NORGES BANK
INVESTMENT MANAGEMENT

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CLIMATE CHANGE AS A FINANCIAL RISK TO THE FUND

ASSET MANAGER PERSPECTIVE

Climate risk is already affecting the markets in which the fund is invested. The changes in the climate system are becoming more intense, widespread, and frequent. The long-term economic implications of climate change could be significant.

Norges Bank Investment Management (NBIM) addresses risk within a general framework set by the Ministry of Finance. This paper considers climate change as a financial risk to the fund and assesses two approaches to measuring climate risk in investment portfolios: carbon footprint analysis and climate scenario analysis.

Carbon footprint analysis has provided us with valuable insights into changes in the carbon intensity of our equity investments and corresponding benchmark index. Since 2013, the carbon intensity of the equity portfolio has decreased by 50 percent. Climate scenario analysis can illustrate how emissions trajectories and corresponding financial outcomes affect the portfolio over time.

The robustness of these approaches is challenged by incomplete data and methodological limitations. A carbon footprint is based on historical data that may have limited relevance to future risk, while climate scenarios designed to test the sensitivity of investment portfolios typically exclude second- and third-order effects of climate change and climate regulation that are difficult to quantify.

Overall, climate change is a financial risk to the fund. We will continue to engage with researchers and practitioners and support the further development of approaches to measuring climate risk in the fund.

Date 11/08/2021

The Asset Manager Perspective series articulates Norges Bank Investment Management's views and reflections on issues topical for the financial industry. They are not meant to be definitive; rather they are intended as timely contributions for the benefit of all market participants. The series is written by employees and is informed by our investment research and our experience as a large, long-term asset manager.

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Introduction

There is overwhelming scientific evidence that the Earth is warming, and that greenhouse gas (GHG) emissions from human activities are the main driver.[1] Climate change and the transition to a low-carbon economy are already influencing the markets in which the fund invests. There is an ongoing shift in energy consumption and exploitation of natural resources[2], and this will probably intensify in the future.[3] The uncertainty about the scale of climate change and its current and future effects on economies and ecosystems, exposes the fund to climate risk.

In financial markets, we distinguish between physical climate risk and climate transition risk.[4] *Physical climate risk* refers to exposure to acute events such as extreme weather, as well as chronic changes such as sea-level rise, droughts, or changes to ecosystems that support economic activities. Company-specific impacts may include asset write-downs and higher insurance costs. In turn, climate impacts may have wider consequences on asset prices by leading to supply- and demand shocks, and sustained losses in economic productivity and output. Physical climate risk could also provide new investment opportunities.

The accelerating impact of climate change has triggered a myriad of policy, technology and market responses, which in combination generate *climate transition risk*. Climate transition risk may manifest itself in the pricing of carbon through taxation or emissions trading schemes, fiscal policies that support innovation and deployment of low-carbon technologies, shifts in consumer or investor preferences towards green technologies, and increased liability risk associated with carbon-intensive production. Climate transition risk would be expected to impair some investments, while benefitting others, across markets, sectors, and time scales.

This paper considers climate change as a financial risk to the fund and presents two approaches to measuring climate risk in investment portfolios: carbon footprint analysis and climate scenario analysis. We provide our perspectives on the methodologies behind these approaches and how these affect their usefulness as proxy measures of climate risk in the fund.

1 *IPCC (2021): Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani* et al. *(editors)]. Cambridge University Press. In Press.*

2 *Dasgupta, P. (2021): The Economics of Biodiversity: The Dasgupta Review. (London: HM Treasury)*

3 *IPBES (2019): Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Brondizio, E. S., J. Settele, S. Díaz, and H. T. Ngo (editors). IPBES secretariat, Bonn, Germany. 1148 pages. doi.org/10.5281/zenodo.3831673*

4 *TCFD (2017): Recommendations of the Task Force on Climate-related Financial Disclosures – Final Report. June 2017.*

Climate change as a financial risk

Norges Bank Investment Management (NBIM) addresses risk within a general framework set by the Ministry of Finance. We aim to achieve long-term returns with an acceptable level of risk as defined in the mandate laid down by the Ministry. As part of this objective, we use a variety of approaches to address the fund's exposure to climate risk and opportunities associated with the transition to a low-carbon economy, which are described in a separate *Asset Manager Perspective*.[5]

The fund's investment strategy is reflected in the choice of a strategic benchmark index set by the Ministry of Finance and a mandate requirement to follow this index closely. The fund invests in public equities, fixed income, unlisted real estate and unlisted renewable energy infrastructure. At the end of 2020, the fund's investments spanned 73 countries and 49 currencies, including equity holdings in over 9,000 companies. Diversification helps the fund reduce its overall risk and achieve its objective of generating the highest possible long-term return within the general framework set by the Ministry.

The fund is mainly exposed to climate risk through its equity investments given the strategic allocation to equities.[6] Since the fund is invested with a long-term time horizon and across markets and sectors, the well-functioning of markets and the collective performance of entire classes of financial assets are a more significant determinant of expected portfolio returns than the short-term performance of individual companies and assets. As we effectively own a slice of the global economy, the fund stands to benefit from developments in human, natural, and social capital that are conducive to higher global economic productivity and growth.[7]

Overall, climate change is a financial risk to the fund. All other things being equal, climate economists suggest a warmer world entails higher net costs to the global economy.[8] The expected transition to a low-carbon economy will take place within a time scale that is relevant to the investment horizon of the fund. Limiting warming to 2°C or less has been projected to benefit long-term diversified investors relative to warming of 3°C or 4°C.[9] We benefit when companies are incentivised to internalise their indirect costs, including those related to greenhouse gas emissions, that would otherwise be borne by other companies in the fund's portfolio, society at large, or future generations. Over time, the fund would stand to benefit from an early and gradual introduction of policies that place a cost on carbon emissions

5 *We provide a comprehensive overview of approaches and tools to address climate-related financial risks and opportunities in NBIM 2021. Addressing Climate Change Risks and Opportunities, NBIM* Asset Manager Perspectives*, 01/21.*

6 *The equity allocation in the strategic benchmark index has been set at 70 percent, with fixed income accounting for the remainder. These allocations are subject to market, sector and currency weights. Norges Bank may also decide that the fund should invest in unlisted real estate, up to a maximum of 7 percent of the fund's investments.*

7 *Ang, A. (2012): "The Four Benchmarks of Sovereign Wealth Funds",* In Bolton, P., F. Samama and J. Stiglitz (editors.) Sovereign Wealth Funds and Long-Term Investing, pp 94–105. Columbia University Press.

