefore, 1) it's hard to rely on renewables for **peak demand**; 2) and renewables reduce **average utilization** and profits
- The result: zombie power plants that rarely run but cannot retire. Their lack of profits (via wholesale prices) is subsidized by consumers (via higher retail prices - *see upper right*)



Souce of "duck curve": CAISO (i.e. market regulator of California's electricity market)



MACRS reflects 5-year depreciation benefit to wind/solar, tax credits reflect ITC credits.
Source: EIA construction cost and operating cost data, Recurrent estimates.

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Understanding the role lithium-ion grid batteries can play

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"The biggest drivers of the next phase of grid-scale battery deployment are likely to be state mandates, rather than [the] market."
– US Department of Energy

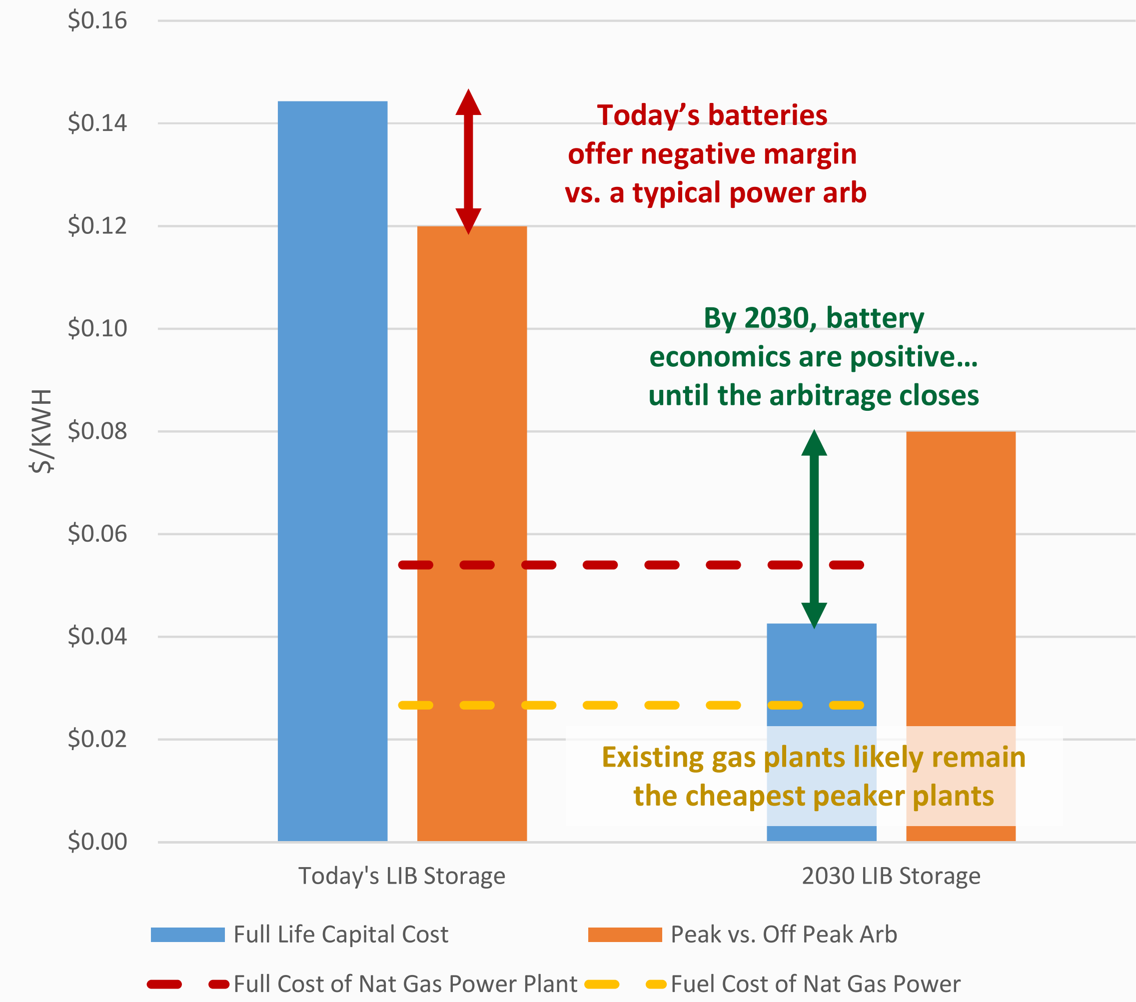
As is the case with most LIB applications in 2017, there is little market-based justification, outside of very high-cost and volatile electric markets, to use LIBs to arbitrage peak and off-peak electricity prices.

