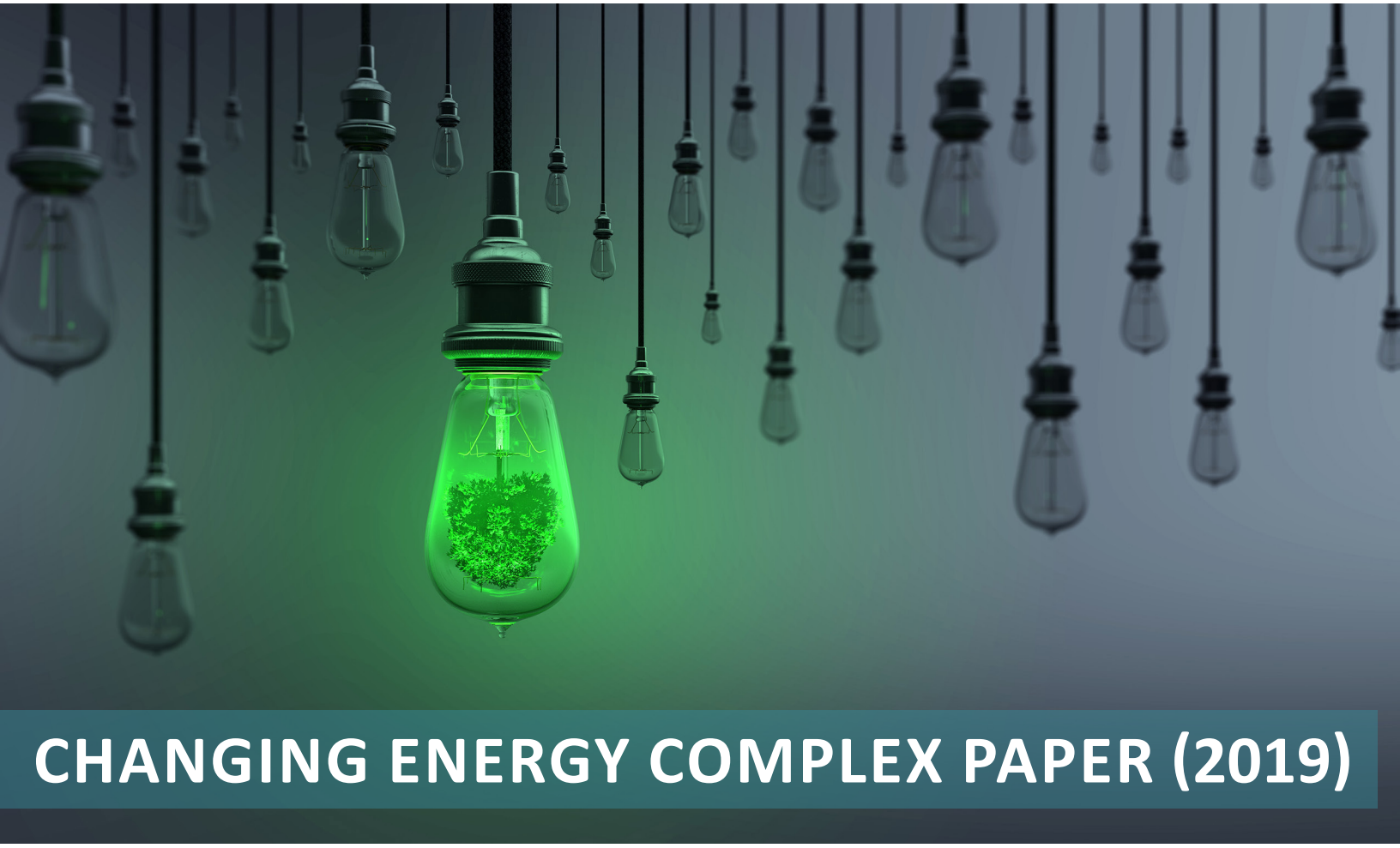
WASHINGTON STATE INVESTMENT BOARD



CHANGING ENERGY COMPLEX PAPER (2019)

THIS PAPER, WHICH WAS PRESENTED TO THE WSIB BOARD ON FEBRUARY 21, 2019, MAY CONTAIN OUTDATED ASSUMPTIONS AND STATEMENTS.

WSIB STAFF ARE WORKING ON AN UPDATE TO THIS PAPER, WHICH WILL BE PUBLISHED IN 2026.

Risks and Opportunities from a Changing Energy Complex and Climate Change

Allyson Tucker
Senior Investment Officer – Risk Management and Asset Allocation

Patrick Martinell
Former Assistant Senior Investment Officer – Risk Management and Asset Allocation

Table of Contents

Executive Summary

Energy is the life blood of the global economy, and, for well over a century, the fossil fuels of coal, oil, and natural gas have been the dominant fuel sources across the globe. Burning fossil fuels allows for the generation of electricity, powers the internal combustion engines that move people and goods around the world, and allows for industrial processes that support rising standards of living. The unfortunate side effect of burning fossil fuels is the release of carbon into the atmosphere, which has been identified as the single biggest contributor to climate change that is now on a path to transform weather patterns, agricultural productivity, and coastlines around the world. The problem of climate change is now well understood, and a complete re-orientation of the global energy complex is required to address it.

Fossil fuels currently represent approximately 85 percent of energy supply globally. Renewables like wind and solar are the fastest growing energy sources, but, even in the most optimistic scenarios, it is difficult to make a sizeable dent in the share of fossil fuels in the immediate future. While some people focus solely on the growth of capacity in the renewable energy sector, it is important to understand its rapid growth within the context of the total energy complex. A handful of factors will impact the future supply and demand of total energy as well as the share of renewables. We believe those factors are:

- Shale gas: Over the last decade, the commercialization of fracking techniques to unlock natural gas from shale deposits has turned the U.S. into the "Saudi Arabia of natural gas." The massive increase in supply has negatively impacted the coal industry in particular, as gas has become more economic. Gas also emits far less carbon than coal and is widely expected to continue to gain share going forward.
- Declining cost of renewables: After 2 decades of subsidies and improvements in technology, renewables have reached cost parity with fossil fuels in power generation in many parts of the world. This cements renewables as the fastest-growing power source globally and will serve to increase the share of renewables at the expense of fossil fuels.
- Emerging market demand: Overall energy demand will continue to grow thanks to rapid growth in emerging markets. Energy is a prerequisite for economic growth, and, as living standards rise for billions of people, energy consumption will rise as well. This means that, although renewables will gain share, fossil fuel demand will grow as well as overall energy demand rises.
- Electric vehicles: One of the biggest variables for fossil fuel demand, particularly oil, is the pace of electric vehicle (EV) adoption. Forecasts for EV adoption vary widely, although there are reasons to believe the pace will be slower than the market currently expects. While EVs are an important factor, they are not likely to make a material dent in oil demand for another 2-3 decades.
- Population and productivity growth: The world's population is expected to reach approximately 9.2 billion by 2040 and billions of people are expected to join the global middle class as global and per capital GDP rise. The increasing prosperity of the developing world will be a key force shaping future energy trends.

In addition to the factors identified above, changes in technology such as battery storage and transmission will also impact the pace of renewables adoption. Similarly, coordination on regulations and implementation of a carbon tax would also speed the transition away from fossil fuel.

Despite recent UN reports sounding the alarm on climate change, absent a full-scale market, political, or regulatory force, the global economy is too dependent on fossil fuel to completely wean itself in the next 2-3 decades; natural gas will even see robust demand growth over that horizon. Coal, with its higher cost structure and status as the highest-emitting fossil fuel, is likely to see the most material decline in demand, although it will remain in use in markets with abundant supply like India and South Africa. However, from an investment point-

of-view, coal is in a slow decline, and, absent a major technological breakthrough, avoiding the sector may benefit a long-term investor like the WSIB.

Assessing the risks and opportunities presented by climate change and the changing energy complex is best accomplished via scenario analysis. In general, taking more aggressive action now comes with a higher up-front cost but ultimately the most damaging and costly aspects of climate change may be avoided. On the contrary, no action today comes with a much larger price tag in the future.

To account for these risks, the energy team, comprised of members from all six units within the WSIB's investment division, developed the following recommendations and key takeaways:

- Asset allocation: The Risk Management and Asset Allocation team recommends studying the feasibility of incorporating the impact of climate change into the WSIB's capital markets assumptions, which are updated every 2 years. This will allow for adjustments (up or down) to account for the impact of climate change and mitigation strategies across a host of scenarios.
- Public equity: The energy sector will be the most directly impacted by a shift away from fossil fuels. Passive equity investors will utilize engagement to push for more disclosure and best practices around climate change risk. Active managers will consider climate change issues when making any investment decision, particularly in those sectors and geographies most likely to be impacted. WSIB staff will continue to focus on evaluating and monitoring how potential and existing managers are incorporating these considerations into their process.
- Private equity: With an investment horizon structure extending more than a decade, private equity managers must be mindful of risks posed by the energy transition and climate change given the lack of liquidity in the asset class. Furthermore, private equity managers are often equipped to take advantage of opportunities from climate change such as building renewable power generation capacity in emerging markets.
- Real estate: The most obvious potential impacts to real estate investments are the physical results of climate change. The most likely physical impact would be damage from increasingly powerful and destructive storms and other natural events, which could result in physical destruction of property. While generally covered by insurance, at a minimum, this would cause business disruption and create opportunity costs. Properties that are not engineered and built to withstand these events, or are located in places susceptible to them, could see weaker demand. There is land, particularly along coastal areas, that could be subject to rising sea levels at some point in the future.
- Tangible assets: Investing in energy infrastructure and weather-dependent opportunities like timber and farmland implies the need to be laser-focused on how climate risk intersects with financial risks and opportunities. Grilling managers on their risk management practices as well as being thoughtful about which opportunities to pursue and which to avoid will help this asset class navigate going forward.
- Fixed income: The WSIB fixed income team will continue to selectively reduce exposure to fossil fuels over time.

Project Overview

This paper represents collaboration among team members representing all asset classes across the investment division of the WSIB. The subject matter touches all asset classes, as the energy transition is an important driver of long-term risks and opportunities across the entire portfolio. This paper seeks to address many questions about the energy transition and its intersection with climate change, with the ultimate goal of helping shape the WSIB's long-term view of risks and returns both at the individual asset class level and across the entire portfolio. Specifically, this paper will address the following:

- The current supply and demand for energy and how that has evolved over the last decade.

- The outlook for energy supply and demand over the next 20+ years and the relative mix between fossil fuels and renewables.
- Scenarios that could unfold pertaining to the reduction in overall carbon dioxide (CO2) emissions across the globe and what it means for the energy complex.
- The likelihood that today's fossil fuel companies possess unburnable reserves or "stranded assets" within their portfolios.
- The impact of the energy transition and climate change on the specific asset classes in which the WSIB invests along with recommendations on addressing risks and opportunities.

This project ties directly to several of the WSIB's investment beliefs for the Commingled Trust Fund:

- Belief 1: The mission of the Fund is to maximize returns at a prudent level of risk.
- Belief 2: Only some investment risks can be clearly defined and measured at the present time (or ever in some cases).
- Belief 4: Risk must be considered at the investment, asset class, and portfolio levels.
- Belief 5: The WSIB has a long investment horizon and therefore is subject to complex and systemic global risks that unfold over time, including financial risks resulting from global climate change.

The work that follows is the result of reviewing numerous reports and papers authored by academics, government agencies, think tanks, sell side research, energy companies, and money managers. Additionally, team members held more than a dozen meetings or phone calls with recognized experts in the field to further discuss specific questions and points of view.

The paper is divided into two sections. The first section provides an introduction to energy and climate change and addresses the evolution of and outlook for the energy market. The second section addresses risks and opportunities for WSIB investments related to the energy transition and climate change.

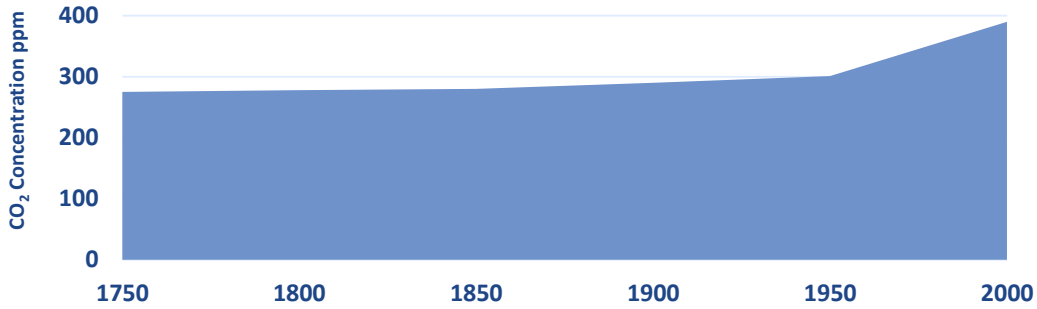
Section 1

Introduction: Climate Change and Energy Basics

Climate Change Today

Climate change can be defined as the statistical change in weather patterns and distribution that lasts for an extended period of time—decades to millions of years. Climate change can be the result of geologic and other natural phenomena such as variations in solar radiation, plate tectonics, or volcanic activity. However, currently there is nearly unanimous agreement in the scientific community that human activity since the industrial revolution has contributed to materially higher carbon levels in the atmosphere, trapping additional heat, and causing the planet to embark on a warming trend.

CO_2 Concentration PPM

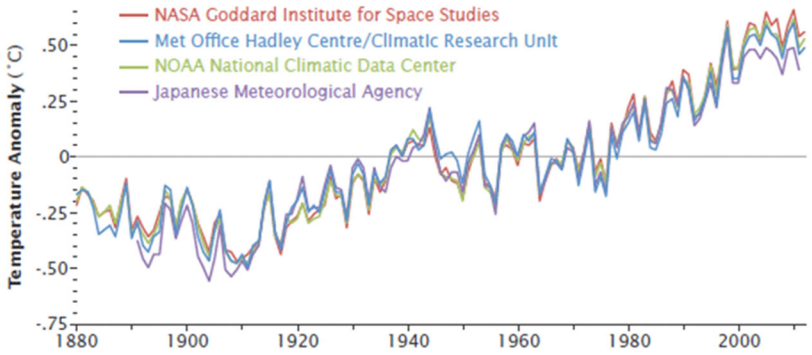


Source: Vostok ice core data/J.R. Petit et al.; NOAA Mauna Loa CO2 record, as cited in Denham Capital, The Future of Energy

The accelerating concentration of carbon in the atmosphere has led to almost annual records in average temperatures across the earth. According to the National Centers for Environmental Information, the 4 hottest years on record were 2016, 2015, 2017, and 2014.

The Four Hottest Years on Record Have Occurred in the Last Four Years

Source: National Centers for Environmental Information, as cited in Denham Capital, The Future of Energy



Rising and more volatile temperatures have had measurable economic impacts including higher intensity of flooding, wildfires, hurricanes, droughts, and storms. Recognizing the existing and potential future impact of steadily rising temperatures, the world's leaders gathered in Paris in 2015 to develop a global climate accord with the goal of limiting global temperature increases to no more than 2 degrees Celsius from pre-industrial revolution levels. Although the treaty contained no binding provisions, it set forth goals for carbon mitigation, adaptation to climate change, and financing. Each country must determine, plan, and regularly report on its plans and actions taken to mitigate the impact of climate change. While the U.S. is in the process of pulling out of the agreement under President Trump, the rest of the world—and indeed several U.S. states and cities—remain committed to achieving the goals to which they agreed when signing the accord.

