ENERGY TRANSITION REPORT

Russell Investments

RESEARCH

EMBRACE THE POSS/BLE™

ENERGY TRANSITION REPORT
BY: PAUL EITELMAN AND PIERRE DONGO-SORIA

EXECUTIVE SUMMARY

- A transition away from fossil fuels is likely required to avert a significant warming of the planet
- Net zero targets require the green transition to be twice as fast as past energy transitions
- Key challenges include politics, intermittency, transmission, and tight supply of raw minerals
- A failure to transition risks physical damages to the global economy
- There is wide disagreement of these damages—ranging from 8% to 35% of global income in 2100
- Disruptions to agriculture appear to be the most relevant concern at an investor’s time horizon
- Food price volatility and shortages could challenge lower-income economies
- The primary risk to markets is the energy transition itself, which would require substantial capex
- An investment boom would likely pressure long-term interest rates higher
- The details of how governments incentivise the transition will inform the growth-inflation mix

---

THE FOLLOWING REPORT IS DIVIDED INTO THREE SECTIONS

PART 1: A PRIMER ON THE CLEAN ENERGY TRANSITION

Introducing key concepts in climate economics

PART 2: THE TRANSITION CHALLENGE

Examining the key obstacles in transitioning away from a fossil-fuel-based economy

PART 3: IMPLICATIONS FOR ECONOMIES AND MARKETS

Assessing the potential implications for global markets and economies

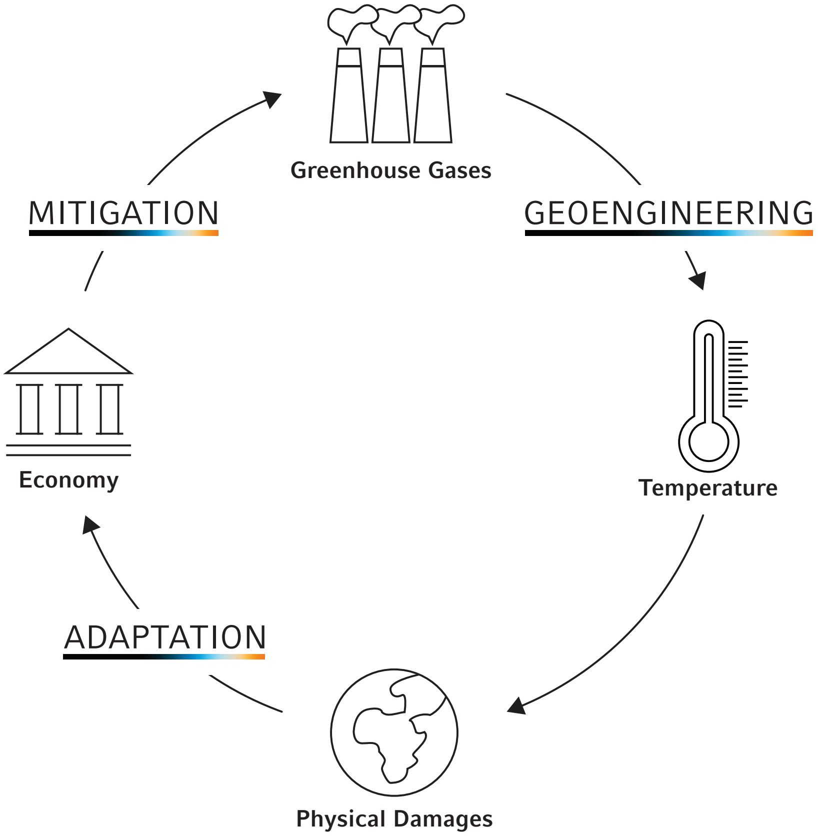
THE ENERGY TRANSITION

PART 1: A PRIMER ON THE CLEAN ENERGY TRANSITION

The purpose of this primer is to introduce key concepts in climate economics, to summarise what the physical sciences have to say about the risks a warming planet poses for the global economy, and to contextualise how an energy transition and other human interventions can reshape that future.

This is a big topic. It sits at the intersection of economics, innovation, politics, commodities, and climate systems—decades, centuries, and millennia into the future. That is not an intersection that invites strong conclusions. The dangers of carbon-based warming are clear. The extent to which and how the world will tackle this challenge is not.

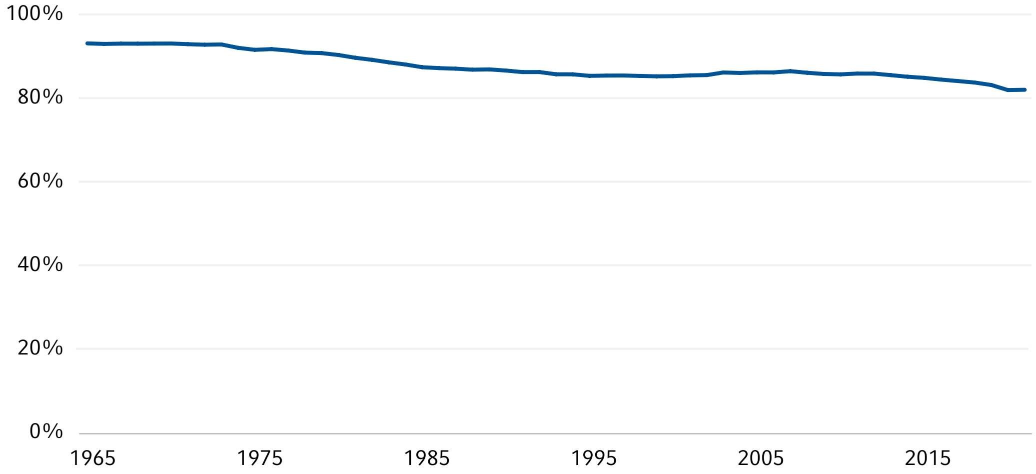
LET'S BEGIN WITH AN OVERVIEW OF CLIMATE ECONOMICS:



ECONOMY. My colleague Pierre Dongo-Soria discusses some of the challenges the global economy faces in transitioning away from carbon-based power in our next report. For now, just observe that the global economy is still overwhelmingly run on fossil fuels.

We are still a fossil fuel economy

% of global primary energy consumption from oil, gas, and coal

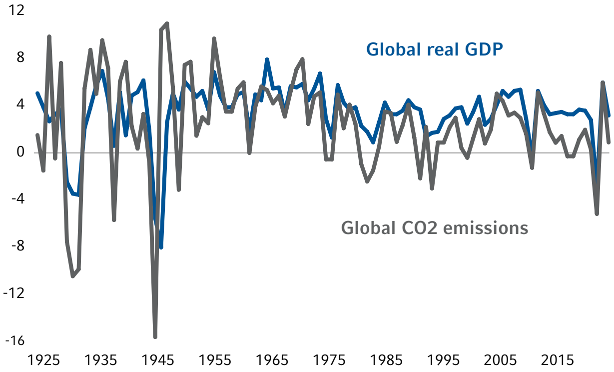


Source: BP Statistical Review of World Energy. 2022.

CO2. Our reliance on fossil fuels means that carbon dioxide (CO2) and other greenhouse gases (GHG) are emitted into the atmosphere when we burn energy to travel, to light, heat, and cool our homes, and to build things.

