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Shades of Climate Risk:
Categorizing climate risk for investors

°CICERO
Climate Finance

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Abstract: Taking a starting point in the latest climate science, this report categorizes climate change risk according to timeframe and probability by region and highlights risks that require immediate attention from investors. Complementing the recent recommendations from the Financial Stability Board's Task Force on Climate-Related Financial Disclosure to disclose potential impacts of climate-related risks and opportunities, guidance on scenarios for stress-testing is also provided. The report finds that some impacts are already happening earlier than anticipated and new ones are expected in the time horizon used by investors.

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Executive summary

What climate risks require immediate attention from investors, and what scientific information is available? This first report from CICERO Climate Finance aims to highlight climate risks that require the immediate attention of investors. Taking a starting point in the existing science, the report categorizes climate change risk according to timeframe and probability by region, coupled with a gap analysis on available information for investors. Complementing the recent recommendations from the Financial Stability Board's Task Force on Climate-Related Financial Disclosure to disclose potential impacts of climate-related risks and opportunities under different future scenarios, guidance on scenarios for stress-testing is also provided.

Many physical impacts that scientists had originally anticipated over a much longer time horizon are being observed today across the globe, and will continue or worsen given growing greenhouse gas concentration levels. This is the case for sea level rise, which is also complicated by interactions with extreme weather events like windstorms, sea-surges, floods, droughts and heat waves. An increasing number of events are leading to exorbitant costs as a result of extreme weather events in many regions. Regardless of the future scenario, climate scientists expect that the frequency and/or severity of certain natural hazards will change. Dry regions will likely face increasing drought, whereas traditionally wet regions are expected to get even wetter (with some exceptions) – with resulting impacts on food production can have cross-regional market impacts.

To assess physical impacts in the next 10-20 years, the choice of scenario does not make much difference, but the Shades of Risk provided in this report can indicate impacts with a high probability for a particular region. Physical impacts around mid-century or later are more dependent on policy changes, where stress-testing against various scenarios, including extreme scenarios, could be helpful. The upper tail of the probability distribution based on current implemented policies is also useful to consider as a worst-case scenario for physical impacts (4-5°C), especially as the potential for, and impacts of, catastrophic change are not well understood.

Physical climate impacts increasingly confront investors with unplanned and abrupt changes or disruptions to businesses or assets**. Not only physical facilities, but also production processes, markets and supply chains are at risk**. In addition, investors face transition risk, as a result of changes in climate and energy policies, a shift to low-carbon technologies and liability issues. While transition risks tend to have a built-in lead time for companies to plan and adjust, the abrupt shocks from physical climate change have not received much attention to date.

Transitional impacts such as policy and technology risk are more dependent on scenario choice as they are subject to regulatory and market developments. This is an ideal opportunity to use scenarios to explore key future uncertainties, and to stress test investments for low probability but high impact outcomes. For example, what may be the impact on future climate policies and fossil fuel markets if key technologies, such as carbon capture and storage, do not work as planned?

The Paris agreement has brought forward the horizon of ambition on climate action. It targets limiting global warming to "well below" 2°C, while pursuing efforts to limit warming to 1.5°C. The effectiveness of the agreement hinges on domestic policy implementation and potentially the wide-spread use of negative emissions technology, such as biomass energy with carbon capture and storage (BECCS). Yet, realistic scenarios assume that negative emissions technology will not be available at the scale that is necessary in time. Our assessment, based on the current climate policies and pledges, is that meeting **a 2°C scenario is not the most probable scenario**. The current pledges, if fully implemented, would lead to closer to 3°C warming by 2100, whereas business as usual with current policies would lead to even greater global warming.

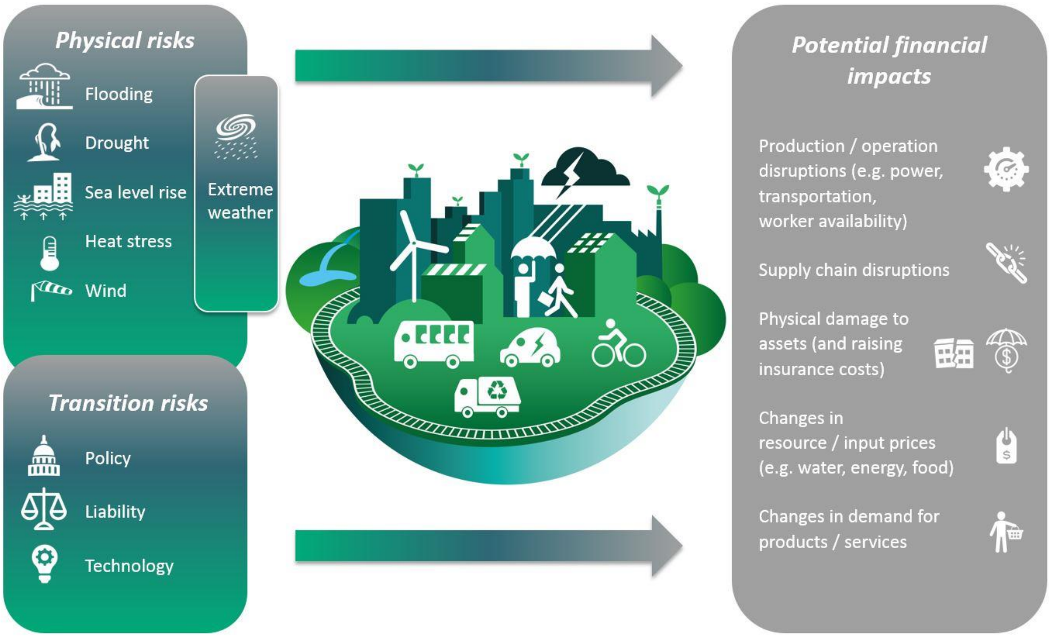

Figure 1: Climate Risk[1] and Potential Financial Impacts

The more we invest with foresight; the less we regret in hindsight, said Marc Carney, Governor of the Bank of England. Yet nearly half of the world's biggest asset owners do nothing to mitigate climate risk. Investors that do account for climate risk are reliant on carbon foot-printing of companies. **Yet carbon footprints do not provide information on how prepared the company is to adapt to future risks, nor do they account for the risk of physical climate change impacts.**

The challenge is moving from the traditional framing of how a company is impacting the climate through greenhouse gas emissions, to how the climate and related policies can impact a company with a more holistic view of climate risk. This report aims to identify the key climate-related risks as identified in the latest scientific information, with a particular focus on physical impacts, and categorize these risks based on the probability and timeframe of the risks occurring in different regions. 'Red flag risks' indicate potential impacts that require the immediate attention of investors, either via target questions in an ownership strategy, or additional analysis at regional, company or asset level.

1 Climate-related risks and opportunities are categorized in this report in a manner largely consistent with the Task Force on Climate-Related Financial Disclosure. However, acute and chronic physical risks can apply to each of the categories of physical risk (e.g. sea-level rise is primarily chronic but can result in breached levees).

How to read this report:

This report is organized in modular sections that can be used as different starting points for readers:

- **Guide to scenarios and shades of risk** provides context for scenario stress-testing and how this report can supplement scenario analysis.
- **Shades of risk** categorizes physical risks by region to highlight to investors where priority areas are for additional company or asset level information. Transitional risks (policy, liability and technology) and expected trends are also described.

  Physical risks are shaded according to their probability:

  Immediate attention required: impacts are already observed with a significant probability to increase

  Some attention is required: impacts are expected in the next few years

  Caution: impacts could manifest towards mid-century
- **Observed impact examples** describe cases of observed risks and opportunities to bring attention to cross-sectoral climate impacts.

Information gap analysis provides a brief overview of investors' approaches and available information on climate risk.
A list of useful sources on physical impacts is provided on online at www.cicero.oslo.no/en/climateriskreport.

1 Guide to Scenarios and Shades of Risk

Key messages:

To assess physical impacts in the next 10-20 years, the choice of scenario does not make much difference, but the Shades of Risk can indicate high probability impacts by region. Physical impacts are being observed today around the globe, and will continue or worsen given growing GHG concentration levels. This is where the Shades of Risk are most useful to guide investors and companies where additional information and analysis is necessary.

Physical impacts around mid-century or later are more dependent on policy changes, where stress-testing against various scenarios, including extreme scenarios, could be helpful. The upper tail of the probability distribution based on current implemented policies is also useful to consider as a worst-case scenario for physical impacts (4-5°C), especially as the potential for catastrophic change is not well understood.

Transitional impacts are more dependent on scenarios, including in the short term, as they are subject to policy and technology changes. This is an ideal opportunity to use scenarios to explore key future uncertainties, and to stress test investments for low probability but high impact outcomes. For example, what may be the impact on future climate policies and fossil fuel markets if key technologies, such as carbon capture and storage, do not work as planned?

1.1 Scenario stress-testing

The Task Force on Climate-Related Financial Disclosure[2] recently recommended disclosure of potential impacts of climate-related risks and opportunities under different future scenarios. It is important to understand which scenarios are more likely, and what impacts they could reveal.

