RAPID SUBSTITUTION

Source Paper

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Rapid Substitution

Rapid substitution is an approach that will dramatically lower fuel prices with only a small reduction in oil consumption.This approach to an energy transition requires a concerted combination of renewable energy investments, government policies, and popular demand.

Based on past oil market shocks, we have observed that only a five percent (5%) reduction in oil demand will result in a fifty percent (50%) decrease in price, saving energy users, consumers, and commercial sectors billions of dollars in energy costs.

Rapid Substitution isn't just good for consumers—by lowering oil prices, rapid substitution also discourages future oil production, keeping billions of barrels of oil in the ground. Rapid Substitution also provides the government with an opportunity to generate hundreds of billions of dollars in revenue which can be invested in green energy technologies, thus accelerating the transition to renewable energy.

How Rapid Substitution Affects Oil Demand

Oil Supply

To understand why this works, it's important to grasp oil's supply curve. Consider that the amount of oil that can be produced at any given time is *relatively* fixed due to a couple of factors. First, there is a certain amount of oil that can be easily extracted from the ground - much of which has existing infrastructure built around it. Second, it takes time to explore for oil and build new production infrastructure - consequently, in the short-term, large increases in demand have a relatively muted effect on the quantity of supply. Instead, increased demand succeeds merely in driving up price, as desperate consumers compete for the last, marginal barrels of oil.

The nature of oil production makes the supply curve appear like a sideways hockey stick: there is a 'handle' portion of the graph, where a gradual increase in price is met by a gradual increase in production (and defined by the world's more easily extracted oil), followed by a 'blade' portion, where the curve turns sharply upwards, demonstrating the increasing difficulty and expense of pumping more oil from the ground. In the blade portion, producers require higher prices in order to undertake the much more costly exploration and production of oil—examples include tar sands, deep water, and arctic.[1] At some point, supply hits a wall where no amount of price increase will result in further, near-term production capacity. This is demonstrated by the chart below.

The fact that tar sands and other, unconventional methods of oil extraction have become an increasing portion of global production since 2000 (when prices shifted skywards) tells us something about both the exigent nature of oil demand and the increasing difficulty and expense of oil production.

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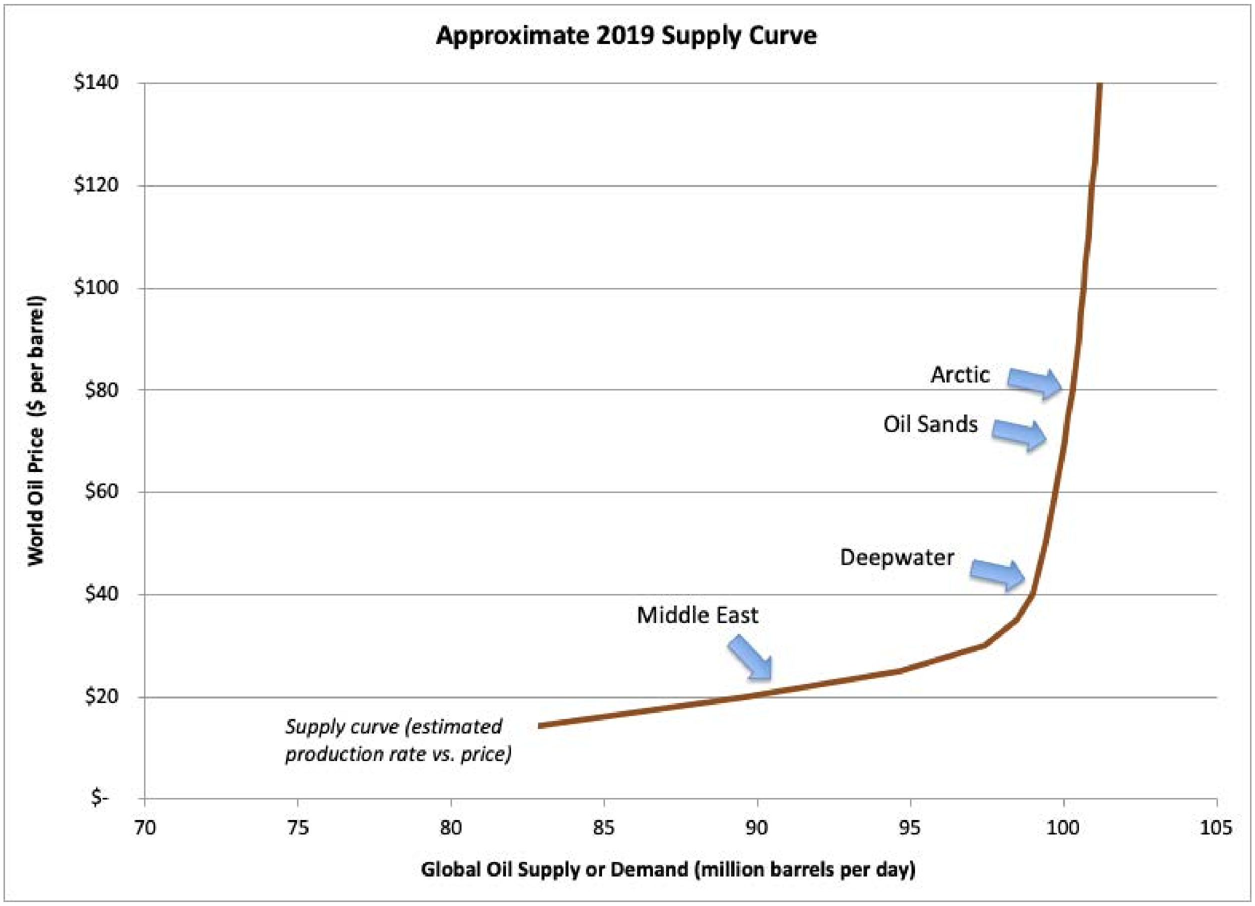
1 https://energynorthern.com/2020/10/22/oil-production-costs-reach-new-lows-making-deepwater-one-of-the-cheapest-sources-of-novel-supply/



