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THE UNINTENDED CONSEQUENCES OF HIGH GRADING

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"The base decline production rate for the Permian Basin has increased dramatically, and we expect those declines to continue to accelerate." Raoul LeBlanc, IHS Market December 12, 2019

The slowing of shale oil production growth has become an accepted fact; however, we believe new forces are now at work that could very well produce another downward revision to US shale growth assumptions. These new forces are poorly understood and seldom mentioned, and we believe it is important the we bring them to your attention. In previous letters, we have outlined how the industry's high-grading effort positively impacted drilling productivity over the last five years. We also discussed what would happen to future shale oil production growth once "Tier 1" drilling prospects dwindled. But high-grading produces other unintended consequences that few energy analysts mention. For example, we all understand how high grading significantly improves an E&P company's drilling productivity when drilling activity increases. You simply put more and more of your rigs to work drilling the best prospects. After years of high-grading however, when a drilling retrenchment cycle forces you to drop rigs, the positive impact of high grading reverses itself, with significant negative impacts to production growth. We are now over a full year into just such a cycle and we believe the consequences of the last five years' worth of high-grading is about to become widely felt and understood.

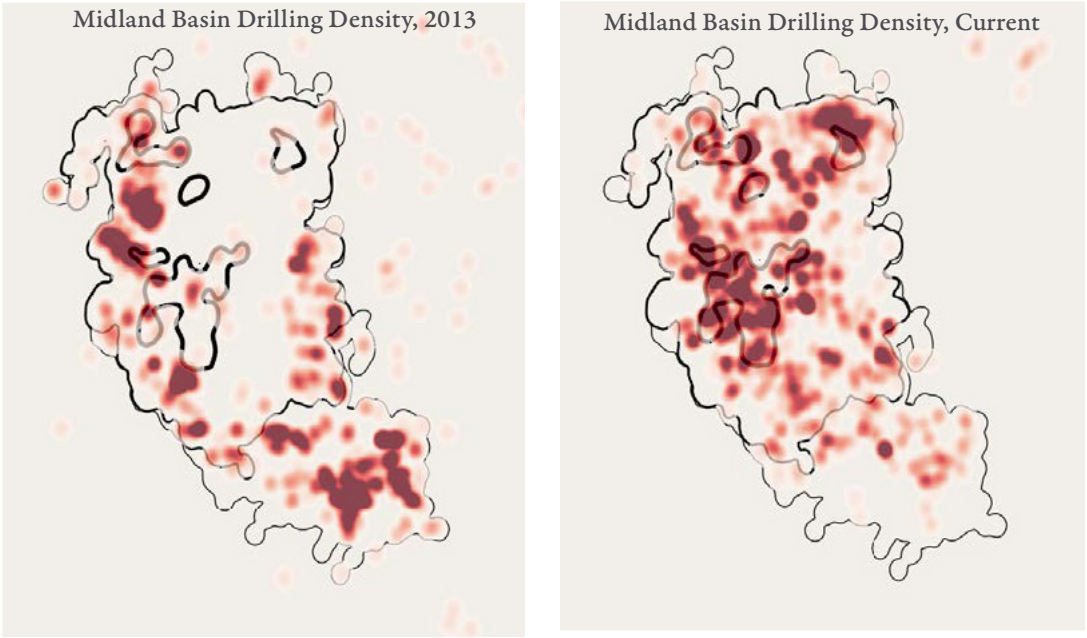
To understand the relationship between drilling retrenchment, high-grading, productivity growth and production, consider an energy company that is forced to cut back its drilling

activity in response to falling oil prices and reduced cash flows. It is logical to assume a company will stop drilling its least productive wells first. The remaining drilling activity becomes concentrated in the most productive areas and the average productivity rises. The larger the gap between a company's least productive rig and its most productive rig, the more this phenomenon positively impacts average productivity and future production.

Between 2008 and 2019 we have experienced four periods of drilling retrenchment in the oil shales. During the 2009 slowdown, the Bakken, Eagle Ford, and Permian lost 60% of their rigs. However, the difference between the most productive and least productive rig was so great that drilling productivity soared by 75% and total production from new drilling activity only fell by 35% -- much less than the fall in the rig count. In 2013, the three basins lost 15% of their rigs. Once again, the material difference between the most and least productive rig caused productivity to jump by 60%. Production from new drilling activity actually accelerated by 35%. In 2016, drilling activity declined by a massive 80% in the three basins. Productivity was able to skyrocket by 200% as companies were still able to lay down a large number of relatively unproductive rigs. Oil production from new drilling activity slowed by only 50%, again much less than the 80% drop in the rig count.

We used our neural network to shed some light on these periods of drilling retrenchment. We divided all of the drilling activity in the three plays into two tiers based upon acreage quality. According to our neural network, in 2009, 50% of all shale activity took place in Tier 1 areas. In 2013 and 2016 Tier 1 drilling still only represented 50% and 60% respectively. Today, that has changed dramatically. We believe that by 2019, Tier 1 activity approached 75% of all drilling. The following map shows the drilling activity on the Midland side of the Permian basin in 2013 and 2018. As you can see, the operators have honed in on the best parts of the play and are hardly drilling the less productive areas at all. The same trend is true in the Bakken and Eagle Ford and we invite those that are interested to please reach out for similar drilling activity maps.

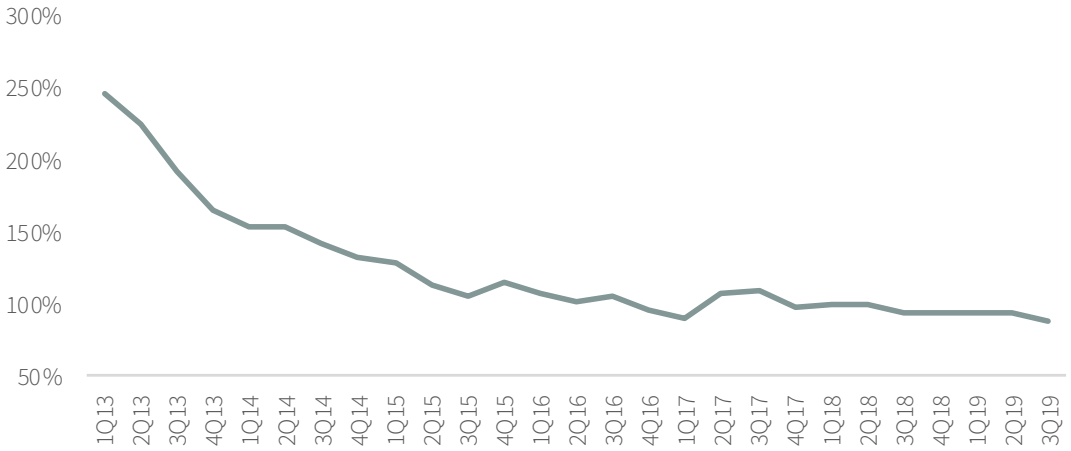
FIGURE 1 Permian Sweet Spot in 2013 - Present



Source: Goehring & Rozencwajg Neural Network

We also calculated the spread between the best wells and worst wells drilled during previous downturns. In 2013 we estimate the top half of all shale wells were 200% more productive as the bottom half. By 2019 this spread had collapsed to only 90% more productive. As rigs are laid down, our research tells us that the narrowing in drilling productivity will have a large impact on shale oil production growth. In previous drilling downturns, the E&P industry had the luxury of being able to lay down a significant number of relatively unproductive rigs. Years of high grading has taken this luxury away. Today, far fewer rigs are drilling unproductive wells compared to the downturns of 2009, 2013 and 2016 - a phenomenon clearly shown on the map above.

FIGURE 2 Tier 1 Productivity / Tier 2 Productivity, 2Q MVA



Source: Goehring & Rozencwajg Neural Network, ShaleProfile Data

The rig count has now fallen by 200 rigs or 23% since peaking in late 2018. Because of the high-grading, we believe the impact of this slowdown could affect production much more acutely than analysts expect. Unlike in past cycles, where productivity surged by 75%, 60% and 200%, our models tell us this cycle will be much more muted. In fact, based upon preliminary data, 2019 productivity may have actually declined year-on-year, despite the slowdown in drilling activity.

Shale oil production has already surprised analysts by slowing materially in 2019. However, the bulk of the slowdown occurred earlier in the year before much of the impact of the drilling retrenchment took hold. In our last letter, we explained how the unexpected slowdown in shale oil growth was the result of an acceleration in Permian Basin base declines. In 2018, newly completed Permian wells surged. These younger wells sported first-year decline rates as high as 70%, much greater than the field's base decline as a whole. Bringing this surge of high decline wells on-line pushed the Permian base decline from 54% for the first eight months of 2018 to 57% for the same period in 2019. The acceleration in base declines, coupled with a slowdown in shale drilling productivity, slowed production growth by nearly 60% even though the number of completed wells increased by 10% compared with 2018.