Prior to the Paris Agreement, the prevailing assumption was that emissions growth would continue, and temperatures would head towards 4-5°C above pre-industrial levels. However in the lead up to the Paris Agreement, the picture has changed dramatically. Global emissions have been flat for the last three years, albeit with a weaker Chinese economy driving the slowdown. Nearly all countries put forward emission pledges to the Paris Agreement. The momentum since Paris has continued, with an aviation agreement, an agreement on refrigerants (HFCs), and a reaffirmation of Paris just as Trump was elected President.

The Paris Agreement locks in voluntary country emission pledges, specifying the broad climate policy plans of each country. After adding the country-level emission pledges together, some of which depend on financial transfers from other countries, most studies suggest they will lead to a 3°C temperature increase by 2100 relative to pre-industrial levels. The good news is that this means that the previously feared 4-5°C world is less likely, as are the risks of high-end climate impacts. The bad news is that there is still a considerable gap between the level of ambition required to get to a 2°C world.

2 TCFD Recommendations Report, December 14, 2016

The policies leading to a 3°C world are still leading to considerable transition risk around the world. The coal industry is dying in the US, with, at best, weak climate policies. The standard electricity utility model is struggling in Germany, some US states, and elsewhere, due to rapid deployment of intermittent and small-scale renewable technologies. Electric, and self-driving, vehicles are potentially on the verge of changing the mobility model, and a steady stream of legal cases are being aimed at the fossil fuel industry.

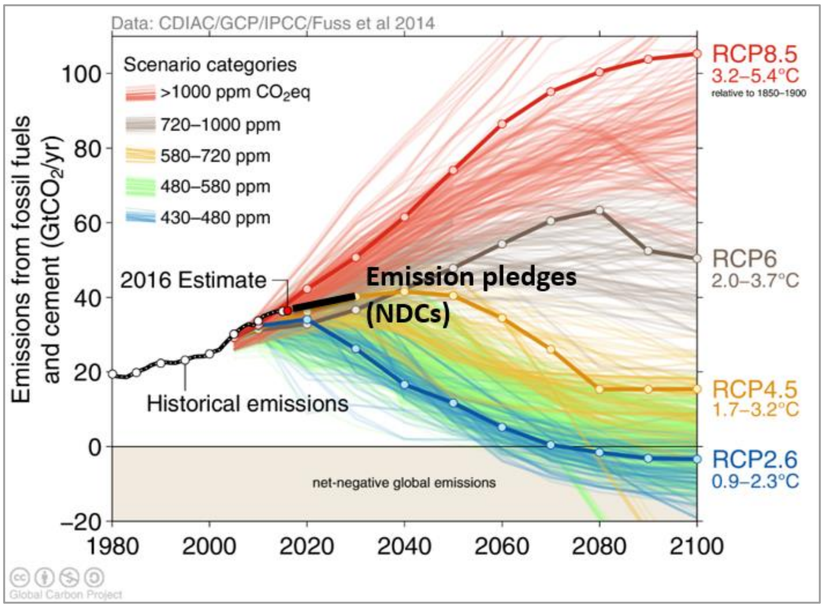

Figure 2: IPCC Emission Scenarios (source: Global Carbon Project).The IPCC considers a range of scenarios from the extremes of approximately 2°C (RCP2.6) to between 4-5°C (RCP8.5). A 3°C future, based on the current emission pledges under the Paris Agreement, falls somewhere in between the mid-range of the IPCC scenarios

Regardless of the scenario, the physical impacts in the next 10-20 years are mainly the same. Physical impacts are already being observed today around the globe, and will continue or worsen given growing GHG concentration levels. This is where the Shades of Risk are most useful to flag high probability impacts to investors and companies, which can then seek additional information and analysis.

Physical impacts mid-century and later are more dependent on policy changes, where stress-testing against various scenarios, including extreme scenarios, could be helpful. The upper tail of the probability distribution based on current implemented policies is also useful to consider as a worst-case scenario for physical impacts (4-5°C), especially as the potential for catastrophic change is not well understood.

Transitional impacts are more dependent on scenarios as they are subject to policy and technology changes. This is an ideal opportunity to use scenarios to explore key future uncertainties, and to stress test investments for low probability but high impact outcomes. For example, what may be the impact on future climate policies and fossil fuel markets if key technologies, such as carbon capture and storage, do not work as planned?

Scenarios roughly fall into three categories of lower emissions targeting 2°C, mid-range following the pledges under the Paris Agreement, and high emission or business-as-usual trajectories:

- A 2°C scenario reveals the lower tail of the probability distribution, with uncertainties regarding the ability to reach ambitious targets, and the reliance on negative-emission technology such as biomass energy with carbon capture and storage (CCS). Using only a 2°C scenario for stress-testing can shed light on implications of a low-carbon policy future, but overlooks more probable physical impacts around mid-century and later.

- A more likely future pathway builds on current emission pledges submitted under the Paris Agreement that would lead to a mid-range scenario of around 3 °C warming by 2100. Mid-range scenarios reflect the most probable future, but given the uncertainty particularly in policy and physical developments, consideration of more extreme scenarios is also advised.
- A higher emission business-as-usual scenario closer to 4-5°C is less likely after the Paris Agreement, but still within the realm of possibility and useful for exploring extreme physical impacts in mid-century and beyond.

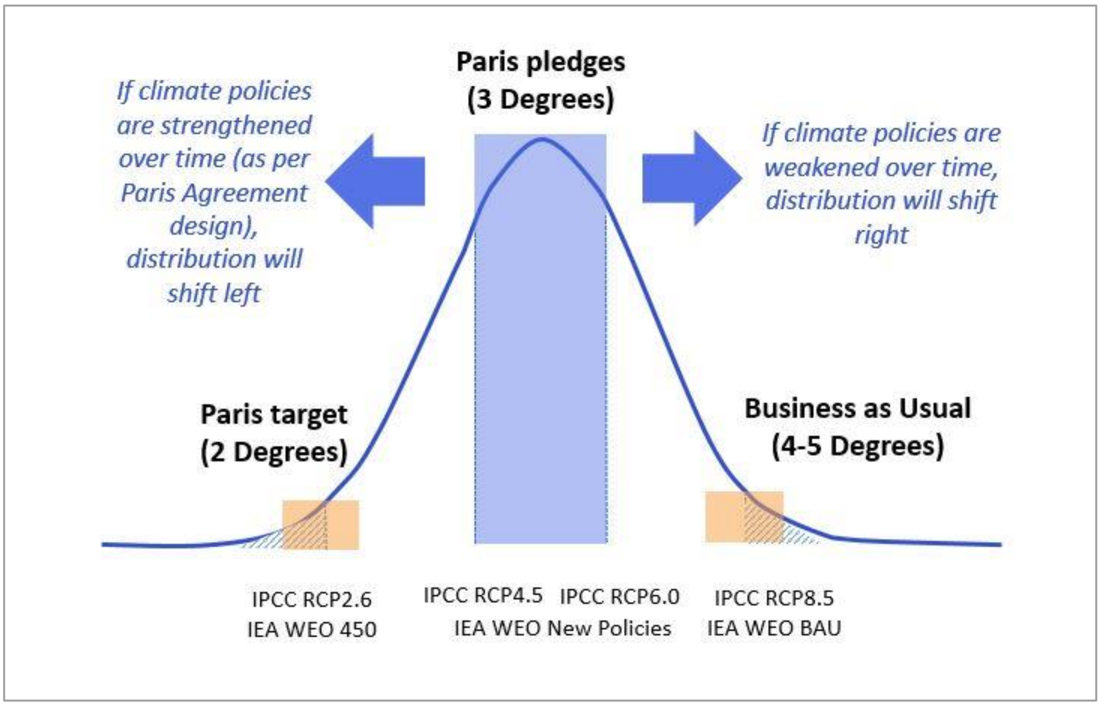

Figure 3: Probability Distribution of Scenarios. The International Energy Agency (IEA) WEO scenarios are commonly used to understand shifts in the energy system under various climate change targets: WEO 450 is close to a 2°C target; WEO New Polices is close to 3°C; and WEO BAU is closer to 4-5°C. The IPCC Representative Concentration Pathways (RCPs) reflect economy-wide climate change: RCP 2.6 follows a path close to a 2°C pathway; a 3°C target falls somewhere between RCP4.5 and RCP 6.0; and RCP8.5 represents the high-end extreme of 4-5°C. Strengthening or weakening of climate policies over time will shift the distribution.

1.2 Method for shading climate risk

The risk of climate change impacts occurring is a function of probability, vulnerability, and exposure (see Figure 4)[3]. The Shades of Risk tool developed in this report is meant to help guide to investors to areas where additional information and analysis is necessary to determine more detailed probability of the risk occurring.