In October 2018 the UN Intergovernmental Panel on Climate Change released a progress report on carbon mitigation efforts along with an updated projection on the progression of climate change. The report noted a more dire picture than had been previously thought with many of the most serious impacts of climate change—including food shortages, wildfires, and mass die-offs of coral reefs—likely to occur with only 1.5 degrees Celsius of warming. It states that on the current trajectory, this level is likely to be reached as soon as 2040 unless the global economy is transformed at a speed and scale with "no documented historical precedent." The report calls for drastic measures including dropping net emissions to zero globally by 2050, driven by a massive uptake in the use of renewables as well as a hefty carbon tax, both of which are extremely challenging economically, let alone politically. Coal is also identified as needing to drop to essentially 0 percent of the global fuel mix by 2050.

From an economic standpoint, the report indicates that the U.S. is expected to lose 1.2 percentage points of GDP for every 1 degree Celsius of warming. Additionally, at 1.5 degrees of warming, the U.S., along with a

handful of other populous nations—including Japan, China, and Indonesia, could see more than 50 million coastal residents displaced due to rising sea levels. If warming hits 2 degrees Celsius, the planet could experience rapid migration away from the tropics, noting that "in some parts of the world, national borders will become irrelevant."

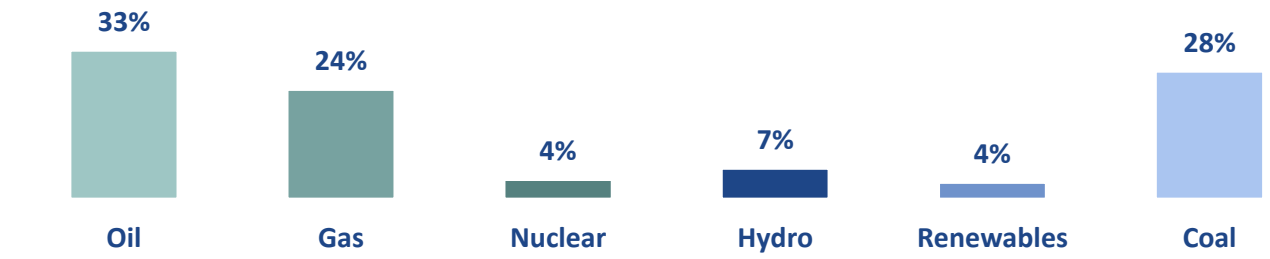
Overall, the picture painted by the report is alarming in that it notes a lower threshold of 1.5 degrees, spells out some of the potentially dire economic consequences, and notes the planet has roughly 22 years to turn on a dime and reshape the global energy complex to avoid the worst outcomes.

Energy Markets

Energy markets, just like any commodity, are a function of supply and demand. Trade-offs in costs, pricing, distribution infrastructure, regulatory environment, and technology help determine the relative mix of fossil fuels and renewable energy sources and ultimately will shape the future of global energy.

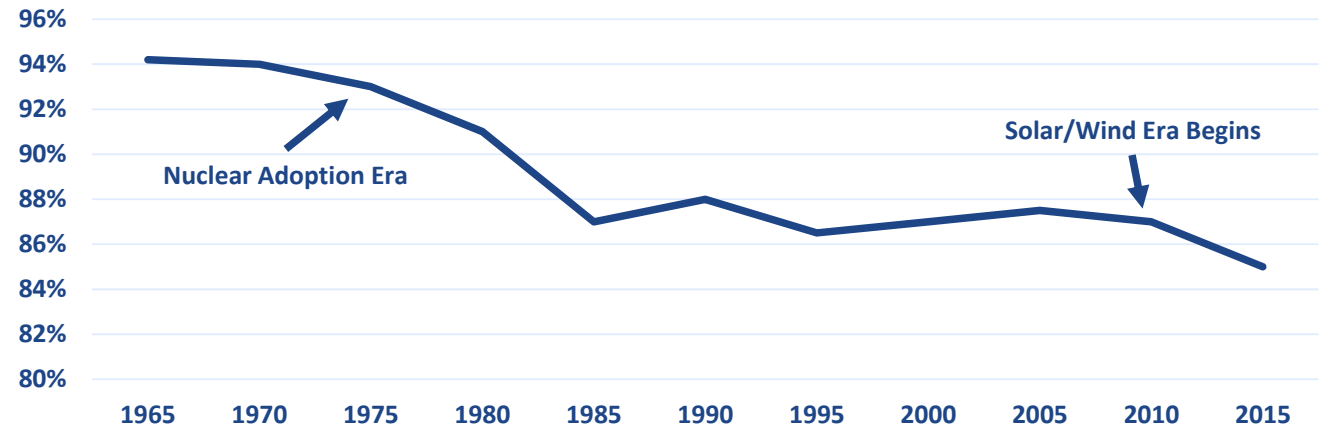
Supply is a mix of fossil fuels and non-fossil fuels, which includes renewables (solar and wind), nuclear, and hydro, each of which has its own economics, accessibility, and end use. Currently fossil fuels (coal, oil, and natural gas) represent about 85 percent of total global energy supply; this share has been trending downward as growth in renewables has taken off.

Global Energy Supply, 2016



Source: BP Energy Outlook 2018

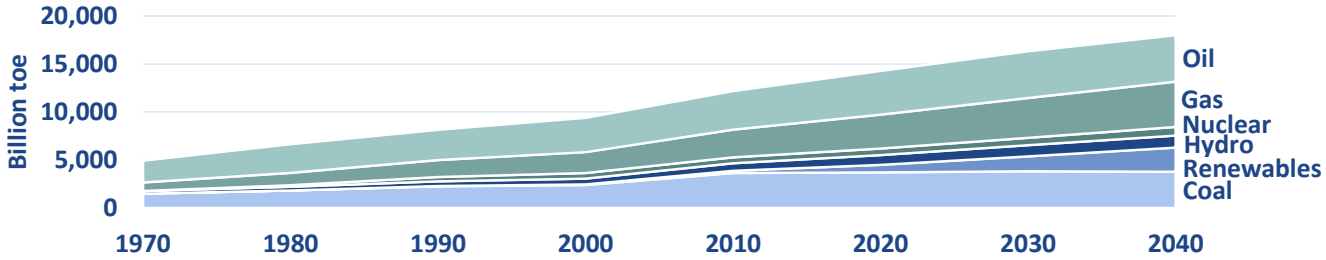
Percent of Global Primary Energy Consumption from Coal, Oil, and Natural Gas



Source: BP 2016 Statistical Review of World Energy, as cited in Michael Cembalest, J.P. Morgan Asset Management, Energy Outlook 2018

Going forward, overall energy supply rises by 48 percent from 2010 levels in BP's base case scenario due to higher demand fueled by global growth. Renewables are projected to have the largest increase in total share of energy supply going from 4 percent in 2016 to 14 percent by 2040, according to projections by BP. Coal and oil are projected to have the largest decline in share falling from 28 percent to 21 percent and 33 percent to 27 percent, respectively. Natural gas is projected to increase slightly as a share of energy supply, going from 24 percent to 26 percent by 2040. Nuclear power's share of primary energy is projected to be flat, as the ability to build new plants is limited by regulations in most jurisdictions, while older plants are expected to see a steady share of retirements. Hydro power is expected to grow modestly, but it will be limited by geographical considerations, as many of the best sites have already been developed. Interestingly, most dams in the U.S. were constructed for the purpose of controlling floods and are not fitted to produce electricity. A future source of hydropower could be in fitting existing dams with generators.

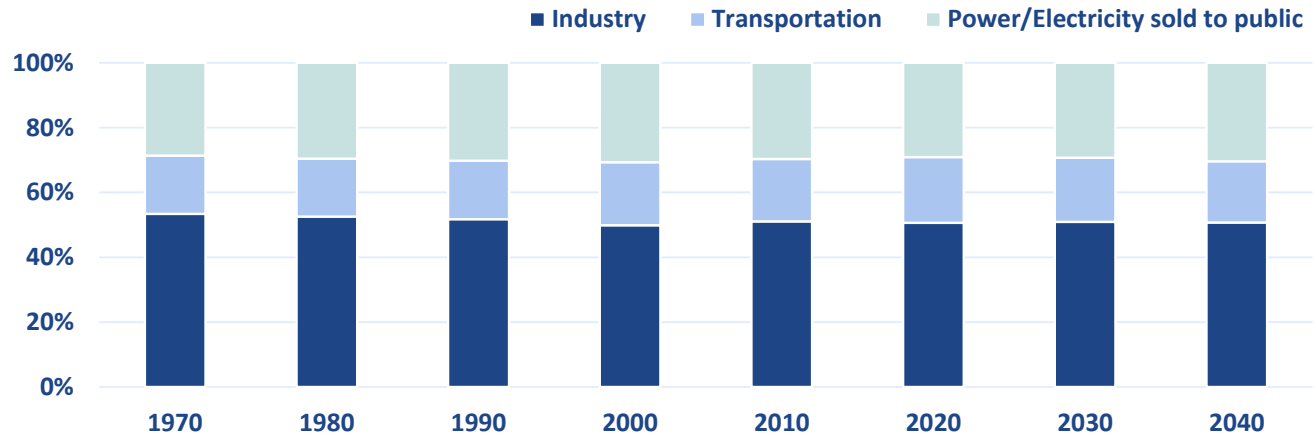
Historical and Projected Energy Supply



Source: BP Energy Outlook 2018

Energy demand can be grouped into three large categories: 1) power/electricity sold to the public; 2) transportation; and, 3) industrial uses, including power generation. Power, representing about 17 percent of final energy demand and 1/3 of total fossil fuel demand , is generated by power plants that use a specific feedstock (e.g., coal, natural gas, nuclear enriched uranium, sun, wind, water) to generate electricity, which is then passed into a transmission grid for first long-haul and then last-mile distribution to homes and businesses. Transportation, accounting for 20-25 percent of energy demand and about 20 percent of fossil fuel demand, served by refined petroleum products in its majority, is used to power consumer and industrial vehicles as well as ships, rail, and airplane transportation. Industrial use, comprising the majority of the demand for energy and about 50 percent of fossil fuel demand, involves direct use of fossil fuels as feedstock or in energy-intensive industrial processes such as the manufacture of chemicals, steel, iron, paper, and food.

Fossil Fuel Demand Sources, 1970-2040



Source: BP Energy Outlook, 2018

Fossil fuels have delivered enormous socio-economic benefits to the developed and emerging world alike, helping to fuel a rapid rise in economic growth and development; access to reliable sources of energy is a prerequisite to sustained economic growth. Unfortunately, burning fossil fuels has been identified as a key contributor to rising carbon levels in the atmosphere, leading to a direct impact on the planet's climate.

The Evolution of Energy Markets

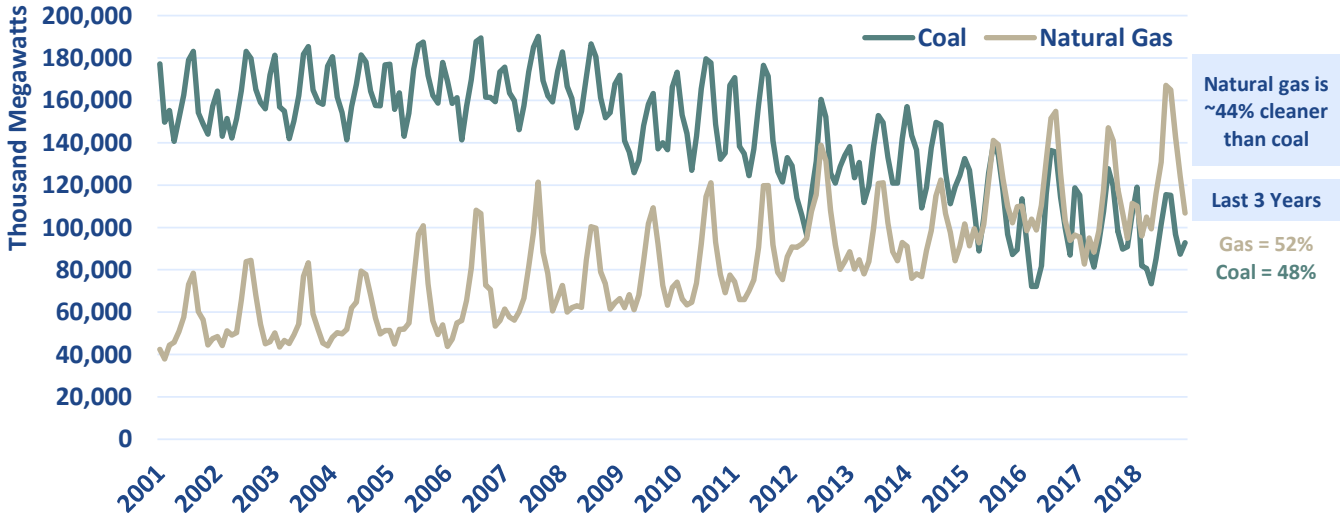
Understanding supply and demand are critical in assessing the outlook for the energy market. Over the last decade and moving into the future, several factors are affecting supply and demand.

Supply

Shale Gas and Oil

Arguably the largest recent trend to positively impact energy supply, particularly in the U.S., is the commercialization of hydraulic fracturing technology to extract natural gas and oil from shale deposits. This trend has had several effects including a plummeting in the price of natural gas, nearly eliminating the need for the U.S. to import foreign oil and displacing coal as a more economic means of generating power. Indeed, coal has been on a steady decline within the U.S. over the last decade, due in large part to the economic impact of shale gas.

U.S. Electricity Generation from Coal and Natural Gas, 2001-2018



Source: EIA electricity data browser and EIA Annual Energy Outlook 2018 assumptions, as cited in Denham Capital, The Future of Energy

As noted in the chart above, this shift has had a positive impact on CO2 levels, as natural gas emits 44 percent less carbon than coal, on average. While this trend has been led by the U.S., shale gas is rewriting the economics of fossil fuels around the globe, and construction of new coal plants has essentially halted. Coal's status as the "dirtiest" fossil fuel has meant that getting loans or guarantees from international agencies like the World Bank has become next to impossible, and the only countries in which coal use is still currently growing is where there are large state-controlled financial arms to help finance construction; India and South Africa stand out as two such countries.

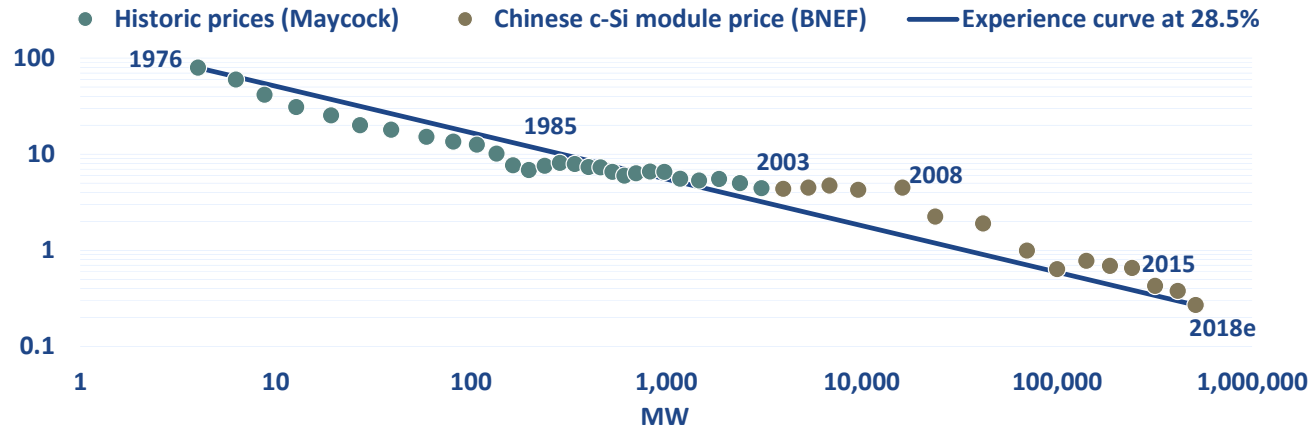
The combination of high emissions and low profitability versus alternatives has put coal on a slow and steady path of decline. It is likely to remain part of the mix going forward, but overall use of coal is likely to be stagnant at best, and we could see severe declines at worst if more stringent regulatory standards on emissions go into effect. Natural gas, by contrast, is expected to have a robust demand profile going forward. Its more economic

and cleaner profile have caused many to label it as the "transition fuel" as the planet looks to fully decarbonize decades into the future. Renewables are expected to see strong growth, but gas is expected to play a prominent and growing role in the overall fuel mix for decades to come.