However, we believe, new underappreciated forces are now at work in the shales. As we progress through 2020, the retrenchment of drilling activity, combined with the inability for drilling productivity to rise because of "high grading" will produce the potential for a significant disappointment in oil production. If rig counts turn much lower or if productivity

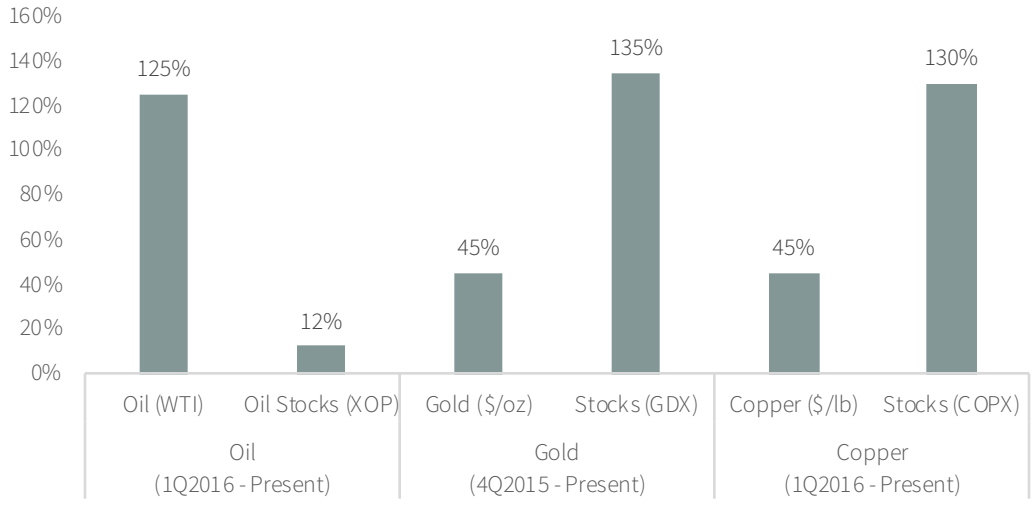
continues to disappoint, US shale production growth might even start to turn negative as we reach the end of 2020. Most analysts are still very optimistic about US oil growth in 2020. Estimates range from as low as 1.1 mm b/d to as high as 1.7 mm b/d, but we believe these growth estimates are far too aggressive. Several prominent oil industry veterans are calling for growth as low as 400,000 b/d, which could also turn out to be optimistic. Our Oil Markets section will outline our estimates for US shale growth, as well as global oil supply-and-demand balances.

2019 Q4 Natural Resource Market Commentary

After extensive weakness in both Q2 and Q3, natural resources enjoyed a modest rebound in Q4 2019. For example, after pulling back 35% from the April highs, oil rebounded 12% in Q4. The rally was driven by a combination of reduced trade war rhetoric, looser US monetary policy, and an increased understanding that US shale oil production growth will slow in 2020. Continuing a trend of the last several years, exploration and production stocks lagged the oil prices. For example, the S&P E&P Index (the XOP ETF) rose only 6.4% for the quarter. A bright spot among energy related equities was the oilfield service sector. After being pummeled on news of continued weak North American upstream capital spending trends, oil service stocks rebounded 15% during the quarter (as measured by the OIH ETF), outpacing the oil price itself. For the year, energy related stocks performed terribly. While the S&P 500 and WTI each rose over 30%, E&P and oil service stocks fell by 9% and 4%, respectively.

With the global investment community now gripped by environmental and sustainability (ESG) concerns, capital continues to pour out of investments perceived to be most impacted. Companies that produce and service the global oil and gas industry are being liquidated as a result. The impact of this liquidation is clear when you compare the performance of oil and gas stocks with other commodity producers. For example, since commodity prices bottomed in Q1 of 2016, oil prices have rallied 125% while the average E&P stock advanced only 12%. By comparison, gold has only rallied 45% from its bottom while the average gold stock (as measured by the GDX ETF) advanced 135%. Similarly, copper rallied 45% from its 2016 low while the average copper stock (as measured by the COPX ETF) advanced by 130%.

FIGURE 3 Oil Stocks Have Lagged the Commodity



Source: Bloomberg

"THE EXTREME BEARISHNESS TOWARDS ENERGY RELATED EQUITIES REMINDS US OF THE PRECIOUS METALS MARKETS BACK IN THE LATE 1990S."

The extreme bearishness towards energy related equities reminds us of the precious metals markets back in the late 1990s. Today, energy bears believe that the industry is faced with both "peak demand" and potential financial liabilities stemming from climate change damages if and when they occur. Back in the late 1990s, investors were convinced global central banks would continue selling the remainder of their gold reserves--a process that had started ten years earlier and had accelerated throughout the decade. With announcements that the newly formed Euro would not require any gold backing and the UK would sell its remaining gold, it seemed as though the bears would prevail. The final blow occurred when the Swiss announced they would abandon the Franc's gold backing and liquidate half of their substantial reserves. By 1999 investors were convinced that European Central Banks would sell all their remaining gold--a process that would take at least 25 years.

But something strange happened to the bearish thesis that was accepted unanimously in 1999: it never happened. Instead of selling persistently for the next 25 years, European central banks slowly wound down their liquidation and by 2009 central banks had turned into significant gold buyers. We covered this in our introductory essay "The Gold Bull Market is Here" in our Q2 2019 letter. For the few contrarian investors, the rewards were huge. Between 1999 and 2011, gold prices rose over seven-fold while gold equities rose twelve-fold.

We believe today's oil market is in the same position. Investors have constructed an extremely bearish thesis resulting in massive liquidation. This liquidation in turn has created incredible value in the related equites. If we are right, this bearish thesis will fail to materialize just like with gold in the late 1990s.

Natural gas prices were weak in Q4. Warmer than normal weather in December and mild forecasts for January produced significant downward pressure on prices. For the quarter, natural gas prices declined 6%, finishing near their lows for the year at $2.18 per MMBtu. The quarter capped a terrible year for North American natural gas that saw prices fall over 25%. Surging production continued to weigh on the market. For the three months ending in October, gas supply grew by over 8 bcf per day (up 9%) year over year, according to the Energy Information Agency (EIA). Growth was widespread with production surging in the Permian Basin, Marcellus, and Haynesville. Given the mild weather and growing natural gas supply, we remain neutral on natural gas prices. However, as we outlined in our last letter, 2020 may be the last year the Marcellus or Haynesville see any significant production growth. The two fields represent almost 35% of total US dry gas production and so any slowdown in growth would have a material impact.

Natural gas drilling activity has retrenched significantly over the last nine months. The US natural gas rig count bottomed back in the summer of 2016, with only 80 rigs operating. By the end of 2018, the rig counts inched higher until nearly 200 rigs were actively drilling gas wells. However, since the beginning of 2019, natural gas drillers have laid down 80 rigs or almost 40% of 2018's average rig count. Given the geological constraints in the Marcellus and Haynesville combined with the drop in natural gas related drilling activity, we believe the great gas bear market (now in its tenth year) could be nearing its end. Demand for natural gas continues to grow, driven in part by exports. By the end of 2019, the US became a natural gas net exporter for the first time in over sixty years, driven by increased LNG exports and pipeline expansions into Mexico. We are still not bullish towards gas; however, we watch with keen interest as the end of the great bear market seems to get closer and closer.

Precious metals were firm during the quarter as the Fed reduced interest rates by another 25 basis points and responded to instability in the Treasury repo market by introducing new policies that included aggressive balance sheet expansion. Gold advanced 3% for the quarter while silver rose 5%, platinum rose 10%, and palladium rose a strong 16%. Gold stocks were also strong performers with the GDX ETF advancing over 10%. For all of 2019, gold rose by 18% while silver rose15%, and gold stocks advanced a strong 40%.

Gold demand remained robust during the quarter. Although they slowed their pace in Q4, the 17 physical gold ETFs we track accumulated 10 tonnes. For the year, these same ETFs accumulated 325 tonnes of gold and now hold 2,535 tonnes, surpassing the previous high reached back in the Q1 of 2012. After having added a massive 3,200 tonnes in Q2 and Q3, the nine physical silver ETF's we follow shed 650 tonnes in Q4. Given the huge accumulation of physical silver, some pullbacks are to be expected which we believe will be temporary. Meanwhile, India continues to be a gold buyer on any price weakness. For example, as the gold prices advanced by a robust $250 last summer, gold demand from India weakened. The ex-duty premiums traditionally paid in the Indian market turned negative during this period, suggesting the Indian buyer largely stepped aside. As gold pulled back in November and December, the ex-duty premium paid by Indian buyers surged, suggesting they had resumed their purchases. Confirming these premiums, Reuters reported gold imports into India surged 80% in November alone. China--now the world's largest gold consumer–saw demand remain subdued over the last six months. Trade war fears and rising gold prices have led many to conclude Chinese demand is faltering, however premiums paid for physical gold on the Shanghai Exchange indicate that demand remains healthy.

While we are still awaiting final Q4 data, central banks were strong gold buyers through the end of September. According to the World Gold Council, central banks bought 156 tonnes of gold in Q3, bringing their total to 550 tonnes through the first nine months of the year and surpassing the previous peak set during the same period in 2013.

Going forward, we believe the recent policy decisions by the US Federal Reserve will be the largest drivers pushing gold prices higher. Over the last 12 years, global central banks have undertaken a massive money-printing experiment. In 2007, the combined balance sheet of the Federal Reserve, ECB, Bank of Japan, and Swiss National Bank equaled $4 trillion or 12.5% of their combined GDPs. Today this measure approaches $16 trillion and instead of equaling 12% of combined GDP, it now approaches 40%. Incredibly, the explosion of money printing has not been accompanied by any increase in inflationary expectations -- which explains why gold has lagged. For example, gold first hit $1000 in the summer of 2008. Since then gold has advanced by 55% while the Federal Reserve's balance sheet has swelled by 380%. In other words, gold has severely lagged the explosion of the Fed's balance sheet over the last 12 years. We believe this is all about to change. For the first time in 14 years, the Fed has started changing the composition of its balance sheet and not just its size. Please read about this controversial subject in the Precious Metals section of this letter.

Uranium markets remained extremely quiet in Q4. U308 prices were unchanged at $25 per pound. For the year, all of the weakness in uranium occurred in Q1 when prices fell from $29 to $25 per pound. We continue to believe uranium is setting up for a massive price spike. The market today is clearly in deficit. In January 2018, Cameco announced the indefinite closure of its world-class McArthur River mine, overnight removing almost 16mm lbs. of production from a world supply base of 165 mm lbs. Following this announcement, Kazatom-

prom, the world's largest uranium producer, announced supply curtailments of its own amounting to 9 mm lbs. In 2018, world uranium demand totaled 155 mm lbs. while supply had grown to 175 mm lbs. (140 mm lbs. in mines supply and 35 mm lbs. of secondary supply), leaving the market in surplus by almost 25 mm lbs. We estimate the Cameco and Kazatomprom cuts total 25 mm lbs. Additional demand growth in 2019 has pushed the uranium into deficit today.