CO2 emissions are highly correlated with global growth

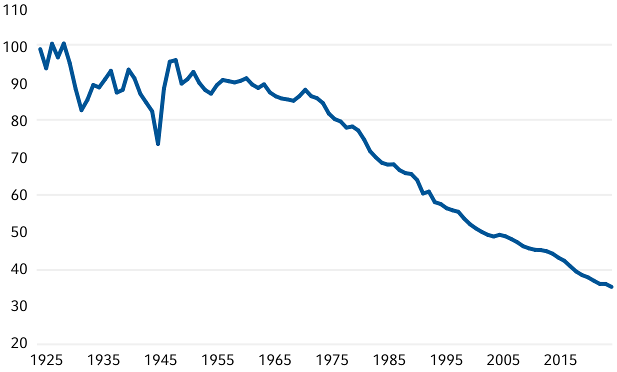
YoY% change



Source: World Resources Institute, BP, IMF, OECD, Angus Maddison. 2022.

Carbon intensity of global output

Index, 1925=100



Source: World Resources Institute, BP, IMF, OECD, Angus Maddison. 2022.

THE GOOD NEWS: we aren't using as much carbon per unit of output as we did decades ago—large and consistent energy efficiency gains have been observed since the 1960s. The bad news: those efficiency gains are not enough. When I began to research this field, I wondered if the combination of energy efficiency and slowing economic growth—due to declining birth rates in China and developed markets—could be enough to solve the warming problem without a disruptive energy transition. Unfortunately, they aren't. Hitting net zero in 2050 via efficiency gains alone would require global real GDP (gross domestic product) growth to average -1.5% for the next 37 years. That sounds bad if you're accustomed to looking at U.S. data. It's awful in a global context. It's a 2009 global financial crisis for 37 years in a row—a devastating scenario for living standards and our ability to invest, innovate, and adapt to this and future challenges.

TEMPERATURE. Greenhouse gases in the atmosphere trap heat near the Earth's surface[1]. The Intergovernmental Panel on Climate Change (IPCC) estimates temperatures on Earth could rise by 4.4°C/8°F by the end of this century in an adverse emissions scenario. That might not sound like a lot, but—over time—it could create severe negative consequences for the planet and the economy as we discuss below.

PHYSICAL DAMAGES. A rapidly warming planet generates risks for people, economies, and markets. The below is a summary of the major known physical risks from the scientific literature. Amongst them, the threats to food security appear to be the most relevant for investors right now.

CROP FAILURE

Corn, wheat, rice, and soybeans are the four most important crops in global agriculture, respectively. Crop yields can obviously be impacted by temperature, precipitation, and other factors. A recent study evaluated the comprehensive effects of climate change for these key crops.

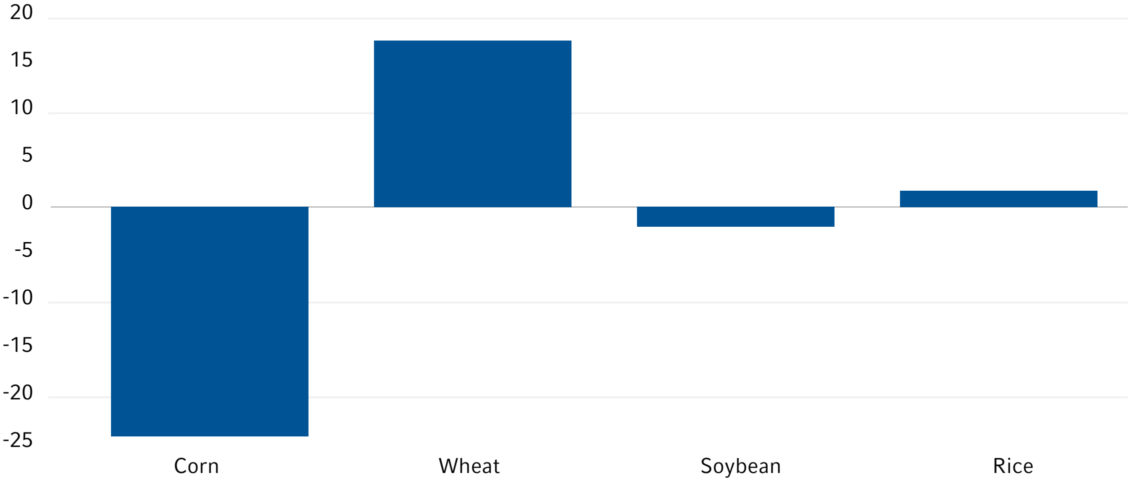
Corn—the most important crop ranked by tonnage of global consumption—was estimated to be severely adversely affected by global warming. Hot temperatures during corn's pollination phase (e.g., July in the Northern Hemisphere) inhibit kernel growth. Adverse impacts from warming onto corn are likely to be felt soon. The Time of Climate Impact Emergence (TCIE) for corn was estimated to be just nine years away, in 2032[2].

[1] Incoming radiation from the Sun has a short wavelength (high heat) and is able to freely pass-through CO2 molecules in the Earth's atmosphere. Infrared radiation emitted by the Earth's surface back into outer space has a longer wavelength (lower heat). Carbon molecules absorb this radiation, vibrate, and emit the energy (heat) in all directions – some back down to Earth, warming the planet. This feature of the CO2 molecule is not a new discovery. It has been known by scientists since the 1800s.

[2] TCIE is when the negative effects of carbon-based warming are expected to become distinguishable from the normal historical volatility in crop yields.

Impact of severe warming on crop productivity

2069-2099 forecast vs. 1983-2013 baseline, % change



Source: "Climate change signal in global agriculture emerges earlier in new generation of climate and crop models" (2021). Figure 1. Scenario SSP585.

In contrast, wheat may benefit from climate change due to a broadening of cultivable land (i.e., into southern Canada) and from a higher concentration of carbon dioxide in the atmosphere, which improves wheat's photosynthesis and water retention. The estimated (positive) Time of Climate Impact Emergence for wheat is 2023, i.e., right now.

In addition to its impact on agriculture, more extreme rainfall patterns are likely to contribute to water shortages in some regions—the IPCC estimates that roughly half of the world's population already experiences episodic water shortages.

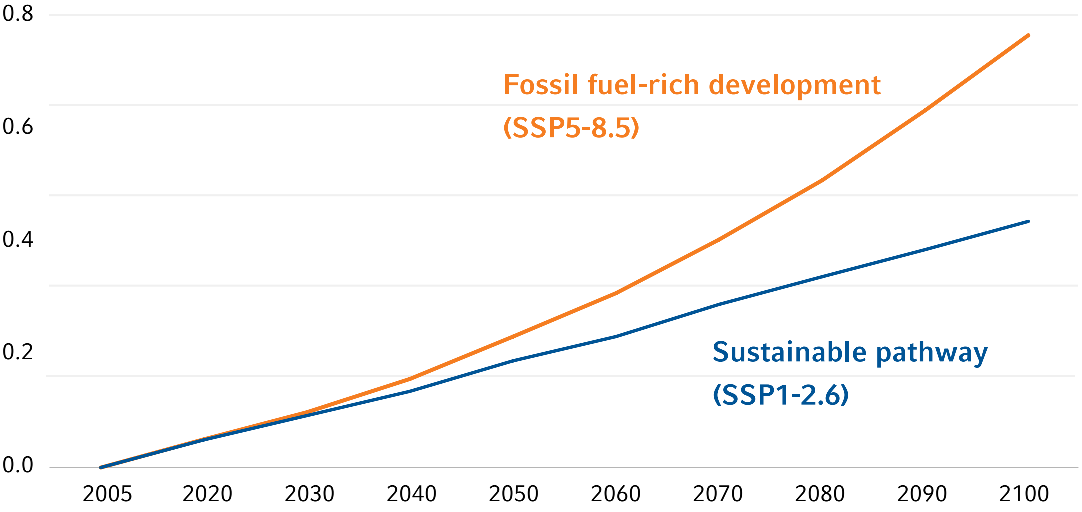
Bottom line: physical effects onto agriculture are expected to be material, to vary by crop, to be damaging on balance, and to become apparent at a time horizon that is relevant for investors. Water and food shortages contribute to geopolitical instability (e.g., Arab Spring), higher food prices, and weaker economic growth in impacted areas. More volatility in the agricultural supply chain would suggest increased price volatility in soft commodity markets is likely.