Yet, legislation and regulation have both encouraged the use of LIBs in power storage and peak shaving, and as intermittent renewables continue to grow, this segment of the LIB market will continue to grow.

Viewed as a type of "peaker" power plant, LIBs are unlikely to compete with new fossil fuel plant costs for some time *(see graph at right).* As battery prices drop below $100/kwh in 2030, we see potential for grid storage to be economically justifiable, albeit unlikely to be cheaper vs. already-installed natural gas peaker plants *(shown in yellow dashed line).*

Importantly, arbitrage assumptions are important for battery economics to work. Storage arbitrages, based on floating US wholesale power rates, have averaged 10c over the past year; we assume the battery is able to capture a 12c arb in the graph at right. As we see more batteries enter the grid, the opportunities to "capture the arb" will naturally be competed away, challenging battery economics. Still, we assume that even as arbs fall to 7c or 8c (by 2030+), battery costs likely fall faster, leading to decently attractive investment cases for batteries (10-20% undiscounted returns).

Today, grid batteries offer negative returns outside of highest-price markets; by 2030, 60% cost savings support economics



Source: Recurrent research.
Notes: Today's arbitrage based on peak vs. low prices over 3 day periods in US wholesale electric markets.
Arbitrage assumed to be reduced by increased availability of storage in 2030.
Capital costs are assumed to be install of Powerwall battery, less 20% salvage value, undiscounted.
Nat gas cost of generation based on new $650/KW plant, fuel cost is $2.75/mcf

info@recurrentadvisors.com

Can utility-scale batteries support an EV-intensive, renewable grid?

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"Electric vehicles are becoming a tool for grid stability" – Greentech Media / Wood Mackenzie

We saw on the previous slide that renewables hurt power profitability by **reducing utilization** for fossil fuel plants, while **failing to replace peaking capabilities of fossil fuel plants**.

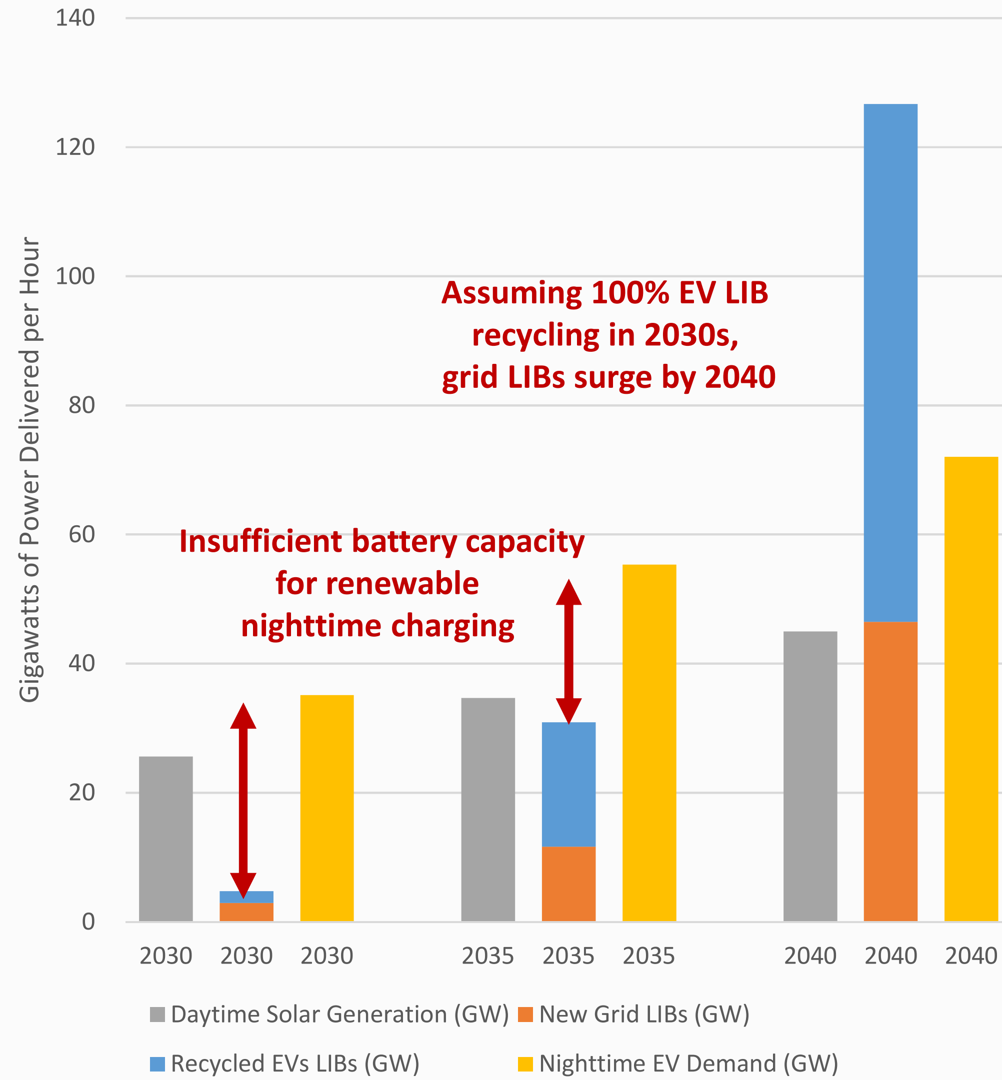
Assuming the economics work, lithium-ion batteries (LIBs) could bridge renewable generation during periods of low demand with late afternoon peak demand (primarily served by fossil fuels).