Source: EIA, Rystad Energy, Skibo Energy Analysis

Oil Elasticity—A Brief History

One metric for understanding the effect of a drop in demand on price is the 'demand price elasticity'. Recent history makes clear that a relatively small, short-term drop in oil demand leads to an exponential drop in price.

We saw evidence of this in 2008 when, over a six-month period, a 3% drop in demand[2] led to a 70% drop in price[3], and again, in the Spring of 2020, when a sudden decline in demand briefly resulted in negative oil futures.[4] But these were short-term shocks, which caught suppliers off guard, and therefore don't provide a clear picture of how the market might respond to a more gradual and expected decline in oil demand (such as will occur through the adoption of EVs).

If a similar, albeit more gradual, drop in oil demand results in a likewise disproportionate price drop (utilizing the Long-Term Elasticity figure), we would expect oil prices below $30 by 2030. For that we must look back to the 1970s, when the introduction of vehicle efficiency standards

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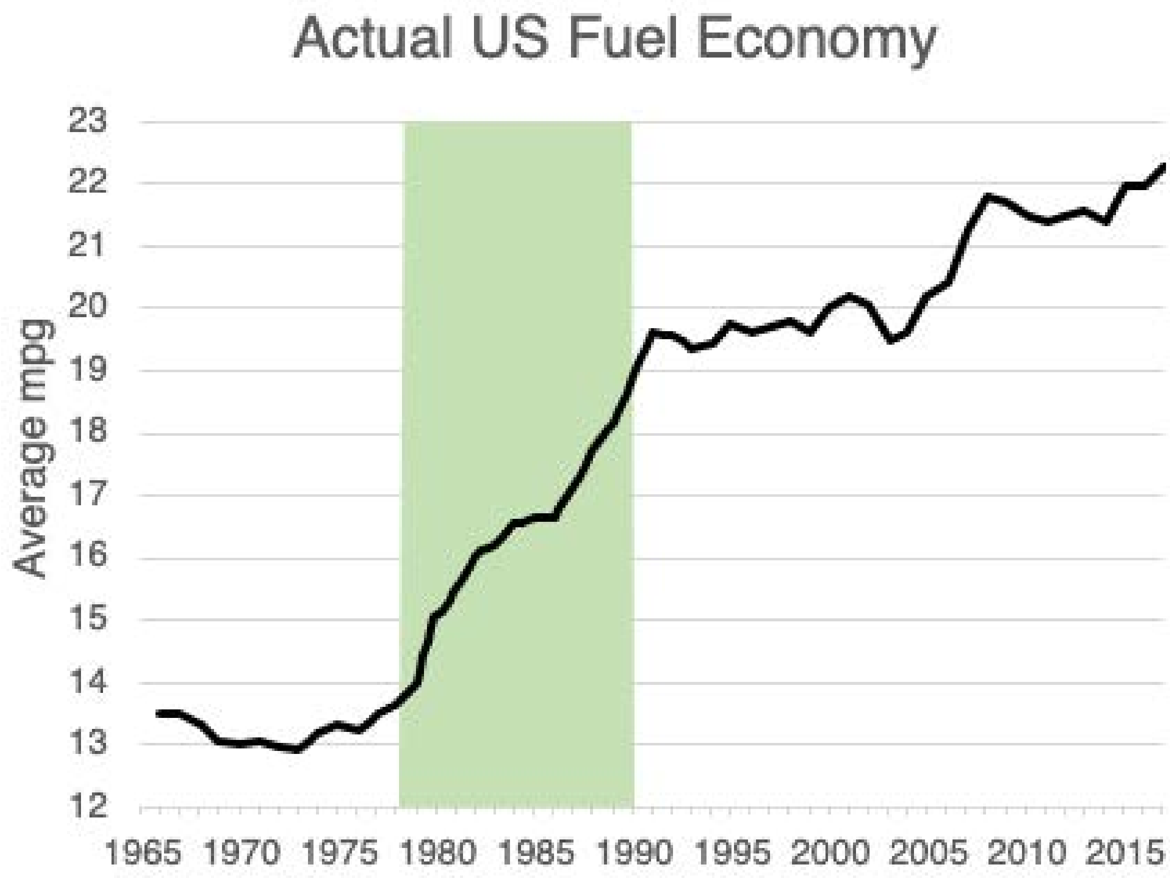
2 https://www.eia.gov/international/data/world/petroleum-and-other-liquids/monthly-petroleum-and-other-liquids-production;%20https:=

