

Autonomy Capital



I N S I G H T

Pricing Carbon Dioxide Emissions

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Increasingly, we are waking up to the realization that one of the next (and possibly the next) market crashes could be driven by climate change. There is now an area of media focus on the growing belief around climate change and its impacts,¹ along with the anecdotal signs of these impacts – such as melting ice, rising sea levels, Arctic heat waves, and more extreme droughts, floods and forest fires. We believe investors must ask themselves how climate-related events – and the measures that are being introduced to mitigate and adapt to them, along with changing consumer attitudes – will impact their investments in the years to come. We believe investors should consider how they can prepare for the climate risks that may have the capacity to affect our world and give thought to investing in the transition to a low carbon emissions world that may be coming.

The expected transition to a lower-carbon economy is estimated to require, on average, approximately \$2.4 trillion in energy sector investments every year for the foreseeable future,² thereby in our view having the ability to generate a range of new investment opportunities. Additionally, we believe there will be the inevitable bill to cleanup and reduce the carbon already emitted and still being emitted, which alone is likely to cost another \$89 to \$535 trillion over the next 80 years,³ should we become serious about a potential 1.5 degree warming limit,³ and should technology improve markedly from where it is today.

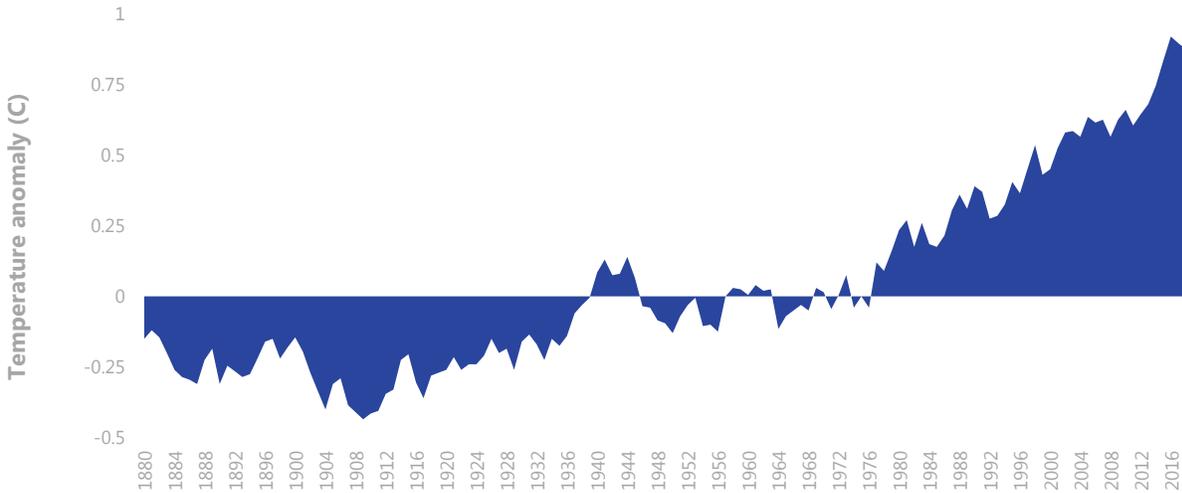
These are very rough figures, but they suggest the magnitude of the challenge. To those with foresight, this may represent opportunity, but to others this may represent losses. Already, we see it beginning: in South Africa in the past months, it is becoming increasingly clear that ESKOM's power generation which is hopelessly dependent on coal will be a barrier to economic development. South Africa lacks a cleaner energy generation infrastructure and may increasingly lack access to funding via multilateral agencies due to its energy mix going forward.⁴ We believe these sorts of events including limitations on flood⁵ and fire insurance to parts of the property market are just beginning and will become more widespread.⁶

Where Are We Today, And Where Are We Headed?

The chart below, produced by NASA, illustrates global surface temperatures. It is clear that temperatures have been on a break-out tear higher since 1980 and show no signs of slowing down. And, as the Global Fossil CO₂ Emissions chart illustrates, man-made carbon emissions, from burning fossil fuels, have also increased dramatically since 2000. The Global Carbon Project reports that man-made emissions rose from 22.3 Gigatons (Gt) of CO₂-equivalent in 1990 to 36.2Gt CO₂e in 2016.⁷ The accelerating rate of emissions is serious cause for concern. We've already started to experience the consequences of past greenhouse gas (GHG) emissions, and the impacts of this change are starting to translate into real economic and social costs.⁸ As CO₂ emissions may increase, they could lead to higher temperatures and more serious impacts.⁹