We know from our lithium study (pp. [x]) that EV fleets will consume the vast majority of lithium supply for decades. There is a possible way out: recycled or depleted EV LIBs can, hypothetically, serve in lower-intensity grid applications (although the viability of large-scale recycling is unproven).

GRID BATTERIES UNABLE TO LINK EVs WITH SOLAR UNTIL 2040

- We estimate >80% of EV charging takes place at night.
- Given limited nighttime generation from renewables, EV charging is typically supported by fossil fuel generation.
- Nighttime charging for EVs in the US, assuming 20-25% fleet penetration, will add 4-6 bcf/d of natural gas power demand.
- To avoid charging EVs with fossil fuels, we need batteries. Assuming 100% EV recycling and newbuild grid LIBs are used, batteries still will not support EV charging until close to 2040.
- In reality, it makes little sense for LIBs to store higher-value daytime power and transfer that power to low-value nighttime applications, like EV charging.
- It is more likely that LIBs will be used for "peak shaving", reducing generation needs during peak demand periods.

Even if 100% of EV LIBs are recycled, EVs will not be fueled with renewables until 2040+



Source: Recurrent research.
Notes: 100% of 12 year old EV batteries from Recurrent model are recycled for grid usage. We assume 5 year life for recycled batteries, and 50% of original EV capacity available for EV storage. Charging and discharging cycles are assumed to average 18 hours (36 total) across entire US