Agriculture has a long history of adaptation—experimenting with crops to increase yields and to make them more resilient to temperature extremes and drought. Some of that research is conventional—in the laboratory. Some of that research reads more like a science fiction novel, with seeds being placed outside the International Space Station to gain exposure to extreme temperatures and cosmic radiation.

SEA LEVEL RISE

Global warming causes sea levels to rise due to both melting land ice and thermal expansion. Sea level rise (SLR) is likely to be a relatively slow process in the short-term with little dispersion across warming scenarios through 2050.

Global mean sea level rise, meters



Source: IPCC AR6, Working Group 1, Chapter 9, Figure 27. 2021.

It's difficult to contextualise what a 0.2-meter (8-inch) sea level rise in 2050 looks like. But there are useful mapping tools in the public domain, such as Climate Central's coastal risk screening tool. Existing infrastructure in major economic centers—which tends to have an average lifespan of 50 years—is unlikely to be permanently impaired. However, there are still risks. Sea level rise can interact in non-linear ways, with storm surges leading to larger flood damages.

Stretching out the time horizon further, sea level rise has the potential to reshape the map. The IPCC's severe warming scenario suggests water levels could rise by nearly a meter in 2100 (enough to put my parent's house in Wilmington, North Carolina underwater), 2 meters by 2200, and 3.5 meters by 2300—at which point many major port cities, particularly East Asian ones like Shanghai, Osaka, and Hong Kong—would regularly flood.

Bottom line: sea level rise is not a major issue for the global economy and investors right now, but the threat and impacts are likely to build in the decades ahead.

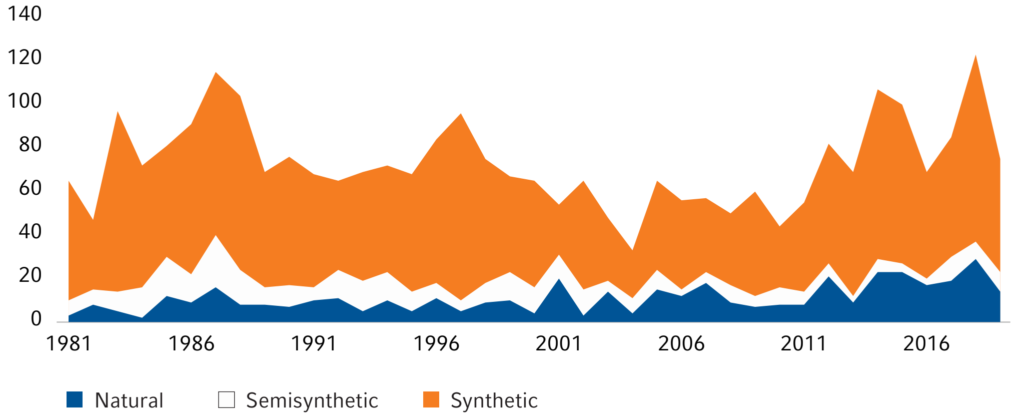
Adaptation to sea level rise is possible, but costly. The Netherlands is famous for its Maeslant Barrier which protects Rotterdam Port from flooding. The cost of sea barriers increases exponentially with height. Moving to higher ground is another, much more disruptive form of adaptation.

BIODIVERSITY LOSS

Many species will struggle to adapt to a rapidly warming planet. The threat to coral reefs from global warming is among the most well-known. Another example—certain reptiles have a temperature-dependent sex determination. For example, 99% of non-adult sea turtles are female in the northern Great Barrier Reef, which risks the extinction of the species.

Assigning an economic cost to species loss is a fraught exercise. One cost of species loss would be the elimination of natural compounds that could be used in developing new therapeutics. However, the hard reality is that over 70% of approved drugs over the last 40 years were synthetic, as the chart below shows. Furthermore, efforts have been made to build some resilience to species loss, with The Millennium Seed Bank being a prominent example.

Approved drugs by calendar year



Source: "Natural Products as Sources of New Drugs over the Nearly Four Decades from 1981 to 2019". Journal of Natural Products (2020).

Other effects from biodiversity loss onto the global economy could be much more significant. Damaged fisheries and a loss of pollinators may amplify the adverse effects of warming onto agriculture and exacerbate global food security. In its Global Risks Report, the World Economic Forum ranked biodiversity loss and ecosystem collapse as one of the top five threats humanity will face in the next decade. In fact, their research found that more than half of the world's economic output is moderately or highly dependent on nature.

Ecosystem services include clean air, water purification, climate regulation, soil fertility, and food production.

To illustrate some of the tangible benefits of these services, consider the economic value of insect pollination in the U.S., which in 2012 was estimated at US$34 billion annually, or around 0.2% of GDP. Or the benefits that coastal wetlands provide in reducing the impacts of floods—it is estimated that they save the insurance industry around €50 billion annually in the EU[3]. Conversely, the overexploitation of fishing resources is estimated to cause US$50 billion in damages at the global level.[4]

STORM INTENSIFICATION

Warmer air can hold more water vapour, increasing the risk of extreme rainfall events. More water vapour and warmer oceans are also expected to cause tropical cyclones to become more intense—but also less frequent—with these effects roughly offsetting in terms of the total frequency of severe storms that make landfall.

The National Oceanic and Atmospheric Administration (NOAA) tabulates the dollar cost of severe weather events like drought, flooding, hurricanes, wildfires, and other storms. We've scaled NOAA's data by trend GDP to contextualise economic significance. A few

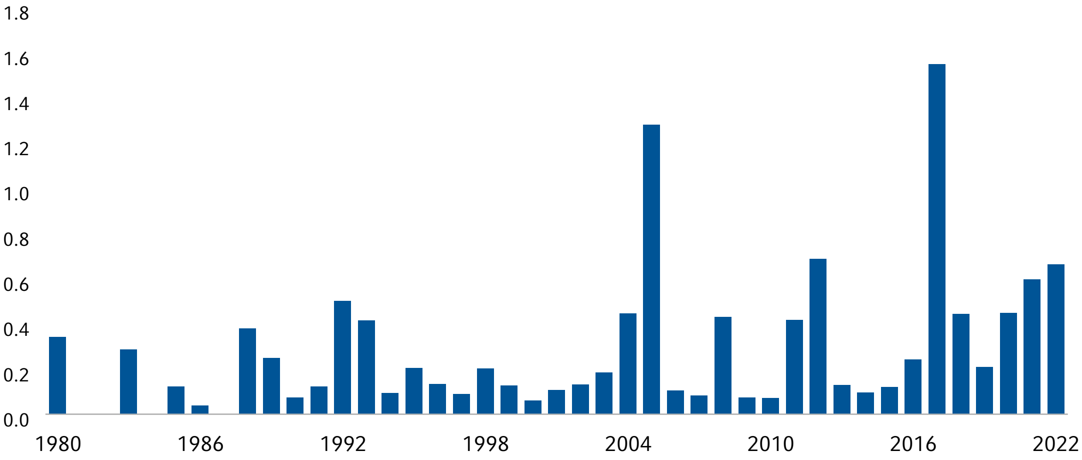
[3] European Commission, 2023.