8 *Among a survey of 738 economists who have published climate-related research in the field's highest-ranked academic journals, the median estimate of global climate damages projected was 1 percent of GDP per year by 2025, and up to 5 percent per year by 2075 [Howard, P. and D. Sylvan (2021): Gauging Economic Consensus on Climate Change. Institute for Policy Integrity, NYU School of Law, March 2021].*

9 *Mercer (2019): Investing in a time of climate change – the sequel.*

or otherwise incentivise the substitution of carbon-intensive technologies and practices with low-carbon alternatives. This would allow the market to gradually adjust, and would entail lower net costs to the global economy as a whole than a response which is delayed and/or abrupt.[10]

The characteristics of climate risk

Climate risk has a number of characteristics that impacts how we understand, measure and manage it in the fund. First, climate change generates highly correlated policy actions and effects across countries, sectors, and assets. Given its systemic nature, climate risk cannot be mitigated entirely through diversification.[11] The government of major economies collectively representing more than half of world GDP have pledged to reduce their CO_2 emissions to net-zero by mid-century. Meeting this ambition will require deep transformations in a variety of markets and sectors, and generate climate transition risk and opportunities, particularly in energy-related investments, while reducing the long-term exposure of the fund to physical climate risk.[12] If the ongoing energy transition and corresponding emissions cuts do not accelerate, the scale of physical climate risk in the form of acute events and chronic changes will increase dramatically in the medium to long-term.[13]

Companies are embedded within local and global markets, which in turn are nested in the broader system of societies and ultimately the natural environment.[14] Studies have identified a number of second- and third-order effects of climate change that could influence individual companies as well as broader economic trends, such as the impact of droughts on agricultural yields, extreme heat on labour productivity,[15] higher temperatures on pathogens,[16] and natural capital loss on migration and trade flows (Figure 1).[17] The degree of insurance penetration, government recovery capacity, and other risk mitigating factors can help limit the extent to which economic losses spread beyond those directly affected.[18]

10 *NGFS (2019): A call for action - Climate change as a source of financial risk. Network for Greening the Financial System (NGFS), April 2019.*

11 *CISL (2015): Unhedgeable risk: How climate change sentiment impacts investment, Cambridge Institute for Sustainability Leadership (CISL), November 2015.*

12 *IEA (2021): Net Zero by 2050. International Energy Agency.*

13 *Houser, T., S. Hsiang, R. Kopp and K. Larsen (2015): Economic Risks of Climate Change: An American Prospectus. Columbia University Press.*

14 *Levin, S., M. Reeves and A. Levina (2020): "Business and sustainability: From the firm to the biosphere",* In Bril, H., G. Kell and A. Rasche (editors). Sustainable Investing: A Path to a New Horizon. London, UK: Routledge.

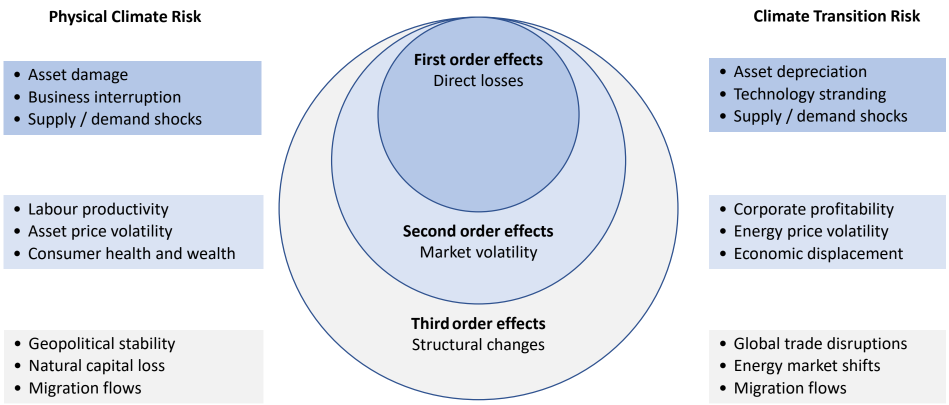
15 *Burke, M., S. Hsiang and E. Miguel (2015): "Global non-linear effect of temperature on economic production",* Nature 527:235–239. doi.org/10.1038/nature15725

16 *Cavicchioli, R., W. J. Ripple, K. N. Timmis* et al. "Scientists' warning to humanity: microorganisms and climate change, Nature Reviews Microbiology 17:569–586. doi.org/10.1038/s41579-019-0222-5

17 *Schlenker, W. and M. Auffhammer (2018): "The cost of a warming climate",* Nature 557:498–499. doi: 10.1038/d41586-018-05198-7

18 *International Monetary Fund (2020): Global Financial Stability Report: Markets in the Time of COVID-19. IMF, Washington, DC, April 2020.*

Figure 1: Projected effects of physical climate risk and climate transition risk on the global economy



Source: NBIM, derived from NGFS 2019.

Secondly, the magnitude, timing, and geographical distribution of climate-related risk is highly uncertain, which itself represents a risk to long-term investors.[19] The mean global surface temperature has increased by 1.1°C relative to pre-industrial levels.[20] The stated ambition of the G7 countries that collectively account for roughly 40 percent of global GDP is to seek to limit warming to 1.5°C.[21] The International Energy Agency (IEA) states that achieving this goal would require a complete transformation in how energy is produced, transported, and stored.[22]

If warming exceeds 1.5°C, economic damages are projected to increase exponentially relative to GHG concentrations in the atmosphere (Figure 2, panel A) for a variety of reasons, including biosphere tipping points that can trigger the abrupt release of carbon back to the atmosphere and further exacerbate warming.[23] The regional effects of various rates of warming and the extent to which economies are able to adapt to changing climate conditions are also highly uncertain, as they will depend on risk aversion, the resources available for adaptation, and the capacity to do so before hazards materialise.[24] Combined, these factors make it difficult to assign probabilities to specific emission scenarios and associated outcomes.