Some 32 new nuclear reactors are scheduled to come online in the next three years, pushing global demand through 200 mm lbs. by 2022. This new demand alone would absorb more than all of today's curtailed production. However, additional supply pressure is now coming from the uranium enrichment market according to Cameco. Enrichment prices have soared in the last six months, confirming that global demand for uranium is very strong. High enrichment prices imply that fewer uranium "tails" (a significant source of secondary uranium supply) will be available to the market, further tightening the market.

Since closing McArthur River, Cameco has announced it must enter the global spot market to purchase over 20 mm lbs. of uranium annually to meet its long-term obligations. When they first made this announcement in the summer of 2018, Cameco disclosed 27 mm lbs. of uranium inventories and stated they preferred to keep this level unchanged to meet any potential mine disruptions. By Q3 of 2018, they had nevertheless drawn their inventories by 70% to less than 8 mm lbs. Since closing McArthur River nearly two years ago, we estimate Cameco has needed over 40 mm lbs. more than they produced to meet their committed contracts. We believe these volumes have come through drawing down their inventories (20 mm lbs.), purchases from their Inkai joint venture in Kazakhstan (5 mm lbs.), and spot purchases (~15 mm lbs.).

Going forward, Cameco will again need another 20 mm lbs. of uranium to meet their committed sales. Given their inventories have already been drawn so low, where will they source this material? Assuming Cameco again purchases 3 mm lbs. from their Inkai joint venture, they will need nearly 17 mm lbs. of uranium to meet their obligations. Given how low their inventories stand today, most of this will have to come from the spot market–a sharp increase compared with their purchases in 2018 and 2019.

Cameco stated it has become increasingly difficult to secure additional uranium in global spot markets. Long-term uranium contracting over the last two years had ground to a halt as potential Section 232 trade disruptions forced many buyers to the sidelines. Given the partial resolution of Section 232, Cameco has now told investors they have seen significant utility interest seeking long-term contracts. Given how under-contracted the utility industry has become in the last two years, we believe there will be a significant uptick in utility contracting. Increased utility demand, combined with Cameco's need to fulfill its own contracted demands, could result in severe upward uranium price pressure. We are extremely bullish on uranium and recommend investors maintain a significant position in uranium-related equities.

Something else developing in uranium markets is worth mentioning. We closely follow the global climate debate and its potential impact on all natural resource markets. We cannot help but notice that leaders of the green movement are coming to the realization that a world that relies strictly on renewable power has "intermittency" issues. As a result, wind and solar power still require huge amounts of back-up electricity generated from conven-

tional sources for times when the wind ceases to blow and the sun does not shine.

If we ever solve the problem of "grid-level" electricity storage, this would become less of an issue, but as of today our research tells us that any breakthrough in battery storage is still years away. Later in this letter, we discuss the difficulties in further reducing lithium ion battery costs. But there is a potential solution that would solve much of our CO2 problems today without any breakthrough in new technologies. Also, in this letter, we explain how nuclear power can largely solve today's CO2 problems with little impact on the price of electricity or global economic growth in the essay, "Why can't we admit France has solved the world's CO2 problem?"

"IN THE NEXT SEVERAL YEARS, WE BELIEVE WE WILL SEE ANOTHER SURGE IN NUCLEAR POWER PLANT PERMITTING, POTENTIALLY LED BY THE GREEN MOVEMENT, WITH RESULTING SURGING LONG-TERM DEMAND FOR URANIUM."

Germany has already experimented with making a massive investment in renewable power with little thought on how the back-up power is generated. The result has been a doubling of electricity prices and the destabilizing of the political system with little slowing of CO2 output. Even the New York Times (a journalistic leader of the green movement) admits that nuclear power generation must be part of the green revolution. In the next several years, we believe we will see another surge in nuclear power plant permitting, potentially led by the green movement, with resulting surging long-term demand for uranium.

Base metal markets were mixed in Q4. Copper advanced 13%, while aluminum advanced 5%, zinc slumped 3%, and nickel gave back almost 18% after having surged 50% over the summer following Indonesia's export restrictions. Base metal stocks as measured by the Global S&P Base Metal Index (XBM ETF) rose 13% for the quarter. Reflecting the stronger performance of copper, the copper stocks (as measured by the COPX Copper stock index) advanced 19%.

In response to Trump-related trade war fears, the base metals had a mixed year. Copper rose 6.3% and nickel rose a strong 31.1% in response to the Indonesian export ban while aluminum and zinc fell 2.4% and 6.3%, respectively. Base metal stocks (as measured by the XBM ETF) rose 10% while copper stocks (as measured by the COPX ETF) rose almost 13%. Copper equities continue to be our favorite base metal investment. Strong demand, coupled with little in the way of supply growth, gives copper one of the best fundamental profiles among any of the base metals. The continued need to build out the electricity grids in China and India, along with the push to invest in copper-intensive renewables produces a robust demand story over the coming decade. On the supply side, a drop in the number of large copper development projects means almost no supply growth is forthcoming.

During Q4, we saw a definite rebound in copper demand, especially from China. This marked a noticeable shift from earlier in the year. For example, Chinese copper demand in the first six months of 2019 was down3% year-on-year, according to the World Bureau of Metal Statistics (WBMS). This changed suddenly as demand rebounded for the three months ending in October to the point that, for the first 10 months of the year, Chinese copper demand actually grew year-on-year. Preliminary data suggests this strength continued into year-end as well. For example, Chinese refined copper production surged 12% in December, according to Bloomberg news, confirming both the strength of Chinese concentrate imports during Q4 and the potential rebound now taking place in the broader Chinese economy. Because of the dislocations caused by the trade war fears this year, global copper demand likely fell by 1% in 2019, according to the WBMS, driven almost entirely by the OECD countries. On the supply side, copper mine supply continues to stagnate. For the first 10

months of 2019, mine supply registered only 1.5% growth year-on-year.

"WORLD COPPER MINE OUTPUT TOTALED 20,370 TONNES IN 2016. OUR MODELLING INDICATES 2019 WILL COME IN AT APPROXIMATELY 20,500. IN OTHER WORDS, THERE HAS BEEN ALMOST NO MINE SUPPLY GROWTH OVER THE LAST FOUR YEARS."

World copper mine output totaled 20,370 tonnes in 2016. Our modelling indicates 2019 will come in at approximately 20,500. In other words, there has been almost no mine supply growth over the last four years. Our research tells us this lack of supply growth will continue, particularly given recent developments from the Oyu Tolgoi block cave in Mongolia. First production from the underground Oyu Tolgoi mine was expected by the end of 2020, ultimately ramping to 400,000 tonnes per year over the next several years. Due to underground rock conditions that were more challenging than expected, the start date has now been pushed out to between mid-2022 and 2023. With this change, this new startup timeline is far too optimistic, according to a number of people who have visited the project.

Nationwide protests in Chile almost brought the country to a standstill this fall as well. Although the protests now seem to have had no impact on mine supply, Chile produces over 25% of the world's copper. Any future unrest has the potential to seriously disrupt supply.

Combined copper inventories on the London, Shanghai, and COMEX exchanges continue to contract. After having built by 900,000 tonnes at the beginning of 2019, they have reversed course, finishing the year up only 300,000 tonnes.

Now that the Trump-related trade war fears have receded, we believe the world will see a large rebound in global copper demand. Other than the ramping up of First Quantum's Cobre Panama mine, we do not expect to see any material mine supply growth in 2020. With listed exchange inventories already suggesting that the global copper market has slipped into deficit, we believe copper prices will be strong as we go through 2020. We continue to recommend a full investment weighting in copper-related equities.

Grain markets were quiet in Q4. Corn prices started and finished the quarter at $3.88 per bushel. Soybeans fell 2.5% during the quarter to finish at $9.43 per bushel. Wheat benefited from both the drought in Australia and poor harvesting conditions in Western Canada and the Northern Plains, rallying by 13%. Grain prices were buffeted by climate-related and political forces in 2019. Flooding in the Midwest produced the latest planting season on record. An early frost and a near record-setting October blizzard in the upper Midwest impacted the harvest. On the political side, escalating Chinese trade war rhetoric and fears of a breakdown in global trade put large downward pressure on grain prices for most of 2019. In retrospect, these two forces mostly offset each other, leaving grain prices mostly flat for the year. For all of 2019, corn was up 4%, soybeans were up 7%, and wheat was up 11%.

In our last letter, we suggested that both corn and soybean yield estimates for the 2019 US harvest would need further downward revisions. However, it does not look like this will happen. In their most recent World Agricultural Supply and Demand Estimates (WASDE), the United States Department of Agriculture (USDA) actually slightly increased its most recent corn yield estimate to 168 bushels per acre. Because of the late planting season and the resulting relatively poor condition of the corn crop, we believed significant downward yield revisions were necessary. Planted corn acres came down slightly in the most recent WASDE from 81.8 mm acres to 81.5 and demand was revised higher because of increased feed use. As a result, corn carryout is now expected to be 1.8 bn bushels–lower than the original USDA 2.0 bn bbl estimate but still bearish overall. Because of strong demand, corn's stock-to-use ratio for the US declined slightly to 13.4%--a neutral figure. On a global basis, the USDA calculates the global corn-to-use ratio stands a little over 25%, which again is a

neutral figure. Soybean harvest estimates were revised slightly higher to 47.4 bushels per acre, up from 46.9 in October. Given the relatively poor condition of the soybean crop, we were looking for further reductions from the 46.9 level. However, because of strong demand, the USDA left their 2020 carryout figures at 475 mm bushels, up only slightly from their 460 October carryout estimates, which still remains well below the 750 mm bushel estimated carryout figure the USDA put out last summer. The US soybean's stock-to-use ratio remained at 11.8 and on a global basis the stock-to-use ratio has now fallen from 32% down to 27.6%. Both the figures now reside solidly in neutral territory.