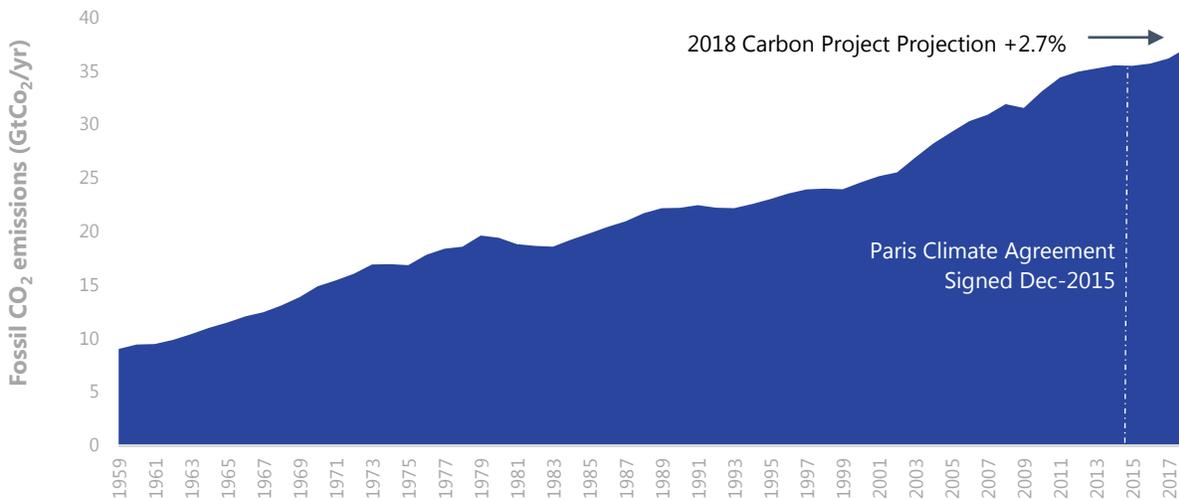
Note: Autonomy may or may not have active positions related to carbon markets.

Changing Global Surface Temperatures



Data courtesy of NASA/JPL-Caltech as of June 13, 2019.

Global Fossil CO₂ Emissions

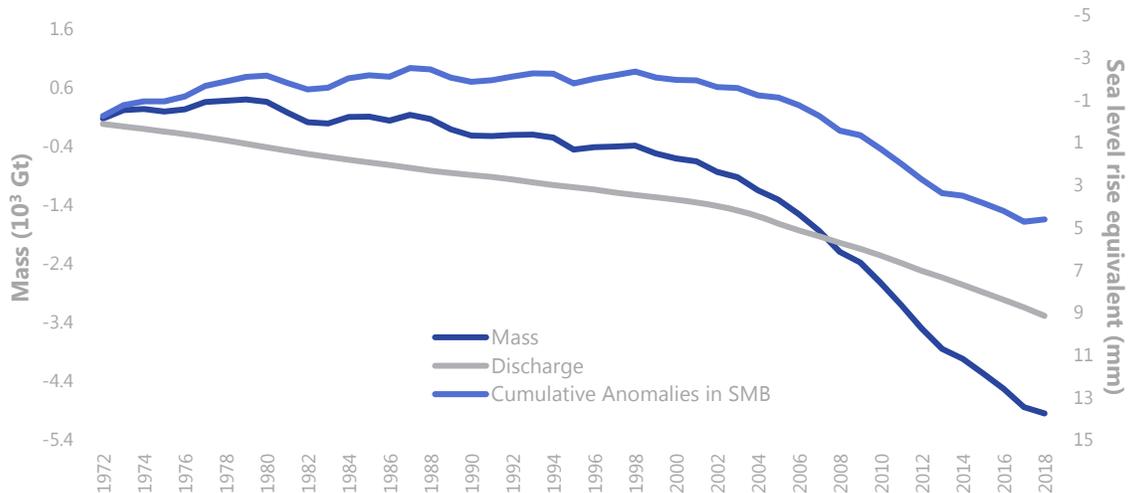


Data courtesy of Global Carbon Project. (2018). Supplemental data of Global Carbon Budget 2018 (Version 1.0) 2018 Global Budget v1.0. Global Carbon Project. <https://doi.org/10.18160/gcp-2018>. Chart formatted by Autonomy Capital.¹⁰