If LIB recycling is successful, power would face pressure post-2030

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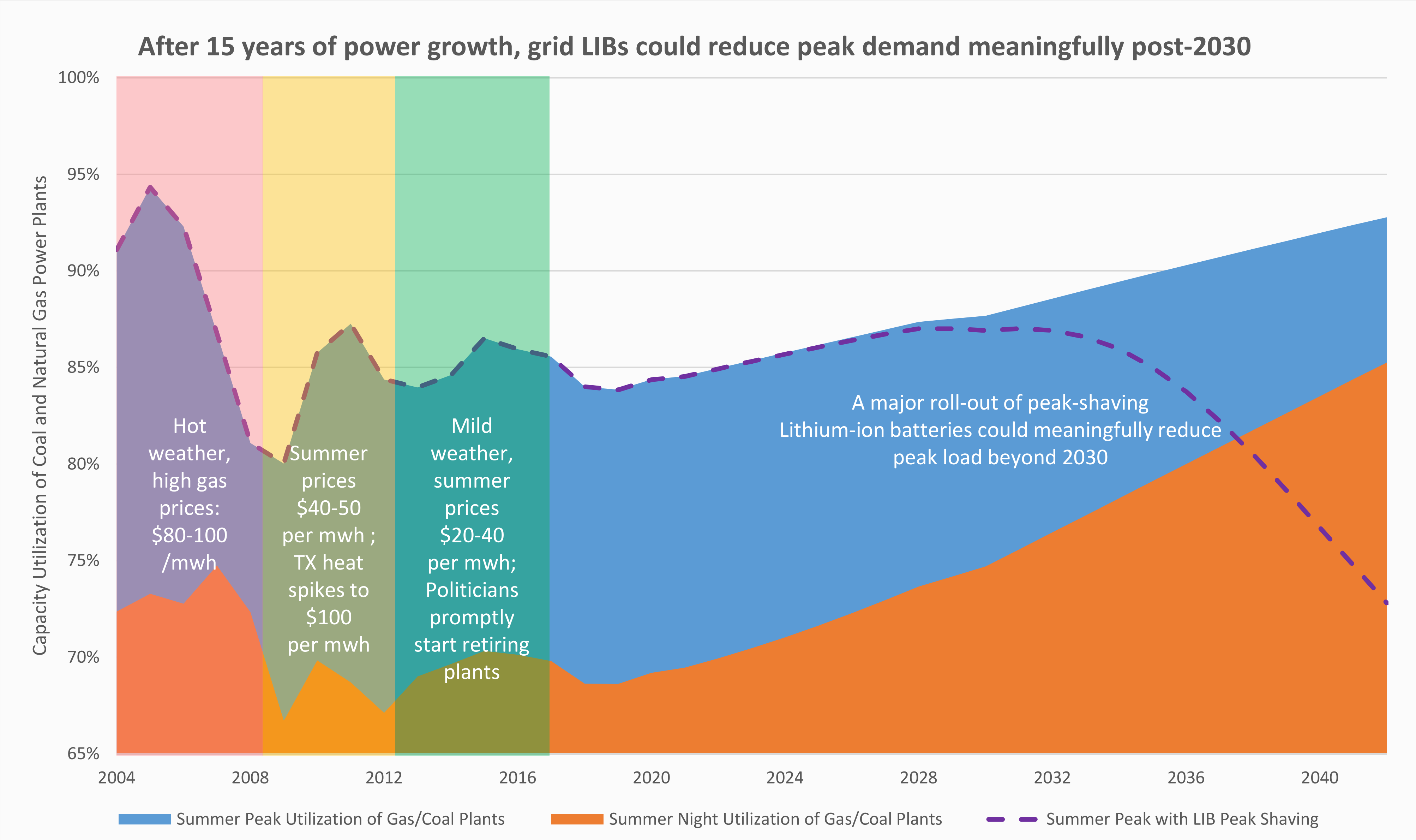

Source: Recurrent research.
Notes: Total generation capacity assumed flat between 2017 and 2042. Capacity through 2021 based on EIA projections; coal retirements continue at 3% annually, gas grows 1% annually, nuke and oil retire at 3% annually, wind grows 3% annually, solar grows 7% annually.
Base power demand grows 0.2%, EV demand modeled separately. Summer peaks are 170% of average, summer nights 115% of yearly average. To calculate need for fossil fuels, we assume solar runs 25%, wind 34%, nukes 95%, hydro 40%.