Given extremely strong global grain demand, the world continues to need excellent growing conditions and near-record crops. We continue to believe that the world agriculture markets today sit on a knife edge. Any severe global weather events, which significantly impact crops yields, will produce major upward price pressure. We see this process as already underway. The US corn crop peaked at 15.1 billion bushels back in 2016, followed by the second biggest harvest in 2017 at 14.6 billion bushels. The USDA estimates now that the US corn crop will reach 13.7 billion bushels--the lowest figure since the drought year of 2012.In soybeans, US production peaked at 4.5bn bushes in 2018. The USDA estimates that 2019 soybean production reached 3.6 bn bushels which is the lowest level since 2013. Given pervasive deflationary psychology and trade war-related fears that gripped global grain markets, it's no surprise that these reductions in crop size had little impact on price.

Given our theory that global weather patterns are about to change significantly this decade (you can find our essay on sunspots and their impact on global weather in our Q1 2019 letter), we believe that the disruptive weather events of 2019 are going to be repeated, with resulting impacts on global crop yields and harvest size.

Regarding the upcoming 25th solar sunspot cycle, we have little new to report. The 24th sunspot cycle is now over and, in retrospect, with just over 100 daily sunspots, appears to have been the weakest in almost a century, continuing a trend of progressively weaker solar activity. Sunspot cycle 21, which ended in 1986, averaged 225 daily sunspots at its peak. The 22nd cycle, which ended in 1997, peaked at just over 200 daily sunspots, while the 23rd cycle, which ended in 2008, peaked at 175 daily sunspots.

On July 2019, a small sunspot emerged in the sun's southern hemisphere, displaying reversed polarity from those of the 24th cycle--a sure sign that the 25th cycle has begun. How active will sunspot activity become in the upcoming cycle? The sun's current output of magnetic energy continues to suggest that the upcoming cycle will be weak. The latest report from NASA/NOAA incorporates these observations. They state: "Cycle 25 will be similar in size to cycle 24, preceded by a long deep minimum. Solar cycle 25 may have a slow start, but is anticipated to peak with solar maximum occurring between 2023 and 2026, and a sunspot range of 95 to 130. This is well below the average number of sunspots, which typically ranges from 140 to 220 sunspots per solar cycle." As our readers know, we believe that reduced sunspot activity results in global cooling and that global cooling trends result in increased instances of disrupted weather events. We believe the record-breaking flooding experienced in the upper Midwest last year is representative of the type of disrupted weather event that the world will experience more and more often in years ahead.

Shale Production Has Slowed

"THE MOST IMPORTANT ISSUE FACING OIL MARKETS IS SLOWING US SHALE GROWTH."

The most important issue facing oil markets is slowing US shale growth. As we have discussed in these pages, the shales have been the only material source of non-OPEC production growth over the past decade and have been critical in meeting growing global demand. Any slowing in the shales would materially impact oil balances. We continue to believe this is happening today.

"AS A RESULT, THE FULL IMPACT OF THE CURRENT DRILLING SLOWDOWN HAS NOT YET BEEN FELT."

Since we last wrote, the data has confirmed that US shale growth in 2019 was only 50% that of 2018. Last quarter, we explained how a surge of new wells drilled in 2018 increased the base decline rate (younger wells decline faster), making it harder to achieve the robust growth of prior years. Making matters worse, the US oil rig count peaked in late 2018 and has since fallen by 25%. There is often a three-month lag between drilling and first production, followed by another two-month reporting lag. As a result, the full impact of the current drilling slowdown has not yet been felt.

Activity is not expected to accelerate anytime soon and in fact could get much worse. Well permits (a good leading indicator of drilling activity) plummeted in December reaching their lowest level since at least 2008 when the dataset began, according to Evercore ISI. For 2019 as a whole, permitting was down marginally, but the decline was mostly weighted to the second half of the year suggesting activity will be weak as we progress throughout 2020.

The most important question going forward revolves around well productivity, which we discussed at length in the introduction. In summary, can well productivity grow enough to offset the activity slowdown or will growth continue to trend lower? Given how much high-grading has already taken place in the shale plays, productivity gains will be much more muted than in past downcycles and as a result production growth will continue to slow.

We are beginning to see reports confirming our analysis. In their recent research report, Bernstein concludes that shale well productivity (as measured by peak-month oil production) fell last year for the first time ever.

Our dataset (from Shale Profile), along with our neural network, confirms the slowdown in peak-month productivity across many basins including the Bakken, Eagle Ford, DJ Basin, and parts of the Permian. We used our neural network to estimate the total ultimate recoverable reserves per well and observed a slowdown there as well compared with a year earlier. The median well productivity declined by approximately 2% in 2019 across all oil producing shale basins. While this may sound modest, the consequences are profound. Not only is well productivity not growing enough to offset the rig declines, it is now falling outright. As a result, the impact of less drilling will be much more acute than in past cycles.

"WHEN WE USE OUR NEURAL NETWORK TO ISOLATE FOR WELL QUALITY (PLEASE SEE OUR Q2 2019 LETTER WHERE WE DISCUSS THIS METHODOLOGY), WE NOTICE A 5% DECLINE IN 2019 COMPARED WITH 2018."

According to our neural network, the productivity slowdown was driven by operators developing marginally less productive areas. Lateral length actually increased by 7% across the major oil regions last year while frac intensity increased in all regions except for the Bakken. This suggests to us that the slowdown in well productivity was not caused by smaller well designs. When we use our neural network to isolate for well quality (please see our Q2 2019 letter where we discuss this methodology), we notice a 5% decline in 2019 compared with 2018.

On a short-term basis, we should point out that it is possible well productivity could rebound slightly going forward. There is clearly a degree of variability in terms of drilling locations and the slowdowns we observed are still relatively minor. However, what is critically important is that well productivity was unable to move higher during this most recent drilling slowdown

"RECENT COMMENTS FROM HALLIBURTON AND SCHLUMBERGER REINFORCE THE IDEA THAT THE SHALES MAY BE PAST THEIR PRIME–SOMETHING WE HAVE BEEN EXPECTING FOR SEVERAL QUARTERS."

as it had in past cycles. The industry seems unable to high-grade any further and as a result, this drilling cycle will have much more impact. On a longer-term basis, we believe 2019 results are just the beginning. Of the two major shale oil basins, two are showing signs of exhaustion (the Eagle Ford and Bakken). Even the Permian is starting to show its age. Recent comments from Halliburton and Schlumberger reinforce the idea that the shales may be past their prime–something we have been expecting for several quarters. The underlying issues are geological in nature: the industry is running out of high-quality Tier 1 acreage. While there was hope that drilling and completion technologies could overcome these forces, our data suggests this is unlikely. We believe that a careful analysis of company-by-company drilling inventory is critical at uncovering value in the E&P space and that is where we continue to focus the majority of our time and effort. Not all E&P companies are created equal and that is particularly true as we enter into this new mature phase of US shale oil development.

The only bright spot in non-OPEC production growth over the last decade is now slowing and yet most analysts still fail to realize it. For example, even after lowering their estimates for 2020, the EIA still expects US liquids production to grow by 1.6 m b/d (1.1 m b/d of crude and 500 k b/d of natural gas liquids) year-on-year. This implies only a modest slowdown compared with 2019's growth rate of 1.7 m b/d despite the fact that the rig count has fallen by 25% and productivity has stagnated. Our models instead suggest that crude oil growth could be as low as 400,000 b/d. Assuming NGLs can also grow 400,000 b/d, total US production growth might only reach 800,000 b/d in 2020. Many oil executives confirm our estimates. Notably, Mark Papa, CEO of Centennial Development Corp and Chairman of Schlumberger, is calling for 400,000 b/d of US shale growth in 2020. Scott Sheffield, CEO of Pioneer Natural Resources, has lowered his estimates as well. Furthermore, our models suggest that while 2020 will still see growth on a full year-on-year basis, on an exit-to-exit basis US shale production could be flat, surprising many market watchers.

Outside of the US, much attention is being paid to two major non-OPEC projects currently starting up in Norway (Johan Sverdrup) and Brazil (Santos Basin), each of which are expected to pump in excess of 400,000 b/d. The International Energy Agency (IEA) believes these projects will drive strong non-OPEC ex US growth of 920,000 b/d in 2020. While we agree these two projects are impressive, the IEA estimates are overly optimistic. As we have explained in past letters, the IEA has chronically over-estimated non-OPEC ex US production and this year will likely be no different. In their initial estimates for 2019 (published in the summer of 2018), they called for non-OPEC ex US growth of 500,000 b/d. Since then, they have revised that figure lower by 80% to 100,000 b/d and we believe further revisions are forthcoming. This modest level of net growth was based upon 1.5 mm b/d of gross new projects starting up in 2019. In other words, base declines amounted to 1.4 m b/d in 2019–a number that has been fairly consistent over the past few years. Looking at 2020, even with Johan Sverdrup and the Santos Basin, gross new projects are not expected to surpass 1.9 mm b/d. Assuming base declines remain consistent at 1.4 m b/d, non-OPEC ex US growth might only be 450,000 b/d in 2020–half the rate the IEA expects.

Our biggest mistake in 2019 concerned apparent demand. While demand stayed resilient in the first half of the year, it weakened during the third quarter. Making matters more complicated, the change occurred in the "missing barrel" figure. As our readers remember, the IEA's estimates for supply and demand often do not explain actual inventory behavior.