The key point we should stress is this: natural systems appear now to be reacting to increased carbon in a non-linear fashion – that is, we appear to be approaching a climate tipping point that could lead to temperature rises and other climate changes accelerating further and behaving much more unpredictably. For example, if Arctic permafrost melts, it will start releasing billions of tons of methane, a gas that is more efficient at trapping heat than CO₂.¹¹ As a consequence, we expect the markets that are based on those natural systems also to experience increased volatility. The Greenland ice melt shows the considerable non-linear increase in melting

after 2000 (see the Non-linear Greenland Ice Sheet Loss chart below). But let's be clear: while this chart appears non-linear, some scientists believe the non-linear pace of the ice melt can accelerate very radically further.¹² This is an important concept. Once we accelerate temperatures through certain "tipping points," we might not be able to undo or avoid a series of climate events that will radically reshape our world. Similar to taking a bag of ice out of your freezer and putting it on the kitchen table (the tipping point), we can then discuss whether we should keep the kitchen thermostat stable versus increasing the temperature further, but make no mistake, that ice is going to melt, and the water is going to spread across the kitchen floor. We believe we need to think about tipping points not only in terms of time frame, but also in terms of what aggregate natural system changes we have committed to as a consequence of our actions to date. This is important because our understanding of these consequences is changing, and they tend to be worse than previously expected or modeled.¹² Our resolve to take action in pricing carbon or regulatory frameworks can, in our view, also similarly rise quickly as a consequence of this new understanding.

Non-linear Greenland Ice Sheet Loss



Cumulative anomalies in SMB (blue), discharge (D, red), and mass (M, purple) in gigatons (gigaton = 1012 kg) for the time period 1972–2018. Source: <https://www.pnas.org/content/116/19/9239> as of June 17, 2019.

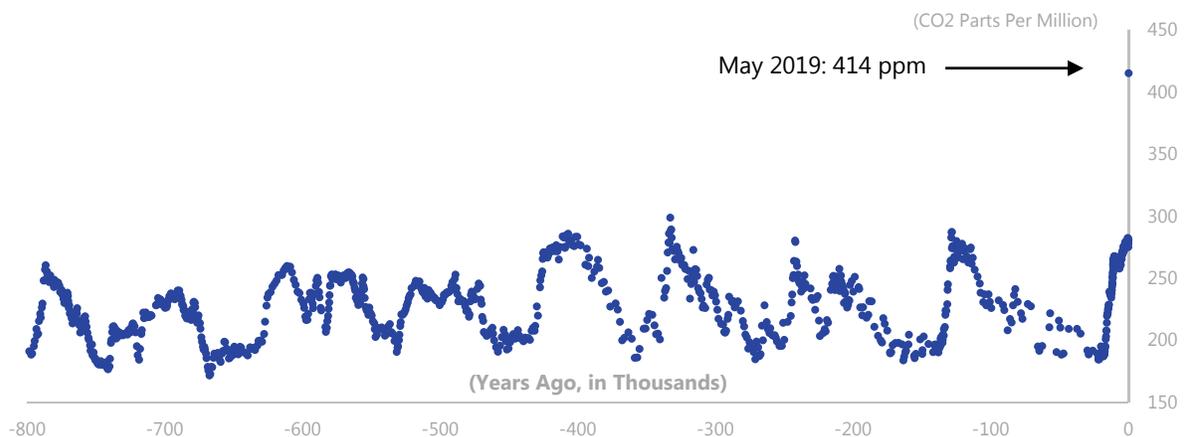
How do we limit the effects of climate change? Since its first assessment report in 1990,¹³ the IPCC has made clear that we must reduce global CO₂ emissions.¹⁴ Its last report released in 2018 stressed that in order to limit warming to 1.5 degrees, emissions need to peak as soon as possible and reach net zero within 30 years before turning negative.¹⁵ Even limiting warming to 2 degrees requires emissions to reach net zero by 2070 before turning negative.¹⁶ However, the reality, as the Global Fossil CO₂ Emissions chart shows, is that instead of falling, the pace of emissions has been increasing. Further, it appears these calculations were based on models that

may not have included certain knock-on effects and feedback mechanisms such as permafrost melt, the loss of sea ice, or the destruction of natural carbon sinks, which may underestimate the ultimate impact and scope of future climate change consequences.¹⁷ As a result, we believe the model calculations appear to be somewhat simplistic and therefore possibly misleading in their potential understatement.

What about the emissions reduction pledges countries have made under the UN Paris Agreement?¹⁸ Surely that process is a viable solution? Well, quite unfortunately, the increase in emissions since the signing of the Paris Agreement¹⁹ indicates that the agreement may not be catalyzing the deep emissions reductions necessary, for a number of reasons.