info@recurrentadvisors.com

Now for the 95 million barrel-per-day question…

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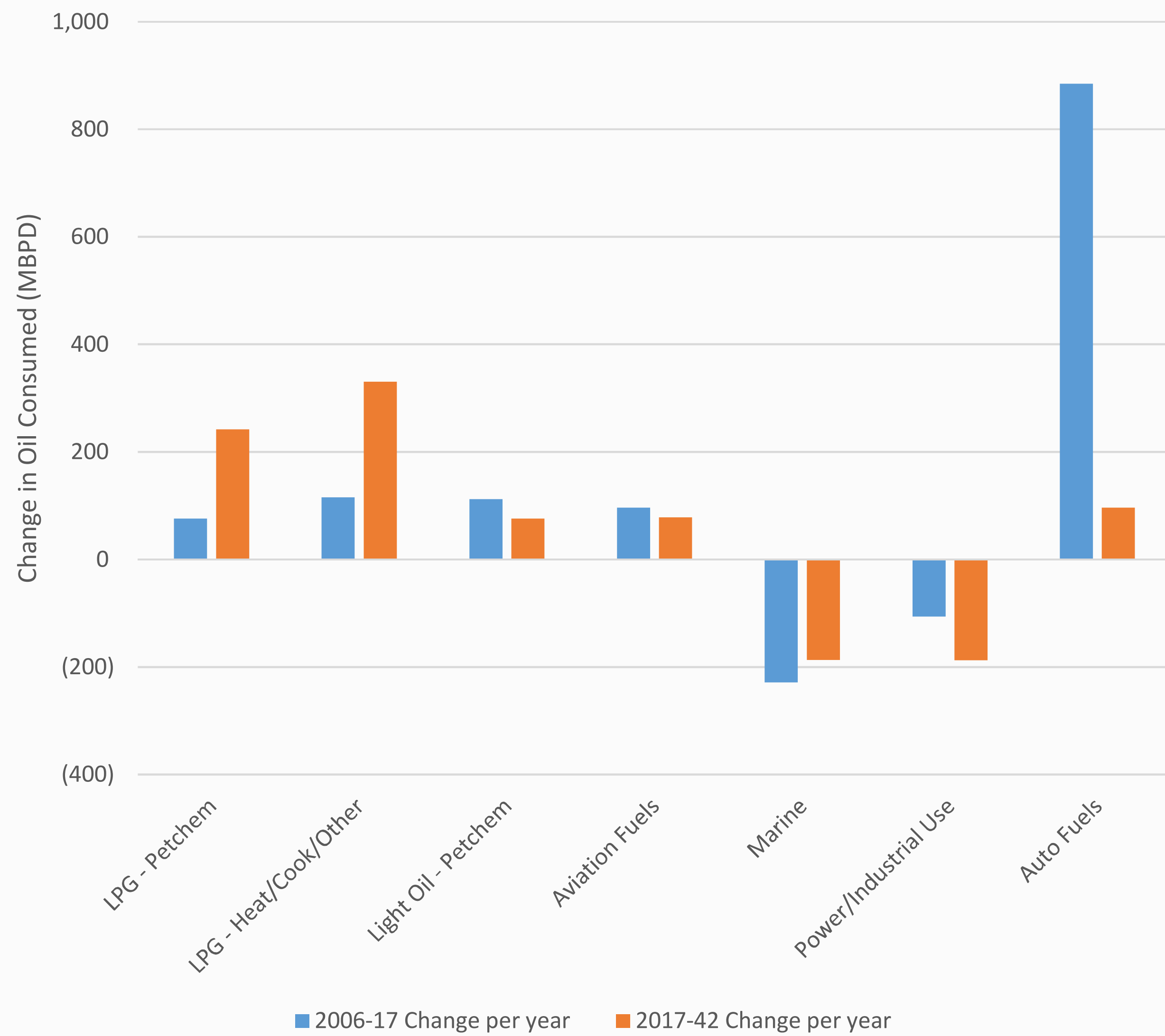
OIL GROWTH DECLINES 50% FROM LAST 10 YEARS TO NEXT 25, MARKET STABILIZES AROUND 106 MMBPD

- We see next 25 years average growth at 400-500 MBPD per year, vs. 1 MMBPD of average growth over the past decade.
- The electric vehicle meaningfully slows oil demand growth, particularly in 2020-2030. Demand growth actually reaccelerates in 2030s as mineral shortages, increasing power prices depress EV demand.
- While auto demand growth slows meaningfully, light oil and LPG grows meaningfully, specifically in petrochemical and portable fuel applications. Aviation fuels also continue to grow along with GDP.
- Meanwhile, heavier, dirty-oil applications, such as marine fuels and petroleum-based power plants (already <5% of global power generation), continue their decline as they are displaced primarily by natural gas.
- As we discuss on the following slides, this 50% decline in oil demand growth translates to a roughly ~15% decline in average annual investment in the oil and gas industry, due to the continued need to replace global oil production declines.

The next 25 years of oil growth will be much more modest than the last 10, with demand peaking in late 2030s



Source: IEA, EIA data. Recurrent research.

We made it this far, and EVs aren't the main driver of falling demand?