Third, the possibility of significant long-term economic implications cannot be ruled out. For example, mass loss of glaciers, permafrost thaw, and decline in snow cover and Arctic sea ice extent are projected to continue

19 *Hsiang, S. (2019): Congressional testimony on economic consequences of climate change. Presented June 10 to: United States House Committee on the Budget, hearing on "The Costs of Climate Change: Risks to the U.S. Economy and the Federal Budget".*

20 *IPCC (2021): Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani et al. (editors)]. Cambridge University Press. In Press.*

21 *2021 Carbis Bay G7 Summit Communiqué: Our shared agenda for global action to build back better.*

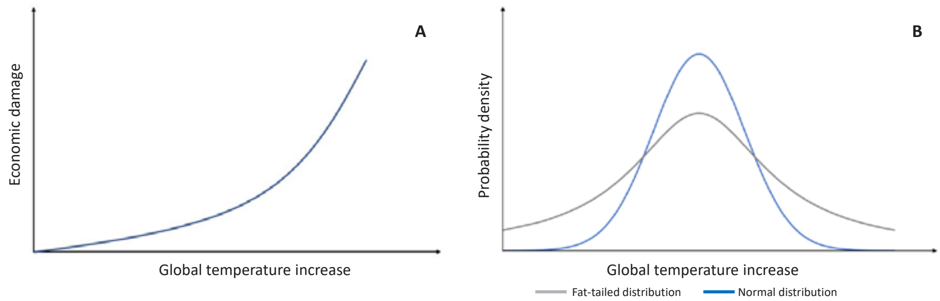
22 *IEA (2021): Net Zero by 2050. International Energy Agency.*

23 *IPCC (2018): Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.*

24 *Schlenker, W. and C. A. Taylor (2019): "Market Expectations About Climate Change", NBER Working Paper No. 25554, February 2019.*

until mid-century with unavoidable consequences for river runoff and local hazards.[25] Feedback loops and tipping points in the climate system itself, and also among species and ecosystems, could have cascading effects.[26] This implies that the probability of outcomes with very large, irreversible, and uninsurable damage costs is probably higher than a normal distribution would predict (Figure 2, panel B).[27] On the basis of emissions locked into existing infrastructure and current policy pledges from governments, warming could reach 3°C by 2100.[28] The scientific certainty around this best estimate is greater now than in 2014.[29] If significant and abrupt, the physical impacts of climate change can severely curtail the natural resource base underpinning economies and trigger a write-down of assets that are no longer capable of generating economic value, referred to as "stranding".[30]

Figure 2: Panel A: Non-linear increase in damages to the global economy with increasing temperature. Ilustrative adaptation from Burke et al. (2015). Panel B: Fat-tailed probability distribution of global temperature increase. Illustrative adaptation from Weitzman (2016).



Finally, it is possible that climate-related financial risk is not systematically reflected in asset valuations.[31] Climate change is a market failure given that those emitting greenhouse gases are not forced to account for the external costs of their emissions, leading to misallocation of resources and inefficient market outcomes.[32,33] However, the extent to which this leads to a systematic mispricing of financial assets that could be exploited through portfolio management techniques is less certain. According to finance theory, the market portfolio will give the best trade-off between expected return and risk in a situation where markets are efficient. There is some evidence that the pricing of assets reflects how their payoffs relate to the state of the economy

25 *IPCC (2019): Summary for Policymakers. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [Pörtner, H.O., D.C. Roberts, V. Masson-Delmotte* et al. (editors)]. In Press.

26 *Lenton, T. M., J. Rockström, O. Gaffney* et al. (2019): "Climate tipping points - too risky to bet against", Nature 575:592–595. doi.org/10.1038/d41586-019-03595-0

27 *Weitzman, M. (2011): "Fat-Tailed Uncertainty in the Economics of Catastrophic Climate Change",* Review of Environmental Economics and Policy 5(2):275–292. doi:10.1093/reep/rer006

28 *Hausfather, Z., and G. P. Peters (2020): "Emissions – the 'business as usual' story is misleading",* Nature 577(7792): 618–620. doi.org/10.1038/d41586-020-00177-3

29 *IPCC (2021): Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani et al. (editors)]. Cambridge University Press. In Press.*

30 *Dell, M., B. F. Jones and B. A. Olken (2012): "Temperature Shocks and Economic Growth: Evidence from the Last Half Century",* American Economic Journal: Macroeconomics 4(3): 66–95. doi.org/10.1257/mac.4.3.66

31 *NGFS (2019): A call for action - Climate change as a source of financial risk. Network for Greening the Financial System (NGFS), April 2019.*

32 *Stern, N. (2007):* The Economics of Climate Change: The Stern Review, Cambridge: Cambridge University Press. doi:10.1017/CBO9780511817434

33 *Crona, B., C. Folke, V. Galaz (2021): "The Anthropocene reality of financial risk",* One Earth 4(5):618–628. doi.org/10.1016/j.oneear.2021.04.016.

in different climate transition scenarios. However, limited data availability and the time horizon of impacts mean that it is hard to model and assess other than the most immediate risks. On balance, we do not believe there is sufficient evidence to claim that climate risk is systematically mispriced. We do however, for many of the same reasons, believe that climate change is an area that may be well-suited to active management, within our existing framework for such decisions.[34]

In a recent paper, we use two theoretical frameworks that illustrate how environmental, social, and governance (ESG) considerations may impact asset prices.[35] Specifically, assets with high carbon intensity ("brown" assets) have lower cash flows in adverse climate scenarios, implying lower prices and higher risk premiums, while assets with comparatively lower carbon intensity ("green" assets) have higher prices and lower risk premiums. The nature of cash flow risks can change depending on the investment horizon, for example if the economy is able to adapt following climate shocks. If a significant fraction of the market holds uniform investment preferences regardless of the underlying motivation, it can influence asset prices irrespective of information asymmetries in the market.[36,37]

Carbon footprint analysis

Given the characteristics of climate risk, it is inherently difficult to measure risk exposure across portfolios, companies, and assets. A common approach recommended by the Task Force on Climate-related Financial Disclosures (TCFD) is carbon footprint analysis. We have measured and publicly disclosed the carbon footprint of the equity portfolio since 2014. A carbon footprint consists of the emissions associated with a particular asset, economic activity or portfolio in a given reporting period, and can be expressed in absolute terms or normalised by financial metrics. Given the lack of standardized corporate disclosure of GHG emissions across markets and sectors, most of the emissions data used to calculate the carbon footprint of the fund is estimated.