[4] TEEB, 2012.

observations: the costs are episodic (e.g., Hurricane Katrina in 2005, Hurricane Harvey in 2017) and the economic significance of the damages appear to be increasing over time, but the damages are modest at only 0.5% of national income.

Annual cost of US severe weather events

% of potenial US GDP



Source: NOAA "Billion-Dollar Weather and Climate Disasters" as of 2022.

Bottom line: Storm intensification is likely to disrupt activity and raise the cost of doing business somewhat, with impacts onto the availability and pricing of insurance and the all-in costs of owning property in coastal and other risk-prone areas.

OCEAN ACIDIFICATION AND DEOXYGENATION

The ocean will become more acidic as it absorbs carbon dioxide. The chemistry is relatively straightforward—mixing water and carbon dioxide forms carbonic acid. Paradoxically this is an area with very little uncertainty, but it is also an area that was not recognised as a threat by the IPCC until 2001—an example of what Nobel-prize winning economist Bill Nordhaus refers to as an "inevitable surprise."

The impact from acidification onto man is likely to be through impacted fisheries, particularly those for oysters, shellfish, plankton, and corals. Carbonic acid dissolves calcium carbonate, which forms the shells of these marine organisms. And such acidification is another—in this case longer-term—threat to food security[5].

Ocean deoxygenation occurs due to warming, agricultural runoff, and other factors. Scientists estimate that 2% of the ocean's oxygen content has been lost since 1960. This is an added stressor which is likely to adversely impact a range of marine life.

ADVERSE IMPACTS TO HUMAN HEALTH

Extreme warming scenarios could eventually pose a threat to our survival as a species. 10 minutes in temperatures of 140 degrees Fahrenheit causes hyperthermia—a lethal form of heat stroke. Regions that approach these temperature limits could become unlivable and face mass emigration.

[5] Mortality rates are estimated to spike higher at carbon dioxide levels three times higher than current levels.

A warmer temperature can exacerbate existing cardiovascular disease and lead to malnutrition via the impacts to food security described above. Warmer temperatures would also likely widen the range of latitudes exposed to tropical diseases.

The overall effects of warming onto human health are difficult to assess due to adaptation. In a gradually warming world, rising income levels in the developing world and increased access to advanced medical technology could offset many of these challenges. However, some studies suggest the adverse impacts to human health could be even larger than the economic costs from agriculture.

INFRASTRUCTURE

Warmer temperatures can decrease the transmission capacity of power lines by 2-6% in the summertime when demand is at peak levels. Concrete and asphalt can crack or buckle when exposed to wide variations in temperature. Drought conditions can disrupt green hydroelectric power generation and can disrupt thermoelectric power plants (nuclear, coal, gas, oil) where water is used in the cooling systems.

TIPPING POINTS

Tipping points are events that have the potential to cause large and irreversible changes to the planet. Net zero targets are established, in part, to avoid the worst of these outcomes. We are, unfortunately, already nearing temperature thresholds that risk the collapse of the Greenland and West Antarctic ice sheets over the next several thousand years. Note that many of the timescales involved here are well beyond the horizon over which investors price assets, but the effects could (eventually) be catastrophic. I'd recommend this study if you are interested in learning more about tipping points.

Global tipping points

Event	Threshold (°C)	Timescale (yrs)
Greenland Ice Sheet Collapse	1.5	10k
West Antarctic Ice Sheet Collapse	1.5	2k
Labrador-Irminger Seas Sup-Polar Gyre Convection Collapse	1.8	10
East Antarctic Subglacial Basins Collapse	3.0	2k
Amazon Rainforest Dieback	3.5	100
Boreal Permafrost Collapse	4.0	50
Atlantic Meridional Overturning Circulation Collapse	4.0	50
Arctic Winter Sea Ice Collapse	6.3	20
East Antarctic Ice Sheet Collapse	7.5	>10k

Source: McKay et. al "Exceeding 1.5°C global warming could trigger multiple climate tipping points." Science (2022). Estimated values from Table 1 are shown. Uncertainty bands around these point estimates are often very wide.

In summary, agriculture is likely to be the sector that is impacted the most over a time horizon that matters for markets. That statement is not meant to dismiss other physical risks. Uncertainty at the time horizons involved here is extremely high. Tipping points and the potential for other non-linearities in the physical system amplify this problem.

Returning to our opening diagram on climate economics, the orange arrows show interventions—or ways that humans might break this cycle.

Mitigation includes all interventions that slow or reverse climate change by reducing GHG emissions. An energy transition—which is the major focus of this work—is one key mitigation strategy. Slowing down the economy would be another mitigation strategy, albeit an unrealistic one given the scale of damage that would be required. Conserving energy—as Europe did recently in response to its energy crisis—is another mitigation strategy. Carbon capture and sequestration is another mitigant. Mitigation is generally believed to be the safest solution from an environmental perspective, but it is also the costliest from an economic perspective.

Geoengineering involves changing the planet to counteract global warming. Geoengineering techniques include direct air capture (DAC) technologies which remove carbon dioxide from the atmosphere, installing large sunshades in outer space, injecting aerosols into the stratosphere, and painting large surfaces of the Earth white to improve reflectivity. Geoengineering could be orders of magnitude cheaper than an energy transition. However, in the absence of large-scale experiments, the risk of a miscalculation could be catastrophic. Furthermore, geoengineering strategies that seek to shade or reflect sunlight would not cure all of the physical damages from carbon emissions (e.g., ocean acidification).

Adaptation includes all strategies that help humans cope with and thrive on a warmer planet. Air conditioning is an obvious form of adaptation to warmer temperatures. We briefly touched on other adaptation strategies in describing the physical damages above. Modifying crops to survive in a changing climate is an important and well-established form of adaptation. Sea walls are an adaptation to sea level rise. Importantly, adaptation does not cure the root cause environmental problem. It simply makes the environmental problem less impactful to our lives and the global economy. Studies that exclude adaptive measures tend to overstate physical damages to the economy and markets.

Summary. Transitioning the global economy away from fossil fuels would be an enormous undertaking. A report from the International Energy Agency (IEA) estimated that global clean energy investment would need to more than triple to US$4 trillion by the early 2030s to align the global economy with the goals set forth in the Paris Climate Agreement. However, it is not guaranteed that the global economy will actually pursue an aggressive energy transition. The threat from CO2 emissions is not a new scientific discovery. I was particularly struck by testimony from Carl Sagan to the U.S. Congress in 1985 about the threats posed by GHG emissions. Sagan's speech is just as relevant today. And very little has been done about the challenge in the last forty years.