Renewables

Another trend in the shifting supply of energy has been the cost-competitiveness of renewable energy—solar and wind power—in the generation of electricity. Years of subsidized installation have allowed both technological and cost improvements such that, in most developed and emerging economies, renewable power sources are cost competitive or even the low-cost source, although specific regional and time-of-day based differences may occur. According to a report by Bloomberg New Energy Finance, solar and/or onshore wind are now the lowest cost source of new bulk power in all major economies except Japan.

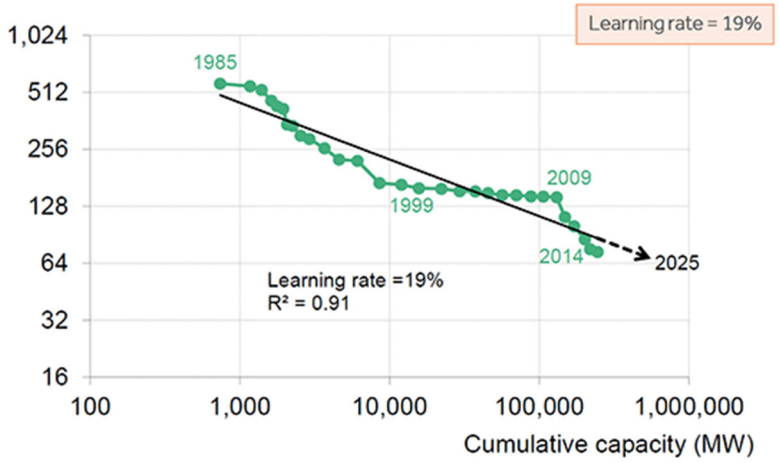
Cost of Solar Panels ($/W), 2018 Real



Source: Bloomberg New Energy Finance New Energy Outlook 2018

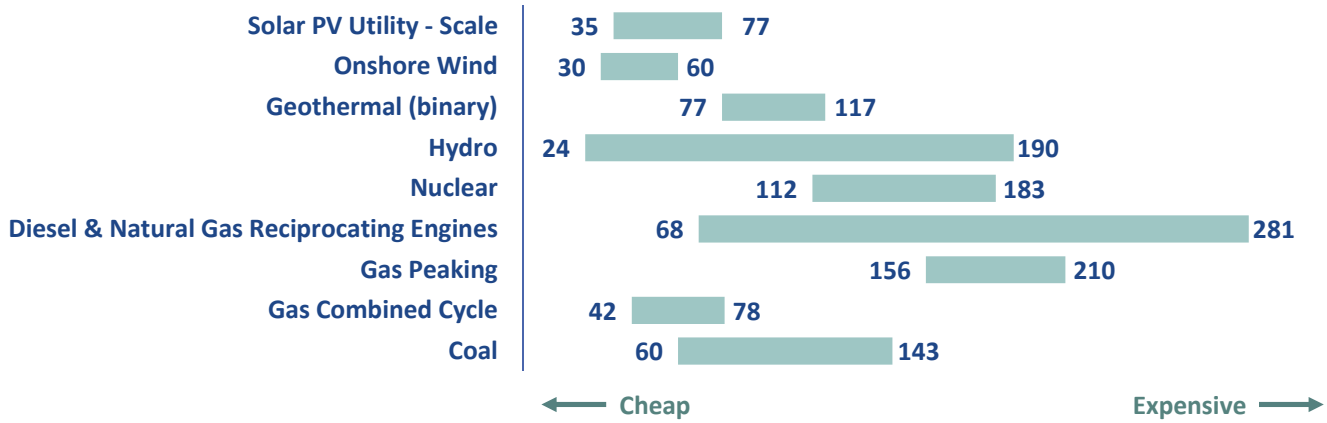
Cost of Wind Turbines

Source: BloombergNEF, Lawrence Berkeley National Laboratory (LBL), Ex Tool study (Neij et al. 2003), Vestas annual reports, as cited in Actis, The Energy Transition



According to a study by Lazard, the result of decades of improvements in cost is that solar and wind are now globally cost-competitive with fossil fuels in electricity generation on an unsubsidized basis.

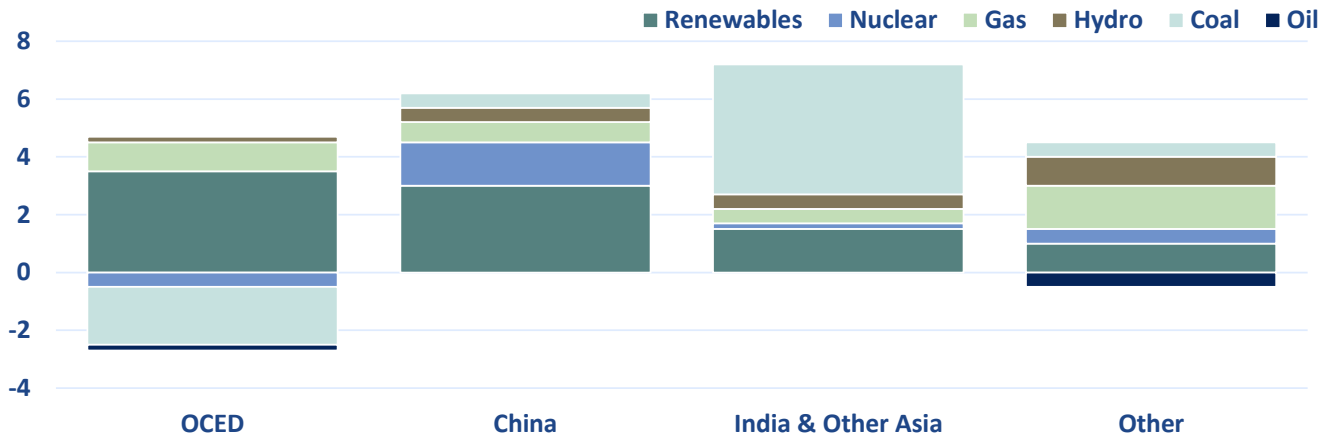
Unsubsidized Levelized Cost of Electricity (US$/MWh), 2017



Source: Lazard's Levelized Cost of Energy Analysis – Version 11.0

The combination of lower cost and growing electricity demand in emerging markets (discussed below) will make renewables the fastest-growing segment in electricity generation going forward. However, issues with renewables imply that they are not likely to entirely displace fossil fuels. Because electricity generation is a function of when the sun shines and the wind blows, renewables cannot guarantee an uninterrupted source of power, particularly at times of peak demand in the evening when the sun has gone down and the wind tends not to blow. Battery technology remains expensive and inefficient, and, while the same dynamics of a learning curve are occurring in this space, utility-scale batteries are not close to being commercially feasible to help to solve some of the availability issues with renewables. Furthermore, given the sheer size of demand, it is simply not feasible for investment in renewables to be the only solution to meet growing demand. As shown in the chart below, renewables are estimated to grow the fastest at the expense of fossil fuels in overall share; however, demand growth could be so robust that absolute levels of fossil fuels are still poised to increase from current levels.

Growth of Power Generation (Thousand Terawatt Hours), 2016-2040



Source: BP Energy Outlook 2018

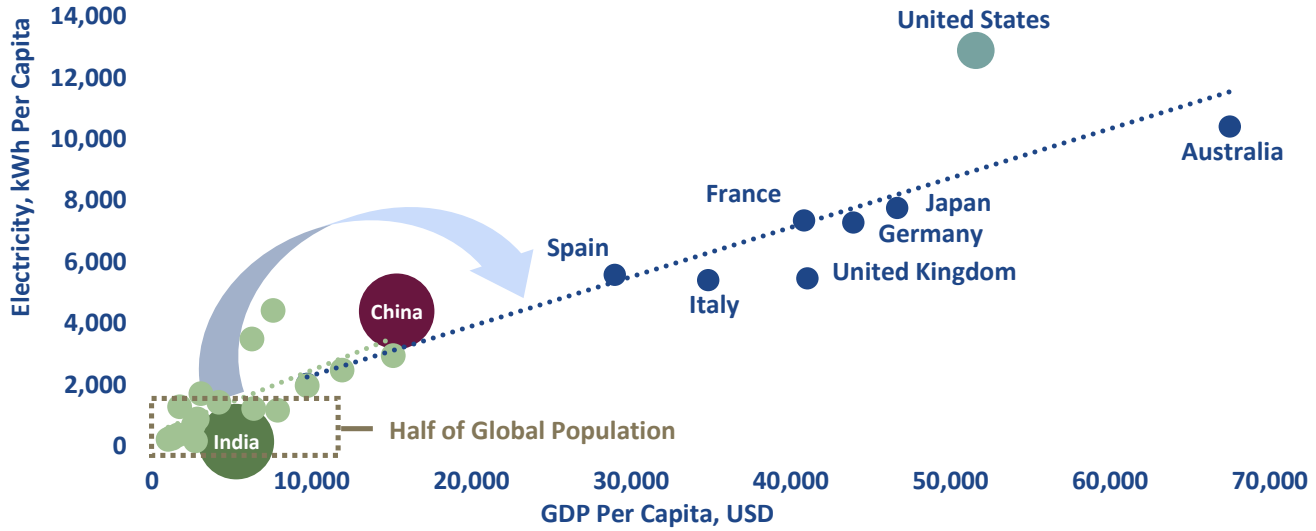
Demand

Emerging Markets

Historically, growth in energy demand has correlated strongly with economic growth; access to energy is one of the prerequisites needed to spur economic development. For instance, according to The World Bank about

40 percent of Nigeria's 190 million people did not have access to electricity as of 2016 (latest data available). This inhibits the country's ability to grow as the supply shortfall keeps power prices high. The following chart shows the strong correlation between GDP per capita and energy consumption.

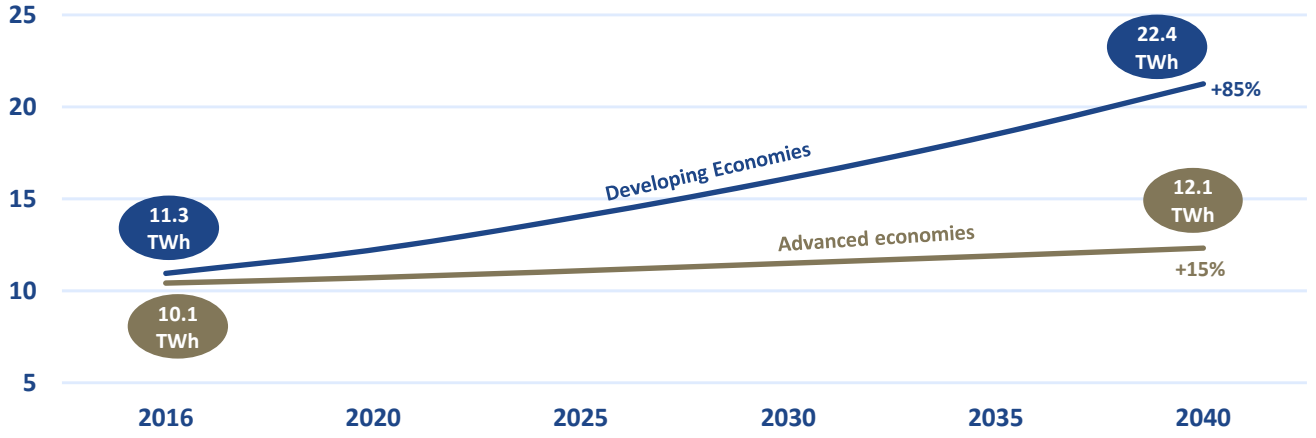
Energy Supports Living Standards



Source: World Bank, IEA, HIS, US EIA, The World Bank, as cited in Denham Capital, The Future of Energy

The key takeaway from the chart above is that half the global population resides in poor countries without high energy consumption. These economies also happen to be growing much more rapidly than the developed world and, therefore, will move up and to the right along the line. In other words, the outlook for energy demand for the next several decades is underpinned by strong growth and rising living standards in emerging markets. The growth in demand will impact all end uses, but it is likely to be particularly acute in power generation. Looking ahead to 2040, projections call for nearly doubling the electricity demand in emerging markets while developed markets' electricity demand grows much less.

Electricity Demand (Trillion kWh), 2016-2040



Source: IEA World Energy Outlook 2017, as cited in Denham Capital, The Future of Energy

This growth, if realized, will create numerous challenges to meet demand without materially increasing levels of carbon emissions going forward. Given the lack of a large installed base of infrastructure and the cost competitiveness of renewables, the opportunity for renewable power in emerging markets is vast. Indeed, it is forecast to be the fastest growing source of electricity generation over the next several decades. The

opportunity is further bolstered by the distribution of sun and wind resources across the planet, as the capacity utilization of sun and wind generation is especially high in emerging markets. However, as noted above, fossil fuels will still play a large role in global electricity production, even in the most optimistic scenarios. Issues with reliability and availability, storage and transmission, and cost competitiveness will ensure a large role for fossil fuels going forward, even if the mix were to change toward natural gas and away from coal.

Electric Vehicles

One of the biggest variables that will impact the future trajectory of oil and electricity demand is the pace at which EVs displace internal combustion engine (ICE) vehicles. As shown below, transportation is the biggest driver of oil demand worldwide.

Global Consumption of Oil Products	Mtoe	% of Total
Road transportation	1,823	50%
Feedstocks	588	16%
Other transportation (air marine)	539	15%
Heating	313	8%
Industry	303	8%
Agriculture	116	3%

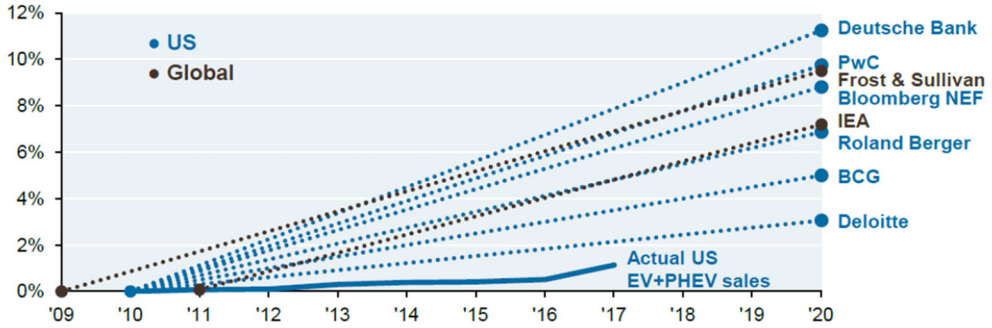
Source: IEA Statistics 2015, as cited in Michael Cembalest, J.P. Morgan Asset Management, Energy Outlook 2018
(Mtoe – Million tons of oil equivalent)

Thus, the potential to shift away from oil is substantial if EV usage can become a meaningful portion of road transportation. Currently, sales of pure EVs and plug-in hybrid EVs comprise about 1.1 percent of global passenger vehicle sales. Forecasts by a host of agencies including the IMF, IEA, Bloomberg, Morgan Stanley, Deloitte, etc. range from a share of 2 percent of the global fleet up to 18 percent of the global fleet by 2020.

In one of the most optimistic forecasts, a think tank called RethinkX recently published an analysis that notes the convergence between EVs and autonomous vehicles (AVs) could essentially mean the end of private car ownership by 2030. They think 60 percent of the U.S. vehicle fleet will be EVs with ICE sales all but stopped and only representing about 5 percent of total passenger miles. One has to assume people will either be required to adopt an AV or choose to, a tricky behavioral guess. In their view, this dynamic will be driven by cost, as safe and reliable Transportation as a Service (TaaS) provided by AVs becomes cost competitive with ICE private car ownership. If the thesis plays out as hypothesized, this would have a transformative effect on transportation in general and remove significant demand for oil in the process. The effect on carbon emissions overall, though, needs to take into consideration that in some areas gasoline would be replaced with nighttime electricity generation, which still utilizes coal as a feedstock in some significant regions.