Our methodology follows the recommendations of the TCFD and is based on estimating the carbon intensity of each company in the portfolio – defined as tonnes of carbon dioxide equivalents (CO_2e) per unit of revenue – and aggregating these to the portfolio level on the basis of each company's share of portfolio value.[38] The estimated carbon footprint of the fund that we disclose covers direct emissions from corporate assets (Scope 1) and emissions associated with procured energy and heat (Scope 2). We do not

34 *Norges Bank (2021). Climate risk in the Government Pension Fund Global. Letter to the Ministry of Finance, July 2 2021.*

35 *NBIM (2021). The asset pricing effects of ESG investing. Discussion note 01/21.*

36 *Berg, F., J. Kölbel and R. Rigobon (2020): "Aggregate Confusion: The Divergence of ESG Ratings",* SSRN Working Paper, May 17, 2020. doi.org/10.2139/ssrn.3438533

37 *Hong, H. and M. Kacperczyk (2009): "The price of sin: The effects of social norms on markets",* Journal of Financial Economics 93(1):15–36. doi.org/10.1016/j.jfineco.2008.09.001

38 *TCFD (2017): Recommendations of the Task Force on Climate-related Financial Disclosures. Final Report, June 2017.*

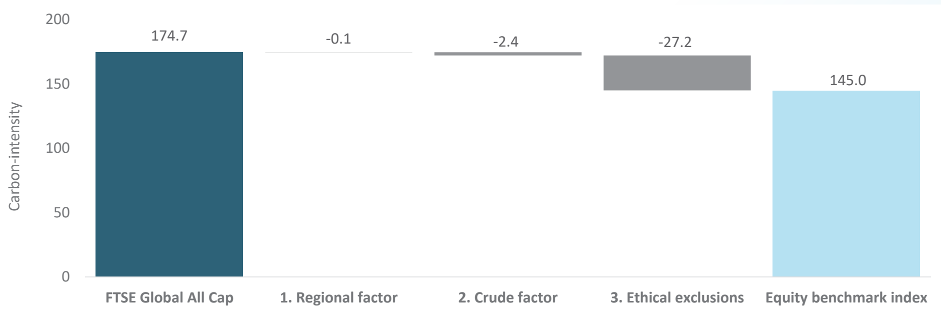
include indirect emissions that occur in the supply chain of a a company (Scope 3) because of significant data gaps and the difficulty of avoiding double-counting of emissions across companies in the portfolio.

Results of carbon footprint analysis

The carbon footprint of the fund's equity portfolio is the result of three layers of decisions. The first layer is the carbon footprint of the standard market benchmark (FTSE Global All Cap) chosen by the Ministry of Finance, and the second layer is the carbon footprint effects of the adjustments the Ministry makes to that benchmark index. The third layer is the carbon footprint of the fund's equity portfolio after NBIM has made adjustments to its holdings through investment management decisions. These latter adjustments create deviations relative to the benchmark index specified by the Ministry, and are made within the risk parameters of the mandate.

We have estimated the relative contribution of each layer of decisions to the carbon footprint of the fund. The equity benchmark index chosen by the Ministry of Finance for the fund deviates slightly from an index weighted by market-capitalisation (FTSE Global All Cap). The chosen deviation results in the carbon intensity of the equity benchmark index being 17 percent lower than that of a global market-weighted index (Figure 3).

Figure 3. Carbon intensity: FTSE Global All Cap vs. equity benchmark index, 2020



Note: Million tonnes of CO_2 equivalents from Scope 1 and 2 emissions per million US dollars of revenue. Carbon intensity at company level is aggregated to portfolio level using each company's respective share of portfolio value.

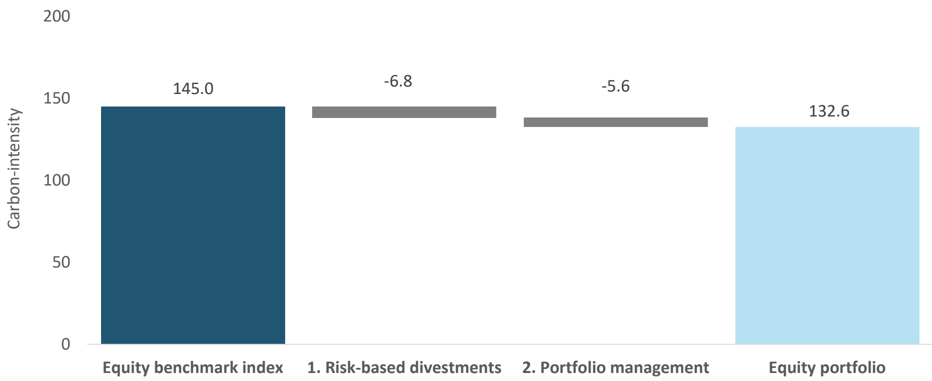
The main contributing factor has been the impact of ethical exclusions from the fund's equity benchmark index recommended by the Council on Ethics and approved by the Executive Board of Norges Bank.[39] In particular, coal-related exclusions have reduced the carbon intensity of the equity benchmark index by 16 percent relative to a market-weighted index. The Ministry of Finance has also decided to remove upstream oil and gas companies from the equity benchmark index (crude factor), resulting in a further reduction in carbon intensity by one percent. In addition, the equity benchmark index has a higher weighting of Europe and a lower weighting of the US than a global market-weighted index (regional factor), but this has only had a marginal effect on the carbon intensity of the fund.

39 *Council on Ethics (2019): Guidelines for observation and exclusion from the Government Pension Fund Global.*

The fund's equity portfolio has for many years had a lower carbon intensity than the equity benchmark index set by the Ministry of Finance. In 2020, the relative difference was 9 percent, mainly due to the effect of risk-based divestments (Figure 4). These are investment decisions made within the risk parameters of the mandate. Divestment may be appropriate if we consider the company to have particularly high long-term ESG risks, if our investment is not significant relative to the size of the fund, and if we conclude that active ownership is not a suitable approach. Returns associated with this strategy hinge on the timing of the divestment decisions relative to whether and when the relevant ESG risk began to be reflected in asset prices.

Since 2012 we have divested from 170 companies on the basis of climate-related risks, which has resulted in the carbon intensity of the equity portfolio being 5 percent lower than the equity benchmark index. These divestments have increased the cumulative relative return of the equity portfolio by 0.21 percentage point. In addition, the requirement in the management mandate to establish environment-related mandates causes a deviation from the equity benchmark index. At the end of 2020, we had invested around 100 billion kroner in equities through our environment-related mandates. This has helped reduce the portfolio's carbon footprint by an additional 4 percent relative to the equity benchmark index.

Figure 4. Carbon intensity: Equity benchmark index vs equity portfolio, 2020

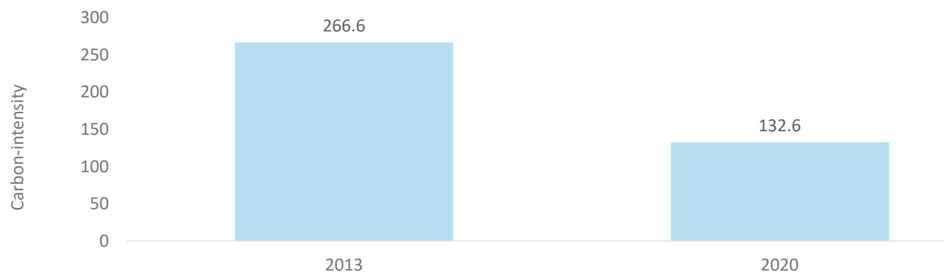


Note: Million tonnes of CO_2 equivalents from Scope 1 and 2 emissions per million US dollars of revenue. Carbon intensity at company level is aggregated to portfolio level using each company's respective share of portfolio value.