So, instead of jumping to a naïve conclusion—i.e., "an energy transition means XYZ for markets"—a more careful consideration of future pathways and their uncertainties is required. In the next section, Pierre Dongo-Soria discusses the key challenges facing a transition away from carbon-based power. In the final section, we explore both a hot earth scenario and an energy transition scenario, including our observations for economies and markets.

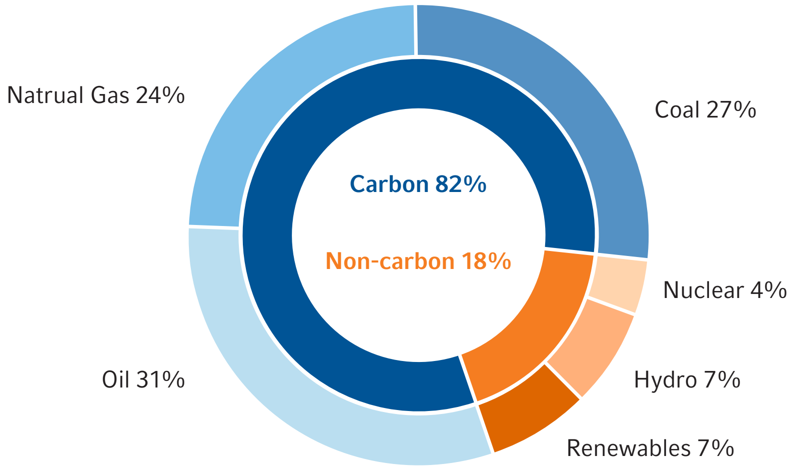
THE ENERGY TRANSITION

PART 2: THE TRANSITION CHALLENGE

Picture the global economy as an enormous machine, tirelessly churning out goods and services day after day. The fuel that powers this machine is predominantly derived from fossil fuels. Interestingly, the energy demand for fossil fuels has been quite sticky; 20 years ago, fossil fuels accounted for 86% of the world's energy supply. Today, even with the increasing prominence of green technology and renewable energy, it remains at 82%[1]. Fossil fuels remain the backbone of economic growth and industrial development.

This reveals how deeply rooted these energy sources are in our daily lives. In a capitalist and globalised world, it's hard to imagine life without fossil fuels. For instance, everyday items like smartphones, non-stick cookware, and synthetic fabrics are manufactured using energy derived from fossil fuels.

Chart: 2021 energy consumption mix



Source: BP Statistical Review of World Energy 2022

Experts agree that the current reliance on fossil fuels is not sustainable due to the environmental consequences associated with their use, such as climate change and air pollution. The need to mitigate these harmful effects is the primary driver behind the push for an energy transition towards more sustainable and renewable sources. However, one should wonder: is it possible to transition away from fossil fuels? What barriers are impeding us to reach the objective of replacing fossil fuels as the main source of energy?

THE STRUGGLE TO OVERCOME OIL DEPENDENCY

A first challenge is that fossil fuels, particularly oil, are amazing sources of energy. Their availability, affordability, and energy density make them difficult to replace. The world has vast proven oil reserves, ensuring a stable and predictable energy supply. Technological advancements and economies of scale have made oil production more cost-efficient, leading to low and stable prices that appeal to both developed and developing nations.

---

[1] Source: https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/oil/062623-fossil-fuels-stubbornly-dominating-global-energy-despite-surge-in-renewables-energy-institute

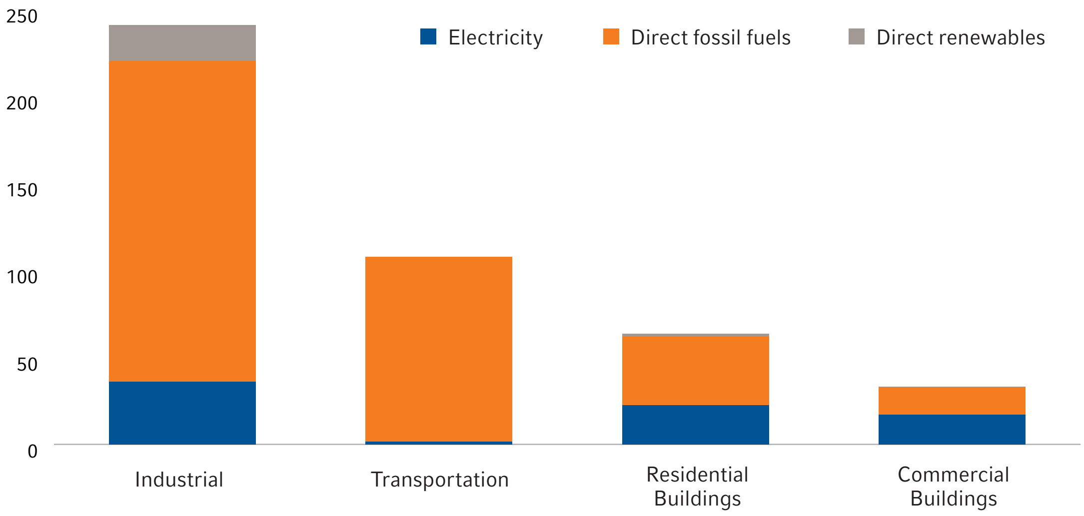
Additionally, oil's high energy density (the amount of energy stored per unit of volume) allows for efficient storage and transportation, which is especially important in sectors like aviation and long-haul trucking.

The higher energy density of oil presents a difficulty for low-carbon alternatives like solar energy, as they need large amounts of space to produce comparable amounts of energy. Cities, for example, would require massive infrastructure investments to accommodate the disparity between concentrated population patterns and dispersed low-carbon electricity-generating systems.

Another challenge is that an energy transition is not as simple as decarbonising electricity generation through the adoption of renewable power. Electricity only accounts for 20-30% of total energy consumption. To truly make a difference, we must address another key aspect of an effective transition: substituting the direct use of fossil fuels with renewable or synthetic alternatives in various industries. Direct fossil fuel use is substantial across sectors and countries, from developed ones like the U.S. to highly industrialised developing ones like China.

Global final energy consumption by sector and fuel

Quadrillion BTUs of final energy consumed by sector



Source: Energy Information Administration, JPMAM. 2021.