Even total compliance with the national pledges made in Paris would suggest a base forecast of about 3°C increase in global warming by 2100,²⁰ with warming continuing thereafter and a considerable risk that the amount of warming could move higher much faster than the IPCC’s central estimate suggests.²¹ The national pledges made in 2015 were never intended to be the last word but are intended to be continuously updated every five years.²² This year and next, countries must come forward with new, stronger pledges.²³ However, in light of the need to achieve net zero CO₂ emissions by mid-century or shortly thereafter²⁴ according to models that in turn may prove to be much too conservative, we believe progress in improving the national pledges has not been enough, and we believe this has been and continues to be hampered by the absence of a legally binding enforcement mechanism. Emissions have thus not fallen since the adoption of the Paris Agreement and have in fact accelerated to new heights.²⁵

Historical Context for Atmospheric CO₂



Source: C. D. Keeling, S. C. Piper, R. B. Bacastow, M. Wahlen, T. P. Whorf, M. Heimann, and H. A. Meijer, Exchanges of atmospheric CO₂ and ¹³CO₂ with the terrestrial biosphere and oceans from 1978 to 2000. I. Global aspects, SIO Reference Series, No. 01-06, Scripps Institution of Oceanography, San Diego, 88 pages, 2001. <http://escholarship.org/uc/item/09v319r9>

There are signs that some governments are starting to step up their ambitions to conform to the Paris Agreement. Countries such as New Zealand, Norway, France and the UK, along with the EU, are considering committing to net-zero emissions targets by 2050.²⁶

But we believe electorates and investors are behind the curve, in part thanks to a decades-long concerted effort to confuse the science. The atmospheric concentration of CO₂ is now at 414 parts per million ("ppm"), from a much safer historical range around 280 (see Historical Context for Atmospheric CO₂ chart), with much of the damage done in the past four decades. We have emitted more GHGs in the past 40 years than in all previous recorded activity.²⁷ Atmospheric CO₂ in our view will likely peak at a much higher level given our current trajectory. The Paris pledges imply a peak around 650 ppm by 2100.²⁸ However, such an extreme concentration (650 ppm) may not be likely as we believe the damage being caused already at today's levels suggests a societal shift is underway in our thinking about this issue. This leads us to conclude that we will peak at a higher carbon dioxide concentration than present, and we will have to take carbon out of the atmosphere at industrial scale at some point in the future to stabilize our natural climate systems.

Towards a Carbon Dioxide Waste Management System

As the increasingly apparent costs of carbon dioxide emissions will, in our view, drive government policy, regulation and carbon emissions pricing, we are of the view that it's prudent to anticipate the pricing of carbon throughout our economic system, markets, and asset valuations. We have seen through time that certain resources, once considered plentiful and free, are subsequently rationed and priced as we collectively realize their value and their scarcity. Societal values have changed with respect to resources in the past and we will likely rethink certain societal values again. We created urban sewage as a societal solution to the health risks related to people throwing their waste into the streets of densely-populated cities. As we learned more about the source and cause of disease, we became more willing to accept and price a waste management solution.²⁹

In the 1970s, restrictions on dumping toxins into the water as a form of waste disposal arose as we understood the society-wide implications of our actions. With CO₂, as with other substances in the past, we believe we are moving towards an understanding of the necessity of waste management solutions.

Pricing Industrial Scale Abatement

What we are getting to is simple: we believe we have a waste management issue, and as our society comes to understand this it will demand regulatory and judicial changes within which the free market can work to find solutions. We believe this means we will have to price carbon waste – emissions – and the price will go to the price of the cost of the cheapest at-scale marginal abatement and storage solutions. For now, without a clear and hard price of carbon we don't believe the market can allocate resources effectively. Yet carbon dioxide emissions pricing will affect the economic system in our view.

Have investors thought through these issues? We believe we need to be prepared for this potential inflection point, because the markets may move in advance of a potential regulatory shift. In this case, we anticipate a

potential widespread regulatory shift around how carbon can be priced fairly and effectively. This could involve monitoring the use of carbon, along with changes to our existing trade arrangements.³⁰ It also potentially includes a mechanism to verify and certify when carbon has effectively been taken out of the atmosphere and stored successfully. The creation of a new 45Q federal tax credit to capture and store carbon³¹ may be the beginning of these sorts of frameworks being put in place.

What is the Price of CO₂ Removal Today?