Over time, decisions taken by the Ministry of Finance on adjustments to the equity benchmark index, by the Executive Board of Norges Bank on ethical exclusions, and NBIM on risk-based divestments, have had a significant impact on the fund's aggregate exposure to carbon-intensive sectors. Since 2013, the market-weighted carbon intensity of the equity portfolio has declined by 50 percent (Figure 5).[40] This can be attributed to the effects of the aforementioned ethical exclusions and risk-based divestments in sectors with high carbon intensity, notably coal-based power generation, as well structural changes in the market, notably the growth of technology companies relative to companies in other sectors with comparatively higher carbon intensity.

40 *The carbon footprint of our portfolio as measured by our ownership shares in companies declined 8.5 percent between 2017 and 2020.*

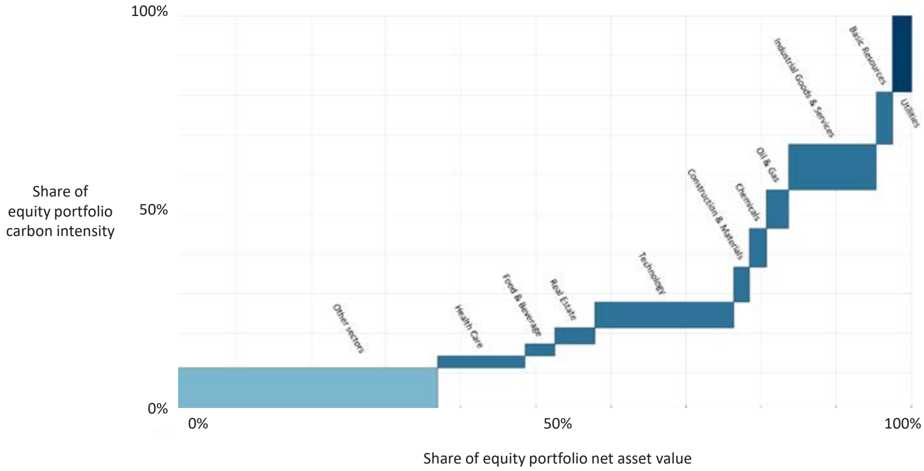
Figure 5. Carbon intensity of the equity portfolio



Note: Million tonnes of CO_2 equivalents from Scope 1 and 2 emissions per million US dollars of revenue. Carbon intensity at company level is aggregated to portfolio level using each company's respective share of portfolio value.

Even after exclusions and divestments from the coal sector, the distribution of the carbon footprint of the fund's equity portfolio remains concentrated in a few industries that collectively account for a small share of portfolio value. At the end of 2020, less than 20 percent of the equity portfolio by net asset value accounted for more than 50 percent of the portfolio's carbon intensity (Figure 6). This concentration is also reflected in the equity benchmark index and, by and large, is not the result of investment management decisions.

Figure 6. Carbon intensity and net asset values in the equity portfolio by industry sector, 2020



Note: The figure shows the net asset value weighted contribution of each sector to the carbon intensity of the equity portfolio. Includes Scope 1 and Scope 2 emissions. Carbon intensity at the sector level is the sum of the contributions to carbon intensity of the individual companies within the respective sector.

Strengths and weaknesses of carbon footprint analysis

Carbon footprint analysis has a number of strengths as a climate-related metric for investment portfolios. First, it is primarily designed to be based on actual data reported by companies, and only secondarily, on estimates derived from historical data. The methodology is transparent and can be subject to quantitative scrutiny. There are no projections based on factors associated with significant uncertainty. As a result, the data output is an objective measure that can be easily understood. Second, the carbon footprint of an investment portfolio is a measure of the underlying investments' emissions, irrespective of the risk associated with these emissions, and can be used to measure the carbon intensity of relative risk taken through investment management. For instance, the carbon footprint of a portfolio relative to a benchmark index can tell us whether investment management decisions have increased or decreased relative exposure to carbon-intensive companies. Third, a carbon footprint can reveal the concentration of emissions in an investment portfolio by geography, sector or other dimensions. While it is not a given that higher emissions equate to higher risk for companies and assets, concentrations of emissions reveal potential concentrations of risk.

However, several methodological challenges restrict the usefulness of a carbon footprint as a proxy measure of climate transition risk.[41] First, common methods of normalisation assume that a company's equity and debt-holders are equally exposed to a company's carbon emissions, even though seniority in the capital structure probably matters in the case of default. Second, carbon footprints of investment portfolios typically negate emissions generated in a company's value-chains (Scope 3) even though these can account for a significant share of its risk exposure. At portfolio level, this leads to an underestimation of climate transition risk, particularly among companies that are highly exposed to carbon-intensive supply chains or growing consumer preferences for low-carbon products and technologies. Third, a carbon footprint by itself does not illustrate how emissions are distributed across constituents of an investment portfolio. Whether emissions in a portfolio are distributed normally or abnormally is important for understanding risk magnitude and concentration. Similarly, whether emissions are concentrated in markets with aggressive climate policies, or weak climate policies, is an important measure of the portfolio's total exposure to climate transition risk. Fourth, a carbon footprint is a point-in-time representation of exposure to emission-intensive companies and does not consider fluctuations in holdings or carbon-intensities during a reporting year, or the extent to which companies in the portfolio are likely to reduce or increase their carbon intensity over time.

The accuracy of a carbon footprint calculation, moreover, depends on the availability and quality of data on the carbon emissions of the underlying companies and assets. There are basic errors of corporate reporting that may go unnoticed given that most of the disclosed data is not externally audited, such as emission figures incorrectly denominated in tonnes rather than kilos, and errors associated with how companies choose to consolidate emissions across their holding structures. Companies may also choose to align their emissions calculations with different carbon accounting standards. This not only risks making disclosures across companies incomparable, but it can create errors in how emissions data are normalised, for example, by revenues or market value. There is also commonly a lag in the reporting of carbon emissions relative to the reporting of financial results. As a result, some companies may normalise emissions data from one year with financial data from another year. The significance of this error to the overall results

41 *As the TCFD states, "The Task Force acknowledges the challenges and limitations of current carbon footprinting metrics, including that such metrics should not necessarily be interpreted as risk metrics." (TCFD 2017:37).*

increases during times of market instability when both emissions and financial results deviate from the long-term mean.