While the potential for EV adoption remains great, there are several factors working against near-term widespread adoption. The optimistic forecast cited above is not unique; prognosticators have often been incorrect in forecasting a level of adoption of new technologies that has not matched reality.

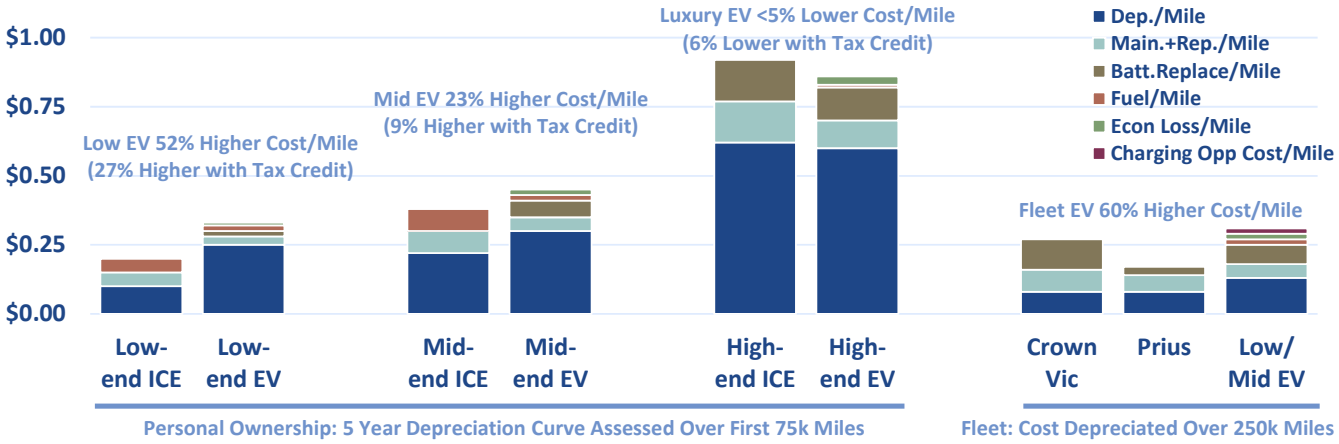
Prior Generation of Electric Car Projections Out of sync with Reality, EV+PHEV Sales as % of Total Car Sales



Source: DOE, BEA, hybridcars.com, and listed organizations 2017, as cited in Michael Cembalest, J.P. Morgan Asset Management, Energy Outlook 2018

One major reason for the lack of adoption has been cost; the economics of EVs have shown them to be cost competitive only at the high end, explaining the success of Tesla in gaining share in luxury vehicles. However, for low end/fleet vehicles, EVs have an inherent cost disadvantage versus ICEs, which is difficult to overcome given the cost of the battery as a percentage of the value of the vehicle. While battery costs will continue to decline over time, the raw materials component is likely not to decline as demand ramps up, meaning there is likely a floor as to how low EV prices can fall. Another factor in the consideration of widespread EV adoption, is that mining of cobalt, a key component of batteries in a wide range of high tech devices, has been shown to allegedly violate labor rights by utilizing children in some mining operations.

ICE versus EV Operating Costs per Mile Across Various Price Points, 2017

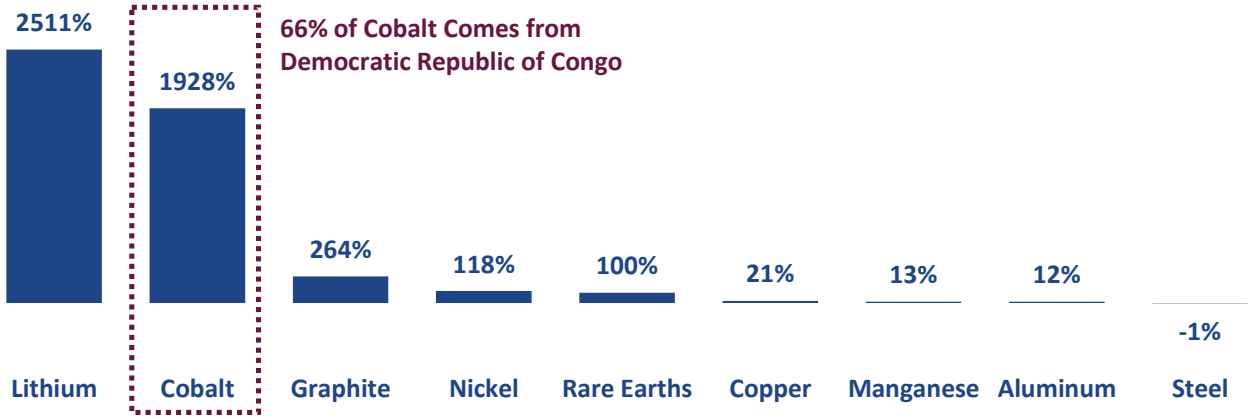


Source: Recurrent Investment Advisors, From Gasoline to the Grid.

Technology may serve to reduce this gap over time, but EVs need to pose a clear cost advantage (estimated to be about 30 percent) before widespread adoption can take off. Recurrent Investment Advisors, in an in depth analysis of projected pricing, notes that high end EVs could enjoy a 15 percent cost advantage versus ICE, while low end and fleet EVs could still be 10-15 percent more expensive than ICEs.

Furthermore, to achieve 100 percent EV penetration, the resources required to produce the batteries would be staggering, particularly of lithium and cobalt.

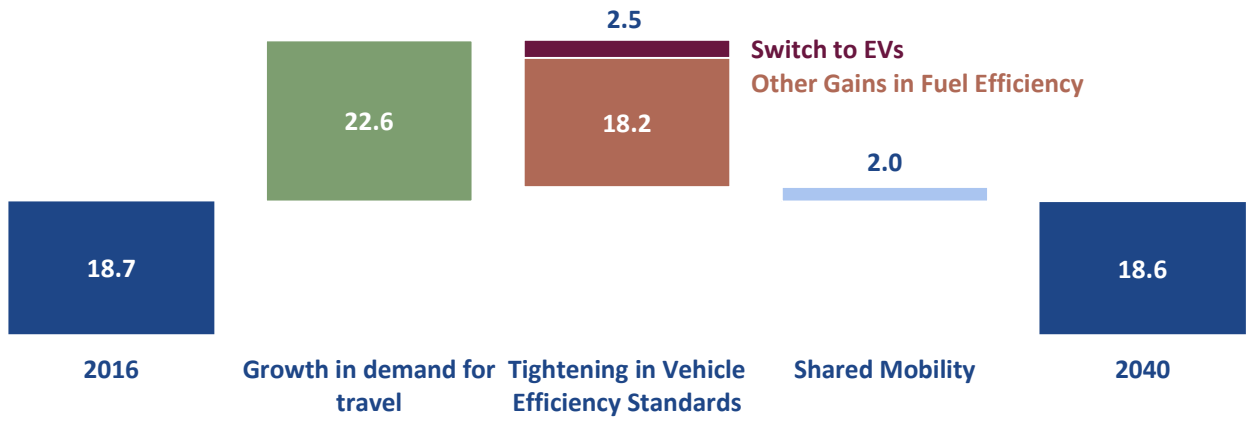
Change in Demand for Commodities in a 100% Electric Vehicle World



Source: UBS Research, BP Statistical Review of World Energy 2018, as cited in Denham Capital, The Future of Energy

Notably, with pure EV sales representing less than 1 percent of global vehicle sales, lithium and cobalt prices have already increased by more than 100 percent. Achieving higher penetration multiples will either cause prices to soar or require a technological breakthrough in batteries. Based on their analysis, Recurrent Advisors estimates 20 percent EV penetration by 2030, driven almost entirely by high end vehicles. In such a scenario, BP estimates roughly flat demand for oil used for transportation as EV and improving fuel efficiency will be offset by increasing demand from developing economies.

Changes in Liquids Demand from Cars (Million Barrels per Day), 2016-2040



Source: BP 2018 Energy Outlook

Thus, while the projections vary widely, the practical limitations in terms of cost and resource availability point to a slower pace of EV adoption than might otherwise be expected. This is consistent with the historical pattern as actual penetration has consistently undershot projections. EVs will certainly gain share in the future, but, given the overall expected increase in transportation demand due to economic growth, oil will likely not see a material reduction in demand from current levels for the foreseeable future.

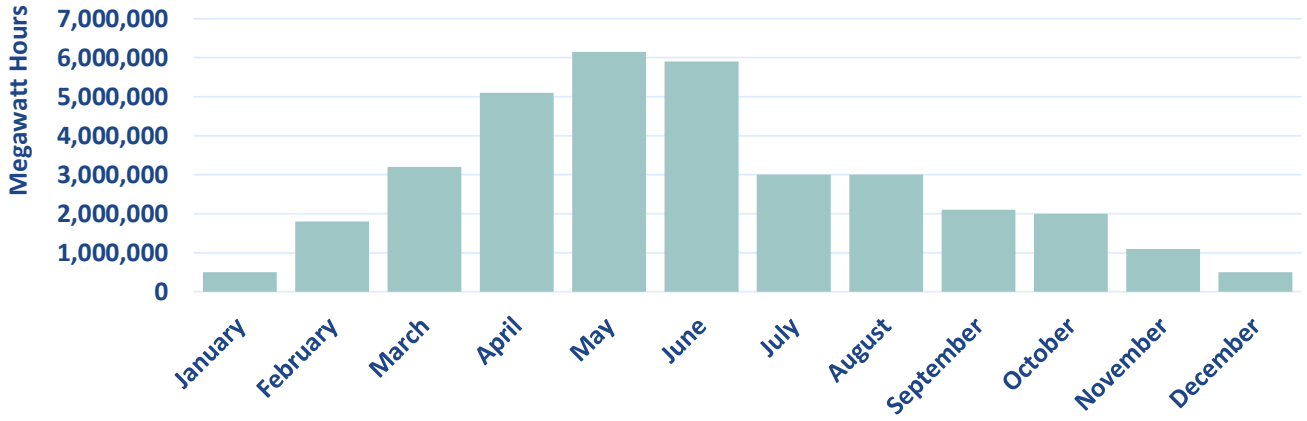
Other Important Factors to Consider

Battery Storage

One of the biggest problems with solar and wind power is the fact that they are intermittent; the wind may not be blowing and the sun may not be shining at times of peak demand. Fossil fuels enjoy an advantage as a feedstock in that power is reliable and can be increased at times of peak demand. The current thinking is that

battery storage solutions are, therefore, of critical importance if renewable energy is to meaningfully displace fossil fuel. While costs have come down dramatically, significant challenges remain in longevity, scale, and cost. The latency problem of renewable power is more than just day versus night time; it can be seasonal as well. The chart on the next page shows wind and solar generation by month in California; there is a notable spike in the summer months.

California Renewable Electricity Generation by Month



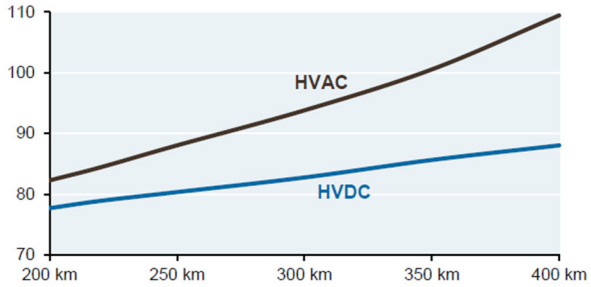
Source: Clean Air Task Force Analysis of CAISO data, as cited in James Temple, MIT Technology Review, The $2.5 trillion reason we can't rely on batteries to clean up the grid

If California were to move to a 100 percent renewable power grid—which has been mandated by the state legislature by 2045—the cost challenges could be enormous. To ensure reliable power with today's generation technologies for the full calendar year, massive excess generation capacity would need to be installed, complemented by higher amounts of battery storage to capture the excess power during the summer months and make it available during the winter. The Clean Air Task Force, a Boston-based think tank, estimated that costs to build such a system would rise exponentially from about $49 per megawatt-hour up to $1,612 for 100 percent renewables. Costs are falling as battery storage technology improves, but clearly time shifting such a huge share of the state's power needs would likely result in massive amounts of capacity needing to be built that would sit idle for much of the year. Ultimately, consumers could be faced with electric bills that are potentially multiples higher than today, likely making achieving the goal politically infeasible. Though environments vary by geography, utilities often become fundamentally political assets, the poorest segments of the population tend to be most sensitive to high prices. Venture capital is intently focused on the battery storage problem, and it is widely believed that a breakthrough will be needed to make renewable energy part of the reliable base load power currently occupied by fossil fuels.

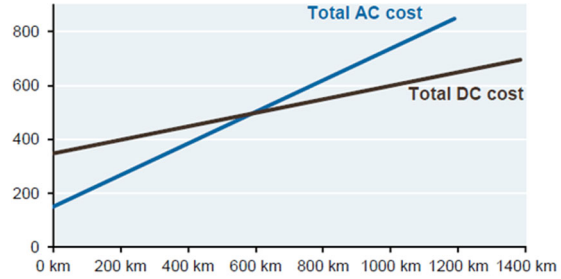
Transmission

Another necessary component of the solution in the move toward renewable energy is transmission. The current system of alternating current (AC) transmission lines is usually best for short and medium distances; however, over long distances AC lines result in large transmission losses, and high voltage direct current (HVDC) lines are more economic. They have higher upfront capital costs but are much more efficient at moving power over long distances as the following two charts illustrate.

Transmission Losses: HVAC versus HVDC (Active Power Loss/MW)



Comparison of HVAC and HVDC Lifetime System Costs (Cost)



Source: Nguyen and Saha, Power loss evaluations for long distance transmission lines, and IEA Energy Technology Analysis Programme, 2014, as cited in Michael Cembalest, J.P. Morgan Asset Management, Energy Outlook 2018

China has been the leader in the installation of HVDC lines as it looks to reduce its reliance on coal and shift its power supply to renewables. HVDC lines allow for a much wider distribution of power from where it is generated with less transmission loss, helping to mitigate some of the issues with the seasonality of renewable power. Plans to build HVDC lines in the U.S. have run into a myriad of permitting and regulatory issues, particularly as they look to be built across state lines. These issues will need to be resolved as storage alone is not enough to facilitate the transition to a renewable power grid.