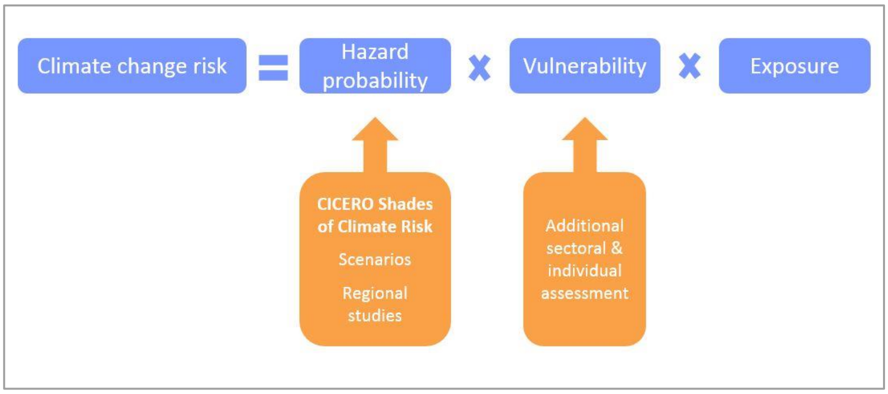

Figure 4: Risk equation

The **probability** of a hazard or physical event occurring (e.g. flooding or heat waves) or a policy being implemented (e.g. resulting in a price on carbon) is presented in this report as the projected outcomes between lower and upper bound emissions scenarios. Even without climate change there are risks to assets from climate variability, but this report focuses on the additional risks from climate change (not the inherent risks from background climate variability). Results from the Intergovernmental Panel on Climate Change (IPCC) results, representing international scientific consensus, are presented with an indication of confidence level. Given the potential consequences of a 'tail' risk, it is useful to use scenarios to help bound the range of likely outcomes. The lower bound is based on a 2°C target (represented by IPCC Representative Concentration Pathway[4] (RCP) 2.6 and International Energy Agency's (IEA) World Energy Outlook (WEO) 450 scenarios), whereas the upper bound builds on a business-as-usual pathway (represented by IPCC RCP8.5 and IEA WEO Business-as-usual scenarios). The most likely projections lie in between these bounds and are based on the country pledges submitted under the Paris Agreement, which are closer to a 3°C pathway (which falls somewhere between IPCC RCP4.5, RCP 6.0, and the IEA WEO New Policies scenario). In this report, we present results by region to reflect the large regional variability in observed and expected impacts, noting where there is a poor level of information available.

The **vulnerability** of an investment to risk depends on how well the sector or asset can adapt to the impact. Several factors can influence vulnerability, including the location of the asset, whether the impact could be acute with a rapid onset or a chronic issue, the degree to which an asset can respond to the impact, and any resilience measures that have been implemented. In this report, we highlight the impacts that could have the most abrupt onset, to provide guidance on which regions are most vulnerable. However, investors will need to supplement this general information with more specific

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3 IPCC (2014). Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., et al. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.

4 Collins, M., et al. (2013). Long-term Climate Change: Projections, Commitments and Irreversibility. In T. F. Stocker, et al. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1029–1136). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

analysis at a regional, company and asset level. Investors themselves are best suited to understand the **exposure** of their portfolios to the risks, based on diversification at a portfolio, sectoral or asset level.

The **Shades of Risk tool** presented in this report can help guide investors to the 'red flag' risks that require further analysis of information at a sub-regional and/or company or asset level. Climate scientists used expert judgement based on the latest scientific literature to categorize the identified risks to indicate where immediate attention by investors or additional analysis is required, based on current observations of impacts and a qualitative assessment of probability based on scenario ranges. Where possible, the report also identifies opportunities, e.g. in the form of avoided risk or reduced vulnerability to risk.

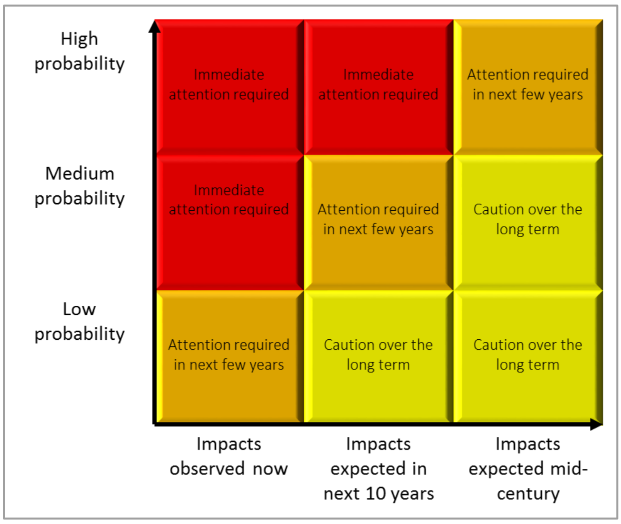


Figure 5: The Shades of Risk tool

The focus of the report is on risks that could cause abrupt impacts that have relevance for investors, e.g. extreme weather events rather than gradual increases in temperature. We include climate-related risks, both physical and transitional, with potential for direct financial impacts. We exclude some important social risks such as ecological disruption and disease that are addressed in other research. We focus on impacts observed now to what is expected mid-century. However, it is important to note that the strongest physical impacts are likely to be felt after mid-century and many of the climate scenarios project impacts to 2100. We have attempted to consider the full range of possible risks, including those with a low probability but with a potentially disruptive magnitude, as well as the 'known unknowns'. However, there may still be 'unknown unknowns' that are not covered in this report.

The method used to categorize risk in this report takes a starting point in a review of scientific literature, anchored in the IPCC and supplemented with the most recent literature and expert input from climate scientists. The information gap analysis in Section 5 builds on a survey of institutional investors and financial actors represented on the Advisory Board of CICERO Climate Finance[5] about their approach to climate risk.

1.3 Applying the Shades of Risk: Statkraft example

More extreme weather patterns will put water resources under increased stress in the future, potentially impacting activities in all sectors. This requires new coordinated and integrated models for water management and flood protection. Water will need to be stored and released in times of excess and scarcity for different purposes, like drinking water, irrigation, flood control, as well as electricity generation.

Taking measures to reduce vulnerability to climate risk, including water stress, can be an opportunity for early movers. Multipurpose hydropower plants can have an important role to play in this regard, both as providers of renewable energy and service providers of improved water management and flood protection.

5 See Advisory Board members here: http://www.cicero.uio.no/en/cicero-climate-finance/advisory-board

Region	Energy Sector Projects[6]	Shades of Risk Red Flags (see Section 2)
South America	Hydro, Wind	Extreme weather (flooding) Heat Stress
Northern & Central Europe	Hydro, Wind, Natural Gas, Bioenergy	Extreme weather (precipitation) Flooding
Southern Europe	Hydro, Wind	Flooding Drought
South East Asia	Hydro	Sea level rise Heat Stress
South Asia	Hydro	Heat Stress

Table 1: Statkraft energy projects and red flags for physical climate risk

Statkraft is a leading hydropower company and Europe's largest generator of renewable energy. With energy projects around the world, climate risk plays a role in the company's investment and planning decisions. For near term physical impacts, the Shades of Risk can guide where additional analysis is recommended to reduce vulnerability and be an early mover on risk mitigation. Hydropower projects are vulnerable to water risk such as extreme precipitation, flooding and drought, but the changing business model for hydro as an important player in water management can benefit from more granular analysis. Using the Shades of Risk presented in Section 2 for physical impacts, the red flags in Table 1 note areas for urgent attention as impacts are already occurring and are expected to increase (orange and yellow shades are not shown here for brevity).

As an example of deeper analysis for South America, CICERO leads a research project HYPRE[7], partially funded by Statkraft, to investigate possible future changes in precipitation patterns and amounts in South America, and more specifically in southern Brazil, where numerous hydroelectric plants are operating. Observations and global and regional climate model data are being used to downscale regional climate change projections[8] to a much finer resolution than in most global climate models[9].

6 http://www.statkraft.com/energy-sources/Power-plants/

7 HYPRE is an ongoing Norwegian Research Council Project on hydropower and precipitation trends.

8 Many of the methods are documented in Hodnebrog, Ø. et al., Local biomass burning is a dominant cause of the observed precipitation reduction in southern Africa, In: Nature Communications, 7, 8, 10.1038/ncomms11236, 2016.

9 Results will be available at 48 km × 48 km horizontal resolution for large parts of South America (see example in Figure 6) and at 12 km × 12 km resolution over southern Brazil. Most global climate models typically have 100 km × 100 km or more (Flato, G., et al. Evaluation of Climate Models, in: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, edited by: Stocker, T. F., et al, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 741–866, 2013.).

Preliminary results visualized in Google Earth show that while global precipitation increases with higher temperatures, the sign and amount of precipitation change can differ substantially depending on region. Figure 6 shows that for a business-as-usual high emissions scenario (RCP8.5), the southeastern part of South America is likely to experience more precipitation towards the end of the century, while a precipitation reduction can be expected over large parts of Chile from mid-century (as evident in nearly all the global climate models assessed in the latest IPCC report, even when a less carbon-intensive scenario is assumed (RCP4.5)). The finer resolution results (12 km × 12 km) modelled in HYPRE reveal that precipitation projections in some areas differ considerably from the coarse-resolution results, and illustrates that high resolution may be important when studying local effects, especially for areas located in complex terrain.