The adverse effects of such methodological issues are further compounded when incorrect data points are used to generate assumptions and estimate emissions of companies that do not measure and disclose their emissions. In 2020, only 10 percent of the emissions included in the fund's carbon footprint were based on figures reported directly by companies, with the remainder being estimated on the basis of other corporate disclosures (55 percent), modelled based on sector, market value, and underlying asset mix (34 percent), or based on the sector median as a proxy (1 percent).[42] Estimation can be error-prone and lead to extreme outliers in sectors with a large spread in emission-intensities among companies. Our analysis shows that the 95 percent confidence interval for predicting the median is very wide, suggesting there is considerable uncertainty in these numbers. These methodological issues have an unknown impact on the carbon footprint when aggregated to a portfolio level.

Climate scenario analysis

The potential scale of climate change could subject the global economy to unprecedented biophysical pressures in the future that are dissimilar in form and intensity to any previous large-scale structural breaks.[43] This renders analytical tools using historical data – such as carbon footprinting – less effective for assessing portfolio risk. As an alternative, climate scenario analysis is based on different methodological explorations of a large variety of possible future pathways for climate change and societal responses to it. Approaches used in financial markets are typically limited to modelling direct effects of the physical impacts of climate change, and the effects of carbon prices and green revenue opportunities on companies and assets. The most commonly studied asset classes are public equities, real estate, and infrastructure.

Most climate scenarios start with a set of five Shared Socioeconomic Pathways (SSPs) used by the Intergovernmental Panel on Climate Change (IPCC) to describe different socioeconomic futures up to 2100. The SSPs align with GHG concentration trajectories, known as Representative Concentration Pathways (RCPs).[44] In combination, SSPs and RCPs define a broader storyline of future biophysical changes and corresponding policy, market, and technological responses. In turn, these are used to define inputs to Integrated Assessment Models (IAMs), which describe different components of the global economy, such as energy systems, demography, land use, and climate conditions. While a single scenario illustrates an outcome space

42 *The fund was invested in 9,123 companies at the end of 2020 (NBIM Annual Report 2020).*

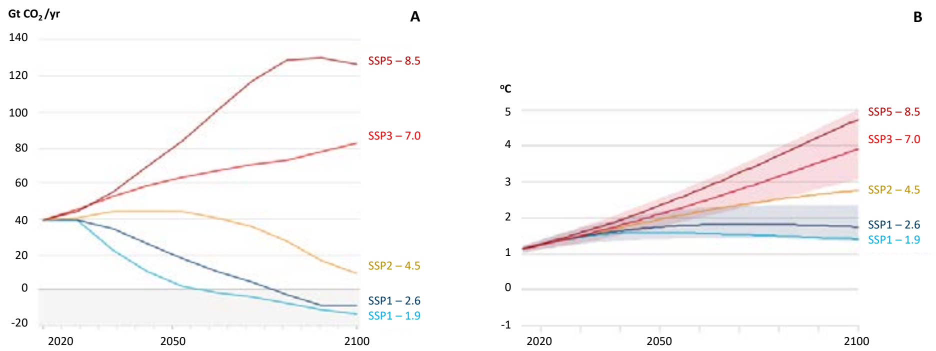
43 *Lenton, T. M., J. Rockström, O. Gaffney* et al. (2019): "Climate tipping points - too risky to bet against", Nature 575:592–595. doi.org/10.1038/d41586-019-03595-0

44 *O'Neill, B.C., T.R. Carter, K. Ebi* et al. (2020): "Achievements and needs for the climate change scenario framework", Nature Climate Change 10:1074–1084. doi.org/10.1038/s41558-020-00952-0.

rather than a probability outcome, projections can in principle be customised to reflect risk preferences, assumptions, and expectations.

Figure 7 illustrates a set of five emissions scenarios and corresponding warming projections from an IPCC report released in 2021.[45] The IPCC uses scenarios to illustrate the impact of future rates of emissions on global average temperatures. A particular emissions pathway can have a range of different temperature outcomes with different probabilities. Beyond mid-century, the range of plausible temperature outcomes widens, with corresponding impacts on the climate and natural system ranging from relatively benign to truly catastrophic.

Figure 7. Panel A: Future trajectories of annual anthropogenic CO_2 emissions across five illustrative scenarios (IPCC 2021, p.18). Panel B: Global surface temperature change relative to 1850-1900 across five illustrative scenarios. "Very likely" ranges are shown for SSP1-2.6 and SSP3-7.0 (IPCC 2021, pp.30-31).



Source: NBIM. Derived from IPCC (2021).

Each emissions scenario is associated with a range of projected global mean temperature increases by 2100, illustrated in Figure 7 by the uncertainty bands around the SSP1-2.6 and SSP3-7.0 emissions scenarios. SSP1-1.9 is a scenario in which emissions peak as early as 2025, and rapidly decline to zero by 2060. In this best-case emissions scenario, warming is projected to be below 1.5°C in 2100. Emissions scenarios that overshoot 1.5°C run a greater risk of passing through tipping points beyond which certain severe impacts are much more likely to occur.[46] Moreover, warming may well exceed 2°C even if emissions peak during the next decade and gradually decline to zero by 2080, as illustrated by SSP1-2.6. In SSP2-4.5, emissions rise gradually throughout the century, resulting in 2.0°C of warming by mid-century and nearly reaching 3°C by 2100. SSP3-7.0 and SSP5-8.5 are high emission scenarios which assume a doubling of CO_2 emissions from current rates by 2100 and 2050, respectively.

The impact of warming on fund returns depends on the first-order effects of climate change, regulations, and technological developments on companies and assets, and the second- and third-order effects on global economic

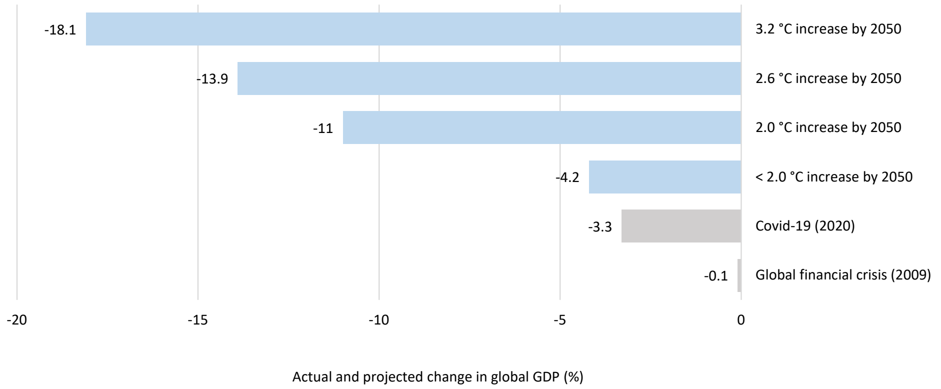
45 *IPCC (2021): Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani* et al. (editors)]. Cambridge University Press. In Press.