One commercial price point for direct air capture CO₂ abatement and storage is \$600 per ton currently, but some service providers believe it may potentially dip below \$100 in 5-10 years.³² We do expect both capacity to rise in the future and prices to fall in the coming years due to increased investment in direct air capture technologies for carbon dioxide removal. We won't have the capacity required for significant negative emissions without significant investment in this technology, which in turn we see requires a market price for carbon and significant government and regulatory support. Our estimates suggest that to reduce the ppm from a peak of say 475 to the safer level of 350³³ over the next 40 years would require the removal of 24 gigatons of carbon per year for 40 years.³⁴ Roughly, with significant improvement in technology, to reduce it to 350 ppm may cost \$97 trillion.³⁵ This is not a prediction, because we think that underinvestment in these technologies to date will not continue, and so the improvement in technology with adequate investment may reduce prices more than the initial \$100 per ton used at the start of the previous example. Additionally, with policy changes as well as natural carbon sinks this can help to reduce some of the amount of carbon that needs to be removed in our view. But these examples speak to the enormity of the issue. And we believe it speaks to the need to incentivize technological investment in this area by establishing a price for carbon.

Toward the Future

We will rely on technology to bring this cost down significantly in the future and we trust we will find a way. We believe that with innovation and research, this price could fall significantly. It is important to remember that research has been going on in this field for at least a decade with minimal results – in part because of the lack of proper funding by governments or a sufficiently-high carbon price (although there has been progress in California and new tax incentives).³⁶ Given that we are in the initial stages of utilizing carbon capture and storage technology to produce negative emissions, the price set for carbon may end up vastly different than some expect. Eventually, we see the price to capture and store carbon collapsing as technology and efficiency improve, but in the initial stages, just like the price of the first car or the first transistor, we believe the price is going to be higher. Importantly, we believe this price has little to do with market emissions prices today.

- 1 <https://thehill.com/policy/energy-environment/426411-record-number-of-americans-consider-climate-change-a-personal-issue> as of January 22, 2019.
- 2 https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf as of May 2019 (“IPCC Report”).
- 3 <https://www.earth-syst-dynam.net/8/577/2017/> as of July 18, 2017.
- 4 Bloomberg article “ANC Wants Banks to Be Forced to Fund South Africa Coal Mines” as of May 6, 2019.
- 5 <https://www.wsj.com/articles/is-your-home-at-risk-of-flooding-the-data-is-hard-to-find-11560418204> as of June 13, 2019.
- 6 <https://mg.co.za/article/2019-06-07-00-heat-is-on-insurance-companies> as of June 7, 2019.
- 7 <https://www.sciencedirect.com/science/article/pii/S1674927818300376> as of December 2018.
- 8 <https://www.edf.org/true-cost-carbon-pollution> accessed on June 12, 2019.
- 9 IPCC report.
- 10 License found here: <https://creativecommons.org/licenses/by/4.0/legalcode> as of June 17, 2019.
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- 16 Ibid.
- 17 <https://www.sciencedaily.com/releases/2019/04/190430121755.htm> as of April 30, 2019, <https://www.theguardian.com/environment/2018/oct/09/tipping-points-could-exacerbate-climate-crisis-scientists-fear> as of October 9, 2018, <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3849278/> as of December 3, 2013, and <https://www.sciencedaily.com/releases/2015/11/151126104046.htm> as of November 26, 2015.
- 18 https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-7-d&chapter=27&clang=en as of December 12, 2015.
- 19 <https://www.nytimes.com/2019/01/08/climate/greenhouse-gas-emissions-increase.html> as of January 8, 2019.
- 20 <https://news.un.org/en/story/2017/10/569672-un-sees-worrying-gap-between-paris-climate-pledges-and-emissions-cuts-needed> as of October 2017.
- 21 <https://www.nytimes.com/2019/01/10/climate/ocean-warming-climate-change.html> as of January 10, 2019.
- 22 https://wedocs.unep.org/bitstream/handle/20.500.11822/22070/EGR_2017.pdf?sequence=1&isAllowed=y as of November 2017.
- 23 Ibid.
- 24 IPCC Report.
- 25 <https://www.theguardian.com/environment/2018/dec/05/brutal-news-global-carbon-emissions-jump-to-all-time-high-in-2018> as of December 5, 2018.
- 26 <https://eciu.net/briefings/net-zero/net-zero-why> accessed in June 2019.
- 27 <https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions> accessed on April 12, 2019.
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- 32 <https://www.nature.com/articles/d41586-018-05357-w> as of June 7, 2018.
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- 34 Based on Autonomy Capital analysis as of May 31, 2019.
- 35 Based on Autonomy Capital analysis as of May 31, 2019.
- 36 <https://www.usatoday.com/story/news/2019/05/01/climate-change-tax-california-restaurants-add-fee-diners-bills/3632478002/> as of May 1, 2019.

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