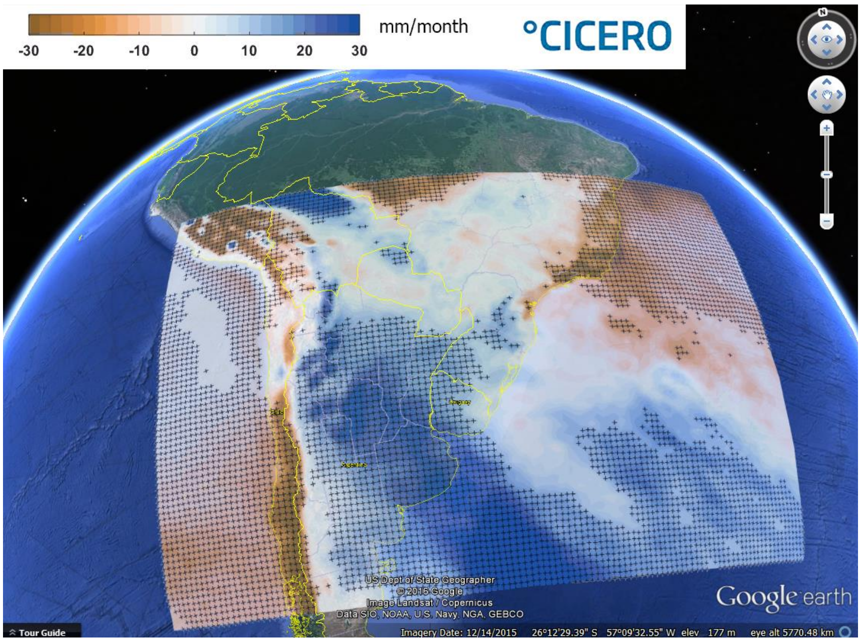


Figure 6: Projected future change in annual precipitation (mm month^{-1}) in South America from a regional climate model[10] downscaled from a global climate model[11]. The figure shows end-of-the-21st century (2081-2100), assuming the business-as-usual RCP8.5 pathway, compared to present-day climate (1986-2005). Black '+' symbols denote grid boxes where projected changes are significant (P value < 0.05) according to a two-tailed Student's t-test. Results are from the HYPRE project[12].

10 Skamarock, W. C. and Klemp, J. B.: A time-split nonhydrostatic atmospheric model for weather research and forecasting applications, In: J. Comput. Phys., 227, 7, 3465-3485, 10.1016/j.jcp.2007.01.037, 2008.

11 Neale, R. B., et al. (2010): Description of the NCAR Community Atmosphere Model (CAM 4.0), In: NCAR Technical Report, NCAR/TN-485+STR, 2010.

12 Hodnebrog, Ø. et al. (2016): Local biomass burning is a dominant cause of the observed precipitation reduction in southern Africa, In: Nature Communications, 7, 8, 10.1038/ncomms11236, 2016.

2 Physical Risk

This section identifies key uncertainties for each category of physical climate risk and shades them based on timeframe and probability estimation. The primary source for this section is the IPCC WGII AR5 report, which reflects a wide range of scientific literature. In addition we have reviewed relevant newer literature and reports. **A list of useful references for physical impacts at the global and regional level are provided on the** website www.cicero.uio.no/en/climateriskreport**, which we plan to update regularly.**

Key messages:

Physical impacts are observed in all regions today and can have abrupt consequences (see also Section 4 for descriptions of observed examples), with some changes occurring at a faster rate than expected previously. For example, sea level rise was previously thought to be a long-term issue, but it is accelerating and can lead to significant damage in combination with extreme weather events.

We are **on a pathway that could lead to well above 2°C global warming**. We are already experiencing physical impacts of 1°C warming, and locked-in to a long period of 1.5°C warming, in all but the most extreme emission reduction scenarios.

Physical impacts are likely to continue in the short term (next 10-20 years), regardless of the scenario, and manifest mainly by rare events becoming (sometimes much) more frequent. This is where Shades of Risk can help guide investors to indicate areas where additional attention and analysis is required. In the long run, policy changes could affect physical impacts to some degree.

Impacts towards the end of the century or later are more scenario dependent. Systemic risk is highly uncertain, e.g. how El Niño will progress and impact weather patterns around the Pacific Ocean. Natural climate variability can also, in periods, both strengthen and weaken climate-related risks. Although the focus of this report is current and mid-century risks, in some scenarios, risks continue to worsen after 2100.

Physical impacts are very local. This report gives an overview by continent, with shading indicating where investors should seek additional information, e.g. at a sub-regional level. This report does not distinguish between climate-related risks and those attributed to anthropogenic or human-induced climate change, as costs and opportunities for investors remain the same regardless of attribution of the risk trends. Some general climate-related risk trends are:

Extreme weather: Significant damage can results from extreme weather in combination with other impacts listed below. Stronger hurricanes (but lower frequency) are expected, and combined with sea level rise in coastal regions can be particularly damaging (e.g. Hurricane Sandy).

- **Flooding**: In general, wet areas projected to become wetter (and dry areas projected to become drier), and the increased precipitation often comes as extreme rain.
- **Drought** is observed in all regions.
- **Sea level rise** is accelerating (due to thermal expansion and melting glaciers/snow, loss of Greenland ice).
- **Heat stress**: Heat waves are having a significant impact worldwide.

Wind: It is uncertain how wind patterns will shift – an example of a 'known unknown'.

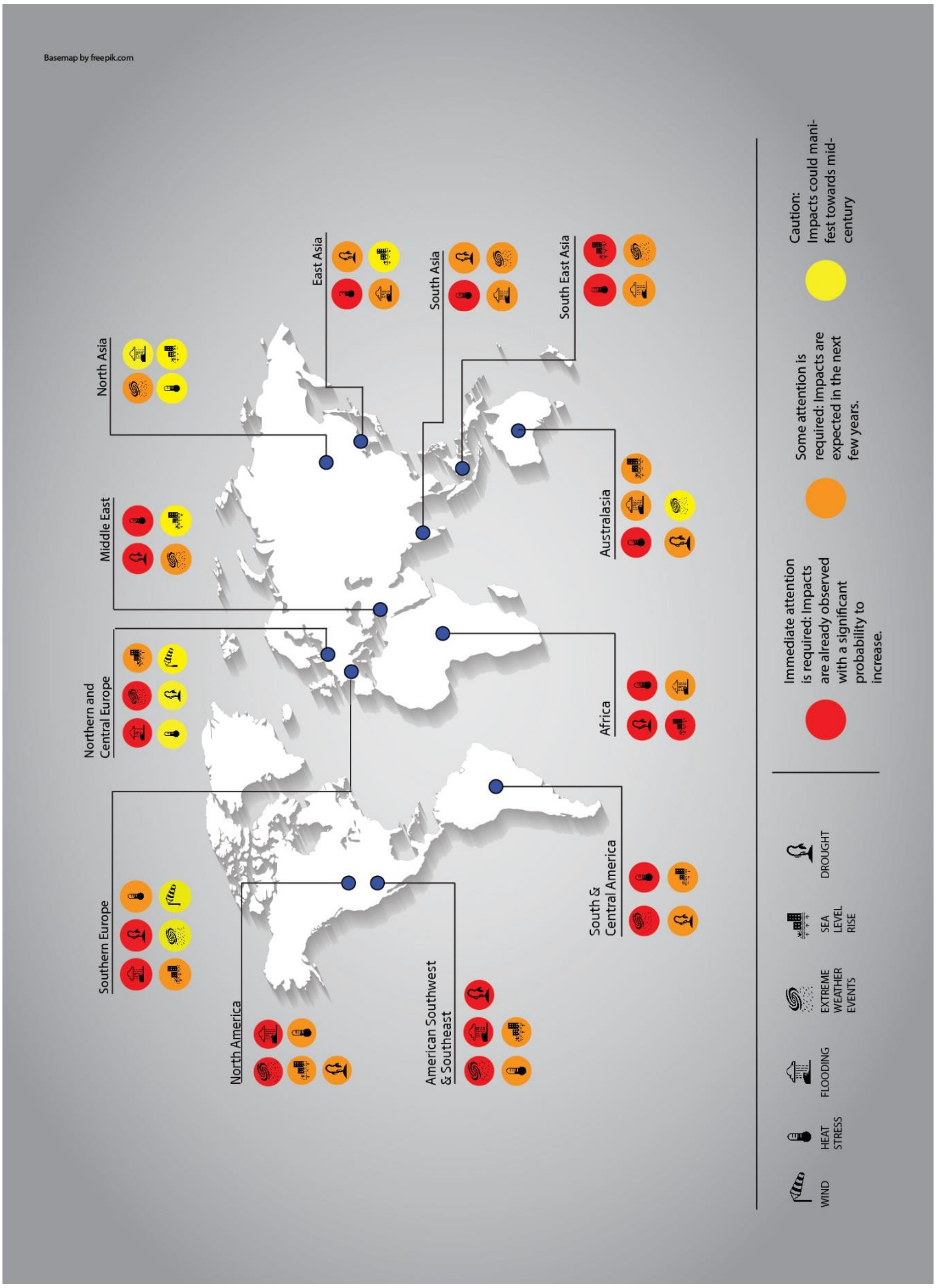


Figure 7: The most important physical climate risks by region

Europe

Top risks		Key message	Observed Impacts	Projected Impacts towards 2050 (for a range of scenarios between 2°C and Business-as-Usual)[13]	Examples of Impacted Sectors	Shade of Risk
Extreme weather events	Landslides	Mountain regions are especially sensitive to landslides but trend is unclear	Some increases seen, but often insignificant (see boxes below)	Across all scenarios: Inconsistent changes in the South. Likely increase in intensity and frequency in the North[14], especially for winter (high confidence for North, low confidence for South)	Transport, energy, tourism, infrastructure	
	Extreme precipitation[15]	High variability expected in precipitation, greater intensity in North. Precipitation could become more extreme in Mediterranean when it does occur after long dry spells (see also drought)[16]	Increases seen in some parts, especially for winter. Often insignificant and inconsistent results due to natural climate variability, except for Central Europe where severe summer flooding has been seen[17] (medium confidence for North, low confidence for South)		Infrastructure in high density urban areas	Northern and Central Europe[18] Southern Europe
Flooding		Flooding from precipitation patterns and snow melt is observed and expected to increase	Observed increase (but some uncertainty as to attribution to climate change). See Observed Example in Section 3.	Increase and decrease regionally, decrease especially in South	Infrastructure (high density areas and along rivers), Energy (reduced hydropower generation in South, increased in North), Agriculture	
Drought[19]		Reduced water availability in the South	Regional variance, but tilted toward dryness trends. In South overall increase in dryness observed, especially in Mediterranean (medium confidence)	Across all scenarios: No major changes in the North. Consistent increase in dryness in South. Central Europe will also see more dryness and short-term droughts (medium confidence)	Agriculture (combined with ground water sinking from irrigation)	Northern Europe Southern Europe