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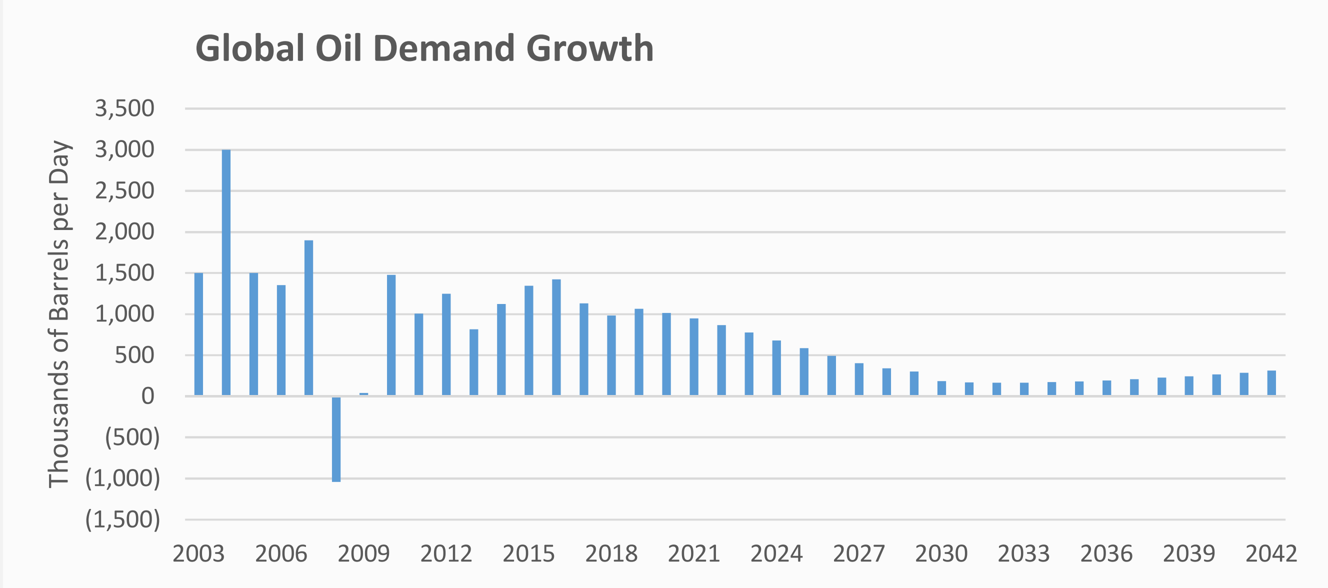
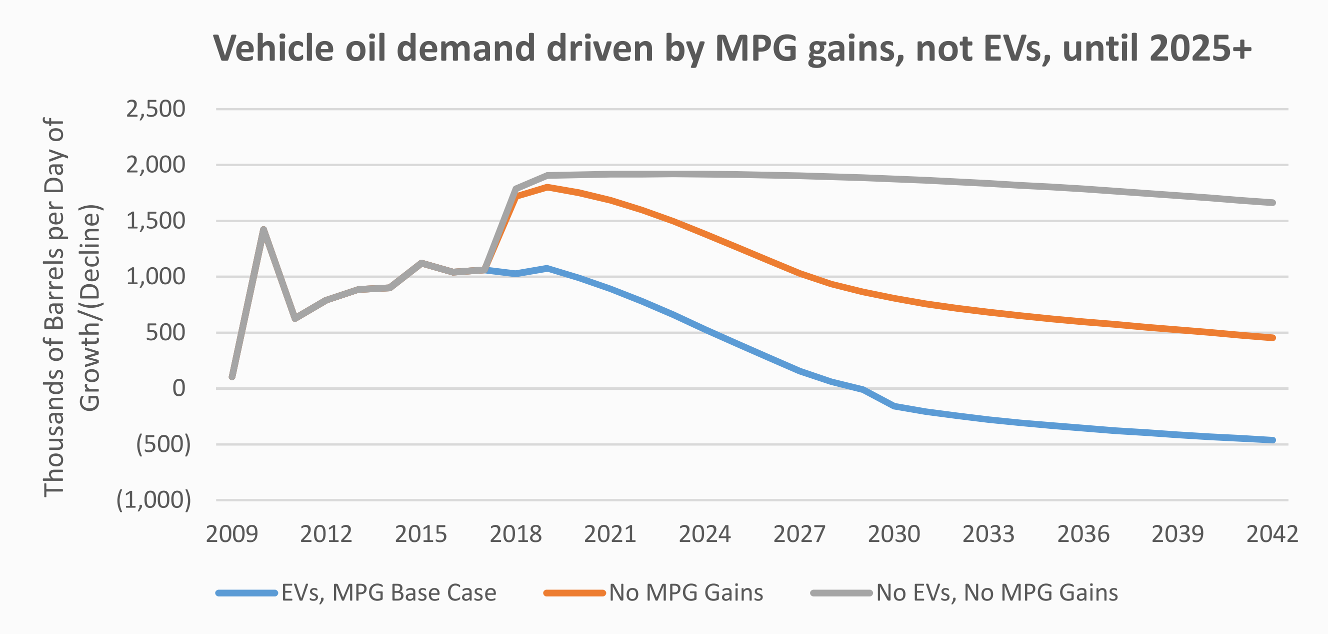
The answer to the question above is: ***"not for another decade."***