We call the discrepancy "missing barrels" because they represent oil that was produced but allegedly neither consumed nor placed in inventory. In reality, we believe the missing barrels represent the under-estimation of non-OECD oil demand. During the second half of the year, the slowdown in apparent demand was entirely the result of "missing barrels" abating. While we cannot be certain, we believe this weakness caused by industrial and physical traders in China trying to destock their commercial inventories in response to trade war concerns. If we are correct, then a "catch-up" might be forthcoming as these same parties are forced to rebuild their commercial inventories, which have now become depleted. In any event, the worst now seems to be behind us as recent import data from China and India suggest much more robust activity.

Market watchers are extremely concerned at present with the recent outbreak of Coronavirus that started in Wuhan. We are monitoring the situation very closely, but believe the impact to global oil demand will likely be muted unless things get materially worse. During the 2002-2003 SARS outbreak, markets were equally concerned, although in retrospect global oil demand did not weaken at all and instead grew by a very strong 2.0 m b/d.

Looking forward to 2020, we expect global oil markets will be in deficit helping put upward pressure on prices. According to the most recent IEA data, global demand is expected to average 101.6 m b/d, representing growth of 1.3 mm b/d year-on-year. The balancing item, which mysteriously vanished in the second half, will likely re-emerge in 2020 as industrial buying in China and India resumes. Whereas 2018 saw a balancing item of 1.0 m b/d, we prefer to be conservative in 2020 and are only modeling 200,000 b/d. That would result in global demand averaging 101.8 m b/d.

The IEA expects US production will grow by 1.2 m b/d to 18.26 m b/d. Despite being more conservative than the EIA, we still think this figure is too optimistic. Driven by the slowing rig count and muted productivity trends we explained earlier, we believe the US total liquids (including NGLs) will only grow by 900,000 b/d to 17.96 m b/d. The IEA expects the rest of the non-OPEC world will grow by 900,000 b/d driven by Norway and Brazil. As we explained, this underestimates base declines materially and we believe non-OPEC ex US will only grow by 450,000 b/d to reach 43 m b/d. Given processing gains, biofuels and OPEC NGLs (produced outside the OPEC quota system), we expect total non-OPEC liquids production of 71.7 m b/d, leaving the call on OPEC crude at 30 m b/d. OPEC produced 29.44 m b/d in December and has announced further cuts totaling approximately 400,000 b/d. This would leave global oil markets undersupplied in 2020 by nearly 1.0 m b/d.

If we are correct, inventories will decline materially throughout the year. As our readers know, we use inventories as our "mile-marker" to tell us if we are on the right path. We accurately predicted seasonally-adjusted inventories would decline sharply beginning in early 2017 (at a time when few others agreed with us). We were correct and inventories fell at their fastest pace on record throughout all of 2017 and the first six months of 2018. Since then, the global oil markets have been buffeted by both Iranian-sanction confusion (see our Q1 2019 letter) and trade war impacts. While we had expected inventories would keep declining, they built relative to seasonal averages from June 2018 until August 2019. While this has been disappointing, our models tell us the worst is now behind us and that inventories will resume their declines relative to seasonal averages, as we progress through 2020.

Energy investors remain extremely bearish. After a strong performance at the end of 2019,

"CLEARLY IN RETROSPECT, THAT WAS AN EXCELLENT TIME TO BE AN ENERGY INVESTOR AND WE WOULD NOT BE SURPRISED IF THIS TIME IS NO DIFFERENT."

energy shares have once again sold off in January 2020. Energy now makes up 3.9% of the S&P 500 – the lowest reading in at least 30 years. Apple's market capitalization is now greater than that of the entire S&P energy sector. This reminds us of the technology bull market of the late 1990s. By 2000, Cisco System (the last cycle's darling stock) also boasted a market capitalization that was larger than the S&P energy sector. Within twelve months, Cisco had fallen by 82% while energy stocks started an eight-year rally that saw them rise nearly four-fold. Clearly in retrospect, that was an excellent time to be an energy investor and we would not be surprised if this time is no different.

Energy investors are so complacent today they risk ignoring many of the underlying trends, particularly in supply. Besides the US shales and the dearth of non-OPEC ex US growth, investors are also unfazed by recent geopolitical developments. The last year has experienced a ratcheting up of Middle Eastern tensions including attacks on the Straits of Hormuz, Iranian attacks on Saudi oil infrastructure, US attacks on Iranian generals in Iraq, and most recently terrorist attacks on oil pipelines in Libya. In past cycles, any of these events would have be enough to send oil prices higher. Today, all of them together have had no impact on the oil price.

While we may sound like a broken record, we must reiterate how bullish we remain on energy shares. Since bottoming in February 2016 at $26 per barrel, oil prices have more than doubled on steadily improving fundamentals. Since then, the market has remained in backwardation, confirming a physical oil deficit. Despite these bullish developments, E&P shares are 15% lower today than they were when oil was $27 per barrel. We believe that investors will look back on this period as an anomaly and wonder how markets could have priced these stocks so low. We are frustrated by how long it is taking to break the investor psychology in the oil markets, but we are patient investors and remain bullish. Our models continue to tell us we are on the right track and are convinced that long-term investors will eventually be rewarded.

Lithium-Ion Batteries Redux

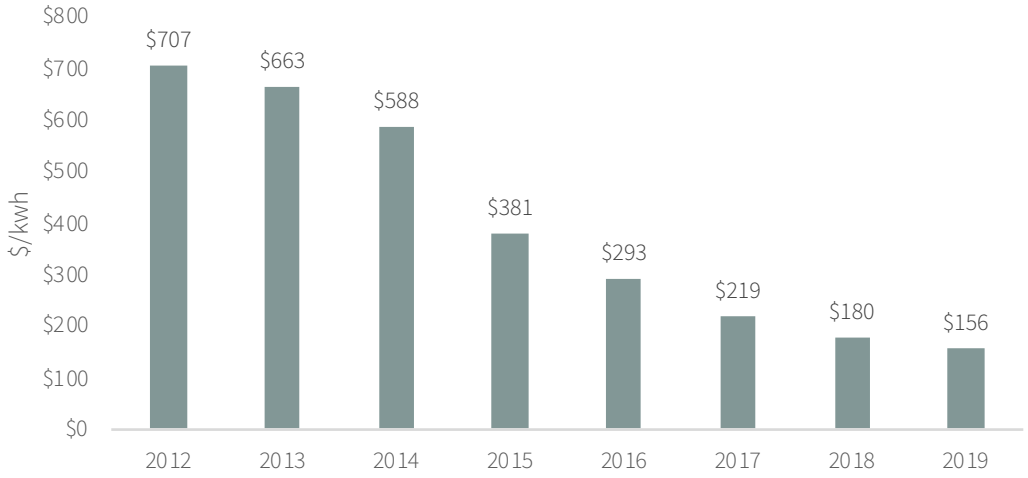
We first discussed lithium-ion batteries in our Q1 2018 letter. In that essay we compared the total energy consumed by an electric vehicle versus an internal combustion engine on a per-mile basis. Our results were quite surprising. For those interested, please refer back to that letter for much greater detail. In the two years since we wrote that essay, we have tried to teach ourselves as much as possible about trends in battery technology and today we would like to share what we've learned. We believe what follows will have a significant impact on the potential adoption of both electric vehicles and renewable power generation as we progress through the coming decade. Our research indicates that neither the EV nor renewable power can gain material adoption without further major reductions in battery costs. Yes, battery costs have dropped dramatically over the last decade, but we believe these costs reductions were one time in nature and will be near impossible to repeat. Further cost reductions will be entirely dependent on major advancements in battery technology--which, as of today just don't exist.

Renewable energy's major problem is intermittency: the sun doesn't always shine and the wind doesn't always blow. As a result, it's impossible for renewables to provide reliable baseload power at scale without storage. While batteries could provide the necessary buffer to overcome the problem of intermittency, the costs of renewable plus storage remain prohib-

itive and uncompetitive. Similarly, the battery pack has become the limiting factor to widespread EV adoption. Analysts estimate that the battery pack on an EV represents one-third of its total cost. Unless the EV reaches cost parity with the combustion engine it will not gain widespread adoption, unless the EV is subsidized or the ICE is outlawed. Materially reducing the cost of the battery is the only way for the EV to become competitive.

Many analysts believe that EVs will reach cost parity once lithium-ion batteries can be produced at $100 per kwh. Costs would have to fall further to allow for grid-level storage. Battery proponents argue these thresholds are just around the corner. As recently as 2012, lithium-ion batteries cost more than $750 per kwh. Bloomberg New Energy Finance estimates these costs have now fallen by an impressive 80% to reach $156 per kwh by 2019. The bulls argue that even if cost improvements slowed by half, $100 per kwh will be achieved within three to five years.

FIGURE 4 Lithium-Ion Battery Cost



Source: Bloomberg New Energy Finance

Since we first wrote about batteries, we have been fascinated by the chart above. While the cost reduction experienced over the last seven years is truly impressive, we are curious about the drivers behind the improvement. Many battery analysts tend to apply a version of Moore's Law to explain the sharp reduction in cost. While this is a convenient analogy, there are material differences between microchips and battery cells. Given how important battery cost trends are to the broader energy markets, we tried to research the cost reduction topic, but we found the data hard to find. Many battery commentators spoke about economies of scale, but few were willing to give details. Battery companies also consider their manufacturing process to be their greatest competitive advantage and, as a result, few give information or breakdowns of their cost structure.

Through our research, we came across an excellent book detailing the inner workings of the battery industry. In *Powerhouse*, Steve LeVine explores the challenges in developing lithium-ion batteries. He also describes the ground-breaking work conducted at the Argonne National Laboratory outside of Chicago. Levine explains how Argonne maintained meticulous cost models for all major lithium-ion battery formulations over time and regularly released these models into the public domain.

Argonne's models are invaluable in understanding what caused the 80% fall in battery costs over the last seven years. After carefully analyzing the Argonne data, we now believe costs have come down mostly through a series of one-time improvements. Instead of continuing to fall materially (à la Moore's Law), we believe that most of the drop in lithium-ion costs is now behind us. The first $600 move from $750 to $156 per kwh was relatively easy-- the next $56 move from $156 to $100 will be extremely difficult. If we are correct, lithium-ion batteries will not be able to reach the threshold for mass adoption in either EVs or grid-level storage for the foreseeable future. We should point out that many battery experts privately acknowledge that the trajectory of the past decade is not repeatable.