46 *IPCC (2018): Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.*

productivity and output. This includes various spillover effects from low-income countries, which are projected to be disproportionately directly affected by climate change, to high-income countries that may be less vulnerable to the direct impacts of climate change and have greater adaptive capacities to manage them.[47]

Figure 8 illustrates how projected GDP losses rise exponentially with each degree of additional warming. It suggests that surpassing 2.0°C of warming relative to pre-industrial levels could lead to significantly higher GDP losses, in line with IPCC projections of climate impacts,[48] and are potentially larger than recently experienced economic shocks in absolute terms.[49]

Figure 8. Estimated permanent GDP losses by 2050 under different warming scenarios compared to temporary GDP losses associated with selected economic shocks.



Source: NBIM, derived from Swiss Re Institute 2021; International Monetary Fund 2021

Results of climate scenario analysis of the equity portfolio

Climate scenario modelling in asset management is a nascent field. There are significant methodological challenges and technical limitations in the mapping of global climate models for portfolio returns in ways that are scientifically robust. We have explored various approaches to using climate scenario analysis to understand long-term portfolio exposure to climate risk. MSCI, a provider of data and research for investors, has analysed the impact of different climate scenarios on the long-term value of the fund's equity portfolio as well as the climate risk exposure generated by the deviation of the equity portfolio from the equity benchmark index, referred to as relative risk.

In MSCI's Climate Value-at-Risk model, climate transition risk is estimated using the aggregate of the policy-related risks and opportunities implied by four alternative climate scenarios expressed in degrees of warming relative to pre-industrial levels; 1.5°C, 2°C, 2°C with late policy response, and 3°C (MSCI, Table 1). Physical climate risk is estimated solely against RCP 8.5, the very high GHG emissions scenario that assumes continuous emissions

47 *Cruz, J. L. and E. Rossi-Hansberg (2021): "The Economic Geography of Global Warming",* NBER Working Paper *No. 28466. doi: 10.3386/w28466.*

48 *IPCC (2018): Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.*

49 *Swiss Re Institute (2021):* The economics of climate change: no action not an option. April 2021.

increases throughout the century above the current rate. The outputs of the model are expressed in estimated losses in Norwegian kroner associated with four different GHG concentrations and associated emission pathways and temperature increases, split between climate transition risk and physical climate risk. The results suggest that the fund's exposure to climate transition risk is positively correlated with carbon prices and is particularly sensitive to the carbon price slope between today and 2080.

Table 1. Estimated loss in value in the equity portfolio across various climate scenarios (MSCI).

Climate transition risk	Estimated loss in value, percent by 2080	Estimated loss in value, billion kroner by 2080
AIM-CGE | 1.5°C | SSP2	8%	650
AIM-CGE | 2°C | SSP2	4%	300
AIM-CGE | 2°C (delayed) | SSP2	9%	750
AIM-CGE | 3°C | NDC	1%	50
Physical climate risk	**Estimated loss in value, percent by 2080**	**Estimated loss in value, billion kroner by 2080**
RCP 8.5	4%	300

Note: Estimated value losses in the equity portfolio are expressed in present value. This entails that potential losses in the long-term are attributed lower value today than potential losses in the short term. Losses as a share of the equity portfolio can be much larger at the time they are incurred than their present value today (Source: MSCI's Climate Value-at-Risk model)

The 2°C scenario with a late policy response would generate an estimated 750 billion kroner in losses measured in fund value today, the largest adverse impact on the value of the equity portfolio across the various scenarios. Subsequently, emissions reduction costs are assumed to peak by mid-century before eventually decreasing linearly to zero based on an expectation of global carbon neutrality. Higher carbon prices associated with the 2°C scenario with a late policy response relative to the other scenarios are the primary reason for the higher estimates of portfolio losses.

The model results suggest a large portion of the policy costs across all scenarios are offset by revenue associated with low-carbon economic opportunities. The 3°C scenario, which is a proxy for the temperature increase that would result from current government pledges being implemented,[50] is projected to decrease the value of the equity portfolio the least of any of the scenarios, by approximately 50 billion kroner. Overall, the impact of climate transition risk is lower in the equity portfolio than the equity benchmark index across all four transition scenarios assessed, albeit not substantially. The estimates do not include uncertainty measures and confidence intervals.

With regards to physical impacts of climate change, the model aggregates company exposures to estimate figures for the equity portfolio and equity benchmark index. It includes risks and opportunities across acute climate risks (coastal flooding, fluvial flooding and tropical cyclones) and chronic climate risks (extreme heat, extreme cold, heavy precipitation, heavy

50 *International Energy Agency Stated Policy Scenario illustrates the consequences of existing and stated policies for the energy sector, and predicts warming of 2.7 °C by 2100, with a 50 percent probability [IEA (2021): Net Zero by 2050. International Energy Agency].*

snowfall, and wind gusts). The analysis uses the 95th percentile of RCP 8.5 to illustrate tail risk associated with physical climate change. Modelling portfolio costs against this scenario therefore isolates the effects of physical climate risk on the portfolio. It projects the value of the equity portfolio to decline by approximately 300 billion kroner if this particular physical climate risk scenario materialises. The model suggests that the primary driver of the impact on the portfolio related to physical climate change is coastal flooding. Extreme heat has a noticeable impact on portfolio valuation while the remaining hazards have minimal effects.

Results of climate scenario analysis of the real estate portfolio

The fund has a concentrated global real estate portfolio spread across listed and unlisted investments in the US, Europe, and Japan. Exposure to physical climate risk is driven by the geo-location of real estate assets and their resilience to hazards such as heat waves, coastal flooding, extreme weather, and heavy precipitation. At the end of 2020, real estate accounted for 3.7 percent of the fund's market value. We had invested 273 billion kroner in an unlisted real estate portfolio of 868 properties across the US, Europe, and Japan. Based on historical records of hydrological events, we estimate that 4 percent of our unlisted real estate portfolio by value is located in areas that have flooded at least once during the past century.