The EV has attracted the vast majority of attention when it comes to the expected decline in oil demand growth, but simple math tells us that it's efficiency of ICEs, not the introduction of EVs, that drive declining oil demand

STRUCTURAL DRIVERS OF PEAK DEMAND

- The global oil market is roughly 95 million barrels per day, with approximate growth of 1 million barrels per day *(a lot of ink is spilled arguing whether it's less than 1.0, 1.2 million, or something higher… we'll spare you and assume an even 1 million).*
- 60% of global oil demand goes towards automobile transportation today. Accordingly, a 1.5% annual improvement in ICE efficiency reduces demand by 0.9% *(the last 10 years have seen 20% improvement in the US)*
- Roughly 0.2% of the global fleet is electric. A doubling in total EVs on the road *(very different from doubling EV sales)* reduces oil demand by 0.2%.
- Accordingly, as we see in the graph at lower right, the impact of ICE fuel economy is the dominant driver until roughly 2025, when EVs reach 5-6% of the global fleet.





Source: IEA, EIA data. Recurrent research.

info@recurrentadvisors.com

Significant oil investment is needed even if growth falls to zero

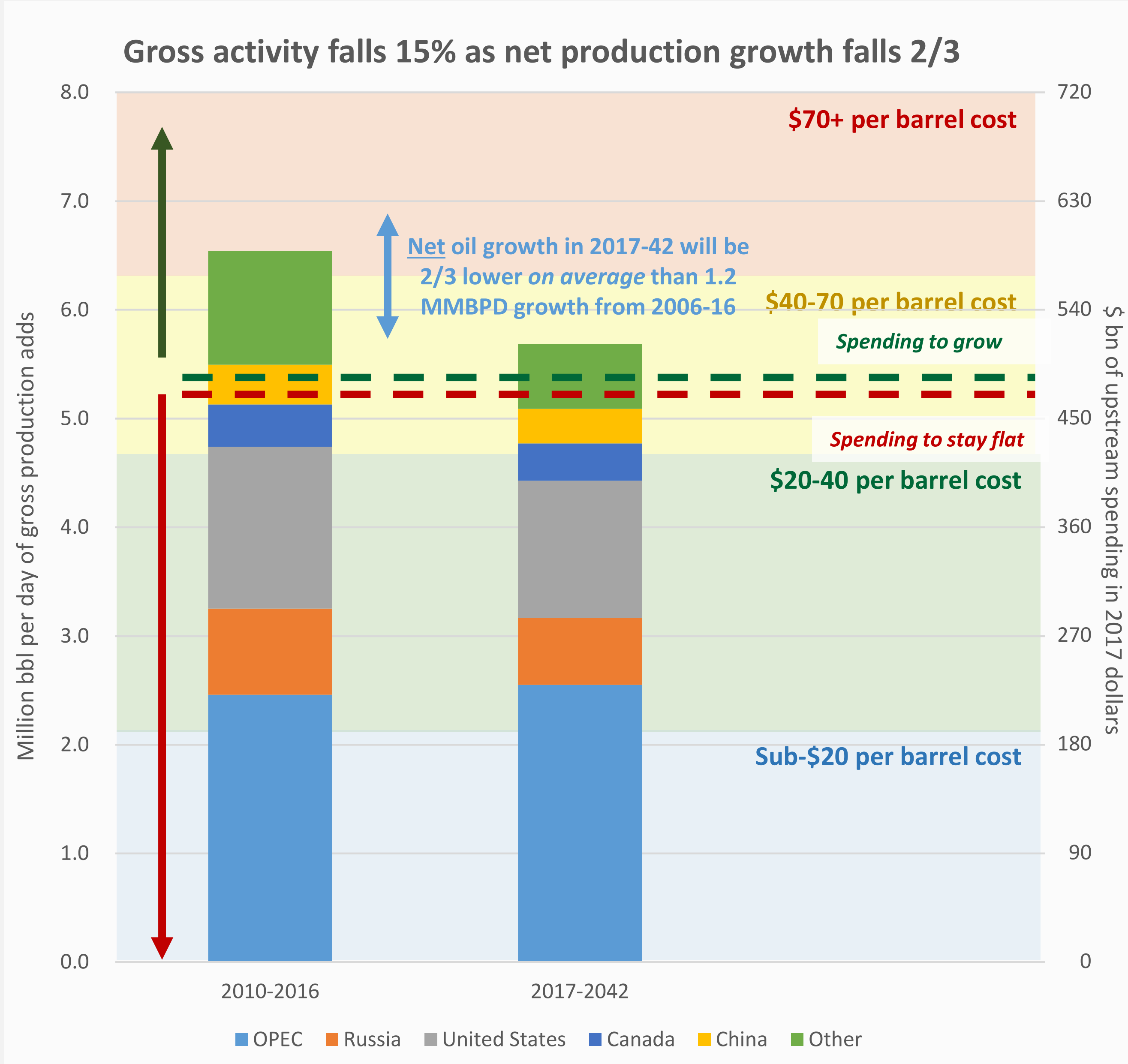
RECURRENT INVESTMENT ADVISORS

The bitter irony is that the concept of "Peak Demand" is based on an inversion of "Peak Oil," a decades-old term describing the threat of sky-high prices to oil consumption

With sky-high prices far from investors' minds, it's worth remembering that 80% of oil investment is dedicated to sustaining, not growing the market.

SUPPLY DECLINES – THE NEXT BEST THING TO DEMAND GROWTH

- For much of the last decade, the developed world has grappled with too much stuff –a decade ago we had too many houses, and today investors are fixated on too many stores, too many malls, too few shoppers.
- With scarcity itself in short supply, investors have turned their backs on the oil industry – it's an industry that does best in times of scarcity. In an "everything available with next day delivery" economy, oil supply is out of sight and mind.
- But unlike many resources, oil has a unique attribute – it disappears on its own. Every year, the world's oil supply declines by 5 million barrels. Growth is approximately 1 million barrels.
- As we debate zero oil growth, we aren't even discussing 80% of activity, only the 20% tip of the iceberg.



Source: IEA, EIA data. Recurrent research.

info@recurrentadvisors.com