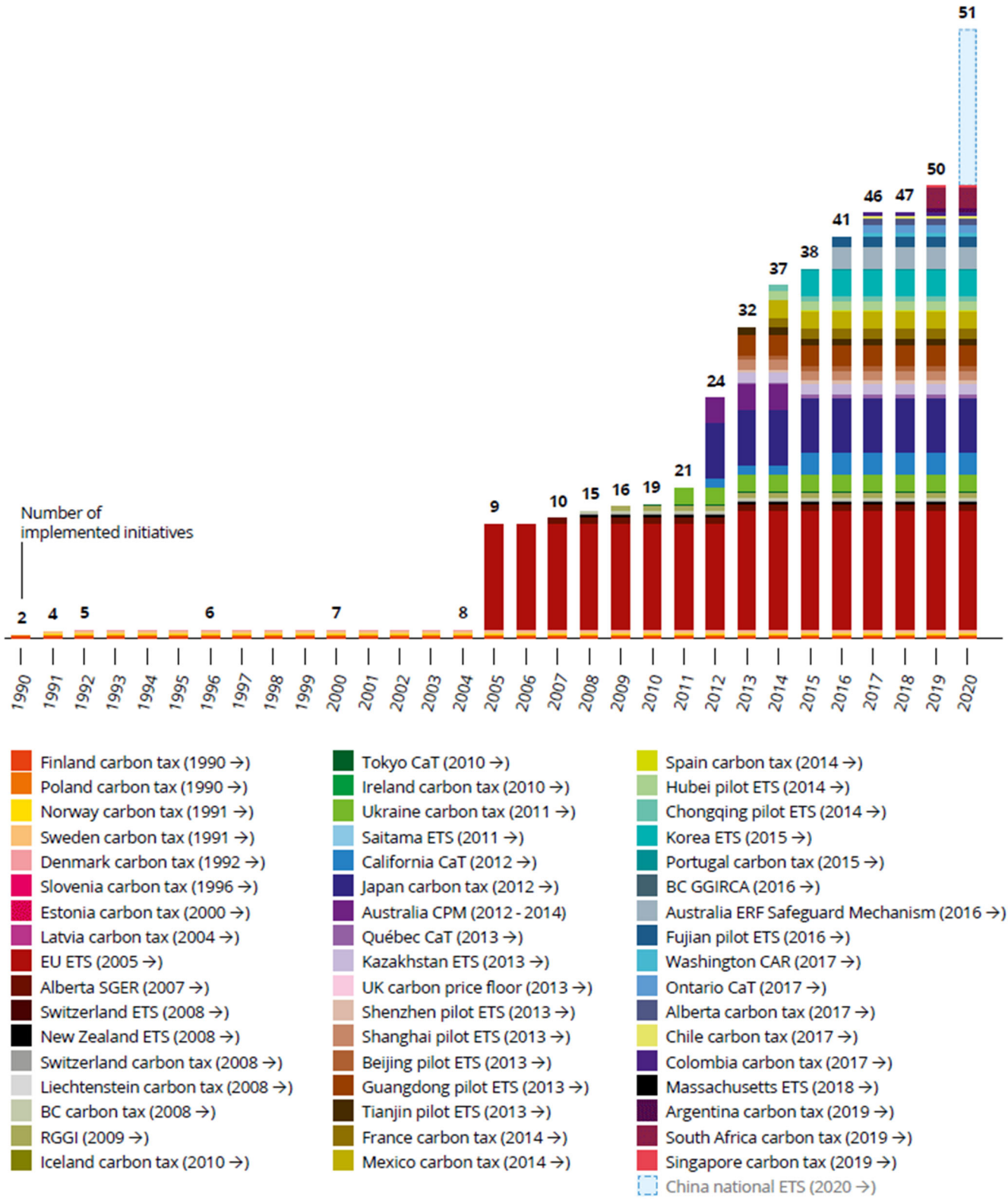
Regulation

To address the issue of climate change, regulators across the globe have been exploring solutions to reduce levels of carbon emissions to be consistent with the Paris Climate Accord goals. The most widespread mechanism is to put a price on carbon—i.e., charge a tax for every ton of CO2 emitted in an economy. Effectively carbon emissions represent a negative externality that is not properly valued, and a carbon tax, in theory, can help raise the cost of emissions commensurate with the harm being done to the environment. To take a simple example, assume a utility owns both a coal fired and a gas fired power plant with roughly similar cost structures. However, burning coal releases much more carbon into the atmosphere than burning natural gas; thus, if the utility is charged a tax for every ton of CO2 produced, it will be more likely to use the gas plant and invest future capital expenditure dollars in lower-carbon power plants.

To date, 51 entities (including countries, states, provinces, and cities) have implemented or plan to implement some sort of carbon pricing scheme by 2020, covering approximately 20 percent of global carbon emissions. The EU has been a leader in this regard, implementing a member-wide carbon tax beginning in 2005; China is expected to roll out its carbon pricing scheme in 2020. The U.S. remains notably absent, as it has been politically infeasible thus far. France introduced a carbon tax and has taken action to reduce the original targets due to citizen protests over higher gas prices. Canada's carbon tax is expected to go into effect in April 2019.

As a local example, on the recent election ballot, the state of Washington considered WA 1631, which would have imposed a "fee" for carbon emissions that would essentially have been tantamount to a carbon tax. Washington voters rejected the measure. This episode illustrates the difficulty in developing such policy changes and achieving forward progress on a carbon tax, even at local and state levels.

Regional, National, and Subnational Carbon Pricing Initiatives: Share of Global Emissions Covered (Share of Global Annual GHG Emissions)



Source: World Bank Group, State and Trends of Carbon Pricing

In projecting the trajectory of energy supply going forward, the pace and breadth of adoption of carbon taxation policies will be a key variable to understand—particularly within the United States, as the second-largest global emitter of carbon dioxide.

However, as the effects of climate change become more acute under current projections and global momentum to fight climate change builds, several big oil companies—ExxonMobil, BP, Royal Dutch Shell, and Total SA—have actually come out in favor of a carbon tax, recognizing its inevitability and wanting to be proactive in shaping such a measure. While not the only solution to reduce emissions, carbon pricing mechanisms continue to be rolled out in countries around the world and will likely play some measure in curbing fossil fuel demand in the future—especially for a carbon intense fuel like coal.

Stranded Assets and Oil Company Valuations

While this paper will not address the science behind climate change, we believe its existence and impact on weather patterns has been well established as fact. In 2009, an influential article in Nature magazine noted that in order to keep warming below 2 degrees Celsius—a level above which irreparable harm to the atmosphere may be incurred—roughly 80 percent of known fossil fuels reserves would have to remain in the ground. The conclusion of this article has been cited by activists in calling for the wholesale divestiture of fossil fuel companies noting that the vast majority of reserves should be considered "stranded assets," unable to be safely burned without causing irreparable harm to the planet.

The impact of stranded assets on the future prices of publicly listed oil companies, and therefore on the performance of the WSIB's energy related public equity investments, is important to understand.

Within the energy sector, upstream Exploration & Production (E&P) companies are most directly involved in the business of exploration and extraction of oil and gas reserves. Once reserves are discovered, the E&P company will invest substantially in the drills, wells, pipes, and other equipment to extract the oil and gas and then sell it into the marketplace. Higher levels of reserves are often associated with higher stock prices and vice versa. This makes sense, as reserves in the ground can be viewed as future sources of revenue and cash flow for E&P companies.

To understand how levels of reserves impact company valuation, we first need to understand how reserves are categorized; E&P reserves can be classified into three groups: proved, probable, and possible. Significant geological work, engineering work, and cost estimation needs to be completed in order to classify reserves into these categories. In the U.S., E&P companies are required to report proved reserves in their financial statements. They may also report probable and possible reserves, but this is not required and less common. The categories break down as follows:

- Proved reserves are quantities of oil and gas that are recoverable in current and future years (no time limit) from known reservoirs under existing economic and operating conditions. They can be further broken into developed and undeveloped reserves:
  - Proved developed reserves are expected to be extracted from wells that are already producing. Infrastructure is in place, and minimal incremental capital expenditure is required in order to recover the reserves.
  - Proved undeveloped reserves are reserves that are expected to be recovered by drilling new sites and will require a potentially significant amount of capital expenditure in order to bring reserves into production.
- Probable reserves include those that are still in development and may require further analysis and significant capital expenditure to bring reserves into production. There is generally a 50 percent chance

that actual reserves will be lower than the estimated amount (and a 50 percent chance that actual reserves will be higher).

- Possible reserves have a 10 percent chance of being greater than expected and a 90 percent chance of being less than expected. This is the most speculative category and generally given little weight by investors.

Several academic studies have been published over the last 3 decades looking for a definitive link between levels of (or changes in) reserves and stock prices of E&P companies. One such comprehensive study, published in 2017 by Misund and Osmundsen, did find a statistically significant and positive link between stock prices and changes in proved developed reserves, consistent with prior studies focused on this topic. Simply put, if a company announces a large increase in its proved developed reserves, the stock price is likely to increase as well. Investors are able to easily forecast the number of years of cash flow the reserves are likely to produce without the uncertainty of an associated large capital expenditure.

The authors did not find a statistically significant link between stock prices and either proved undeveloped or probable reserves. This is likely due to the uncertainty of recovery; in the case of both proved undeveloped and probable reserves, significant levels of capital expenditure are likely, and investors are hesitant to bid up a stock price knowing that significant investment is still required to begin extracting the reserves.

In one interesting wrinkle, the authors did note that for recent data since 2009—which is agreed to be the beginning of the shale gas revolution—a significant relationship emerges between probable reserves and stock prices for natural gas E&P companies. This indicates investors began assigning a value to probable reserves given the impact of new shale gas extraction methods. It remains to be seen whether this relationship holds in the future.

In addition to standard measures of discounted cash flow, some important industry-specific factors are important to consider in the valuation of an E&P stock.

- Lifting cost: This is the estimated cost to extract proved reserves, usually expressed in terms of operating expenses per barrel of oil. All else equal, higher lifting cost will result in a lower cash flow and company valuation.
- Proved developed reserves/total reserves: This ratio shows what percent of a company's proved reserves are developed. As noted from the study above, there is a significant positive relationship between proved developed reserves and stock price.
- Reserves/production: This is proved reserves divided by last year's total production. This gives an estimate of the number of years of proved reserves a company has. A higher number of years will result in a higher stock price, especially if the reserves are developed.
- Enterprise value/proved reserves: This ratio shows how the market is valuing each barrel of oil the company has in its proved reserves. In a cross section of E&P companies, higher EV/Proved Reserve companies often have a higher proved developed reserves/total reserves and reserves/production ratios.

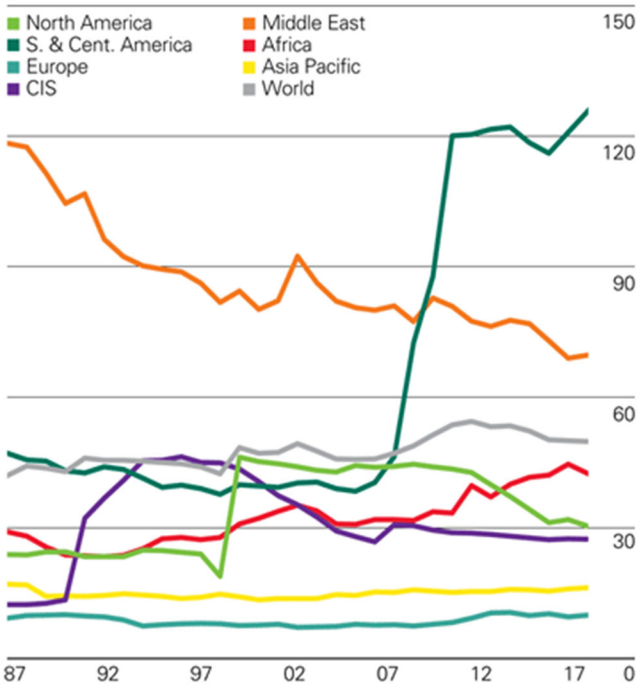
Based on both academic research and the specialized industry metrics detailed above, the market tends to focus on proved reserves. Changes to probable reserves do not tend to move stock prices with the exception of the potential one-off change that happened post-2009 with the popularization of shale gas. Within proved reserves, only the proved developed reserves tend to move stock prices. Given the significant cost involved in assessing the size of reserves and the cost to bring a new field into production, investors tend to focus only on those

assets with a seemingly predictable runway and cashflow pattern, even if such estimates reach far into the future.

As a frame of reference, the graph below shows historical reserves-to-production ratios by region for the 30 year period from 1987 to 2017. The BP Statistical Review of World Energy notes that the 2017 global proved oil reserves would meet 50.2 years of global production at that year's level.

Oil Reserves to Production Rates

Source: BP Statistical Review of World Energy, 67th Edition



While renewables have made significant progress, the combination of reliability issues and projected demand growth means that some portion of the market will rely on fossil fuels for the foreseeable future in order to maintain a stable and growing global economy. The outlook for natural gas is robust as its lower emissions and low cost make it a strong transition fuel. Oil demand is expected to be flat to slightly positive with EV demand being the biggest variable to consider—but even high EV adoption will not likely derail oil and in some cases it could be replaced by coal. Coal has the most uncertain future as a fuel source, but even it is expected to continue to provide reliable base load power, particularly in emerging market economies with large supply and less stringent local regulations. As the chart below notes, even as demand for individual fossil fuels has historically peaked as a share of the total energy complex, overall use of each resource has continued to grow in line with the ever-higher demand for energy globally.

Growing Demand for All Forms of Energy (Exajoules = 1 Exajoule is Approximately 170 Million Barrels of Oil)					
	Wood	Coal	Oil	Natural Gas	Nuclear
1800	20	0.4	0	0	0
1850	26	2	0	0	0
1900	22	21	1	0.2	0
1950	27	45	8	3	0
1980	36	80	110	52	8
2015	40	160	155	125	25

Source: Vaclav Smil, Energy Transitions: History, Requirements, Prospects, 2017, as cited in Scott Elliott, Wellington Asset Management, Lessons from 200+ years of energy evolution

For example, demand for coal peaked as a share of the overall energy complex back in 1900, but overall usage has increased nearly 8 times, even as it has lost share to other fuel sources. Despite this historical backdrop, overall, coal, given current technologies, is most likely to see the largest decline in demand going forward on a multi-decade timeframe. While it is difficult to forecast how quickly this decline will play out, avoiding investments in the coal sector will likely benefit a long-term pool of capital like the WSIB, as the sector appears to be in a slow and permanent state of decline. That said, the transition will likely play out over a period of decades, and there may be periods of outsized returns in the interim based on the balance between supply and demand.

To summarize some of the takeaways from the above sections:

- Energy consumption will likely increase by nearly 50 percent by 2040 thanks largely to growing demand from emerging markets.
- Supply is becoming "greener" as renewables are cost competitive in many markets and cleaner-burning natural gas continues to displace coal. However, at 85 percent of the energy complex, fossil fuels have a large entrenched position that will make it difficult to fully replace.
- EV penetration will likely continue to grow but challenges with cost and resource availability will likely mean slower-than-forecast growth. Thus, oil demand will likely not see a material reduction for decades due to a shift to EVs.
- Challenges with intermittent availability of renewables means other technologies must be a part of the solution—including utility scale batteries and more efficient power lines. Seasonality, for example, presents a formidable cost challenge, and technology has a long way to go.
- Coal remains the most challenged fossil fuel to date, as it has the highest level of emissions. Natural gas is eroding the economics of coal due to fracking technology, and future regulation will likely further serve to make it unattractive to operate a coal plant. Coal capacity will, therefore, likely decline as older plants are shuttered, and new capacity is effectively nil outside of a handful of emerging markets.

Section 2

Climate Change Scenarios and Asset Allocation

This part of the paper will attempt to describe three possible scenarios with respect to carbon reduction and the resulting long-term impact on climate change. It borrows heavily from a 2015 report by Mercer called Investing in a Time of Climate Change, in which different risks and opportunities are distinguished along four key dimensions, and long-term asset class risk and return assumptions are adjusted based on possible outcomes. The energy team recommends considering adjustments to the WSIB's capital markets assumptions over time that specifically incorporate risk and return elements due to carbon mitigation and climate change. By necessity, these adjustments would be part of the "art" of developing capital market assumptions.

The scenarios utilized in this exercise were developed by Mercer using the latest climate science literature and modelling available at the time. They are intended to provide a range of possible outcomes from the most aggressive action achieving the goals from the Paris Climate Accord to a business as usual scenario where little action is taken to limit emissions. In general, the more aggressive carbon reduction scenarios come with a high cost today to invest in transforming the energy complex, but the most costly impacts from climate change do not materialize in the future. On the other end of the spectrum, the business as usual case assumes almost no cost today but high cost in terms of economic damage from climate change materializing in the future. Specifically the scenarios are:

- Transformation: This scenario assumes aggressive action on limiting emissions that causes global carbon levels to peak by 2020 and begin a downward trajectory; emission levels in 2050 are 56 percent lower

than they were in 2010. Fossil fuels represent less than half of the energy mix by 2050. More than $65 trillion in global investment in renewables and energy supply efficiency is needed to achieve these emissions levels. The economic impacts from climate change including hurricanes, storms, wildfires, rising sea levels, and loss of biodiversity are by-and-large minimized. Increasing intensity in hurricane damage is offset by improvement for agriculture conditions. Aggressive action on carbon pricing in the near term is expected under this scenario.