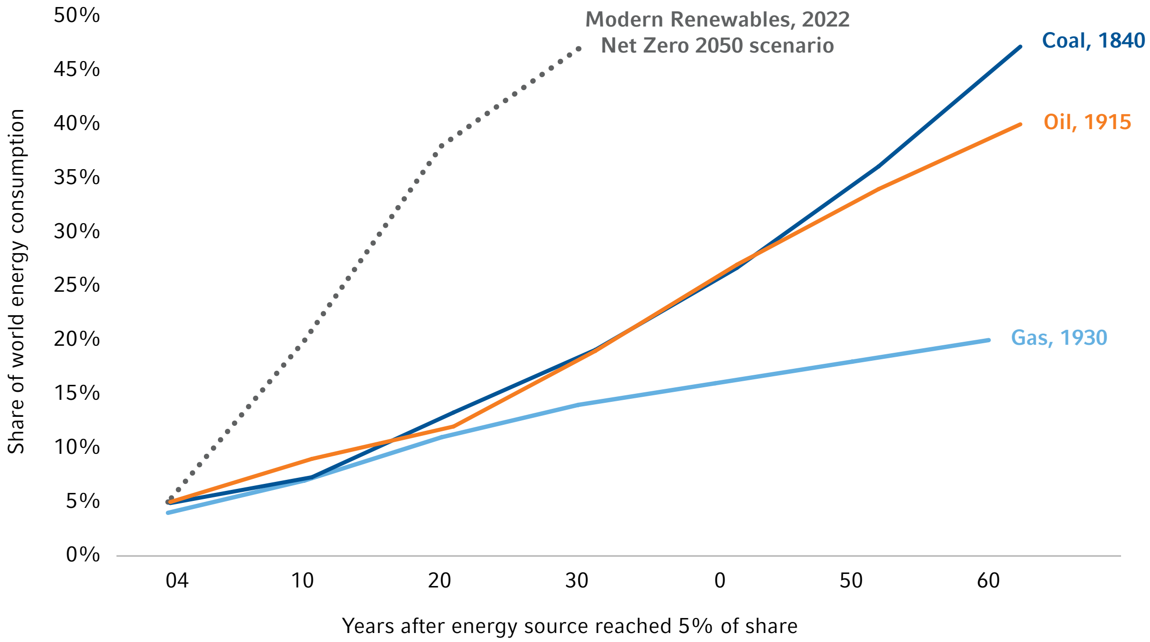
THE NEED FOR SPEED

The historical experience offers little reassurance, unfortunately. Energy transitions are complex and slow processes that historically have taken decades or even centuries to unfold. Even the transition to oil, with its remarkable properties, took a long time to account for nearly 40% of the world's energy supply. Meanwhile, natural gas has only reached 20% of the world's energy supply after 60 years.

What's more, the energy transition required today is unlike any previous ones. For the first time, the driving force behind this change is not economic efficiency but the urgent need to address climate change and its long-term impacts on the planet. A further complication is that, given the severity of the risk, the world needs to force an unnaturally speedy transition to succeed. For example, the Net Zero 2050 climate scenario from

NGFS (Network for Greening the Financial System) implies that in 30 years, nearly 50% of energy will come from renewable sources like solar and wind. This means we are facing the challenge of implementing the biggest energy transition in the history of humankind. Under a ticking climate clock.

Historical energy transitions and expected transition under net zero 2050 scenario



CHALLENGES OF RENEWABLE ENERGY

Despite significant advancements in renewable energy technology, it falls short of enabling a seamless transition at the required pace. A considerable gap exists between our present capabilities and what is needed. Renewable energy sources often prove inadequate in applications where energy density is vital, such as transportation. Similarly, industries like steel and cement, characterised by carbon-intensive processes, grapple with the challenge of reducing their carbon footprint without overhauling established production processes.

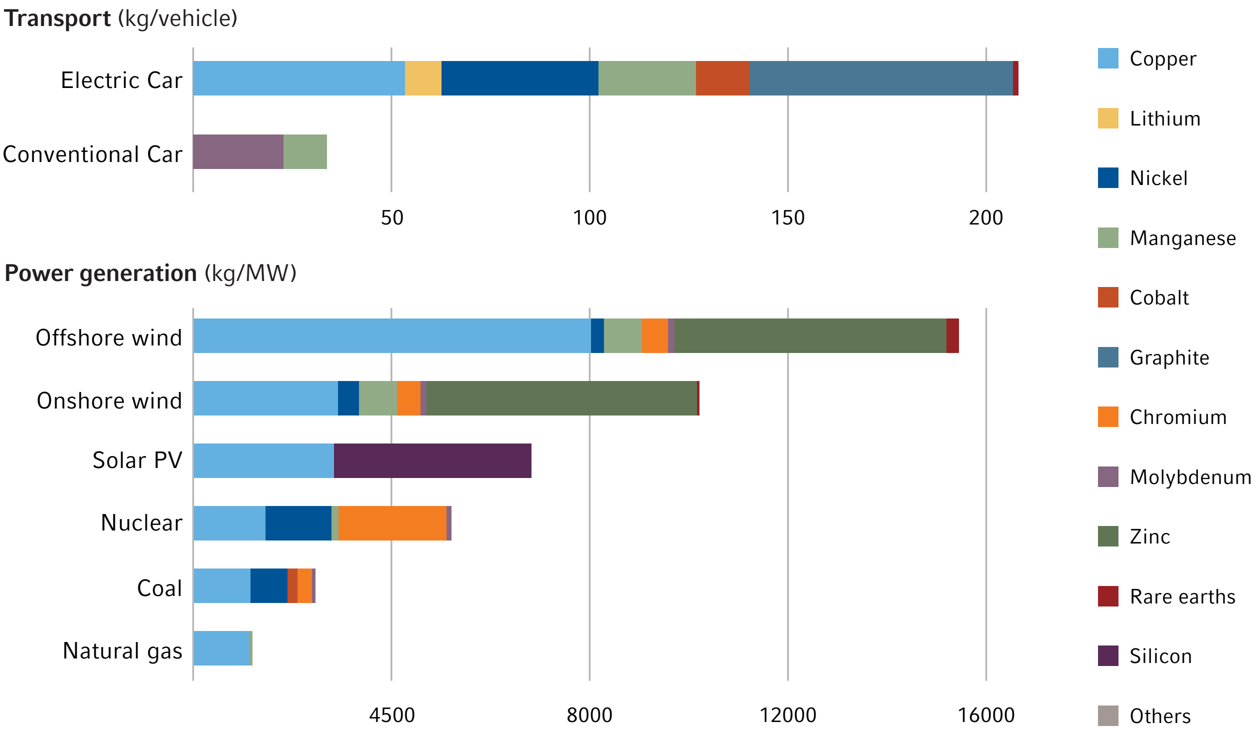
Addressing the intermittent nature of renewable energy is another technical hurdle. As the sun and wind are not constant, robust energy storage solutions are essential for maintaining a reliable electricity supply. Swift advancements in battery technology and grid-scale storage systems will be necessary to facilitate higher levels of renewable energy integration and ensure grid stability. Alongside this, smart grid technologies—featuring advanced sensors, communication systems, and data analytics—can optimise energy resource management and enhance grid efficiency.

The low-carbon transition also warrants innovative carbon capture, utilisation, and storage (CCUS) technologies. By mitigating emissions from hard-to-decarbonise sectors, CCUS can contribute to the broader climate change mitigation effort. However, considerable progress is needed to enhance the efficiency and cost-effectiveness of these technologies.

SUPPLY CHAIN CHALLENGES

As we transition away from fossil fuel-based systems, further difficulties arise in the production and supply chain fronts. The energy transition will necessitate a substantial increase in the use of materials for green technologies, leading to growing demand and the need for complex supply networks to accommodate this shift. In light of these challenges, it is crucial to develop more resilient and diversified supply chains for the minerals and materials vital to renewable energy production.

Minerals used in green technology



One pressing issue is the tight supply of essential minerals for renewable energy production. For instance, palladium, a vital component in hydrogen fuel cells, is a key export of Russia, which accounted for approximately 40% of the global production in 2020. Geopolitical tensions and export restrictions can have a significant impact on the availability of such critical resources.

The ramp-up times for new mines also pose a major obstacle to a rapid transition. For example, copper, an essential metal for electric vehicles and renewable energy infrastructure, has seen its last major mine, the Cobre Panamá mine, take nearly a decade to commence production since receiving approval. As the demand for copper surges with the global push for green technologies, the extended timeframes required to open new mines further complicate the energy transition.