A final word on the future of the EV and energy consumption

RECURRENT INVESTMENT ADVISORS

On the preconditions for EV market growth

- **EV SHARE** will grow meaningfully from ~0.5% today. We think our forecast – 20% of the global auto fleet is EV by 2040 – is (intentionally) aggressive. There are many more ways for us to miss that forecast than to exceed it.
- **EV GOLDEN AGE** is here for several more years. EVs are less than 1% of sales; demands on minerals and electricity have only started to increase. Excess capacity depresses wholesale power in the OECD, and mines are ramping.
- **EV COSTS** must be significantly lower (>30% savings) to <u>phase out</u> ICEs. Even assuming future efficiencies, this is highly unlikely. Some think that autonomous ridesharing will catalyze EV share. However, EVs are high-cost fleet vehicles, and ridesharing itself (outside cities) remains massively lossmaking.
- **EV COSTS** are roughly 40% battery/electronics today, vs. an engine as 20% of an ICE. We assume EV manufacturing efficiencies, but cost parity vs. ICEs by 2030 is hard to reach. Mineral supply puts cost pressure on EVs in 2020s.

On the future impacts of EV market growth on the energy market

- **MINERALS** like lithium (and cobalt) need to increase supply in a manner never before seen in the history of human resource extraction (10x in 20 years), just to support a 20% EV fleet (including replacement and grid batteries).
- **POWER/GAS** demand from EVs will grow (with plant utilization) over the next 20 years, particularly at night. This will be disproportionately natural gas generation, given coal and nuke retirements.
- **POWER** from intermittent renewables (reducing profits without meeting peak demand) will create higher-cost power and less reliable grids. Batteries will not be a solution for grids until 2035+.
- **OIL** demand <u>growth</u> declines 2/3 over the next 20 years. Annual upstream activity will have to decline by roughly 15-20% (since growth represents <25% of investment, and production replacement is >75% of investment).
- **OIL** moves from a "growth" market to a "steady state" market over the next 20 years, with demand growth replaced by (mainly natural gas-powered) electricity (30 bcf/d global EV demand by 2040).
- **OIL INVESTMENT** continues to be focused on shorter lead time assets with higher success rates (unconventional resources), leading to continued investment in shale assets in North America as we remain in $40-70/bbl range.

info@recurrentadvisors.com