- Coordination: Policy action is delayed but eventually comes into effect, limiting global warming to 3 degrees Celsius. Carbon emissions peak in 2030 and then fall; emission levels in 2050 are 27 percent lower than they were in 2010. Fossil fuels represent 75 percent of the energy mix. Cumulative investment in renewable energy and efficiency total $47 trillion. While the impact of the investment is substantial in helping to avoid the worst impacts of climate change, higher frequency incidents of extreme weather cause some areas to experience irreparable harm, largely due to rising sea levels. Carbon pricing measures eventually come into play in this scenario but do not ramp as quickly as in Transformation.
- Business as Usual: Limited policy action and lack of coordination results in a 4 degree Celsius rise in global temperatures. Carbon emissions peak after 2040, and fossil fuels continue to represent 85 percent of the energy mix (same share as today). Higher future damage results from the effects of climate change. Limited investment is not materially different from the current trajectory of $2-3 trillion per year. Economic impact by 2050 is estimated to be a net -1.75 percent GDP loss per year as gains in agriculture are more than offset by losses due to energy and water availability in addition to losses from coastal flooding, wildfire, and extreme temperatures. In this scenario, efficiency investments in developed markets are offset by increases in carbon emissions in emerging markets, leading to increased levels of atmospheric CO2; no global carbon pricing scheme materializes.

In addition to the scenarios above, Mercer identifies four dimensions along which risk and return will be impacted depending on the scenario: Technology, Resource Availability, Impact, and Policy (TRIP).

- Technology refers to mitigation efforts to transform energy production, transmission, and overall efficiency across the various carbon mitigation scenarios. It can be interpreted as a measure of the future investment flows, for which a higher technology value indicates higher investment flows. In general, these will represent investment opportunities in both climate change prevention as well as adaptation to the effects of climate change.
- Resource Availability is defined as the investment impact of chronic weather patterns or other physical landscape changes. It is intended to identify how the effects of climate change impact the availability of natural resources—a particularly relevant consideration for investments in agriculture and energy. Changing weather may impact agriculture in a positive or negative way, for example.
- Impact refers to the physical impact from climate change and is primarily a measure of risk. Some examples could include property damage due to more extreme flooding, the impact of more frequent and more intense hurricanes, or increased instance of wildfires and resulting damage.
- Policy is defined as the cumulative impact of legislative action at all levels meant to reduce the risk of climate change. These actions can span an array of possible outcomes including specific reduction targets, building codes on energy efficiency and fuel economy standards, land use, carbon pricing/taxation, support for research and development, reduction of subsidies for fossil fuel companies, etc.

Using the above scenarios as well as each dimension of risk and opportunity, Mercer models each asset class through 2050, and they reach the following conclusions:

- Climate change, under all scenarios, will inevitably have an impact on investment risk and returns, so investors ought to explicitly view it as a return variable. In the Coordination scenario, aggressive near

term action leads to investment opportunity in carbon mitigation and renewables while adding risk to incumbent fossil fuel producers. In Business as Usual scenario, near term returns remain relatively unaffected while longer term impacts from climate change start to materially impact asset class returns.

- Industry and sector impacts will be the most meaningful; in their modeling exercise, coal has a negative return expectation for both economic and policy reasons, while renewables could earn above-market returns during the forecast horizon.

Asset class-level returns will be material; the Coordination scenario could see return benefits for emerging market equities, infrastructure, real estate, timber, and agriculture, while the Business as Usual scenario would have the opposite effect for these asset classes. In general, growth assets are more sensitive to climate risk than defensive assets.

The chart below shows Mercer's average expected return impact to each asset class across all scenarios using the TRIP framework.

ASSET CLASS	T	R	I	P
Developed Market Global Equity	<0.25	>-0.25	>-0.25	>-0.25
Emerging Market Global Equity	<0.25	-0.25	-0.50	<0.25
Low Volatility Equity	0.00	>-0.25	>-0.25	>-0.25
Small Cap Equity	<0.25	>-0.25	>-0.25	>-0.25
Developed Market Sovereign Bonds	0.00	0.00	0.00	0.00
Investment Grade Credit	<0.25	>-0.25	>-0.25	>-0.25
Multi-asset Credit	0.00	0.00	>-0.25	0.00
Emerging Market Debt	0.00	>-0.25	-0.25	<0.25
High Yield Debt	0.00	>-0.25	-0.25	>-0.25
Private Debt	0.00	0.00	0.00	0.00
Global Real Estate	<0.25	0.00	-0.75	<0.25
Private Equity	<0.25	>-0.25	-0.25	>-0.25
Infrastructure	0.25	>-0.25	-0.50	<0.25
Timber	<0.25	-0.75	-0.50	0.25
Agriculture	0.25	-1.00	-0.50	0.25
Hedge Funds	0.00	0.00	0.00	0.00

Negative Positive

Source: Mercer, Climate Change Scenarios – Implications for Strategic Asset Allocation, Public Report

To take emerging market equity as an example using this framework:

- Technology: Because emerging markets are experiencing demand growth and do not have the same incumbent infrastructure in place, they will disproportionately benefit from investment in new technology that helps with climate change mitigation. They will be early adopters—much like how China has become the global leader in renewables.
- Resource Availability: This will vary by country, but in large part given the importance of agriculture and energy to many emerging markets, the impact of climate change could act as a drag, as changing weather makes it more difficult to achieve returns of the past in these industries.
- Impact: Impact could be higher for many emerging markets given locational challenges; most are located in warmer climates to start with, water scarcity and pollution are already major challenges in many markets, and a lack of wealth as compared to developed markets will make it all the more challenging to invest in adaptation to climate change.
- Policy: Again, given the demand growth in emerging markets, policy is likely to create opportunity in renewables to help meet that demand. Additionally, the most stringent policies are likely to impact developed markets more than emerging, providing a runway for a cost advantage in emerging markets.

While the specific conclusions of Mercer's analysis may be subject to debate, the framework provides a robust approach to analyzing the impact of the energy transition and climate change on risk and return. The impact of climate change and mitigation strategies can be updated as conditions change and explicitly used as an input for capital markets assumptions, allowing changing risk and return to directly influence long-term portfolio construction. Going forward, the energy team recommends development of a framework for introducing climate change into capital markets assumptions. Although quantification of climate change risk is a significant challenge, over time, developing a framework for climate risk should allow the WSIB to explicitly consider the impact of these long-term risks and opportunities on asset allocation going forward.

Asset Class Insights

Insights, strategies, and investment approach vary according to the specific climate-related risk and opportunity characteristics inherent in each asset class.

Public Equity

Risks

Within Public Equity, the financial risks from climate change can be broken down into two categories: those that result from action taken to prevent or minimize climate change (whether the result of political or social pressures, or technological advancement); and those that result from inaction and the resulting impacts. Within each category, there are huge unknowns relating to the effects, magnitude, and timing of the impacts of climate change depending on how society reacts to the risks of climate change, and how quickly. There is a possibility that both categories of risk become a reality.

Sectors

It is important to make the distinction between those sectors and industries which could be directly impacted by climate change, and those that will be impacted based on how society responds to climate change.

Among the sectors widely believed to be exposed to financial risk if climate objectives are not achieved are Insurance, Agriculture, Health Care, and Consumer. The Insurance industry could face significant impacts from increased frequency and magnitude of natural disasters. Increased insurance costs and an unwillingness of these companies to insure certain risks could become the norm. Agriculture may face increased temperatures, less available water and a shortage of arable land, potentially leading to food shortages. The Health Care sector

could face a shortage of clean water and a limited food supply, as well as the increased spread of disease. Any of these would burden the health care system, although certain companies might benefit by offering treatments. Consumer companies that rely on access to natural resources (for example, clean water for beverage companies or cheap ingredients for food companies) could face supply and/or cost challenges.

Sectors believed to be exposed to financial risk if climate change goals are to be achieved include Energy, Utilities, and Transportation. Energy (in the current public equity portfolio) is heavily concentrated in fossil fuel companies. Slow, costly, or unsuccessful adaptation to changing conditions could leave some investments at risk. Coal seems likely to be the first to be replaced under most scenarios. Oil is more at risk as the transportation sector evolves, while natural gas is actually a potential winner as it is seen as a "transition fuel" in the move to a low-carbon economy. In the Utilities sector, those companies that rely on high-cost, high-carbon fuel sources are most at risk. Also, there are issues around the ability of utilities to earn an adequate return in an environment where low-cost renewables are being fed back into the grid from consumers and others. In the Transportation sector, if and when autonomous EVs become the norm, car utilization rates will go up, the number of cars needed will drop significantly, and the manufacturing of automobiles could become commoditized, all hurting auto manufacturers.

Geographies

Overall the emerging markets equities may be more sensitive to the climate change risk factors associated with physical damages of climate change such as storms, floods, droughts, and resource scarcity, largely due to their geographical location and profile. Additionally, emerging market countries have a lesser social and financial ability to cope with climate change impacts.

According to a 2016 Mercer report, European equities could be less vulnerable to climate change policy shocks given existing policy and commitments in place. Mercer expects these markets to be better prepared for additional climate-related policy.

Opportunities

A lot of technologies are emerging. However, the benefits often accrue to society rather than the producers, so one cannot equate growth of a business to an attractive investment opportunity. That said, WSIB's managers see potential opportunities in EVs, batteries/storage (for both transportation and utilities), electricity transmission, renewables, materials (specifically things like lithium, cobalt, and nickel for batteries), carbon capture and storage, and healthcare.

Investment Process

The WSIB's external public equity managers each address the risks of climate change consistent within their specific investment process.

The WSIB's passive managers tend to focus on engagement as a means to achieve climate-related goals. Disclosure of climate-related risks has been an area of focus recently, and companies are taking these conversations more seriously. In years past our managers would typically speak with a company's sustainability expert, whereas today they are having conversations with the C-suite and the Board.

WSIB's active managers that use bottom-up fundamental research into companies incorporate the risks associated with climate change into their assessments of the quality, valuation, and sustainability of a business. For some, cyclical companies do not meet their definitions of quality businesses and will not make it into their portfolios regardless of price. Others use assessments of the financial risks of climate change in their valuation processes. For example, they will not automatically exclude a company from consideration just because it is in a

"dirty" industry, but the risks associated with that industry will come into play in determining the appropriate discount rate to apply to future cash flows, or in deriving their worst-case scenarios.

WSIB's active quantitative managers believe that the effects of climate change will show up in metrics like profitability and therefore be reflected in their process when appropriate.

Overall, the WSIB's managers do not see stranded assets becoming a material issue in the near term, but it is something they take very seriously. Broadly they see the replacement of coal with natural gas as the most effective way of reducing carbon, and thus tend to avoid companies with portfolios heavily concentrated in coal.

Key Takeaways

Public equity's sources believe that the world is well behind in terms of hitting the objectives of the Paris Climate Accord's 2 degree scenario. Paradoxically, it is possible both the risks associated with not hitting the climate objectives and the risks associated with aggressive action to meet climate objectives could materialize, as climate change mitigating technologies are rapidly implemented, but some may be too late to reverse the damage that has been done.

Staff believes that WSIB's public equity managers are doing a thoughtful job of considering the financial risks associated with climate change. Staff will continue to monitor and discuss with both existing and prospective public equity managers how they are addressing the financial risks associated with climate change in their investment processes, the construction of their portfolios, and in their corporate governance/engagement efforts.

Private Equity

Risks

Private equity as an asset class spans across virtually all industry sectors and regions of the world; therefore, most risks associated with climate change are shared with some or all other asset classes.

Accepting that climate change is causing natural disasters with increased frequency, any business will suffer a productivity loss when its operations are interrupted as a result of a hurricane, flood, or fire. In addition to reduced man-hours or to a manufacturing facility's impairment, severe disruption to a company's supply chain and other logistics is typically inflicted by a natural disaster.

However, exposure to some sectors can undeniably pose greater risk than to others. The most obvious is energy, where either regulatory developments or technological advances can render an industry segment uneconomic within a short time frame. For example, clean air regulation has triggered the decline of coal usage in power generation, and a dramatic reduction in the cost of alternative energy production equipment has now hastened such decline.

Other industries in which private equity investors are active that can be adversely impacted by climate change are Travel/Leisure (from airlines to lodging) as well as Consumer/Retail (reduced crop yields impact the price of food raw materials, in turn negatively affecting the cost structure of food manufacturers or restaurant businesses).

Opportunities

As is generally the case, there are also opportunities in some industries as a result of climate change. New technologies to combat or mitigate climate change and its ramifications may emerge, the development and

commercialization of which could produce sizeable profits. Advances in the efficiency and cost effectiveness of power storage represent an example of technology-driven opportunities. Also, as the decline in air and water quality results in a higher incidence of disease, the health care industry is offered a prospect to sell more pharmaceuticals and medical services. The financial services industry can be on both sides of the climate change risk trade: an insurance company could be bankrupted by claims caused by a natural disaster, or conversely generate outsized profits if properly underwriting the risk associated with it. Generally, since the great financial crisis, the energy sector has not been kind to the WSIB's private equity portfolio, as the volatility in commodity prices and other industry disruptions have compounded the negative impact of the crisis just about when the benefits of deleveraging and economic recovery were beginning to be felt by the broader industry as a whole. The private equity staff has since suspended investing in single sector oil and gas exploration and production private equity funds, due to their higher than average volatility characteristics and one's inability to time the market. Private equity staff is currently exploring the possible attractiveness of investing in other sub-sectors of the energy industry that are not fossil fuel or commodity related.

Investment Process

Private equity staff is mindful of climate change risk and, when appropriate, discuss the potentially adverse impact of climate change on portfolio companies with our private equity partners. Staff assesses a manager's focus on climate change risk management into the scoring system of investment opportunities, awarding additional credit beyond that awarded for having an in house dedicated ESG effort, when applicable.

Partially as a result of peer pressure and a desire not to be seen as unconcerned, most of the WSIB's private equity partners are establishing some type of ESG presence, albeit to varying degrees of scale and activity. However, several have always been committed to, or have more recently demonstrated a genuine interest in, ESG in general and climate change in particular. The foremost example is TPG, which in 2017 raised the Rise Fund. Rise is the first impact fund of scale, with an objective to pursue positive environmental change, alongside maximizing financial return, in its mandate. More specifically in our energy private equity portfolio, none of our managers are investing in thermal coal any longer, while some like Actis and Denham have built robust renewable energy platforms investing in emerging markets.

Key Takeaways

Investing in private equity during the ongoing energy transition requires consideration of the opportunities for growth and returns along with avoiding or mitigating value destruction caused by climate change. The convergence of these two concepts may be serendipitously found in in the sizeable opportunity offered by the developing world, which is the growth market for the energy industry, and through a combination of investments in alternative energy as well as less CO2 intensive fossil fuels such as natural gas.

Real Estate

Risks

Impacts on real estate due to climate change can be physical, behavioral, or financial/legal/regulatory. Most often, these impacts will be linked and span across all three categories.

The most obvious potential impacts to real estate investments are the physical results of climate change. The most likely physical impact would be damage from increasingly powerful and destructive storms and other natural events. These events could result in physical destruction of property. While generally covered by insurance, at a minimum, this would cause business disruption and create opportunity costs. Properties that are not engineered and built to withstand these events, or are located in places susceptible to them, could see weaker demand. There is land, particularly along coastal areas, that could be subject to rising sea levels at some point in the future.