Furthermore, the geopolitics of the energy transition will likely become more complex. As countries vie for access to scarce resources and seek to secure their supply chains, tensions and trade disputes may escalate. Additionally, as the energy landscape shifts, new alliances and power dynamics will emerge, with countries rich in renewable energy resources or critical minerals potentially gaining influence on the world stage.

It is crucial to develop more resilient and diversified supply chains for the minerals and materials vital to renewable energy production. This can be achieved through international cooperation, investment in domestic production, and support for advanced materials research to uncover more sustainable and efficient alternatives to current materials. Such efforts will be key to minimising the environmental footprint of green technologies and ensuring a smooth energy transition.

THE BOTTOM LINE

As we can see, the challenges to achieving an effective energy transition are non-trivial. Climate change is a complex problem that needs, but extends beyond, technological breakthroughs. Effective policy and regulatory frameworks, substantial infrastructure investments, and public education and awareness campaigns are critical to fostering public support and driving behavioural change. Clear renewable energy and emissions reduction targets, cross-border collaboration, financial backing for green projects, and comprehensive education and training programs are all essential components of a sustainable and equitable energy transition.

Great efforts are being made, but we need to acknowledge the complexities and challenges that lie ahead. The energy transition is not simply an engineering challenge but rather a monumental task that requires the convergence of technological innovation, bold strategic policy, and deep coordination. And we need them sooner rather than later.

THE ENERGY TRANSITION

PART 3: IMPLICATIONS FOR ECONOMIES AND MARKETS

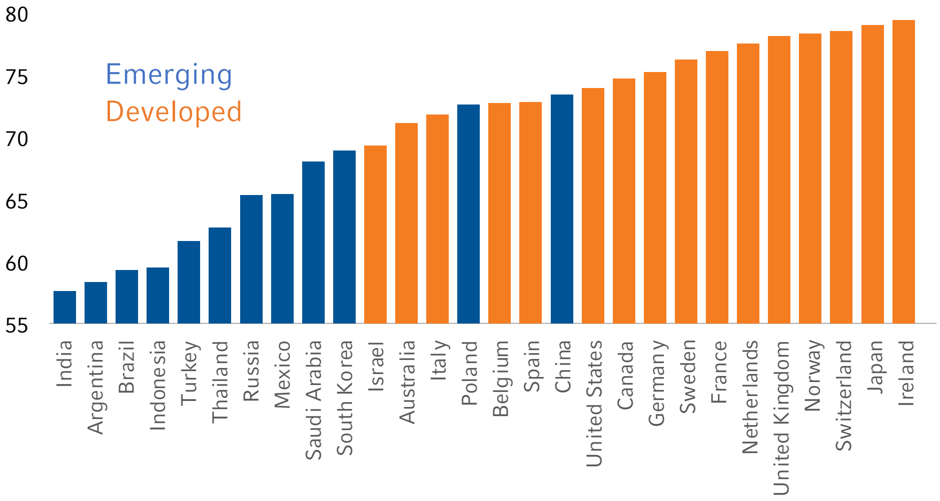
This third and final section applies the lessons from the primer and transition challenges onto the outlook for economies and markets.

HOT EARTH SCENARIO

One lesson from the political and technical obstacles facing a bold energy transition was that investors should not rule out a scenario in which temperatures rise significantly—a hot Earth in the decades ahead. We previewed the physical damages from a warming planet in our primer. To review and build upon them:

- The impacts to agricultural production and food security could be material, timely—with effects becoming distinguishable from normal seasonal variation in the next decade, and variable—with winners (wheat) and losers (corn) by crop and with winners and losers by region.[1]
- Threats to global food security are likely to increase the volatility in soft commodity markets and in headline CPI inflation—particularly in the developing economies where food represents a larger share of consumer spending—and could exacerbate geopolitical instability.

Global Food Security Index



Source: Impact Economist. 2022. Average of Affordability, Availability and Sustainability and Adaptation scores. Countries with >$500bn of 2022 GDP.

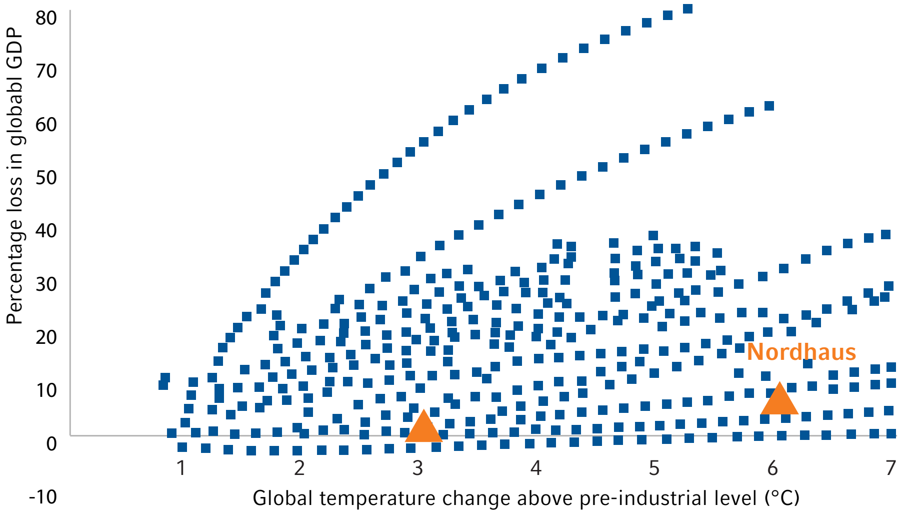
- Warmer temperatures also increase risks to human health through the spread of tropical disease and heat stroke, and by amplifying the adverse effects of other common health problems (e.g., high blood pressure). An aging and more risk prone population would increase the share of national income dedicated to healthcare expenditures in the decades ahead.

[1] Winners may include Canada—which is expected to benefit from a broadening poleward of cultivatable land—and food exporters who are able to maintain a reliable food supply for their local populations. Losers could include importers in the developing economies where food consumption makes up a disproportionately large share of the consumption basket. The Mediterranean could experience greater desertification in the decades ahead. While this region is frequently cited as being at higher risk, there is high uncertainty in the scientific literature about which regions will become more arid in the decades ahead.

- Finally, a more volatile climate system will make incoming data on the economy and earnings harder to interpret in real-time. This is likely to create more volatility in asset prices. For example, unusually warm winters allow construction activity to continue during what would normally be a slower period for the sector. The temperature doesn't increase aggregate demand and shifts it around within the calendar year. Noisier data will make it harder to discern the underlying trend in the cycle. There are more sophisticated approaches available, but this is likely to be a growing challenge for investors.

How does it all add up? In terms of long-run growth, there is broad agreement that economic damages increase with warming. Unfortunately, there is broad disagreement about how large those damages will be. Bill Nordhaus—a Nobel Prize winning climate economist—estimates relatively modest losses totaling 2.1% of global income for 3°C of warming and 8.5% of global income in a severe emissions scenario where global temperatures rise by 6°C (red triangles, chart). Some other structural models—including those from our research partners at Planetrics—also indicate relatively modest damages. The Network of Central Banks and Supervisors for Greening the Financial System (NGFS) estimates damages closer to 20% of income. Other studies suggest damages could total more than 35% of global income in a severe emissions scenario.

Estimates of economic losses from warming are all over the map



Source: IPCC AR6 WG2. Cross-Working Group Box ECONOMIC.1.