Four main factors explain the fall in battery costs over the past decade: increased plant utilization, increased battery size, chemical prices and battery chemistry improvements.

Beginning in 2008, the battery industry built a large amount of lithium-ion manufacturing capacity to meet the expected surge in demand. While the demand projections ultimately proved correct, the timing was initially far too optimistic and by 2010 the average battery plant only operated at 10% utilization. The low level of throughput resulted in substantial operational inefficiencies and artificially high unit costs. Argonne released a version of its model in late 2011 and we used this as a starting point for our analysis. The Argonne model assumes a 100,000 pack per year facility that operates at full capacity. The first thing we did was adjust the model to reflect a plant that only operated at 10% utilization. The result was a cost of $705 per kwh–within 5% of the battery cost reported by the battery industry for 2012.

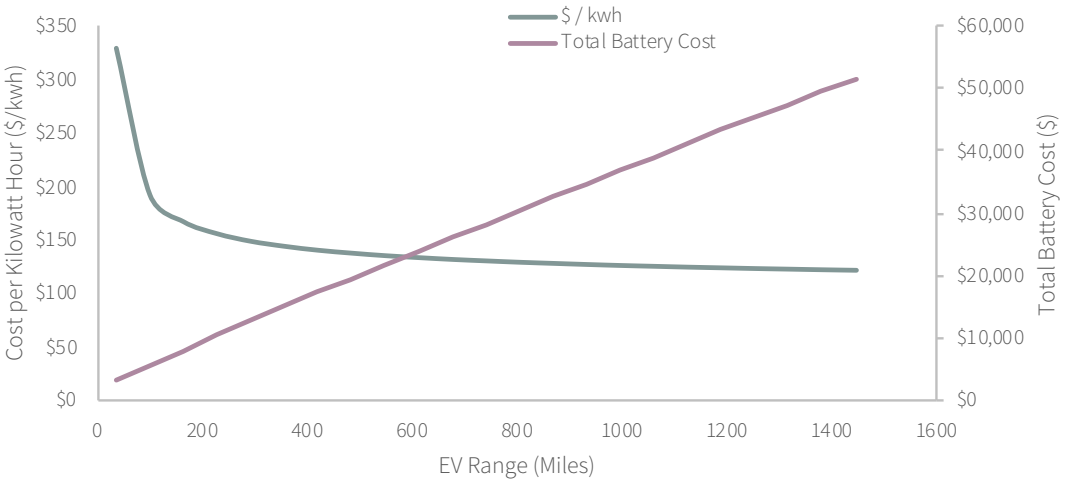
Using this as a baseline, we adjusted the plant utilization to 100%–the base case used in the Argonne model. Immediately the costs collapsed by 50% from $705 per kwh to $360. These results have profound consequences: nearly 60% of the total cost savings of the past decade came from simply ramping up underutilized facilities. The cost savings is the result of the fixed or semi-fixed costs (such as capital equipment, land and labor) being amortized over a greater quantity of batteries. Battery manufacturing plants today are operating near full utilization. Going forward, additional demand will be met by building new plants and not by increasing utilization. As a result, the largest driver of cost reduction over the last decade is unrepeatable.

The second source of cost reduction is the size of the battery itself. In 2012 the average lithium-ion battery had much less capacity than today. For example, the benchmark battery from the 2011 Argonne model only had capacity of 11 kwh compared with 65 kwh in the most recent edition. In any battery pack there are significant costs that are incurred only once per battery. These costs include module terminals, gas release valves, bus bars, and pack jackets as well various integration costs. By increasing the capacity of the battery five-fold, these one-time costs are spread over more kilowatt hours. In a typical 2012 vintage battery, these costs made up as much as 20% of the total battery cost. As the capacity increased materially, we estimate these costs came down from $80 to $20 per kwh--a reduction of 75%.

Again, we believe these cost reductions will not be repeated going forward. There is clearly a tradeoff between capacity, unit cost, and total cost. For example, a 2019-vintage battery has a capacity of 65 kwh equating to an EV range of 220 miles. Such a battery is estimated to cost $156 per kwh or $10,170 per battery. If you increased the capacity six-fold (similar to the increase between 2012 and today), the resulting battery would have a range of nearly 1,000 miles and a total cost of $50,000. While its cost per kwh would indeed have come down from $156 to $120, we doubt any consumer would be willing to incur these extra costs

for such a ridiculously long range. Clearly there is a right-sizing of the battery that dictates capacity and we believe current EVs are close to optimal. The chart below graphs the relationship between capacity, cost per kwh, and total battery cost for a current generation lithium-ion battery.

FIGURE 5 Battery Cost Tradeoff



Source: Goehring & Rozencwajg Models, Argonne National Laboratory

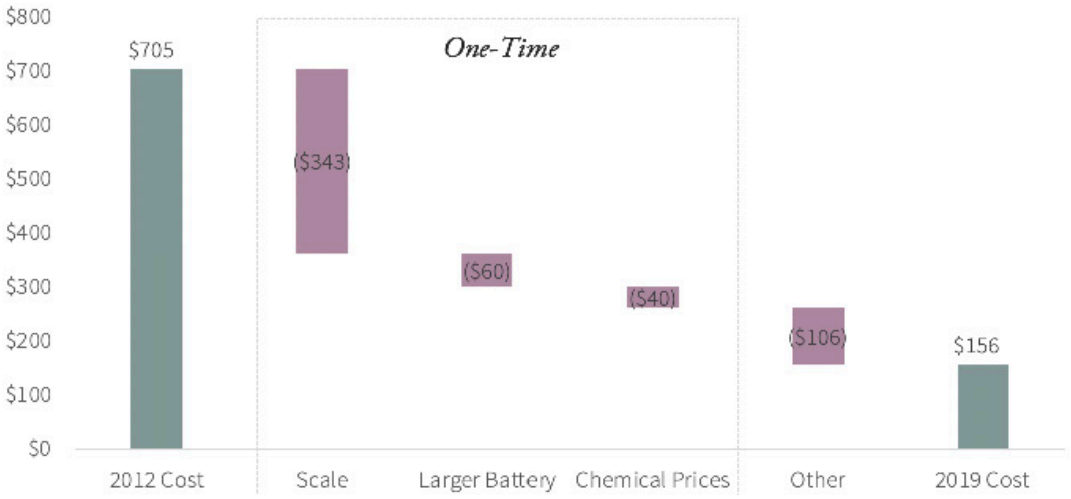
The third driver of cost reduction over the last several years has been chemical prices. A battery's "chemistry" typically refers to the active material used in the battery's cathode. For example, Tesla utilizes a so-called LCA battery where the cathode consists of a compound made of lithium, cobalt, nickel, and aluminum. This compound is purchased from a specialty chemical company which charges a price based upon the cost of the underlying materials and the cost of manufacturing. Over the last several years, the compound price has fallen by nearly 50% as manufacturing costs have declined materially. Our models suggest these cost savings have a limit as the raw material cost becomes a larger and larger percent of the total. For example, we estimate raw material costs made up 40% of chemical price in 2011. By 2018 this had flipped and the raw materials made up 60% of the total chemical price. Moreover, as battery demand picks up we believe metal demand risks exceeding supply in cobalt and nickel. This will put upward pressure on the specialty chemical price. Battery insiders admit metal prices could be a problem going forward. In January 2019, Tesla announced a cobalt offtake agreement with Glencore in an effort to secure long-term supply. These cost pressures are unlikely to be offset by lower manufacturing costs, given they now make up less and less of the total. Over all, we estimate chemical prices have lowered battery costs by $40 per kwh between 2011 and 2019.The remaining cost savings have come from improvements to the underlying battery itself and the manufacturing process. After accounting for cost inputs mentioned above, we believe these additional improvements have resulted in $100 in savings or less than 20% of the total.

"OUR ANALYSIS SUGGESTS A FULL 80% OF THE COST SAVINGS OF THE LAST SEVERAL YEARS HAVE COME FROM ONE-TIME SOURCES THAT CANNOT BE REPEATED."

Our analysis suggests a full 80% of the cost savings of the last several years have come from one-time sources that cannot be repeated. Battery bulls extrapolate the 20% annual cost savings that took prices from $705 to $157 over the last several years. Instead, we believe it is more appropriate to first back out the one-time cost savings in order to isolate the sustainable cost savings going forward. Instead of falling $550, we believe battery prices fell by less

than $100 per kwh over the last seven years, after adjusting for plant utilization, pack size, and chemical cost reduction.

FIGURE 6 Battery Cost Driver



Source: Goehring & Rozencwajg Models, Argonne National Laboratory

Late last year the *Wall Street Journal* reported a spat between Tesla and Panasonic regarding their Gigafactory joint venture. The issue revolved around price with Panasonic claiming it could not operate profitably at current levels. The Gigafactory is the largest battery manufacturing facility in the world, operates at near full utilization, and produces very high capacity batteries. This strongly suggests its costs should be among the lowest in the world – and yet they still are not low enough. If our analysis is correct, it will become harder and harder for battery manufacturers to continue to lower costs. Perhaps the Panasonic headlines are just the start.

Gold: The Composition of Fed's Balance Sheet

"...Bernanke has to open the discount window, that's how bad things are out there... he has no idea how bad things are out there. The Fed is asleep.... we have Armageddon..." Jim Cramer's famous appearance on CNBC, August 3, 2007

"The Fed's reaction to the disruption in repo markets shows how hard it will be for policymakers to reverse their 'money printing." Jim Bianco, January 3, 2020

"Early on across the world, as already noted, the main device for defaulting on government obligations was that of debasing the content of the coinage. Modern currency presses are just a technologically advanced and more efficient approach to achieving the same end." Reinhart and Rogoff, This Time Is Different: Eight Centuries of Financial Folly

Since peaking in Q4 2011, gold prices have shown a distinct lack of response to the explosion of money printing undertaken by global central banks. The Federal Reserve has expanded its balance sheet by 60% since 2011, and yet the gold price still sits almost $350 below its peak made 9 years ago.