13 Based primarily on RCP2.6 and RCP8.5 results for 2046-2065
14 Klima i Norge 2100.
15 Definition of extreme precipitation used here is frequency of 'very wet days,' defined here as the 90th percentile of daily precipitation on wet days
16 Sillmann, J., et al. (2013). Climate extremes indices in the CMIP5 multi-model ensemble. Part 2: Future climate projections. J. Geophys. Res. Atmos., 118, 2473-2493, doi: 10.1002/jgrd.50188.
17 Volosciuk, C. et al. Rising Mediterranean Sea Surface Temperatures Amplify Extreme Summer Precipitation in Central Europe. Sci. Rep. 6, 32450; doi: 10.1038/srep32450 (2016).
18 Central Europe includes France
19 C.F. Schleussner et al. Differential climate impact for policy-relevant limits to global warming: the case of 1.5 and 2C. Earth System Dynamics, 7, 327-351, 2016.

Sea level rise[20]	Sea level rise a concern low-lying coastal areas, especially in combination with extreme events such as hurricanes and spring floods	Current global observed change 3.2 mm/year, but significant regional variations (due to ocean circulation patterns and some land regions still rising since last Ice Age)	+22 cm (16 to 32 cm) sea level rise globally in 2050 compared to 1986-2005 almost regardless of emission scenario (medium confidence). Newer literature indicate that this threshold might be crossed a decade earlier. Northern Atlantic ocean to raise up to 30% more.	Infrastructure in coastal regions, nuclear energy	Coastal areas
Heat stress[21]	Heat stress observed especially in South and expected to increase with high likelihood	Consistent increase in heat wave duration and intensity, but no significant trend in North (medium confidence for North, high confidence for South). Likely increase in hot days in most regions, especially in Iberian peninsula and southern France (high to medium confidence)	Across all scenarios: Likely more frequent, longer, and more intense heat waves, especially in South. Smallest change seen for Scandinavia (high confidence). Very likely increase in hot days, largest trend for South (high confidence)[22]	Impacts on health, labour productivity, agriculture (crop production), wildfires in South	Northern Europe Southern Europe
Wind	No clear trend for wind patterns (beyond those associated with extreme events included above)	No clear trend (low confidence)	Across all scenarios: Uncertain. For North wind may increase in winter and decrease in summer. In South, a general decrease seems likely (low confidence)	Energy (change in wind energy production is uncertain, seasonal variation expected, reductions most likely in South)	
Less snow	Combined impacts of precipitation and temperature are of concern in the Alps	Average snow cover extent in Northern Hemisphere reduced by 2.2% per decade in period 1979-2012 (very high confidence)	Across all scenarios: Likely shorter snow seasons, as well as less snow in most regions. Increased snow depth at high latitudes and altitudes	Tourism (reduced ski season in the Alps)	Alps

Table 2: Top European physical climate risks[23,24]

20 Jevrejeva et al. (2016): Coastal sea level rise with warming above 2 C. S. AND Brown et al. (2012) Sea-Level Rise Impacts and Responses: A Global Perspective, Volume 1000 of the series Coastal Research Library pp 117-149. AND A. B. A. Slangen et al. Projecting twenty-first century regional sea-level changes. Climatic change, May 2014, Volume 124, Issue 1, pp 317–332

21 Extreme heat events definition used is frequency of 'warm days,' defined here as the 90th percentile daily maximum temperature

22 Based on projections for 2071-2100

23 Kovats, R. S., et al. (2014). Europe. In V. R. Barros, et al. (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1267-1326). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

24 Hewitson, B. C., et al. (2014). Regional context. In V. R. Barros, et al. (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment

Asia

Top risks		Key message	Observed Impacts	Projected Impacts towards 2050 (for a range of scenarios between 2°C and Business-as-Usual)[25]	Examples of Impacted Sectors	Shade of Risk
Extreme weather events	Cyclones (tropical hurricanes)	Can be deadly, especially in combination with sea level rise.	Increased deadliness of cyclones (medium confidence)	Across all scenarios: Low confidence in region-specific projections of frequency and intensity. Fewer tropical hurricanes expected, but stronger.[26] Damaging cyclones are "low risk, high impact", with increases in strength expected over the next decade.	Industry (supply disruption, power outages, workers unavailable), Transport (disruption)	South and South East Asia
Flooding[27]		Increased river and urban flooding. Likely more extreme precipitation near centers of tropical cyclones. Future increases in precipitation extremes related to the monsoon are very likely in South and South East Asia.	Spatially varying trends and partially lack of evidence (low to medium confidence). (see Observed Example of Thailand flooding)	Across all scenarios: Increases seen in some regions (such as North Asia and greater Himalayan region[28], high confidence), while inconsistent signal for other areas (low to medium confidence)[29]	Industry, transport, infrastructure	North Asia[30] South & South East Asia[31]
Drought		Drying can lead to water scarcity (medium confidence) in combination with	Varying and inconsistent trends (low confidence). Tending towards	Across all scenarios: Mostly inconsistent signal of change (low confidence). [32]	Agriculture (although irrigation mitigation drought to some degree)	Middle East

Report of the Intergovernmental Panel on Climate Change (pp. 1133-1197). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

25 Based primarily on RCP2.6 and RCP8.5. If 2050 impacts were not available (based on 2046-2065), based on interpretation of 2071-2100 model results

26 Knutson et al. (2015) Global Projections of Intense Tropical Cyclone Activity for the Late Twenty-First Century from Dynamical Downscaling of CMIP5/RCP4.5 Scenarios

27 Extreme precipitation definition used is frequency of 'very wet days,' defined here as the 90th percentile of daily precipitation on wet days

28 Shrestha, A.B. et al. (2015) The Himalayan Climate and Water Atlas: Impact of climate change on water resources in five of Asia's major river basins. ICIMOD, GRID-Arendal and CICERO. Accessible via http://www.icimod.org/?q=20533

29 Based on projections for 2071-2100

30 North Asia is above the Himalayas

31 South Asia includes India

32 Based on projections for 2071-2100

	increased water demand and lack of good management. Drought will lead to water and food shortage (high confidence)	increased dryness in East Asia (medium confidence)	The monsoon may arrive later in southeast Asia.[33]		South Asia (India) and South China
Sea level rise	Threat to low-lying areas and deltas, especially in combination with hurricanes. Asia is a region with fast-rising sea levels in combination with sinking land in some areas (e.g. Singapore)	Coastal erosion (medium evidence, high agreement). Coastal flooding (medium confidence)	+22 cm (16 to 32 cm) sea level rise globally in 2050 compared to 1986-2005 almost regardless of emission scenario (medium confidence). Sea level rise up to 20% higher in equator and subtropical regions.	Human settlements, industry, infrastructure, fisheries, tourism (coral reefs)	South East Asia Rest of Asia
Heat stress[34]	Increased risk when combined with other risks, such as extreme weather	Insufficient evidence and spatially varying trends, but increased heat waves such as in China and India (low to medium confidence). Likely to very likely increase in hot days in most regions (mostly high confidence)	Across all scenarios: Likely more frequent and longer heat waves in most regions (high confidence). [35] Likely increase in hot days (high confidence)[36]	Agriculture (reduced food production)[37], health and labour productivity	Middle East & South Asia (India), East Asia (China) & South East Asia North Asia

Table 3: Top Asian physical climate risks[38,39]

33 Loo et al., 2015. Effects of climate change on seasonal monsoon in Asia and its impact on the variability of monsoon rainfall in Southeast Asia.