Bottom line: The range of uncertainty in economic outcomes is extremely wide. That's not a satisfying conclusion but it is, I think, a fair reflection of the immaturity of how economics will intersect with a warming planet.

For markets, a status quo scenario is—almost by definition—unlikely to be disruptive in the short-term. Most physical damages from a warming planet are expected to occur beyond the effective duration of assets, constraining the effects on prices. The traditional energy sector would continue to play an important role in powering the global economy in this scenario. We currently estimate that the energy sector's equity valuation multiples are cheaper than broad index exposure as of September 2023, and maintaining allocations to the sector within a diversified portfolio could prove beneficial. Developing economies with fewer resources to adapt to a changing climate and those emerging economies with more sensitivity to fluctuations in food prices would face larger headwinds and could underperform over the medium-term. Long-term interest rates would likely decline in this scenario as investors downgrade expectations for capital investment and inflation over the longer-term. The IMF (International Monetary Fund) and other intergovernmental agencies will likely require more funding to promote resilience and equitable growth around the world.

ENERGY TRANSITION SCENARIO

As noted in our primer, achieving current net zero targets will require an investment boom. But it's hard to distill that basic premise down into a single transition scenario. The transition could be fast or slow. It could be smooth or bumpy. And how governments incentivise the transition will be critical. The below details the key variables that will matter for economic and market outcomes in the years ahead:

Speed. The cost of renewable energy technologies is falling sharply as they mature and get produced at scale. But intermittency, transmission and storage challenges remain and implementing a hyper speed energy transition would be more expensive—and more inflationary. Put differently, there is a clear tradeoff where faster approaches carry higher transition costs but lower, eventual physical damages. The optimal solution isn't the fastest one—it's the strategy that minimises those total costs.

Obstacles. Revolutionising how the global economy works isn't going to be easy. Key commodity markets cannot smoothly accommodate a rapid energy transition. As discussed in the second installment, export restrictions and long ramp-up times for new mines are likely to be a recipe for bottlenecks and higher prices. That would create a bumpy pathway for the economy but would likely be a beneficial scenario for the materials sector and EM commodity exporters[2].

Incentives. How governments incentivise the transition will be critical. For example, a transition that is motivated through a carbon tax or windfall profits on the energy sector and redirects those proceeds towards clean energy alternatives would: be very disruptive to the traditional energy sector, generate greenflation as retail gasoline prices spike while consumer demand rotates toward more immature and expensive technologies, and would pressure the prices for raw minerals. By contrast, subsidising green energy could dampen the inflationary effects somewhat. Whether the incentives are fully funded or financed by government deficits is also important, with the latter being more supportive of aggregate demand and economic growth at the expense of higher government debt levels.

Again, it's hard to generalise the outcomes of a future energy transition when the details matter. Nevertheless, two observations generally hold. First, the investment boom itself would likely raise long-term, equilibrium interest rates. Equilibrium interest rates are principally determined by the supply and demand for global savings. All else equal, a large investment boom would increase the demand for savings globally, lifting interest rates. We estimate a green energy transition could lift equilibrium interest rates by 20-30 basis points (bps) and have adjusted our internal modeling in recent months to reflect this.

Second, inflationary pressures are likely to arise—the so-called greenflation. However, this immediately raises an important question. Will central banks tolerate the inflation from an energy transition? Some prominent economists like Gita Gopinath (IMF) and Olivier Blanchard (Peterson Institute) have suggested that—over time—central banks should relax their targets to allow for this. While that could happen eventually, it is very unlikely to happen right now. The current inflation fight is still underway, and if they give up before the fight is over, it could un-anchor expectations in a dangerous manner. The 2% inflation target is regarded as sacrosanct by current Fed and ECB leadership. Put differently, a

---

[2] It would not be appropriate to invest in commodity markets naively based on current headlines and technologies. An active approach is required. Cutting-edge technologies in 2030 or 2040 could be very different from what headlines are focused on right now. For example, sodium-ion and iron-air batteries could eat into the market share of lithium-ion batteries going forward. Naïve strategies (like buy lithium) may fail or may already be in the price.literature about which regions will become more arid in the decades ahead.

consensus view is that an energy transition will lead to higher inflation rates. However, rather than creating higher inflation over the medium-term, the outlet could just be higher policy rates and weaker growth, with inflation steadfastly held to central bank targets.

I also wonder what the new growth model will look like for the emerging markets. For decades, the growth arc from developing economy to developed economy was a progression from primary (agriculture) to secondary (manufacturing) to tertiary (services) industries. An energy transition will disrupt the middle of that journey, mandating high-tech clean manufacturing processes that are powered by clean energy. Separately, if a subsidy war builds across the developed markets—as seems to be the case in the United States and Europe right now—that will skew the competitive landscape globally and make it more difficult for emerging markets to participate in the innovation that will be required.

CONCLUSIONS

Investors should plan for more volatility in markets as volatility in the climate system intersects with and amplifies the normal volatility in the business cycle and security fundamentals.

Don’t naively assume an aggressive energy transition will happen. Accelerating adoption rates for electric vehicles and solar power are encouraging. However, if history is any guide, the transition could be slow and bumpy.

If the planet warms significantly, agriculture is likely to be significantly impacted. Low-income and emerging economies are more vulnerable to food prices than the developed markets. Physical damages increase with warmer temperatures, but damage estimates are all over the place—ranging from GDP losses of 8% to 35% in a severe warming scenario. Some of the highest quality models in the literature suggest physical damages could be on the more modest side of that distribution. But uncertainty is high and tipping points and non-linearities complicate the calculus.

Traditional energy still has a role to play in portfolios. Current valuations are not onerous. And even in an aggressive energy transition scenario, carbon-based power will be needed for years to stopgap the global economy while other energy technologies mature and scale. Large oil and gas companies are likely to adapt and invest based on the risks and opportunities that they see in the marketplace just as the automakers have in recent years.

Private capital markets will play a key role in financing a green energy transition. Impact investments could include exposure to essential global infrastructure, venture capital targeted at exciting new green technologies, farmland, and an active approach for investing in commodity markets. Having a long-term strategic plan is always an important anchor when the clouds roll in.

CONNECT & FOLLOW US

Call Russell Investments at +612 9229 5111
or visit russellinvestments.com.au

ABOUT RUSSELL INVESTMENTS

Russell Investments is a global asset manager with a unique set of capabilities that we believe is essential to managing your total portfolio and to meeting your desired outcome. At Russell Investments, we stand with you, whether you're an institutional investor, a financial advisor, or an individual guided by an advisor's personalised advice. We believe the best way to reach your desired outcomes is with a multi-asset approach that combines asset allocation, capital markets insights, factor exposures, manager research and portfolio implementation.

IMPORTANT INFORMATION

Issued by Russell Investment Management Ltd ABN 53 068 338 974, AFSL 247185 (RIM). This document provides general information only and has not been prepared having regard to your objectives, financial situation or needs. Before making an investment decision, you need to consider whether this information is appropriate to your objectives, financial situation or needs. This information has been compiled from sources considered to be reliable, but is not guaranteed. This document is not intended to be a complete statement or summary.

To the extent permitted by law, no liability is accepted for any loss or damage as a result of reliance on this information.

This material does not constitute professional advice or opinion and is not intended to be used as the basis for making an investment decision.

AUSF1-01161

EMBRACE THE POSS/BLE™