3 https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=RWTC&f=M

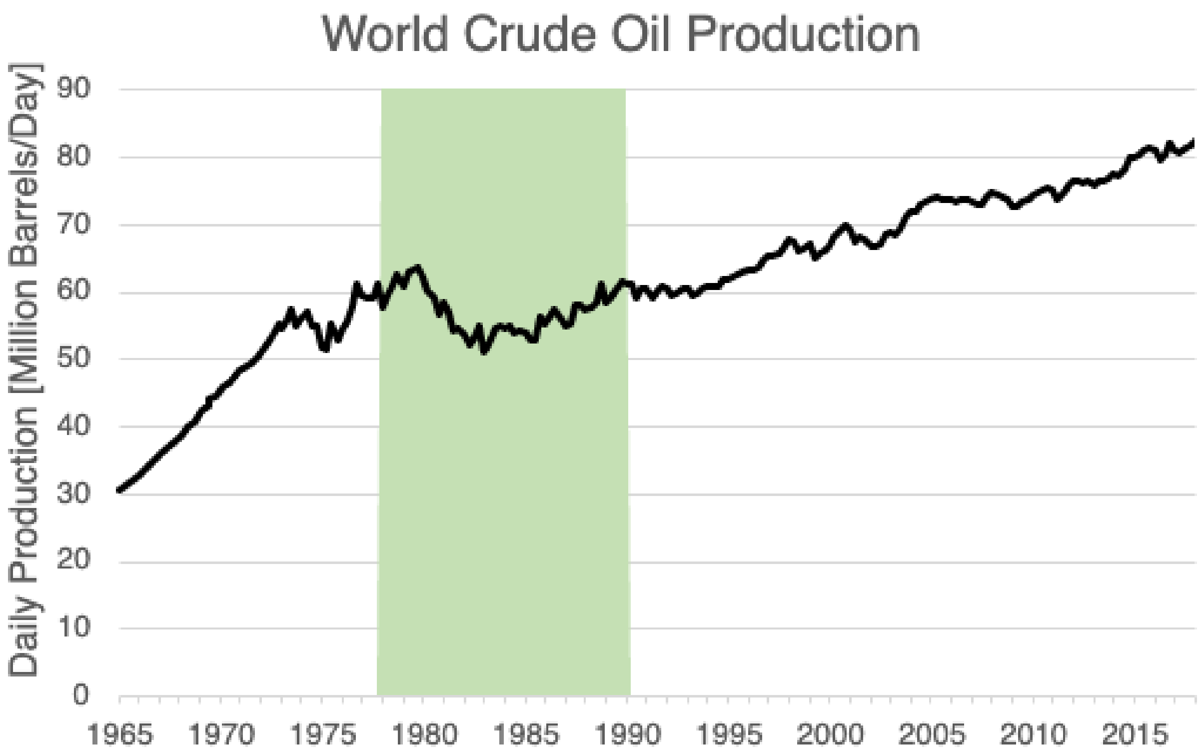
4 We assume production = demand, since storage volume is relatively marginal.

(officially, the Corporate Average Fuel Economy standards or CAFE) contributed to a sharp decline in oil demand, resulting in lower oil prices for decades. In the three graphs below, the green column highlights the twelve-year period following the introduction of CAFE standards, demonstrating the close correlation between changes in the US fleet's efficiency, global oil production and price.



Source: USDOT[5]

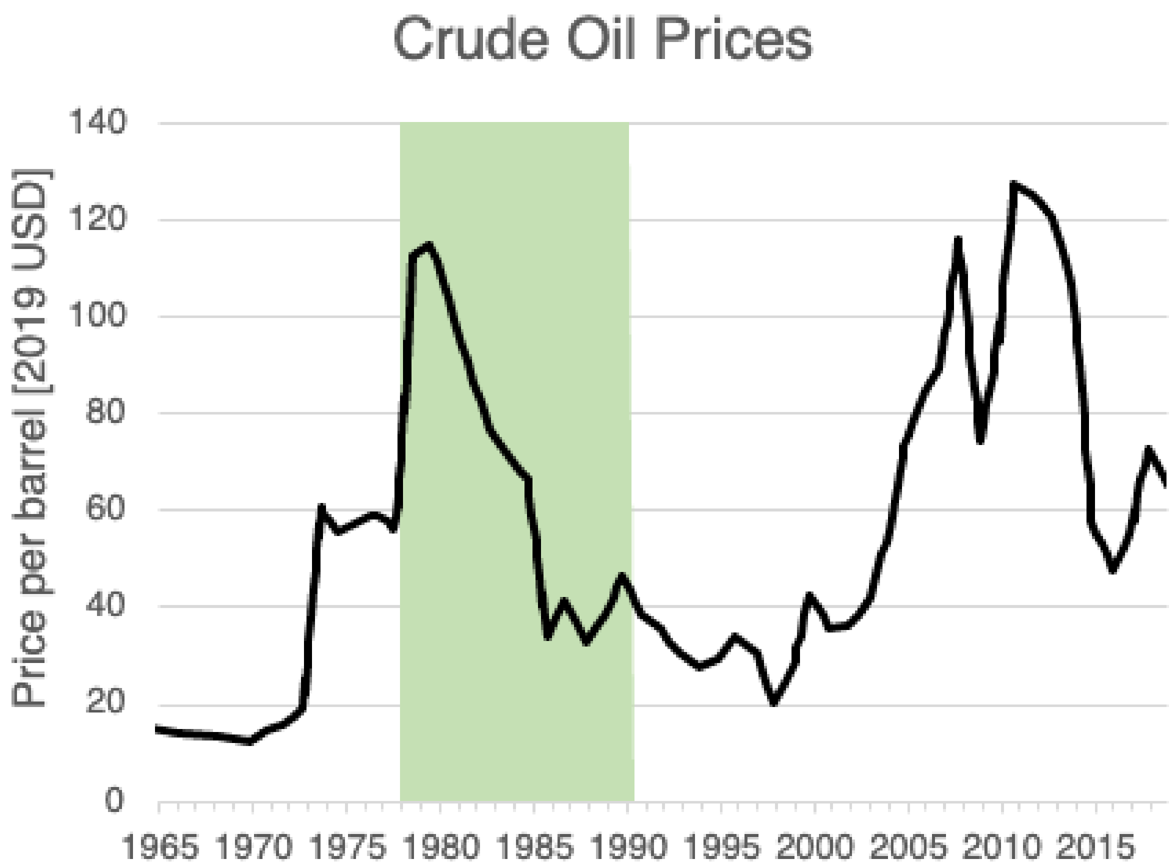
[5] https://rosap.ntl.bts.gov/view/dot/8381