We have used climate scenario analysis from three different third-party research providers to understand the predicted change in physical climate risk in the markets in which we have real estate assets. One analysis suggests that the spread of risk increases over time between cities, neighbourhoods and assets that currently have low exposure to physical climate risk, and those that have high exposure. Some assets in coastal locations may experience flood inundation at mean sea-level rise and daily tidal flooding as early as 2060 under RCP 4.5, a scenario that broadly tracks historical emissions rates. Higher sea levels imply that tidal flooding and storm surge flooding will occur more frequently and with greater inundation areas.

Flood hazards can vary greatly between assets in the same micro-locations in the same area as a result of differences in proximity to waterways and topography. Other climate hazards such as heat waves, extreme wind, and heavy precipitation are more likely to be uniform across larger areas. Modelling their effects does not require data inputs with the same level of granularity. Greater frequency of extreme heat can increase operational and capital costs related to cooling, and water stress can disrupt the availability of water, and increase water rates. Overall, the modelled value-at-risk from physical climate risk in the fund's real estate portfolio is modest.

Strengths and weaknesses of climate scenario analysis

Climate scenario analysis has a number of strengths for assessing long-term climate risk in investment portfolios. First, scenario analysis is uniquely suited to help us understand climate risk, given that historical data has limited predictive power and the future is uncertain, but highly likely to be different from the past. Secondly, scenario analysis allows us to investigate the implications of different future states of the world on long-term portfolio returns. This includes understanding the magnitude of estimated effects of single scenarios, and equally important, the relative estimated effects of different scenarios. And third, climate scenario analysis is a flexible tool in which core assumptions, factors, and the selection of scenarios can in principle be customised in accordance with fund characteristics and risk preferences.

However, a number of limitations influence how we engage with climate scenario analysis and interpret the results, such as those presented in Table 1. First, models developed to analyse investment portfolios necessarily simplify real-world complexities by limiting the number of input factors and assumptions regarding their interactions.[51] They are based on global climate models that provide risk information at very high spatial resolutions based on mathematical representations of the major components of the climate system (atmosphere, land surface, ocean, and sea ice), and their interactions. Downscaling the outputs of global climate models to regions, and even more so to the specific locations of corporate assets, adds uncertainty to modelled results and is fraught with methodological challenges.

Moreover, climate scenarios do not fully consider interactions and inter-dependencies between variables that can be self-reinforcing and lead to both non-linearity and exponential growth or decline. Notably, both physical and transition risk can be stochastic and highly volatile, and invariably interact with one another. Yet, instead of being coupled and integrated into single climate scenarios, physical and transition risk are commonly analysed in separate models that fail to fully account for their inter-relationships.[52] For example, governments may respond to greater physical climate risk by introducing more stringent carbon constraints, while also investing more in climate adaptation. Climate transition risk scenarios fail to incorporate these uncertain interaction effects by being limited to a single optimisation model based on estimates of the most cost-efficient pathway to a low-carbon economy. We believe these limitations lead to a systematic underestimation of physical climate risk since many impacts are unknown or difficult to quantify, whereas climate transition risk may be overestimated because models cannot incorporate the unknown benefits of future technological innovations.[53]

Second, the analytical usefulness of climate scenario analysis is largely determined by the quality of the input data and the assumptions underlying the model. Incomplete information about the geographical distribution of companies' assets, supply chains, and sources of revenue undermine the precision of company-level analysis of climate risk. Moreover, since the model does not quantify second and third-order effects, such as the macro-economic impacts of changes on labour productivity, household wealth, ecosystem functioning and resource scarcities, actual losses will probably be much higher than the model predicts, rather than lower. This is likely to be a particularly significant limitation for physical climate risk scenario models

51 *Norwegian Climate Risk Commission (2018): Climate Risk and the Norwegian Economy, NOU2018:17.*

52 *Riahi, K., D. P. van Vuuren, E. Kriegler* et al. (2017): "The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview", Global Environmental Change 42:153-168. doi.org/10.1016/j.gloenvcha.2016.05.009

53 *Meng, J., R. Way, E. Verdolini* et al. 2021: "Comparing expert elicitation and model-based probabilistic technology cost forecasts for the energy transition", PNAS 118(27):1–12. doi.org/10.1073/pnas.1917165118.

since they may neglect potential long-term structural impacts of extreme weather, sea-level rise, and natural capital loss on the world's economies. Since the interplay between society and the natural world is at the centre of climate change, combining knowledge from a variety of scientific disciplines will be necessary to understand and manage climate risk.

Third, climate scenarios are point-in-time representations of our understandings of the climate system and our assumptions about our own capacity and willingness to adapt and respond. We assume that warming is likely to affect the climate system in ways that are negative to the global economy on a net basis. However, even if the trajectory of warming continues, there is considerable uncertainty as to when various temperature thresholds are breached, and when tipping points and feedback loops that exacerbate adverse effects are triggered. Many scenarios used for portfolio analysis are constructed on the basis of regularly forecasted data for the initial years, and then extrapolated data for future years for which forecasted data is not available. This fails to capture potential exponential, non-linear effects. Given this, it is critical to regularly update climate scenarios to incorporate new information into assumptions and factors embedded in the model.

Conclusion

We have described the characteristics of climate risk and assessed two approaches to measuring it in an investment portfolio: carbon footprint analysis and climate scenario analysis.

First, we explained how climate change is a financial risk to the fund that is already affecting the markets in which we invest. The uncertainty surrounding the scale and rate of climate change, whether it is reflected in asset prices, and the probability of significant economic implications, adds risk to the fund and makes it particularly difficult to measure and manage.

Second, we reviewed the economics of climate change and the results from climate scenario analysis and found that the fund has a vested interest in an orderly transition to a low-carbon economy that prevents severe physical climate risk from materialising. In particular, a scenario in which warming is kept below 2°C raises the probability of avoiding the most severe outcomes with regards to physical climate risk, which should benefit the fund in the long term.

Third, we outlined how carbon footprint analysis and climate scenario analysis are crude measures of climate risk that provide valuable insights into the distribution and change in emissions across companies in the portfolio, and the potential value-at-risk associated with different emissions trajectories and economic outcomes. However, methodological limitations related to data quality, model assumptions, and uncertainty means it can be challenging to use a portfolio's carbon intensity, or a particular climate scenario, as a basis for setting portfolio targets.

To help address the aforementioned challenges, we will continue to engage with academic institutions and researchers from different disciplines to build interdisciplinary knowledge and experience with climate scenario analysis in investment management, and further develop our own capability to measure and manage climate risk in the fund.