34 Extreme heat events definition used is frequency of 'warm days,' defined here as the 90th percentile daily maximum temperature

35 Climate change and labour: impacts of heat in the workplace. UNDP (2016)

36 Based on projections for 2071-2100

37 Kumar, A. (2014). Climatic Effects on Food Grain Productivity in India. Journal of Studies in Dynamics and Change, 1(1), 38–48. AND Pradhan, N. S. et al. (2015). Farmers' responses to climate change impact on water availability: insights from the Indrawati Basin in Nepal. International Journal of Water Resources Development, 31(2), 269–283. http://doi.org/10.1080/07900627.2015.1033514

38 Hijioka, Y., et al. (2014). Asia. In V. R. Barros, et al. (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1327-1370). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

39 Hewitson, B. C., et al. (2014). Regional context. In V. R. Barros, et al. (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1133-1197). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

North America

Top risks		Key message	Observed Impacts	Projected Impacts towards 2050 (for a range of scenarios between 2°C and Business-as-Usual)[40]	Examples of Impacted Sectors	Shade of Risk
Extreme weather events 	Cyclones (tropical hurricanes)	High risk in case of combined hurricane and flooding	Atlantic tropical hurricanes have become stronger but likely not more frequent[41]	Across all scenarios: Coastal flooding. More damaging with increasing sea level.[42] Damage caused by wind. Atlantic tropical hurricanes likely to become stronger[43]	Infrastructure in coastal areas, Industry (supply chain)	Coastal regions (combined hurricane and flooding)
Flooding[44] 		Increases in urban drainage flooding.	Spatially varying trends, but in many regions very likely increase (medium to high confidence)	Across all scenarios: Increase in maximum day precipitation, especially in the north (medium to high confidence). Inconsistent signal in the southern parts and for some heavy precipitation metrics (low confidence)	Transportation infrastructure, industry (supply chain)	Urban areas
Drought 		Drought likely to increase in Southwest. Decline in stored water reserves from less water from melting snowpack in Western USA and Canada.	Inconsistent trends, both likely increase and decrease in dryness (low to high confidence). More frequent low-snow years.	Across all scenarios: Inconsistent signal, but increased dryness in the southern part (low to medium confidence). Increased water stress in southwest and southeast.	Agriculture	Southwest and southeast Rest of North America

40 Based primarily on RCP2.6 and RCP8.5. If 2050 impacts were not available (based on 2046-2065), based on interpretation of 2071-2100 model results
41 Elsner et al. (2008). The increasing intensity of the strongest tropical cyclones.
42 Woodruff et al. (2013). Coastal flooding by tropical cyclones and sea-level rise. Nature, 504, 44-52 (05 December 2013), doi:10.1038/nature12855
43 Knutson et al. (2015). Global Projections of Intense Tropical Cyclone Activity for the Late Twenty-First Century from Dynamical Downscaling of CMIP5/RCP4.5 Scenarios
44 Extreme precipitation definition used is frequency of 'very wet days,' defined here as the 90th percentile of daily precipitation on wet days

Sea level rise	Increased inundation of flooding, erosion, and salinity levels along coast. Risks increase in combination with hurricanes.	Current global observed change 3.2 mm/year	+22 cm (16 to 32 cm) sea level rise globally in 2050 compared to 1986-2005 almost regardless of emission scenario (medium confidence). Northern Atlantic ocean to raise up to 30% more.	Transportation, infrastructure (ports) and energy (nuclear, oil) in coastal areas	low-lying areas
Heat stress[45]	Likely more frequent, longer, and more intense heat waves. Some regions have seen increases in hot days already, e.g. West North America	Spatially varying trends, but increase in warm spell duration seen for some regions (low to medium confidence). Some area have likely to very likely seen increases in hot days (high confidence), West North America is the region where changes are best observed. Spatially varying trends in other (medium confidence)	Across all scenarios: Likely more frequent, longer, and more intense heat waves (high confidence). Very likely increase in hot days (high confidence)	Agriculture, health and labour productivity[46]	

Table 4: North American Top Physical Risks[47,48]

45 Extreme heat events definition used is frequency of 'warm days,' defined here as the 90th percentile daily maximum temperature

46 Climate change and labour: impacts of heat in the workplace. UNDP (2016)

47 Romero-Lankao, P., et al. (2014). North America. In V. R. Barros, et al. (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1439-1498). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

48 Hewitson, B. C., et al. (2014). Regional context. In V. R. Barros, et al. (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1133-1197). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

Africa

Top risks	Key message	Observed Impacts	Projected Impacts towards 2050 (for a range of scenarios between 2°C and Business-as-Usual)[49]	Examples of Impacted Sectors	Shade of Risk
Flooding[50] 	Increased extreme precipitation, complicated by strong population growth and urbanization	Insufficient evidence or mixed trends, but increased rainfall intensity in West Africa (low to medium confidence)	Across all scenarios: Low agreement or small changes expected (low to medium confidence), but likely increase in heavy precipitation in East Africa (high confidence)	Transportation, infrastructure, agriculture	
Drought[51] 	Water stress. Reduced crop productivity. Loss of livestock. Conflict and migration	Spatially varying trends (low confidence), but increased dryness in West Africa (dominated by Sahel dryness in 1970s) (high confidence) and general increase in dryness in Southern Africa (medium confidence)	The trends are inconsistent or varying in different areas (low to medium confidence), but increased in dryness in already dry areas of Southern Africa (medium confidence)	Agriculture (combined temperature and precipitation trends will reduce crop productivity)	
Sea level rise 	Especially cities in coastal areas, wetland and deltas at risk	Current global observed change 3.2 mm/year	+22 cm (16 to 32 cm) sea level rise globally in 2050 compared to 1986-2005 almost regardless of emission scenario (medium confidence). Sea level rise up to 20% higher in equator and subtropical regions.	Tourism, fisheries, transportation, industry, infrastructure	Coastal areas, deltas, cities

49 Based primarily on RCP2.6 and RCP8.5. If 2050 impacts were not available (based on 2046-2065), based on interpretation of 2071-2100 model results

50 Extreme precipitation definition used is frequency of 'very wet days,' defined here as the 90th percentile of daily precipitation on wet days

51 C.F. Schleussner et al. (2016) Differential climate impact for policy-relevant limits to global warming: the case of 1.5 and 2C. Earth System Dynamics, 7, 327-351, 2016.

Heat stress[52]	Heat waves that are currently unusual will occur on a regular basis by 2040 under business-as-usual	Either insufficient signal or increased warm spell duration (low to medium confidence). Likely increase in hot days in Southern Africa (high confidence) and some parts of West Africa, otherwise insufficient evidence (low confidence)	Across all scenarios: Likely more frequent and longer heat waves (high confidence). Likely increase in hot days (high confidence). Heat waves that are currently unusual will occur on a regular basis by 2040 based on RCP8.5[53]	Agriculture, health and labour productivity [54]	

Table 5: African Top Physical Risks[55,56]

52 Extreme heat events definition used is frequency of 'warm days,' defined here as the 90th percentile daily maximum temperature

53 Russo et al. (2016). When will unusual heat waves become normal in a warming Africa?

54 Climate change and labour: impacts of heat in the workplace. UNDP (2016)

55 Niang, I., et al. (2014). Africa. In V. R. Barros, et al. (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1199-1265). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

56 Hewitson, B. C., et al. (2014). Regional context. In V. R. Barros, et al. (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1133-1197). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

Central and South Africa

Top risks		Key message	Observed Impacts	Projected Impacts towards 2050 (for a range of scenarios between 2°C and Business-as-Usual)[57]	Examples of Impacted Sectors	Shade of Risk
Extreme weather events	Flooding[58] associated with extreme events and landslides	Risk could be complicated by uncertainty of El Niño–Southern Oscillation (ENSO)	Increases in many areas, decreases in a few (mostly medium confidence)	Across all scenarios: Inconsistent trends in many areas (low confidence), but increases in Tropics (medium confidence)	Infrastructure	
Drought		Risk of water supply shortages will increase due to less precipitation and increased evapotranspiration in semi-arid regions (high confidence), affecting water supply.	Varying and inconsistent trends (low confidence)	Across all scenarios: Inconsistent signals in many regions (low confidence), but increasing dryness in Central America, Northeastern Brazil, and southwest South America (medium confidence)	Agriculture (in Central America, northeast of Brazil, parts of Andean region, heat stress and decreases in rainfall will result in productivity by 2030), energy	(some regions red e.g. Northeast Brazil)
Sea level rise		Cities, especially those in coastal areas, small islands and deltas at risk	Current global observed change 3.2 mm/year	+22 cm (16 to 32 cm) sea level rise globally in 2050 compared to 1986-2005 almost regardless of emission scenario (medium confidence)	Fisheries, tourism (beach erosion), coastal infrastructure (airports)	Small islands, deltas, low-lying cities

57 Based primarily on RCP2.6 and RCP8.5. If 2050 impacts were not available (based on 2046-2065), based on interpretation of 2071-2100 model results

58 Extreme precipitation definition used is frequency of 'very wet days,' defined here as the 90th percentile of daily precipitation on wet days

Heat stress[59]	In Central America, northeast of Brazil, parts of Andean region, heat stress leads to less agriculture productivity by 2030 (medium confidence).	Insufficient evidence or spatially varying trends (low confidence). Increases in number of hot days in many regions, but also spatially varying trends (low to medium confidence)	Across all scenarios: Likely more frequent, longer, and more intense heat waves (medium to high confidence). Hot days likely to increase (high confidence)	Agriculture, health effects for workers[60]	

Table 6: Central and South American Top Physical Risks[61,62]

59 Extreme heat events definition used is frequency of 'warm days,' defined here as the 90th percentile daily maximum temperature

60 Climate change and labour: impacts of heat in the workplace. UNDP (2016)

61 Magrin, G. O., et al. (2014). Central and South America. In V. R. Barros, et al. (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1499-1566). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