Source: EIA (for period 1973-2017)[6], Hook, Michael (for period 1965-1973)[7]

[6] https://www.eia.gov/international/data/world/petroleum-and-other-liquids/quarterly-petroleum-and-other-liquids-production?pd=5&p=0000000000000000000000000000000000vg&u=0&f=Q&v=mapbubble&a=-&i=none&vo=value&t=C&g=00000000000000000000000000000000000000000000000001&l=249-ruvvvvvfvtvnvv1vrvvvvfvvvvvvfvvvou20evvvvvvvvvvnvvvs0008&s=94694400000&e=1601510400000&

[7] https://www.researchgate.net/publication/46496655_Giant_oil_field_decline_rates_and_their_influence_on_world_oil_production



Source: BP Statistical Review of World Energy 2021[8]

First implemented in 1978[9] in response to declining U.S. control of oil (and oil prices), CAFE standards were intended to double the average fuel economy of the new passenger vehicle fleet—a gradual process, implemented over a roughly twelve-year period. By regulating for more efficient vehicles, and therefore lowering fuel consumption, CAFE standards eventually helped drop oil demand (and production) by about 20%.[10] In the same period, prices[11] gradually fell from a high of $120 per barrel in 1980 to below $40 (inflation adjusted), where they would remain

[8] https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html
[9] https://www.ucsusa.org/resources/brief-history-us-fuel-efficiency
[10] Declining production during this period has also been attributed to economic recession. This would seem an inadequate explanation considering this period also saw economic boom times and that the recession of the early 80's was relatively short-lived. A long-term, gradual improvement in the American fleet's efficiency would seem a more appropriate explanation for a long-term, gradual depression in oil production matching the same time period as the implementation of CAFE standards.
[11] https://www.eia.gov/dnav/pet/hist/RCLC1D.htm

until the 2000s.[12] In other words, a long-term, 20% drop in demand was accompanied by a 70% drop in price. (It's worth noting that during the first years of the new standards, OPEC curtailed production in an effort to defend higher prices—a strategy they were eventually forced to abandon in the mid 80s, resulting in prices briefly falling below $24 per barrel).[13, 14]

In consideration of the events of the 1980s, and an IMF study[15] suggesting that a one percent (1%) drop in long-term demand will result in a fourteen percent (14%) drop in long-term price, Skibo estimates that a drop in demand of about five percent (~5%) over the course of several years will result in a roughly fifty percent (50%) drop in price. We believe this is a conservative estimate, and that savings could be far greater—in part, depending on how fast we transition to oil-alternatives.

Oil demand took a serious hit in 2020, setting up what we believe will be a more permanent shift in the dynamics of oil supply and demand. As renewables begin to replace fossil fuels at a faster clip in a process we call 'Rapid Substitution,' demand for petroleum products will buckle, plummeting oil prices.

Let's consider the example of electric vehicles...

Electric Vehicles as a path to 5%

If we assume that every EV sold represents an internal combustion engine (ICE) vehicle not driven, then we can conclude that EVs cause a negative effect on the demand for oil, commensurate with the oil needs of the ICE vehicle foregone. In this way, the replacement of ICE vehicles with EVs causes a downward pressure on oil price. So how many EVs will it take to significantly reduce the price of oil and thus create massive savings for oil consumers?

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[12] "Initially, all major oil price fluctuations were thought to reflect disruptions of the flow of global oil production associated with exogenous political events such as wars and revolutions in OPEC member countries (for example, Hamilton 2003).1 Subsequent research has shown that this explanation is only one among many, and not as important as originally thought. In fact, most major oil price fluctuations dating back to 1973 are largely explained by shifts in the demand for crude oil (for example, Barsky and Kilian 2002, 2004; Kilian 2009a; Kilian and Murphy 2012, 2014; Bodenstein, Guerrieri, and Kilian 2012; Lippi and Nobili 2012; Baumeister and Peersman 2013; Kilian and Hicks 2013; Kilian and Lee 2014)." Baumeister, Christiane and Kilian, Lutz. "Forty Years of Oil Price Fluctuations: Why the Price of Oil May Still Surprise Us." *Journal of Economic Perspectives*, Vol. 30, No. 1, Winter 2016, pp. 142
https://pubs.aeaweb.org/doi/pdf/10.1257/jep.30.1.139

In Skibo's view, while economic recession in the early 1980's put downwards pressure on prices, the sustained low prices—lasting decades—can more accurately be explained by long-term changes to demand brought about by vehicle efficiency standards. One key point is that while the US's share of vehicle sales is by itself significant, the influence that US efficiency standards have on global production, via their large purchasing power, is far more significant—in fact, capable of restructuring global oil demand. The introduction of new oil sources, in places such as Mexico and Norway, were mostly significant in terms of distributing production away from OPEC's base of control. The new sources, however, did not significantly impact net supply, as shown by historical global production data.