Real estate could be susceptible to behavioral impacts resulting from climate change, such as shifts in consumer preferences and tenant requirements. Many people are choosing to live and work closer to their homes. This leads to increased demand for properties in locations/communities that can serve these needs concurrently. In terms of transportation preferences, increased use of EVs would require the cost of adding charging stations for those using the property. Many tenants are now demanding "greener" properties, with greater energy and resource efficiency. This could lead to higher costs of development and operations, as well as obsolescence of older, less efficient properties.

Lastly, some of the impacts of both physical and behavioral changes have secondary financial, regulatory, or legal risks. These secondary risks can actually be the most impactful to investment returns. Legal and regulatory impacts would most likely occur as a result of public concerns and priorities. These could occur at national, regional, and local levels, and could impact both the development and operations of real estate. At a local level, changes to zoning regulations, construction standards, and environmental/storm water management requirements could result in higher costs. Perhaps the most detrimental impact of climate change to real estate would be an indirect financial result of the aforementioned increase in physically destructive natural events. Damage caused by these events could increase insurance costs, or even result in a complete loss of insurability. A loss of insurability could, in turn, result in the inability to secure financing (mortgage debt) on properties, which would require investments to be both unlevered and self-insured, which could result in lower returns.

Opportunities

While the risks from climate change are myriad and interconnected, opportunities may also result. Almost all of these opportunities are rooted in the traditional wisdom that in real estate investment, location is the most important factor. Simply put, the best-located properties enjoy long-term competitive advantages, with higher levels of demand and stronger rental growth. These characteristics not only help to avoid the risks presented above, but this traditional wisdom also holds true for determining which investments could benefit from opportunities related to changes in energy use and climate.

For example, residential real estate investments that are located near employment, shopping/entertainment and, particularly, public transportation, are likely to see steadier demand. Retail properties that are walkable from residential areas will generally be preferable and likely to remain relevant through market cycles.

Opportunities may become available in adaptive reuse of traditional gasoline stations. If fewer gas stations are needed, alternative uses may be attractive. These properties are sometimes in prime urban locations and possess other positive attributes necessary for successful real estate projects. There may be cleanup costs due to environmental contamination, but the opportunities may justify these hurdles.

Changing Risks and Opportunities

As mentioned above, changes to consumer preferences will be important to monitor in WSIB's real estate investments. While being "green" used to be a competitive advantage, now it is expected and will be necessary to avoid obsolescence.

Also, the physical and operational impacts from natural events (e.g., storms, floods) have increased at a fast rate. This results in additional costs, such as repairs and insurance, as well as reduced revenues from vacancies and closures. As noted previously, these are the risks that present the most significant financial impact to real estate investments.

Lastly, the regulatory environment is becoming increasingly complex and challenging to navigate. More regulations and restrictions from governments and other agencies are being instituted in regard to how projects

are designed, permitted, developed, and operated. This leads not only to increased time and costs, but unpredictability in operations and potential volatility of returns.

Portfolio Examples of Climate Change Mitigation

The WSIB's portfolio includes examples of how these risks are being addressed. Kitson & Partners is building a new city in Florida that aims to be completely solar powered. Pacific Beachcomber, a hospitality investment in French Polynesia, uses state-of-the-art environmental technologies, such as Sea Water Air Conditioning Systems, which result in reduced energy consumption and carbon emissions. The Union Square and Park Place office projects in Seattle were modernized to make them more energy efficient. This was necessary not only to reduce costs, but to keep these buildings competitive vis-a-vis newer buildings. Across the globe, many of WSIB's residential projects are located within a short walking distance of public mass transit, or are even built on top thereof.

Investment Process

The impacts of climate change, both direct and indirect, are considered at multiple points in the real estate investment process, from due diligence through ongoing oversight of operations. These occur at the WSIB, intermediary, and local partnership levels.

First, WSIB's real estate team is currently refining an ESG framework that includes climate change as a primary consideration. This framework will include ongoing assessments of these factors across the WSIB real estate portfolio and each partner in the WSIB portfolio will participate in assessing and monitoring these risks. It is important to note that we are not interested in ESG "window dressing", rather we focus on substantive changes which positively impact our investment results over the long-term. Secondly, WSIB's real estate program tracks a broad set of different risks in each investment it makes, in both initial and ongoing due diligence, and many of these categories capture climate change as an important consideration. Lastly, many of the climate change factors that can impact our investments are addressed naturally through the investment style and philosophy of WSIB's real estate program, which is focused on investments that provide a long-term, high-quality, stable income stream. In order to achieve this, the real estate program targets investments that have steady demand from tenants, and those which avoid obsolescence over long periods of time by being in the best locations. This requires consistently monitoring and assessing the factors, such as climate change, that can change or impact these qualities.

Key Takeaways

All geographies and sectors of real estate will be impacted by climate change, so there are not particular property types or locations to avoid, underweight, or overweight. A major focus of the real estate program will be to identify assets that could potentially become obsolete or "stranded" and avoid holding these investments over the long term.

The WSIB real estate program inherently considers the risks of climate change in its investment process. It will be vitally important to continue to monitor and understand how these factors change behaviors and preferences in regard to how consumers value these issues and, as a result, where they choose to live, work, and shop. Changes in energy sources and uses could change transportation patterns and underlying land uses, which could have an impact on real estate values. Also, the effects of more extensive regulatory requirements and resulting higher construction costs will need to be factored in to investment decisions.

Lastly, the most probable, immediate, and impactful result of climate change will likely be increased costs, in the form of expenses related to weather and other natural events. While the direct costs of these events (e.g.,

repairs and lost revenue) could pose a substantial risk, it is the secondary and indirect costs (e.g., insurance and financing costs) that are likely to have the most significant negative impact to real estate investment returns.

Tangible Assets

Risks

Within Tangible Assets, risks associated with climate change impact all areas of the portfolio. They are likely to take many forms, including regulatory, competition/substitution, reputational, and weather challenges. Risks associated with climate change are most visibly manifested in the asset class's power and energy investments, sectors frequently associated with the causes of climate change; as well as agriculture investments, which not only contribute to greenhouse gas emissions but are also often vulnerable to the predicted impacts of climate change.

Power and Energy

In the case of power and energy, climate risk is often assumed to be found in the potential for regulatory restrictions on fossil fuels to limit operations, inhibit asset development or sales, or otherwise impair asset values, creating "stranded assets." Despite a global trend towards emissions reduction efforts in recent years, such restrictions are uncommon.

While activism has called for the restriction of fossil fuel production in response to climate change concerns, regulators have focused more on supporting renewable resource development, which presents a different set of risks. Interestingly, the renewable assets made possible by regulatory initiatives to address climate change face some of the greatest stranded asset risk. Projects that depend heavily on government support risk closure or economic failure if the incentives that supported their development are reduced or withdrawn, as they have been in numerous jurisdictions including the U.S., UK, Spain, Italy, and Germany.

Conventional energy assets may face competition risks as the energy supply grows and alternative energy becomes more economical to produce. Once again, the changing competitive landscape is a result of several factors, some of which are not driven by climate change. In the aftermath of the shale boom, for example, natural gas has become cheap and plentiful, largely replacing coal, which tends to have higher fixed costs, as a source of baseload power. Emissions reduction is a side effect rather than a cause of this shift. Renewable sources such as wind and solar are too intermittent to meet 100 percent of current demand, and global demand growth continues, albeit weakened by conservation and efficiency developments. However, Tangible Assets staff believes that the energy mix will tend to shift in favor of clean energy and renewables for the foreseeable future and, therefore, seeks exposure to a wide range of energy sector investments in line with the current and anticipated energy mix over the life of the assets.

Agriculture

Within the agriculture sector, livestock production (particularly cattle) faces a unique set of risks. First, animal products typically require more land and water pound-for-pound than plant-based products. In the event that climate change results in less arable land or fresh water, the costs of these resources (and by extension beef and dairy) are likely to increase, and consumers may turn to alternative sources of protein. Furthermore, livestock may be a potential target for regulators seeking to reduce methane emissions.

For crops, the primary near-term risk is that increasing weather volatility, generally believed to be linked to climate change, may damage crops. Countries that lack a strong crop insurance program are particularly vulnerable to this risk. Over the long term, severe climate change could permanently impair the productivity of some land.

Opportunities

In addition to the risks discussed above, disruptions driven largely by climate change concerns, including regulatory changes, technological developments, and shifting consumer preferences, are expected to create new opportunities across Tangible Assets target sectors.

Power and Energy

As the energy mix shifts and more sources of power become economically viable, opportunities may be available in both existing and new areas of the energy sector. The need for reliable power sources during peak demand periods, for example, presents opportunities for natural gas as a "bridge" power source. The last decade has seen a dramatic decrease in the cost of wind and solar power production, providing new and more diversified energy investment opportunities. If this trend continues, opportunities may arise in other renewable resources such as geothermal or tidal, or in entirely new power generation or storage technologies.

Agriculture

As discussed above, crops are vulnerable to weather volatility. However, when a crop suffers large-scale losses due to destructive weather, prices are likely to rise given the relative inelasticity of demand for many agricultural products, benefiting producers in unaffected regions. Further, arable land may develop in new areas, the value of productive land may increase, or existing growing regions may support different crops. Drought could present new and value-add opportunities through investment in water assets, alternative growing systems, crop conversion, and resource management.

Other Opportunities

Strong demand for cobalt, lithium, and other metals or minerals used in the production of batteries may increase mining sector opportunities. New transportation sector opportunities are likely to arise as a result of disruptors including EVs, autonomous vehicles, and ridesharing. Across industries and segments, value-add opportunities can be found through partners that can effectively adapt to changing regulation, provide strong structural and contractual protections, and maintain robust valuation and acquisition discipline in the face of rapid change.

Investment Process

Staff has identified 15 key risk factors and believes that these affect all Tangible Assets investments. The majority of risks arising from climate change are evaluated as part of one of these, Sustainability and ESG Risk, although climate considerations touch on several other risk factors including Reputation Risk and Regulatory and Legal Risk. Staff has found that the overwhelming majority of Tangible Assets partners incorporate risks associated with climate change in underwriting investments, risk management, internal policies, and ongoing monitoring of investments. For example, one agriculture partner articulates its efforts to mitigate weather and environmental risks using technology tools to help collect and measure real-time farm data and combining technical innovation with agronomic best practices.

In addition to ensuring managers are incorporating climate-related risk considerations at the asset level, staff endeavors to mitigate these risks by constructing a diversified portfolio with a forward-looking emphasis, targeting investments with strong cash flows and defensible market positions. Staff does not believe that climate change alone poses a risk significant enough to warrant avoiding any particular segment or industry within the Tangible Assets framework at this time. Staff does, however, recognize that risks associated with climate change may be unacceptably high for specific assets or strategies, and may change over time. Accordingly, staff will continue to consider these risks as part of our comprehensive evaluation process.

Key Takeaways

Risks related to climate change take many forms, often overlapping with other investment risks. These risks are illustrated most clearly in the energy and agriculture sectors. Staff incorporates an assessment of climate-related risks into the evaluation of each investment opportunity, primarily within the context of Sustainability and ESG considerations, and seeks to mitigate these risks through diversification, structural protections, and informed asset allocation. In addition to risks, climate change and the global response are likely to generate both new investment opportunities and value-add opportunities for the Tangible Assets portfolio.

Fixed Income

Within Fixed Income, the risk from climate change is primarily as a result of the asset class's exposure to corporate bonds issued by companies in the oil and gas sector. Other at risk industries that will likely be affected in significant ways include agriculture, automobiles, cement, chemicals, electric utilities, food (particularly livestock), insurance, steel, and transportation.

Risks

The chief risk related to climate change is the potential for stranded assets in the oil and gas sector, although the time horizon for this increasing risk is uncertain given that oil consumption is still rising and the world continues to run primarily on fossil fuels. Modeling climate changes and consequences is extremely difficult. Results from such models may overstate or understate the problems. Because the negative impact to the oil and gas sectors primarily, as well as related industries, could happen sooner than the market currently expects, and because it is hard to know when those industries will be materially impacted or by what mechanism, staff is purposefully reducing exposure to fossil fuel bonds over time. For example, coal company exposure was reduced to zero a few years ago.

The fixed income portfolio currently has exposures to fossil fuels and electric utilities at approximately the level as the fixed income market index. As staff continues to evaluate the risks presented by climate change to the fixed income holdings, we will selectively reduce exposure over time.

Opportunities

The fixed income unit is in the market every day and as staff continues to consider climate change implications, we will assess opportunities as appropriate.

Investment Process

The fixed income unit incorporates a longer-term fundamental view in the investment process. We focus on economic, industry, company, and market fundamentals. However, when industries or government policies are at a turning point, extrapolating from the past does not work. Reduced exposure to fossil fuel companies may result in lost opportunities; this is a risk which staff considers as part of our investment decisions.

Key Takeaways

Fixed Income will continue selectively reducing fossil fuel exposure over time.

Conclusion

Climate change is arguably one of the greatest, if not the greatest, challenge facing the world today. We have already begun to feel the effects of more severe weather events providing just a small view of the future that may await our planet. While the level of climate change impact and the pace of its mitigation remain uncertain, the WSIB (and other long-term investors) must continue to evaluate climate change risks as we invest the funds entrusted to us with integrity, prudence, and skill to meet or exceed the financial objectives of those we serve.

This paper addresses many issues regarding the energy transition and will serve to help shape the WSIB's long-term view of risks and returns at the asset class level and across the portfolio. The paper highlights some of the key issues related to energy supply and demand which the WSIB investment teams will to continue monitoring and researching, such as emerging market growth, EVs, battery storage, transmission, and regulatory issues.

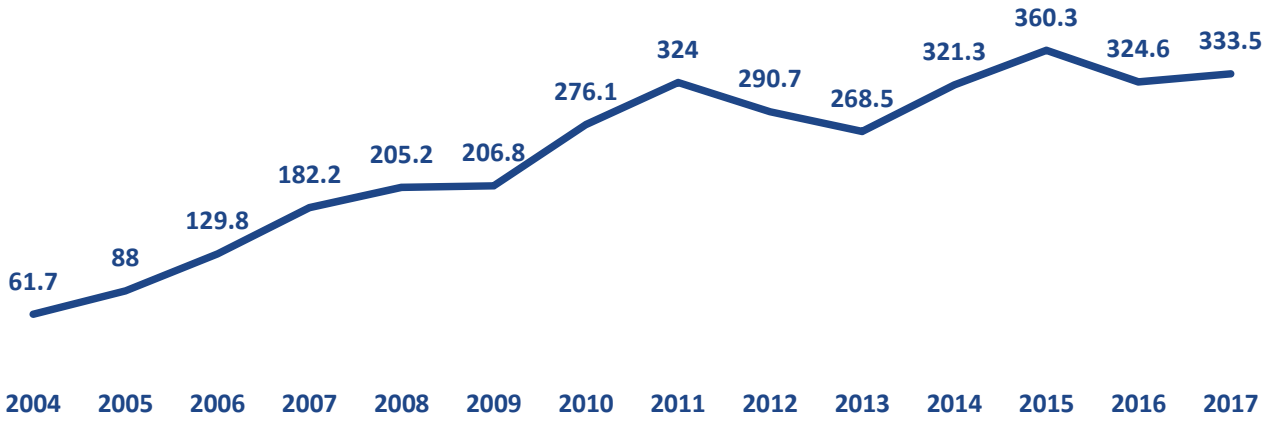
As noted in the Executive Summary, WSIB staff has the following recommendations and key takeaways:

- Asset allocation: The Risk Management and Asset Allocation team recommends studying the feasibility of incorporating the impact of climate change into the WSIB's capital markets assumptions, which are updated every 2 years. This will allow for adjustments (up or down) that account for the likely impact of climate change and mitigation strategies across a host of scenarios.
- Public equity: The energy sector will be the most directly impacted by a shift away from fossil fuels. Passive equity managers will utilize engagement to push for more disclosure and best practices around climate change risk. Active managers will consider climate change issues when making any investment decision, particularly in those sectors and geographies most likely to be impacted. WSIB staff will continue to focus on evaluating and monitoring how potential and existing managers are incorporating these considerations in their processes.
- Private equity: With an investment horizon extending more than a decade, private equity managers must be mindful of risks posed by the energy transition and climate change given the lack of liquidity in the asset class. Furthermore, private equity managers are often equipped to take advantage of opportunities from climate change such as building renewable power generation capacity in emerging markets. Given the control these private equity managers generally have over their investments, they are in the best possible position to manage these risks and take advantage of investment opportunities created by these risks.
- Real estate: The most obvious potential impacts to real estate investments are the physical results of climate change. The most likely physical impact would be damage from increasingly powerful and destructive storms and other natural events, which could result in physical destruction of property. While generally covered by insurance, at a minimum, this would cause business disruption and create opportunity costs. Properties that are not engineered and built to withstand these events, or are located in places susceptible to them, could see weaker demand. There is land, particularly along coastal areas, that could be subject to rising sea levels at some point in the future. Because of the structure of our real estate program, we are well positioned to manage these risks as well as take advantage of any opportunities created by these risks.
- Tangible assets: Investing in energy infrastructure and weather-dependent opportunities like timber and farmland implies the need to be laser-focused on how climate risk intersects with financial risks and opportunities. Close oversight of our managers on their risk management practices as well as being thoughtful about which opportunities to pursue and which to avoid will help this asset class navigate going forward.
- Fixed income: The WSIB fixed income team will continue selectively reducing exposure to fossil fuels over time.