62 Hewitson, B. C., et al. (2014). Regional context. In V. R. Barros, et al. (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1133-1197). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

Australasia

Top risks		Key message	Observed Impacts	Projected Impacts towards 2050 (for a range of scenarios between 2°C and Business-as-Usual)[63]	Examples of Impacted Sectors	Shade of Risk
Extreme weather events	Cyclones (tropical hurricanes)	Increased damages in combination with sea level rise	No clear trend	Across all scenarios: Increase in intensity, but remain or decrease in number (low confidence)	Coastal infrastructure	
Flooding[64]		Increased flood risk. Damage to settlements and infrastructure	Spatially varying trends, mostly in line with general mean rainfall changes (medium to high confidence)	Across all scenarios: Increase in most regions (medium confidence).	Infrastructure	
Drought		Fire weather to increase in most of southern Australia (high confidence) and many parts of New Zealand (medium confidence).	No significant change (medium to high confidence)	Across all scenarios: Increase in drought in southern Australia and many regions of New Zealand (medium confidence). Inconsistent signals in other regions (low confidence)	Agriculture, infrastructure	
Sea level rise		Rising sea level (and increase heavy rainfall) leads to erosion and inundation. Coral reefs and small oceanic island highly threatened	Current global observed change 3.2 mm/year	+22 cm (16 to 32 cm) sea level rise globally in 2050 compared to 1986-2005 almost regardless of emission scenario (medium confidence)	Coastal infrastructure	Coral reefs and small oceanic island highly threatened

63 Based primarily on RCP2.6 and RCP8.5. If 2050 impacts were not available (based on 2046-2065), based on interpretation of 2071-2100 model results

64 Extreme precipitation definition used is frequency of 'very wet days,' defined here as the 90th percentile of daily precipitation on wet days

Heat stress[65]	Constraints on water resources in southern Australia. Wild fire damage to settlements in southern Australia and many parts of New Zealand.	Increase in warm spells across Southern Australia (medium confidence), otherwise, insufficient signal or literature (low confidence). Likely to very likely increase in hot days (high confidence)	Across all scenarios: Likely more frequent and longer heat waves (high confidence). Very likely increase in hot days (high confidence)	Infrastructure, agriculture (reduction in agriculture production in the Murray-Darling Basin and far south-eastern and south-western Australia)	

Table 7: Australasia Top Physical Risks[66,67]

65 Extreme heat events definition used is frequency of 'warm days,' defined here as the 90th percentile daily maximum temperature

66 Reisinger, A., et al. (2014). Australasia. In V. R. Barros, et al. (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1371-1438). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

67 Hewitson, B. C. et al. (2014). Regional context. In V. R. Barros et al. (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1133-1197). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

3 Transition Risk

Transition risk to a low-carbon and climate resilient future has several different angles: policy, liability and technology risk are discussed in this section. Both a 2°C and a 3°C world will require a considerable transition from the status quo**. Transitional impacts are more dependent on changes and decisions in the near term than physical impacts, highlighting the important of scenarios** to explore key future uncertainties, and to stress-test investments for low probability but high impact outcomes.

Key messages:

Current pledges under the Paris Agreement are not consistent with a 2°C target. Although the Agreement provides a strong global signal, current pledges add up to 2.8-3.4°C global warming[68] and are subject to some uncertainty in domestic implementation as well as some requirements for financing. The Agreement encourages increased ambition via a pledge and review cycle every 5 years, but increasing global ambition could prove difficult.

Further, the **availability of negative emission technology is critical** for reaching a 2°C target, e.g. biomass energy with CCS. However this technology is not yet available at scale.

Thus **2°C can be considered a low-probability scenario, and a range of carbon pricing scenarios can be useful for considering policy risk in different regions**. Carbon policy developments are continuing in a patch-work manner: domestic political and regulatory developments in key countries such as the US, China, and EU will continue to drive major carbon pricing developments, and offer different risks and opportunities. Carbon policies typically allow several years of lead time for companies to plan and adjust, so do not pose an abrupt risk.

Liability risk could increase, with potentially large financial consequences, if the policy framework on climate is not strong, and more severe climate impacts occur.

Beyond what is driven by carbon pricing, there is **uncertainty in technological development and deployment, which can represent both opportunities and risks**. IEA has estimated in their 2016 low-carbon scenario that electric cars will displace 6 million barrels per day of oil demand by 2040. Companies producing electric cars and related infrastructure would gain from this development, while it represents a major risk for oil producers. Renewable energy decreasing cost trends also offer an opportunity to align investments with a low-carbon future.

68 UNEP (2016). "The Emissions Gap Report 2016", United Nations Environment Programme, November 2016. Climate Action Tracker (2016)., accessed 17 November 2016.

3.1 Policy Risk

Top policy risks (by region)		Examples of sectors most impacted[69]	Potential impacts within next 5 years	Potential impacts towards 2050
Carbon pricing policy developments are highly country-specific	**US:** Court cases and bipartisanship threaten national policy	Energy, Utilities, Transportation, Industrials	Turnover of Coal Power Plan likely within next 4 years (although first compliance year is 2020, and some states may continue renewables push regardless)	Highly uncertain long term outcome depending on future administrations
	China: Some enforcement uncertainty over long term	Energy, Utilities, Industrials, Materials	5 year planning periods provide strong indication of short term trends	Some uncertainty on implementation in the long term
	EU: Targets agreed but policy uncertainty	Energy, Utilities, Industrials	Uncertain impacts of Brexit	Carbon price expected to increase to 20 EUR/ton by 2030[70]

Table 8: Top Policy Risks

United States: US pledges in Paris[71] are grounded in the Clean Power Plan (CPP) to reduce the sector's GHG emissions by at least 32% by 2030, mainly through cutting coal use[72]. However, President Trump has pledged to remove the CPP. CPP is also threatened by a lawsuit brought by 27 states to stop it on grounds that it would have dire economic consequences for their state[73]. The US Court of Appeals - DC Circuit will present a ruling in coming months, which is expected to be appealed to the Supreme Court (likely in 2018-19). In addition, deep political polarization in Congress over climate change has prevented federal legislative climate action over the past two decades, and is expected to continue which would hinder any new bills aiming to strengthen federal climate action[74].

Regardless of federal political action, energy market developments push in the direction of a low-carbon economy. The 114th Congress extended production tax credits for renewable energy facilities to the end of this decade[75], and this agreement is likely to be upheld by the new Congress. Moreover, states like California are pursuing their own climate policy. For instance, incentive structures to support renewable energy development exist in more than half of the states, and renewable energy is becoming more competitive due to lower costs. At the same time, renewables face strong and increasing competition from shale gas. Natural gas prices are low, and abundant reserves of shale gas secure natural gas availability for the foreseeable future[76]. The future of fracking is bright under the Trump Administration, even given concerns about fracking impacting the quality of groundwater[77], drinking water, rights of native Americans,[78] and the fact that some countries in Europe have banned fracking[79]. Oil and gas pipelines will likely continue to face public protests, but two major pipelines (Keystone XL and Dakota Access) have been revived by the Trump Administration.

69 Using MSCI Global Industry Classification Standard.
70 Point Carbon
71 To cut emissions 26-28% from 2005 levels by 2025
72 On the Clean Power Plan: EPA website
73 The states aim to strip the EPA of its authority to regulate CO2 through the Clean Air Act (On the lawsuit: www.vox.com/energy-and-environment/2016/9/27/13063282/clean-power-plan-dc-circuit-court).
74 Dunlap et al. (2016) http://www.tandfonline.com/doi/full/10.1080/00139157.2016.1208995
75 DOE: https://energy.gov/savings/renewable-electricity-production-tax-credit-ptc
76 EIA: http://www.eia.gov/naturalgas/
77 The Washington Post, EPA's science advisers challenge agency report on the safety of fracking, 12 Aug. 2016.
78 Politico, Obama halts new pipeline that protesters see as Keystone sequel, 9 Sept. 2016.
79 The Guardian, The rise and fall of fracking in Europe, 29 Sept. 2016.

China: China's 13th Five Year Plan up to 2020 targets reduced energy intensity by 15% and carbon intensity by 18% compared with 2015 levels, and, for the first time, introduced an energy consumption cap of 5 billion tons of coal equivalent. By 2030, China aims for peak emissions along with a target of 20% renewable energy sources and carbon intensity reductions of 60-65% below 2005 levels[80]. Despite the national reduction targets and bans on new coal power plants in three regions, China continues to invest in coal abroad building new power plants in India and Southeast Asia, and continues to be the largest exporter of coal equipment[81]. Fuel-efficient transportation is also targeted, and taxes have been eliminated on electric vehicles[82]. China has piloted seven carbon trading systems and plans to launch a nation-wide cap-and-trade program in 2017 covering power generation, iron and steel, chemicals, building materials including cement, paper-making and nonferrous metals sectors. One of the key questions will be to what extent the national program can be enforced and impact businesses behavior[83].