[13] Inflation adjusted.

[14] Baumeister, Christiane and Kilian, Lutz. "Forty Years of Oil Price Fluctuations: Why the Price of Oil May Still Surprise Us." *Journal of Economic Perspectives*, Vol. 30, No. 1, Winter 2016, pp. 146
https://pubs.aeaweb.org/doi/pdf/10.1257/jep.30.1.139

[15] https://www.eia.gov/dnav/pet/hist/RCLC1D.htm

In 2020, global sales of electric vehicles[16] (BEV + PHEV) rose by 43% to more than 3 million units (representing 4.2% of the total car market and despite an overall 20% decline in car sales generally). Most of that growth was seen in Europe and China[17], but as the U.S. market begins a more calculated pivot towards electrification, led by government regulations, legacy automakers, and new EV manufacturers (e.g., Tesla, Rivian), one can expect sales to climb at increasing speeds. A relatively conservative forecast[18] by Deloitte (mid-2020) has US EV sales rising to 27% of market share by 2030. Considering that US transportation accounts for roughly 13.5% of global oil consumption[19] (60% of which is personal vehicles), Deloitte's forecast equates to a greater than 3% drop in global oil demand by 2030 *caused by US EV sales alone*.

That number doesn't account for the possibility of an even more energetic transition fueled by a Biden presidency (the study was done prior to the 2020 election). Catalysts for faster substitution could include Biden's call for an all-electric Federal fleet[20], his infrastructure bill[21], which includes funding for 500,000 EV chargers, or the Clean Transit bill[22] recently introduced by Senators Shumer and Brown. Other policies[23] that would expedite Rapid Substitution include renewable fuel mandates, efficiency standards, the elimination of inefficient fossil fuel subsidies, direct emissions reduction regulations, and continuing federal and state incentive programs for EV consumers and producers. Similar global rapid substitutions will make the transition even faster.

If we take a 50% reduction in oil price as our goal, then we require that enough EVs are sold to reduce demand for oil by 5%. (As suggested in the last section) 5% of all oil produced in 2019—the last year for which we have "normal" data—is *1.8 billion barrels*. A typical ICE vehicle uses between 11.3 (cars) and 15.6 barrels (pickup trucks and SUVs) of oil each year, depending on the type of vehicle.[24] Considering current buying preferences[25]—assuming 72% of EVs sold will replace an ICE truck or SUV and 28% will replace a car—*we predict it would take selling 126 million EVs (91 million trucks and SUVs and 35 million cars) to drop oil demand by 1.8 billion barrels* (or 5% of 2019 demand), pushing oil prices below $35 per barrel.[26]

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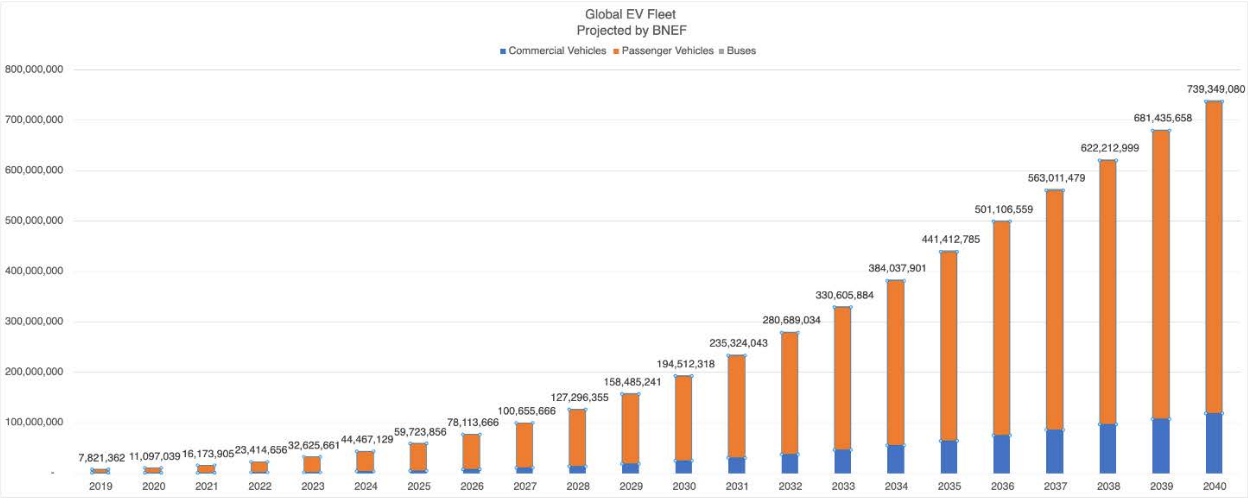
[16] https://www.ev-volumes.com/
[17] https://www.iea.org/commentaries/how-global-electric-car-sales-defied-covid-19-in-2020
[18] https://www2.deloitte.com/us/en/insights/focus/future-of-mobility/electric-vehicle-trends-2030.html
[19] https://www.eia.gov/energyexplained/oil-and-petroleum-products/use-of-oil.php
[20] https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/
[21] https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/31/fact-sheet-the-american-jobs-plan/
[22] https://www.brown.senate.gov/newsroom/press/release/schumer-brown-unveil-new-clean-transit-plan
[23] https://iea.blob.core.windows.net/assets/063ae08a-7114-4b58-a34e-39db2112d0a2/NetZeroby2050-ARoadmapfortheGlobalEnergySector.pdf
[24] Barrels consumed each year depends on the type of ICE vehicle considered. Trucks and SUVs have lower fuel efficiencies than cars and thus have a greater effect on oil demand (and 'negative demand'); both cars and light trucks drive approximately 11,500 mi/year.
[25] https://www.autonews.com/data-lists/us-total-vehicle-sales-make-q4-ytd
[26] 1,800,000,000 = .28X*11.3+.72X*15.5