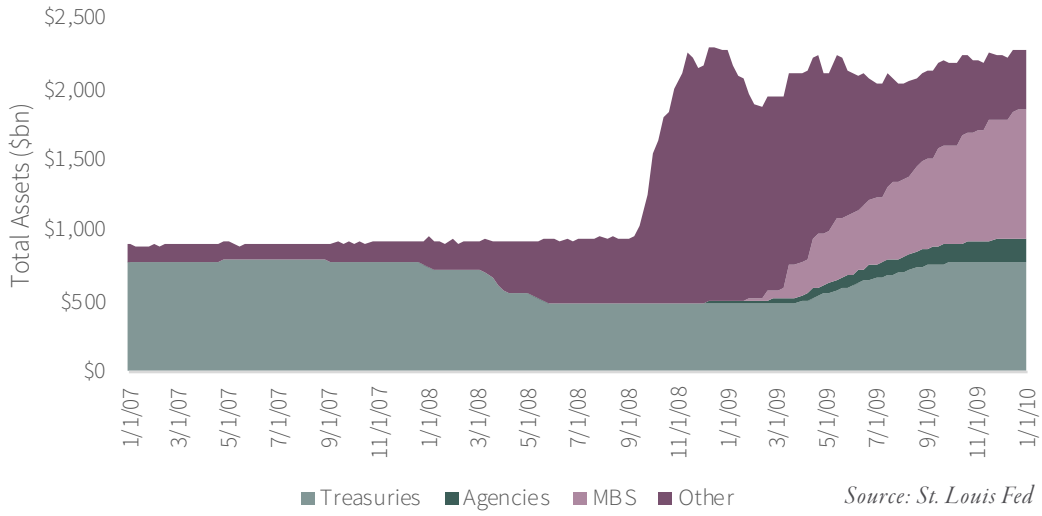
We believe there are good reasons for this. In the summer of 2007, the Fed began an experiment in changing the composition of its balance sheet. For the first time since the late 1920's, the Fed began to shrink its portfolio of short-dated Treasury bills and replaced them

with mortgage-backed securities. From 2007 to 2012, the Fed continued contracting its Treasury bill portfolio until they eventually sold every last one – an event as far as we can tell that had never before occurred.

From 2009 to 2019, all of the Fed's massive balance sheet expansion took place by buying mortgage-back securities, longer-dated Treasuries and various other non-traditional assets. During that period, the Fed did not buy a single Treasury bill. Although the subject is controversial, we believe this radical change in Fed policy explains the collapse in monetary velocity, the lowering of inflation expectations, and the lackluster gold price over the last decade.

We believe this is all about to change. Starting in October 2019, the Fed began a new phase of balance sheet expansion by buying Treasury bills for the first time in 13 years. The $160 billion expansion undertaken in the last four months has been accomplished almost exclusively through the purchase of Treasury bills. We believe gold is about to play massive "catch-up" with the tremendous amount of monetary growth created by global central banks since the 2008 financial crisis. The reason: the Fed in now injecting "high-powered" money into the banking system for the first time in 13 years. In the last four months, the Fed has finally returned to its traditional methods of conducting monetary policy. The impact on the ongoing bull market in gold is going to be huge.

FIGURE 7 Federal Reserve Balance Sheet



Source: St. Louis Fed

Before we talk about Fed policies today, let's take a step back to 2007, just as the global financial crisis was beginning to make itself felt. As this chart clearly shows, for reasons that still remain unclear to this day, the Fed abruptly stopped buying short-dated Treasury bills in Q2 2007. Not only did they stop buying Treasury bills, they actually began to let their Treasury bills and notes run off. For example, after peaking in the first week of May 2007 at $790 bn, the Fed's Treasury portfolio stayed flat until August at which point it started to decline. By the first week of September, the Fed's Treasury holdings had declined by $20 bn with almost all the decline occurring in short-dated bills.

"BY LETTING ITS TREASURY BILL PORTFOLIO SHRINK, THE FED STARTED TO WITHDRAW 'HIGH-POWERED' MONEY FROM THE FINANCIAL SYSTEM, JUST AS THE 2007-2008 FINANCIAL CRISIS INTENSIFIED."

Why would the Fed let their Treasury holdings run off just as the first major cracks were becoming apparent in global financial markets? In "Banking and Finance 101," we are taught that the traditional instrument used to expand and contract the amount of "high-powered" money in a banking system is short-term Treasury bills. By letting its Treasury bill portfolio

shrink, the Fed started to withdraw "high-powered" money from the financial system, just as the 2007-2008 financial crisis intensified.

Given the highly liquid nature of these securities, both the US banking system and the Fed's open-market operations have relied heavily on their use to expand and contract the amount of available bank credit. When the Fed buys Treasury bills, it effectively injects high-powered money into the banking system. Conversely, when the Fed sells Treasury bills it removes high-powered money from the banking system. By the summer of 2007, the Fed carried out a large scale (and in our opinion disastrous) experiment in changing the composition of its balance sheet.

At the same time the Fed was letting its Treasury portfolio run off, it began purchasing mortgage-backed securities (MBS). Although they never explained their motivation, the Fed was likely trying to add liquidity to the collateralized mortgage market – a market that was quickly becoming highly illiquid. The Fed sold Treasury bills to help fund these purchases. The net result was that the Fed removed high-powered money from the banking system (by selling Treasury bills) and replaced it with low-powered money (by buying mortgage-backed securities).

Although we can get few people to agree with us, we believe the change in Fed policy put huge strains on the US financial system. For those interested in how the Fed's actions had begun to impact financial markets, we recommend everyone watch Jim Cramer's famous rant on CNBC back on August 3, 2007. Cramer's observations about the drying-up of liquidity coincided perfectly with the Fed's initial contraction of its Treasury bill holdings. Cramer's tirade demonstrates what can happen when even the smallest amount of high-powered money is withdrawn from the banking system.

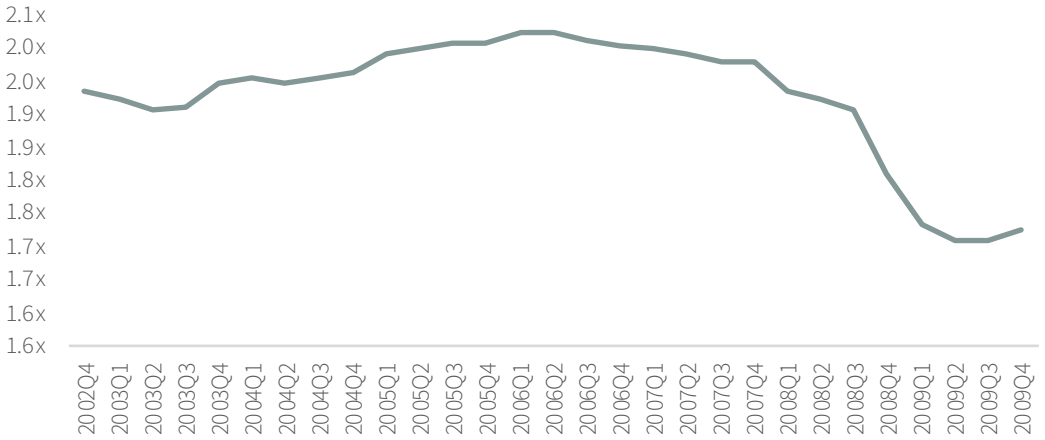
Here is the link: https://www.youtube.com/watch?v=rOVXh4xM-Ww

By August 2008, the Fed had allowed its short-dated Treasury holdings to collapse by a massive $300 bn or almost 40%. These were once again replaced with mortgage-backed securities. The continued replacement of high-powered money with low-powered money had already caused a huge slowdown in M2 growth and money velocity. By the fall of 2008, M2 growth had collapsed from almost 6% over the previous 12 months to only 1.5%. The velocity of money also began a rapid contraction. From the summer of 2007 to the summer of 2008, the velocity of M2 (as measured by the Bloomberg M2 index) had fallen almost 5%.

FIGURE 8A Federal Reserve T-Bill Holdings

Source: St. Louis Fed, Bloomberg

FIGURE 8B US M2 Velocity



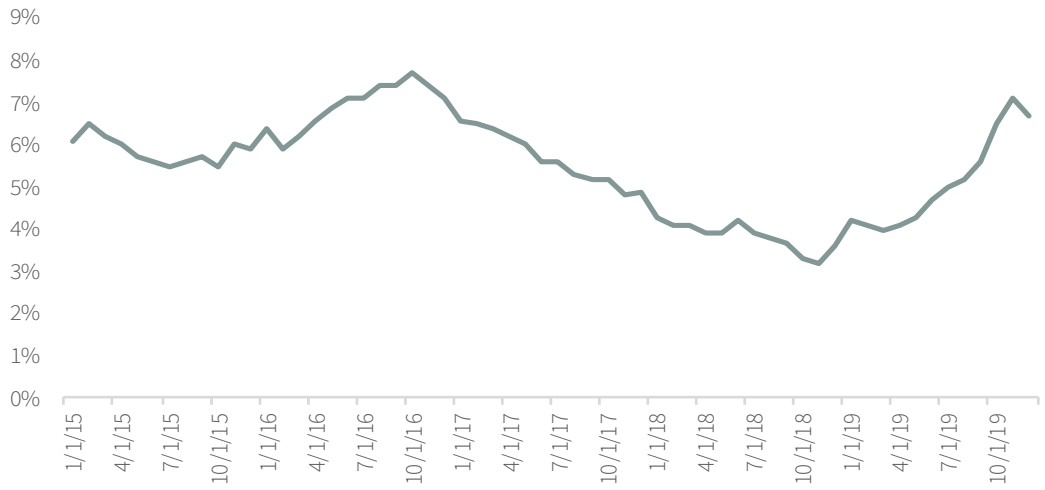
Source: St. Louis Fed, Bloomberg

We believe the Fed's contraction of its Treasury bill portfolio in 2007 and 2008 can only be rivaled only by its actions undertaken between 1928 to 1932. Back then, the Fed shrunk its Treasury bill portfolio by almost 50%, which caused the 90% collapse of the stock market, the banking collapse in 1932, and the Great Depression. The near 50% reduction in the Fed's Treasury bill portfolio, undertaken between 2007 and 2008, created a financial crisis almost as severe---a stock market crash, the collapse of Lehman Brothers, and ultimately a banking system that needed a massive direct $700 billion Federal Government bailout.