Appendix: How Much are Fossil Fuel Companies Investing in Renewables?

Over the last 10 years (from 2007 to 2017), global investments in clean energy almost doubled, registering an increase of 83 percent to a total figure of $334 billion. The graph below shows how new investment in clean energy has grown over time.

Global New Investment in Clean Energy in U.S. Dollars ($ Billions)



Source: Abraham Louw, BloombergNEF, Clean Energy Investment Trends, 2017

While it is difficult to pinpoint the ultimate source of this surge of investment capital, fossil fuel companies are playing a significant and growing role in renewables. According to Bloomberg, the world's biggest oil companies are closing more clean energy deals to diversify their portfolios, having spent about $6 billion dollars on clean energy over the last 15 years.

Below we attempt to summarize investment in renewables by the largest fossil fuel companies using publicly disclosed information.

Largest Fossil Fuel Companies

BP

Currently, BP allocates 3 percent of its capital expenditures to advancing the energy transition towards a lower carbon future, corresponding to $ 0.5 billion of $16 billion annually. Another $0.4 billion is spent on research and development programs, many of which target alternative energy technologies. In 2005, BP created the BP Alternative Energy Group, which spent $8 billion over the subsequent 10 years.

Chevron

Chevron has collaborated with other institutions to conduct research and development on alternative energy sources. In 2012, the company invested in a 49 megawatt-capacity joint venture geothermal facility in California. In 2017, Chevron started to produce diesel fuel containing between 6 and 20 percent biofuel. Chevron invested in five joint venture photovoltaic solar facilities in California, Arizona, and Texas. The company has an 11-turbine, 16.5 megawatt-capacity wind farm, which produces enough electricity to power approximately 13,000 U.S. homes for a year. Nevertheless the details on how much are spent in those projects are not available.

Exxon

Exxon has spent more than $8 billion over the last 18 years to design and implement higher-efficiency and lower-emission alternative energy solutions across operations. The company invested $4 billion in upstream

facilities on emission reduction efforts, including energy efficiency and flare mitigation. Another $2 billion was allocated to refinery and chemical facilities that reduce greenhouse gas emissions, and $2 billion in support of upstream and downstream cogeneration facilities to produce electricity more efficiently and reduce greenhouse gas emissions.

Shell

Shell plans to invest $2 billion per year on renewables, during 2018 through 2020 and cut its carbon emissions from products by 50 percent by 2035. The company has six onshore wind power projects in different locations and recently bought a company that operates over 30,000 electrical vehicle charging stations in Europe.

Total

Total is currently the European leader in biofuels according to Bloomberg report in 2017. It had the highest number of acquisitions and joint ventures with clean energy companies among the top oil companies. Total has created the Total Energy Ventures fund, which is responsible for investing in innovative energy startups, and, since 2008, the company has invested EUR 150 million in more than 20 startups. The company aims to increase its renewably-sourced electricity production capacity to five gigawatts by 2023.

Overall Clean Energy Investments

According to the Oil and Gas Climate Initiative (OGCI) 2017 report, seven of the OGCI companies reported a total investment of more than $19 billion in renewables over the past 5 years and more than $3 billion spent on research and development in low emissions technologies. The international membership is composed of the 13 top oil and gas companies: BP, Statoil, Eni, Equinor, CNPC, Repsol, Total, Saudi Aramco, Reliance, Chevron, ExxonMobil, Petrobras, Pemex, and Occidental Petroleum. It aims to increase the ambition, speed, and scale of the initiatives undertaken by its individual companies to help reduce manmade greenhouse gas emissions. OGCI members represent approximately 30 percent of global oil and gas production and supply and close to 20 percent of global primary energy consumption. Each member is committed to contribute $100 million per year to the OGCI climate investment funds. In November 2016, OGCI launched a joint, billion-dollar investment vehicle, to help catalyze the development and deployment of technology and business models that will reduce greenhouse gas emissions across the oil and gas value chain on a significant scale. While the sums required to transform the energy complex away from fossil fuels to renewables are staggering, big energy companies are directly involved in helping fund a growing share of that investment.

References

Actis. (2018) The Energy Transition. PowerPoint presentation from a meeting with Washington State Investment Board staff, Olympia, WA.

Arbib, J. and Seba, T. (2017) RethinkX. Rethinking Transportation 2020-2030. The Disruption of Transportation and the Collapse of the Internal-Combustion Vehicle and Oil Industries. Retrieved from https://static1.squarespace.com/static/585c3439be65942f022bbf9b/t/591a2e4be6f2e1c13df930c5/1494888038959/RethinkX+Report_051517.pdf.

Barlett, N., Cushing, H. and Law, S. (2017) CDP. Putting a price on carbon. Integrating climate risk into business planning. Retrieved from https://b8f65cb373b1b7b15feb-c70d8ead6ced550b4d987d7c03fcdd1d.ssl.cf3.rackcdn.com/cms/reports/documents/000/002/738/original/Putting-a-price-on-carbon-CDP-Report-2017.pdf?1507739326.

Barth, A., Tai, H. and Wagner, A. (2018) McKinsey & Company. Are US gas utilities nearing the end of their golden age? Retrieved from https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/are-us-gas-utilities-nearing-the-end-of-their-golden-age.

Bishop, A., et al. (2018) BlackRock. Energy Sector discussion. PowerPoint presentation from a meeting with Washington State Investment Board staff, Olympia, WA.

BP. (2018) Advancing the energy transition. Retrieved from https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/sustainability/group-reports/bp-advancing-the-energy-transition.pdf

BP. (2018) BP Energy Outlook, 2018 edition. Retrieved from https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/energy-outlook/bp-energy-outlook-2018.pdf.

BP. (2018) BP Statistical Review of World Energy, 67th edition. Retrieved from https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review/bp-stats-review-2018-full-report.pdf.

Brandily, T. (2018) BloombergNEF. 2H2018 LCOE Update, Global. Levelized cost of generation, capacity and flexibility. Retrieved from https://www.bnef.com/core/insights/19559/view.

Caldecott, B., Tilbury, J. and Carey, C. (2014) Stranded Assets and Scenarios. Discussion Paper. Retrieved from https://www.smithschool.ox.ac.uk/research/sustainable-finance/publications/Stranded-Assets-and-Scenarios-Discussion-Paper.pdf.

Cembalest, M. (2018) J.P. Morgan Asset Management. Eye on the Market, Energy Outlook 2018. Pascal's Wager. Retrieved from https://am.jpmorgan.com/uk/institutional/eotm-2018-energy-edition.

Chevron. (2017) Managing climate change risks. A perspective for investors. Retrieved from https://www.chevron.com/-/media/shared-media/documents/climate-risk-perspective.pdf.

Denham Capital. (2018) The Future of Energy: A Pragmatic And Balanced Approach to Conscientious Investing. PowerPoint presentation from a meeting with Washington State Investment Board staff, Olympia, WA.

Elliott, S. (2018) Wellington Management. Lessons from 200+ years of energy evolution: What comes next? Retrieved from https://www.wellington.com/en/insights/lessons-from-200-years-of-energy-evolution-what-comes-next/?_c=p40v4e.

ExxonMobil. (2018) 2018 Outlook for Energy: A View to 2040. Retrieved from https://cdn.exxonmobil.com/~/media/global/files/outlook-for-energy/2018/2018-outlook-for-energy.pdf.

EY. (2017) How have investors met their ESG and climate reporting requirements under Article 173-VI?. Retrieved from https://www.ey.com/Publication/vwLUAssets/ey-how-have-investors-met-their-esg-and-

climate-reporting-requirements-under-article-173-vi/$FILE/ey-how-have-investors-met-their-esg-and-climate-reporting-requirements-under-article-173-vi.pdf.

Ferguson, C. et al. (2018) CDP. Bridging low-carbon technologies. Which Capital Goods companies are driving the low-carbon transition? Retrieved from https://6fefcbb86e61af1b2fc4-c70d8ead6ced550b4d987d7c03fcdd1d.ssl.cf3.rackcdn.com/cms/reports/documents/000/003/668/original/Bridging_low-carbon_technologies_-_Executive_summary.pdf?1532536324.

Generation Foundation. (2013) Stranded Carbon Assets. Why and How Carbon Risks Should Be Incorporated in Investment Analysis. Retrieved from https://www.genfound.org/media/1374/pdf-generation-foundation-stranded-carbon-assets-v1.pdf.

Global Commission on the Economy and Climate, The. (2016) The Sustainable Infrastructure Imperative. Financing for Better Growth and Development. The 2016 New Climate Economy Report. Retrieved from http://newclimateeconomy.report/2016/wp-content/uploads/sites/4/2014/08/NCE_2016Report.pdf.

Henbest, S., et al. BloombergNEF. (2018) New Energy Outlook 2018. Retrieved from https://www.bnef.com/core/new-energy-outlook.

Intergovernmental Panel on Climate Change. (2018) Global Warming of 1.5° C. Retrieved from www.ipcc.ch/sr15/.

International Energy Agency. (2017) Key world energy statistics. Retrieved from https://www.iea.org/publications/freepublications/publication/KeyWorld2017.pdf.

International Energy Agency. (2017) Renewables 2017. Retrieved from https://www.iea.org/publications/renewables2017/.

International Energy Agency. (2017) World Energy Outlook 2017. Retrieved from https://www.iea.org/media/weowebsite/2017/Chap1_WEO2017.pdf

International Energy Agency. (2018) World Energy Investment. Retrieved from https://webstore.iea.org/download/direct/1242?fileName=WEI2018.pdf.

Investor Group on Climate. (2017) From Risk to Return: Investing in climate change adaptation. Retrieved from https://igcc.org.au/wp-content/uploads/2017/03/Adaptation_FINAL.pdf.

Klement, J. (2018). Fidante Capital. Infrastructure – Renewable Energy. Retrieved from https://www.fidante.com//media/Fidante/resources/Articles/Renewables.ashx?la=en.

Koehler, D.A., and Bertocci, B. (2017) UBS Asset Management. Stranded Assets. What lies beneath. Retrieved from https://www.ubs.com/global/en/asset-management/insights/sustainable-and-impact-investing/si-insights/2017/stranded-assets.html.

Lazard. (2017) Lazard's Levelized Cost Of Energy Analysis – Version 11.0. Retrieved from https://www.lazard.com/media/450337/lazard-levelized-cost-of-energy-version-110.pdf.

Louw, A. (2017) BloombergNEF. Clean Energy Investment Trends, 2017. Retrieved from https://data.bloomberglp.com/bnef/sites/14/2018/01/BNEF-Clean-Energy-Investment-Investment-Trends-2017.pdf.

Ma, B., Nahal, S., and Tran, F. (2017) Bank of America Merrill Lynch. The Clean Revolution – Global Climate Change Primer. Proprietary research article provided to the Washington State Investment Board.

Meinshausen, M., et al. (2009) Greenhouse-gas emission targets for limiting global warming to 2 c. *Nature, 458*. Retrieved from https://www.nature.com/articles/nature08017.

Mercer. (2011) Climate Change Scenarios – Implications for Strategic Asset Allocation, Public Report. Retrieved from

https://www.ifc.org/wps/wcm/connect/6b85a6804885569fba64fa6a6515bb18/ClimateChangeSurvey_Report.pdf?MOD=AJPERES.

Mercer. (2015) Investing in a time of climate change. Retrieved from https://www.mercer.com/content/dam/mercer/attachments/global/investments/mercer-climate-change-report-2015.pdf.

Misund, B. and Osmundsen, P. (2017) Cogent Economics & Finance. Valuation of proved vs. probably oil and gas reserves. Retrieved from https://doi.org/10.1080/23322039.2017.1385443.

NOAA National Centers for Environmental Information. (2017) State of the Climate: Global Climate Report for Annual 2017. Retrieved from https://www.ncdc.noaa.gov/sotc/global/201713.

Nyquist, S. and Manyika, J. (2016) McKinsey & Company. Renewable energy: Evolution, not revolution. Retrieved from https://www.mckinsey.com/industries/oil-and-gas/our-insights/renewable-energy-evolution-not-revolution.

Oil and Gas Climate Initiative. (2017) Catalyst For Change. Collaborating to realize the energy transition. Retrieved from https://www.oilandgasclimateinitiative.com/wp-content/uploads/2017/10/OGCI-2017-Report.pdf.

One Planet Sovereign Wealth Funds. (2018) The One Planet Sovereign Wealth Fund Framework. Retrieved from https://www.ifswf.org/sites/default/files/One_Planet_Sovereign_Wealth_Fund_Framework.pdf.

Recurrent Investment Advisors. (2017) From Gasoline to the Grid. Retrieved from https://www.recurrentadvisors.com/our-complete-electric-vehicle-report/our-complete-electric-vehicle-report.

Ritchie, H. and Roser, M. (2018) Energy Production & Changing Energy Sources. Retrieved from https://ourworldindata.org/energy-production-and-changing-energy-sources.

Soliman, T. and Fletcher, L. (2018) CDP. What does the future hold for oil & gas majors? Retrieved from https://6fefcbb86e61af1b2fc4-c70d8ead6ced550b4d987d7c03fcdd1d.ssl.cf3.rackcdn.com/cms/reports/documents/000/003/428/original/CDP-what-does-the-future-hold-for-oil-and-gas-majors.pdf?1526657919.

Temple, J. (2018) MIT Technology Review. The $2.5 trillion reason we can't rely on batteries to clean up the grid. Retrieved from https://www.technologyreview.com/s/611683/the-25-trillion-reason-we-cant-rely-on-batteries-to-clean-up-the-grid/.

Total. (2018) Integrating Climate Into Our Strategy. Retrieved from https://www.total.com/sites/default/files/atoms/files/total_climat_2018_en.pdf.

U.S. Energy Information Administration. (2018) Annual Energy Outlook 2018 with projections to 2050. Retrieved from https://www.eia.gov/outlooks/aeo/pdf/AEO2018.pdf.

U.S. Energy Information Administration. (2018) June 2018 Monthly Energy Review. Retrieved from https://www.eia.gov/totalenergy/data/monthly/archive/00351806.pdf.

United Nations. (2015) Paris Agreement. Retrieved from http://www.fsmgov.org/paris.pdf.

World Bank, The. (2019) Access to Electricity (% of Population). Retrieved from https://data.worldbank.org.

World Bank Group. (2018) State and Trends of Carbon Pricing. Retrieved from https://openknowledge.worldbank.org/bitstream/handle/10986/29687/9781464812927.pdf?sequence=5&isAllowed=y.