Using BloombergNEF's Electric Vehicle Outlook 2021[27], *we expect there to be at least this number of EVs on the road by 2029*. With supportive government legislation around the globe, manufacturers may reach this milestone even earlier, especially in consideration of recent, large (and increasing) investments by legacy auto manufacturers[28], new startups[29], and Tesla[30] in EV production.



Source: BNEF Electric Vehicle Outlook 2021[31]

Calculating & Capturing Return on Investment

In 2019, the world spent an astonishing $2.4 Trillion on oil - The average price of a barrel of oil was $64 and average consumption was 101 Million barrels per day. [32] The US spent around $479 Billion on oil in 2019. That's based on an average price of $64 for a barrel of oil and domestic consumption of 20.5 Million barrels per day.[33]

Again, based on the historical evidence and industry analysis in the previous section, we estimate that a 5% reduction in oil demand will lead to 50% reduction in oil prices. Global oil consumption in 2019 was 101 million barrels per day so a 5% reduction in oil demand is just over 5 million barrels per day.

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27 https://about.bnef.com/electric-vehicle-outlook/

28 https://www.cnbc.com/2021/06/16/gm-ups-spending-on-evs-and-autonomous-vehicles-to-35-billion-by-2025.html

29 https://www.cnbc.com/2021/03/18/amazon-begins-testing-rivian-electric-delivery-vans-in-san-francisco.html

30 https://tesla-cdn.thron.com/static/R3GJMT_TSLA_Q1_2021_Update_5KJWZA.pdf?xseo=&response-content-disposition=inline%3Bfilename%3D%22TSLA-Q1-2021-Update.pdf%22

31 https://about.bnef.com/electric-vehicle-outlook/

32 https://www.eia.gov/outlooks/steo/report/global_oil.php

33 https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=MTTUPUS2&f=A

There are many potential pathways to achieve this reduction such as by large percentages of Class 8 (semis) trucks, delivery trucks or municipal vehicles (garbage trucks, city buses etc.) moving away from diesel fuel. However, for the sake of making the math easier to follow let's use the example of electric passenger cars replacing ICE cars.

Financial Implications of Electric Vehicles

As we laid out earlier, It would take 126 million cars (or 90 million light trucks/SUVs and 36 million cars) switching from ICE to electric to reduce oil demand by 5% from 2019.

Since the world economy spent around $2.4 Trillion on oil, replacing 170 million ICE passenger cars with electric cars results in 50% savings on oil products, which means the world economy will save roughly $1.2 Trillion each year from the widespread adoption of electric vehicles. Similarly since the US economy spends $479 Billion annually on oil products a 50% reduction would save consumers around $240 Billion. That works out to an annual benefit per vehicle of around $7,000 globally or $1,400 domestically. Over 10 years that's $70,000 per car globally and $14,000 domestically. Naturally, the benefit is larger with the more fuel the vehicle consumes - so vans and trucks switching from gasoline powered to electric would have a bigger financial benefit.

To be clear, using the example of 126 million ICE cars and trucks being replaced by electric cars and trucks is just an example. If, for example, you only replaced ICE cars with EVs, it would take 170 million vehicles to affect the desired 5% decrease in oil demand. In reality, the 5% decrease in oil demand will come through some combination of passenger cars and SUVs, trucks of all sizes, lifestyle changes like biking instead of driving, and industrial uses. It also won't happen in the US alone as countries from China to Germany continue to increase their rate of electric vehicle purchases.

These numbers are also averages and there are several caveats worth further explaining. First, EVs sold today will drive most of their lifetime miles prior to the 5% threshold we predict will produce 50% in savings for oil consumers. But that doesn't mean that EVs sold today won't affect oil prices. To the contrary, the first 1% drop in demand has a greater effect on price than successive percentage drops, as determined by the shape of the supply curve.[34] That being said, it will require a certain 'threshold' number of EVs sold before price is really affected. That's because negative demand must outpace increased positive demand, and push past the ability of both storage and curtailment to bolster higher prices.

The widespread adoption of electric vehicles and associated drop in oil prices provides massive savings to consumers while also presenting a unique opportunity for the federal government to raise revenue.

How to Raise $850 Billion over Ten Years

Rapid Substitution presents an opportune moment for the United States Federal Government to raise billions in revenue without using much political capital. If Congress set a price floor that is automatically implemented when the price of oil drops below a certain price (perhaps $50/barrel), consumers would barely notice since they would be happily paying a low price for

[34] https://www.skiboenergy.com/post/are-we-approaching-a-permanent-collapse-of-oil-prices

gas and the federal government would raise billions of dollars which could be spent on additional clean energy investments.

Here's the math: In 2019 American consumers (included businesses and government entities) spent around $479 Billion on oil products ($64/barrels*20.5million barrels/day*365). When the price of oil drops by 50% to $32/barrel they will be paying around $240 Billion for their oil and saving another $240 Billion!