In attempts to reduce global financial strains, the Fed undertook three rounds of quantitative easing. By the summer of summer of 2014, the Fed's balance sheet had exploded almost six-fold in just five years. Yet in a bizarre twist that has elicited no comments from the financial press, the Fed shed its last remaining Treasury bill from its balance sheet back in 2012. Since then, the financial community has ruminated on the reasons behind the collapse in monetary velocity. Again, we believe there is no mystery. The collapse in M2 velocity from 2.0x in 2007 to 1.4x today occurred exactly as the Fed wound-down its Treasury bill portfolio, withdrawing much of the of high-powered money from the US banking system in the process. This has resulted in both low economic growth and much reduced inflationary expectations. Offsetting this we have the last five years' multiple asset bubbles (crypto-currencies, FANG stocks, cannabis, and the granddaddy of all bubbles—the bond market). All the money had to go somewhere.

After experimenting with unconventional monetary policy for 13 years, the Fed abruptly changed course last September in response to the crisis in the repo market. On October 8, 2019, the Fed announced it would again start expanding its balance sheet, relying almost entirely on the purchase of Treasury bills. By buying almost exclusively Treasury bills, The Fed has now expanded its balance sheet by $160 billion. Given that the Fed has now aggressively resumed the injection of "high-powered" into the banking systems by buying Treasury bills, we believe the period of declining monetary velocity has ended. The impact on inflationary expectations, gold and commodities broadly, could be huge as this "high-powered" money is put to work.

FIGURE 9 M2 Year on Year Growth



Source: St. Louis Fed

In addition to the already purchased $160 billion of Treasury bills, the Fed also announced their plans to "purchase Treasury bills at least into the second quarter of 2020 in order to maintain over time ample reserve balances at or above the levels that prevailed in early September 2019." The renewed balance sheet expansion (now entirely done with Treasury bill purchases) has already caused a jump in M2 growth. In the last six months alone, M2 growth has nearly doubled from 3.8% to over 7% by the end of December.

"NOW THAT THE FED IS ONCE AGAIN BUYING TREASURY BILLS AND INJECTING HIGH-POWERED MONEY INTO THE BANKING SYSTEM, WE BELIEVE THE IMPACTS ON INFLATIONARY EXPECTATIONS WILL BE HUGE."

Now that the Fed has returned to using traditional monetary policies, we believe the impact on gold will be significant. Over the last 12 years, the Fed has exploded its balance sheet with little in the way of inflationary problems. Instead, all of the liquidity has gone into assets that benefited from "disinflation." Now that the Fed is once again buying Treasury bills and injecting high-powered money into the banking system, we believe the impacts on inflationary expectations will be huge.

In Q1 2019, we discussed the importance of the "Death of Inflation" *Bloomberg/Business-Week* cover story published in April 2019. Given the strong contrarian message often contained in business magazine covers, we suspect their announcement that inflation is yesterdays' problem will turn out just the opposite: the 2020s will be defined by surging inflationary problems. The Fed's change in monetary policy could very well be the catalyst. Not only do you have a rapidly expanding Fed balance sheet, but for the first time it is being done by creating "high-powered" money using Treasury bills. Since the end of 2011, the Fed has expanded its balance sheet by 60% and yet the gold price still sits almost $350 below its peak of nine years ago. We believe gold is about to play massive "catch up" with the tremendous amount of monetary growth created by global central bank since the 2008 financial crisis.

Why Can't We Admit France Has Solved the World's CO2 Problem?

Most people believe electric vehicles and renewable energy are the solutions to the problem of global carbon emissions. Saying otherwise often elicits open hostility. Nevertheless, both technologies have critical shortcomings that limit their usefulness: in the case of electric vehicles, the problem is the lithium-ion battery pack; in the case of renewable energy, the

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problem is intermittency. While grid-level battery storage would address renewable intermittency, the same battery challenges exist as with EVs. Professor Donald Sadoway at MIT is exploring very exciting non-lithium-based grid-level storage solutions that could help solve this issue but commercial implementation is likely many years away. Until then, both solar and wind will need to be backed up by another source of power. As you would expect, this results in a massive capital redundancy as well as operational inefficiencies as both power generating sources operate sub optimally. Nuclear power, on the other hand, is carbon-free and can be used as base load power at scale using current technologies. People may be starting to come around. Bill Gates has been a long-time proponent of nuclear power and discusses it at length in the recent documentary, "Inside Bill's Brain." Today, we highlight just how beneficial nuclear power can be in limiting global carbon emissions.

Although a huge amount of praise has been heaped onto Germany and Spain for their aggressive renewable deployments, one European country stands apart in terms of its CO2 emissions: France.

At 4.7 tonnes of carbon output per person, France's emissions are the third lowest in Europe. Only Sweden and Switzerland are lower, both of which are endowed with abundant hydroelectric capacity. In the case of Sweden, they have also embraced nuclear power. On the other hand, Germany's per capita emissions are still double those of France while Spain's are 40% higher. Indeed, France's emissions are more than 50% lower than the OECD as a whole. If the rest of the OECD could achieve comparable levels it would go a long way in meeting even the most ambitious carbon reduction targets.

"REMARKABLY, FRANCE HAS ACHIEVED ITS SUCCESS IN LIMITING CARBON EMISSIONS WITHOUT RESORTING TO EITHER RENEWABLE POWER OR ELECTRIC VEHICLES."

Remarkably, France has achieved its success in limiting carbon emissions without resorting to either renewable power or electric vehicles. In 2018, less than 10% of France's electricity came from renewable sources, compared with 30% for both Germany and Spain. France's EV penetration rate is only 0.2%--less than half the European average.

Furthermore, the gap seems to be widening. In 2000, neither Germany, Spain nor France generated more than 3% of their electricity from renewable sources. At that time, Germany produced 65% more CO2 per person than France, while Spain produced 22% more. Since then Germany and Spain both embarked on a massive renewable installation while France was much more restrained. However, the renewable build-out seems to have had the opposite intended effect. Instead of closing the gap between German and French emissions, the average German now emits 88% more CO2 than his French counterpart compared with 65% more in 2000. In Spain, the gap has grown from 22% to 36%.

The explanation lies with nuclear penetration. In France, nuclear power accounts for 72% of all electricity. While this number is coming down, it is not far off the peak penetration rate of 78% set in 2005. On the other hand, as a percentage of total electricity produced, Germany and Spain's nuclear power generations peaked in 1997 and 1989 at 31% and 38% respectively. Today nuclear power represents less than 12% of electricity produced in Germany and 20% in Spain, a drop in penetration of 62% and 47% respectively.

By looking at the various drivers of CO2 emissions, it's easy just how much of an impact nuclear power can have. Below is a table analyzing the drivers of emissions across select OECD countries. Carbon emissions per capita are a function of energy intensity (how much energy is required to generate a unit of GDP), energy quality (how much carbon is emitted per unit of energy consumed), and wealth (real GDP per capita). Breaking down carbon emissions in this way makes clear that France is neither remarkable in terms of energy inten-

sity or wealth. Instead, what is exceptional is that France generates only 31 kg of CO2 per gigajoule of energy consumed, compared with 53 for Germany, 50 for Spain and 52 for the OECD as a whole. Once again, this is explained entirely by its nuclear contribution. Backing out nuclear consumption, France's remaining energy produces 55 kg of CO2 per gigajoule – exactly in line with the rest of the OECD.

FIGURE 10 Drivers of CO_2

	Energy Intensity kj energy/$ Real GDP	Energy Quality kg CO_2 / gj energy	Wealth Real GDP / person	Emissions per Capita t CO_2 / person
France	3,845	30.6	$39,556	4.7
Germany	3,571	53.3	$45,936	8.8
Spain	3,648	49.7	$34,831	6.3
United States	5,301	53.2	$55,719	15.7
OECD Average	4,506	52.1	$40,537	9.5

Source: World Bank, BP Statistical Review

Incredibly, despite these achievements, France is now moving in the wrong direction. President Macron has announced that he is looking to reduce nuclear power from 72% of all electricity to 50% by 2030 by tripling wind power and quintupling solar capacity. Assuming France can generate non-nuclear power at the same emissions rate as Germany (with its 32% renewable penetration), its CO2 emissions will actually increase by 25% under the new proposal, even assuming no economic growth.

"AT SOME POINT, POLICY-MAKERS WILL COME TO THE REALIZATION THAT THE ONLY PATH TO CARBON MITIGATION IS BY EMBRACING NUCLEAR POWER."

At some point, policy-makers will come to the realization that the only path to carbon mitigation is by embracing nuclear power. Despite common perceptions, nuclear power has an exceptional safety record with fewer attributable deaths per kilowatt hour than any other source of power. Any intellectually honest environmental group serious about carbon must embrace nuclear power and stop attacking it. France has solved a large part of the world's CO2 issue and inexplicably the world fails to acknowledge it. Worse–they are actively looking to undo it.