The federal government could then implement a floor on the price of oil that would be triggered as the price of oil fell below a specific price. Using $50 as an example, the government would be able to collect the difference between $32 and $50. That's $18 per barrel. In this scenario US oil consumption will have dropped from 20.5 million barrels per day to 15.5 million barrels/ day. At 15.5 million barrels/day this would raise $279 Million per day or over $100 Billion/year. Over a decade, that's a Trillion dollars that could be spent to fund clean energy, child care, or any other political priority.

If the federal government implemented a price floor of $50 it would raise $85 Billion/year ($15/barrel*5.7 billion barrels)! While several factors like taxes, refining and distribution costs impact prices at the pump, a price floor of $50 would leave consumers satisfied with low gasoline prices.

Unlike traditional carbon taxes, a price floor on oil is unlikely to cause public outrage. As oil prices fall to $50/barrel consumers will be satisfied with low prices at the pump and won't be focused on the fact that global oil prices have fallen even lower.

To give a bit of context for what these prices mean for consumers at the pump in May 2017, oil prices averaged around $50/barrel. That month US consumers paid an average of $2.30 for gasoline.[35] In November 2019, the average price of oil was $64 and the price at the pump was $2.50. When the oil price fell to $32 in February 2016 gasoline prices were $1.80. If a price floor of $50 a barrel was implemented then it's likely that gasoline prices would hover around $2.30. This is likely inexpensive enough to pass unnoticed by most consumers.

It's worth noting here that in the United States around 53% of the retail price of gasoline comes from the cost of crude oil. The other 47% comes from refining costs (12%), transportation and retail (18%) and taxes (17%).[36]

An additional benefit to this type of price floor is that it provides more certainty for decision-makers. If an executive is thinking about transitioning their fleet from ICE to electric, a price floor gives them a firm low price upon which to make their decision. Since they are sure that they won't ever again pay less than the price floor, they can better incorporate that information into their decision.

Risks of Rapid Substitution

Meeting the goals of Rapid Substitution will take a lot of work. We argue the US needs a "project manager" for that work - in the form of an organization with the skills and authority necessary to

[35] https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=RBRTE&f=M
[36] https://gaspricesexplained.com/#/?section=whatconsumers-are-paying-for-at-the-pump

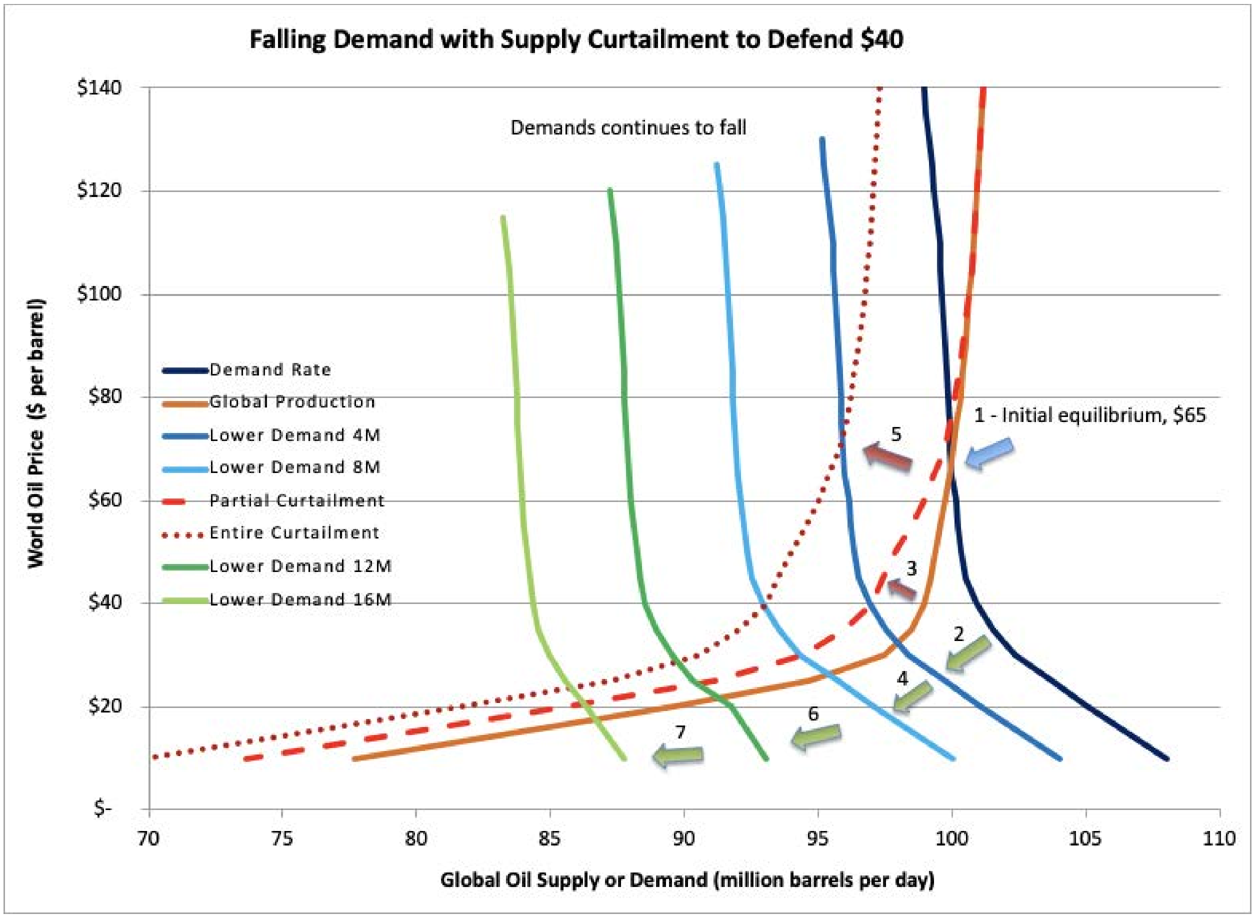
implement the energy transition for the least cost and most benefit to the American People. If the model of establishing a project manager is successful in the US other countries will likely follow to implement the energy transition for the least cost and most benefit for their countries.

There are several risks and complicating factors that can come with Rapid Substitution as well as when the transition is not planned, managed, or sufficiently rapid.

Won't producers respond by curtailing supply to support higher prices?

In the short-term, organized efforts by suppliers to curtail production can effectively rebound prices, as happened in 2009 and again when the price of oil crashed in 2020. But curtailment is only a rational strategy for addressing shocks with relatively short, expected time horizons, such as during an economic crash or a pandemic. That same strategy becomes self-destructive in the face of a prolonged, continuous, and systematic decline in demand, as a revolution in vehicle propulsion represents. In this way, Rapid Substitution is more analogous to the implementation of auto efficiency standards in the late 1970s, which drove oil demand (and prices) down for the next decade as more fuel-efficient cars gradually replaced their gas-guzzling predecessors.

Once suppliers realize that future revenues can only go in one direction, the rational strategy will be to pump while prices remain relatively high, further diluting their premiums - the '*get while the gettin's good'* strategy. This makes sense especially since the lion's share of production costs are up-front capital costs, while the costs of continued operation are marginal. An oil rig, once operational, can continue pumping for decades at marginal cost to the owner, meaning that even without additional supply coming online, existing supply may support lower prices for years to come.



Source: EIA, Skibo Energy Analysis

In the graph above, the initial equilibrium price of $65 (1) is disrupted by a drop in demand by 4 million barrels per day (2). OPEC and other oil producers respond first with a partial curtailment (3), and then, following another 4MBD demand drop (4), with a more expansive curtailment (5) to defend price at $40 per barrel. Demand continues to fall as ICE vehicles are replaced by EVs (6, 7) to some point (5) where, eventually producers are forced to give-up on their strategy of curtailment. Price continues to fall below $30. Notice, in this example, that a roughly 15% drop in demand results in >50% drop in price.

Stranded Assets

For an idea of what those kinds of prices would do to an oil company's bottom line one need only consider the data from 2020, when the average price of a barrel of oil was just $35 (compared to about $52 in 2019). Of the top ten biggest oil companies in the world, only one was profitable under these conditions (Saudi Aramco), and the others weren't even close. At this price, cash flows are unlikely to cover operating costs, and even more unlikely to provide the kind of return on investment that shareholders have grown used to.

Moreover, billions of barrels of oil would become unprofitable to extract, especially from more expensive projects such as Tar Sands and Arctic drilling, meaning companies will be forced to write-off these reserves as "stranded assets" and incorporate the costs of retiring no-longer-viable wells (known as asset retirement obligations or AROs) into their balance sheets.

Such write-downs of an oil firm's key assets—reserves—has a profound effect on valuation and the ability to finance operations and future projects, potentially threatening insolvency. In other words, it’s reasonable for investors and other stakeholders to be worried about their exposure to Big Oil in a changing energy market: the risks are significant and underappreciated.

What about Demand from China

In the twenty years prior to the Covid-19 pandemic, demand for oil rose by an approximate rate of one million barrels per day, every year. Most of that growth came from emerging economies—especially China, which accounted for two-thirds of incremental global oil consumption in 2019.

It’s true that if demand for oil continues to grow at such rates, this may significantly diminish or even cancel out the negative demand generated by just EV adoption. Three factors that may mitigate this headwind include: 1) China is expecting to reach peak oil by mid-decade, joining OECD countries in their declining demand; 2) new sources of oil will continue to enter the market, bolstering supply and depressing prices, since exploration of oil wells often takes decades and represents most of the cost of production (the sunk costs ensure eventual production at almost any price); and 3) more aggressive regulation of oil consumption will lead to faster negative demand — and therefore Rapid Substitution.

Further, it’s worth noting that our analysis centers around passenger vehicles alone—and does not include the negative demand generated by other sectors of the economy, such as residential heat generation. Aviation fuels, petrochemicals, and other industrial and commercial processes.[37]

Broader Significance - Rapid Substitution pays social dividends

The implications of Rapid Substitution’s effect on oil prices are wide-ranging. While many are familiar with the catastrophic futures an energy revolution helps to foreclose (e.g. climate change, pollution, and continued oil exploration in some of the world’s most sensitive ecosystems), few recognize the savings that Rapid Substitution generates for consumers in the form of lower energy costs.

While today most oil is sold well above its cost of production (remember, price is set by the most marginal production required to meet demand) and generates tremendous profits for its owners, in the future those profits will be displaced, instead manifesting as lower oil costs for all. The rise of electric vehicles presents an opportunity for consumers to save billions of dollars in fuel costs and for the federal government to raise a trillion dollars, while avoiding the most environmentally destructive oil production.

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[37] https://www.eia.gov/energyexplained/oil-and-petroleum-products/use-of-oil.php