EU: The EU's climate and energy policy framework aims at achieving a 40% emission reduction by 2030 (also submitted as the EU target under the Paris Agreement), along with 27% in energy efficiency savings and a 27% renewable energy target. While the targets for 2030 are agreed, policies to achieve these targets remain uncertain. In the coming months, the EU will draft implementing legislation, while also deciding on an internal division of mitigation efforts among the 27/28 member states plus Norway and Iceland[84]. This process also includes a reform of the EU's emission trading system - the centerpiece of EU climate legislation which represents approximately 80 percent of world carbon trading. The ETS review attempts to reduce the vast amount of surplus emissions in order to push up the carbon price, which has been around or below 5 euro/tonne CO_2 in recent years.[85] Point Carbon[86] expects the carbon price to increase slowly to 20 euro/tonne by 2030. While it remains uncertain whether the UK will remain a part of the EU climate and energy policy, including the EU ETS, Brexit casts uncertainty over the British and European climate and energy policy in the next decade. It might influence the EU carbon market as well as investments in climate-friendly technologies negatively; especially should the UK decide to leave the EU ETS. If the UK cuts all policy ties to the EU, the remaining member states will have to redistribute mitigation and renewable energy targets. With the UK, the EU is losing an important voice pushing for more ambitious and market-based climate policy, possibly giving climate-sceptic countries, such as Poland and other Central-Eastern European countries, as well as energy-intensive industries, a bigger say and adding to the political tension over the EU's climate and energy policies.[87] In London, climate change is emerging as a lower priority for Theresa May's cabinet than for any UK government since 1997.[88]

Other Emerging Economies

Given the abundant reserves in the BRICS[89] and growing demand for energy, coal is expected to remain a significant input into energy production for the near future[90]. Russia, with the second largest

80 UNFCCC (2015). "China's intended nationally determined contribution: Enhanced Actions on Climate Change," Retrieved 19 August, 2015, from http://www4.unfccc.int/submissions/INDC/Submission%20Pages/Submissions.aspx.

81Walker, B (2016)."China Stokes Global Coal Growth", China Dialogue, 23 September 2016.

82C2ES (2015). "China and Climate Change", Fact Sheet, Center for Climate and Energy Solutions.

83 White, N., and G. Hearty (2016). "China's 13th Five-Year Plan: Expanding Attention to the Green Economy", CSIS Asia Program Blog, Center for Strategic and International Studies, 18 July 2016.

84 EC (2016). Proposal for a regulation of the European Parliament and of the Council on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 (...). COM(2016) 482 final. Brussels: European Commission.

85 Birger Skjærseth, Torbjørg Jevnaker, Jørgen Wettestad. The Paris Agreement: Consequences for the EU and Carbon Markets? Politics and Governance, Vol 4, No 3 (2016).

86 Point Carbon

87 Elin L. Boasson, Brexit will influence climate policy at all scales. KLIMA, 24 June 2016

88 Financial Times Brexit briefing.

89 Brazil, Russian, India, China, South Africa

90 BRICS Research Centre, (2016). Personal Communication with BRC Researchers. 2 November 2016

global coal reserves, has committed to increase coal production to 30% by 2030, in response to increased demand from China[91]. How development and climate change agendas will play out in other key emerging economies is unknown:

- **India:** India may push back the December 2017 deadline to cut pollution from coal-fired power plants amid pressure from generators. Despite very bad air pollution in India's cities (driven in part by coal-fired power accounting for 75% of electricity), the development agenda dominates emission reductions. Almost one-fourth of Indians do not have access to electricity. Bloomberg New Energy Finance forecasts India's electricity demand to grow 3.8 times between 2016 and 2040, resulting in a trebling of its annual power sector emissions by 2040. Despite investing $611 billion in renewables in the next 24 years, and $115 billion in nuclear, it will continue to rely heavily on coal power stations and imports to meet rising demand[92]. The Indian government has announced an ambitious and demanding goal of achieving 100GW of solar capacity by 2022. To meet its goals India will need to increase its pace of renewable energy capacity addition seven times, from an average 3GW/year to 20+GW/year. Although large photovoltaic systems could be more economical than plants powered by imported coal by 2020[93], analysts warn this will require a serious overhaul of the power infrastructure as well as new incentives to drive investment[94].
- **Brazil**: Brazil is already close to fulfilling its INDC goal of reducing absolute emissions by 37% by 2025 (from 2005 emission levels). The main climate uncertainty will continue to be deforestation, in part because most of the low-hanging fruit has already been picked, and in part due to the shift in government in 2016 (previous shifts have caused peaks in deforestation because of managerial instability)[95]. Because of the low oil price, the use of gasoline is increasing and the sale of biofuels is stagnating. Except for a small decrease in coal use, all energy sources, including renewables, are expected to increase until 2035 to meet increasing energy demand[96]. New renewables (wind and solar) will increase if they can compete on price, as governmental subsidies are not likely[97]. Changing rain patterns due to climate change make hydropower a more uncertain source than before[98]. The petroleum reserves found in 'pre-salt' geological formations off Brazil's east coast are expected to make Brazil a net-exporter of oil in 2023[99]. The volatile oil prices, the change of government, and the corruption scandal originating in Petrobras, are factors of uncertainty for the development in the Brazilian oil sector. According to a recent change in the petroleum concession law, however, Petrobras is no longer required to have a 30% share in concessions, which may help Petrobras to recover economically.

91 Josie, J., (2016). Mitigating Effects of Climate Change: Action for Financing Clean Energy Technologies in Coal Rich Countries in BRICS. Presentation at the ORF and Economic Policy Forum

92 Bloomberg New Energy Finance

BP Energy Outlook 2016

93 Bloomberg New Energy Finance

94 Bang, G. et al. The Domestic Policies of Global Climate Change. Elgar, 2015.

95 Rodriguez-Filho, S. et al. (2014). Election-driven weakening of deforestation control in the Brazilian Amazon. Land Use Policy, 43, 111-118.

96BP (2016). BP Energy Outlook, Country and regional insights – Brazil.

97 Aamodt, Solveig 2015. "To be – or not to be – a low-carbon economy: A decade of climate politics in Brazil." In: G. Bang et al. The Domestic Politics of Global Climate Change - Key Actors in International Climate Cooperation. Cheltenham: Edward Elgar Publishing

98 Lucon, O. et al. (2015). Bridging the gap between energy and climate policies in Brazil. WRI Brasil report.

99 EPE, 2014

3.2 Liability Risk

Top Liability Risks	Regions most impacted[100]	Examples of sectors most impacted[101]	Potential impacts within next 5 years	Potential impacts towards 2050
The more likely severe climate impacts will become, and the less successful the implementation of the climate regulatory framework, the higher the risk for immense financial consequences from climate change liability. 	All	High-emitting sectors (Energy, Utilities, Industry)	Limited but uncertain	High uncertainty

Table 9: Liability Risk

Mark Carney, Governor of Bank of England, has highlighted liability as a financial stability risk arising from climate change.[102] Scholars have for a long time discussed if those responsible for climate change should pay compensation directly to those that suffer the consequences. Legally, in addition to proving that climate change is real and caused by humans, it is challenging to establish a direct causal link between the behavior of one private or public actor causing global greenhouse gas emissions, and a particular climate change damage.[103] It might take some time before we know if any will be held directly liable for harmful climate actions. If the answer is affirmative, however, the financial consequences could be huge.

There are new studies that together draw an increasingly close link between emissions and particular climate impacts.[104] For example, probably as much as half of observed flood days over the last decade in coastal areas in the US would not have happened without human contribution to global sea level rise.[105] While currently about 18% of daily precipitation extremes are attributable to the increased temperature level, this share is expected to rise to about 40% when global warming reaches 2°C.[106] Companies' contribution to historical cumulative emissions has been traced in a study from 2014.[107] Chevron (3.52%), ExxonMobil (3.22%), Saudi Aramco (3.17%), BP (2.47%), Gazprom (2.22%) are the five top contributors among fossil fuel and cement producers.

100 Using IPCC WGII regions: Africa, Europe, Asia, Australasia, North America, Central and South America, Polar Regions, Small Islands, The Ocean (or more specific where possible)

101 Using MSCI Global Industry Classification Standard.

102 Mark Carney - Resolving the climate paradox. Speech given at the Arthur Burns Memorial Lecture, Berlin. 22 September 2016.

103Martin Skancke, et al. Fossil fuel investments in the Norwegian Government Pension Fund Global: Addressing climate issues through exclusion and active ownership: a report by the expert group appointed by the Norwegian Ministry of Finance (3. December 2014)

104 L M.J. Mace and Roda Verheyenoss, Damage and Responsibility after COP21: All Options Open for the Paris Agreement, RECIEL 25 (2) 2016.

105 B.H. Strauss et al., Unnatural Coastal Floods: Sea Level Rise and the Human Fingerprint on U.S. Floods Since 1950 (Climate Central, 2016)

106 E.M. Fischer and R. Knutti, 'Anthropogenic Contribution to Global Occurrence of Heavy-Precipitation and High Temperature Extremes', Nature Climate Change (2015).

107 R. Heede, 'Tracing Anthropogenic Carbon Dioxide and Methane Emissions to Fossil Fuel and Cement Producers, 1854–2010', Climatic Change January 2014

It could be argued that a successful implementation of the Paris Agreement, including its burden sharing commitments, will soften the climate justice debate and make climate litigation less necessary. The Paris Agreement recognizes the concept of loss and damage, opening up for a more focused international dialogue on the issue. However, the language in the agreement clarifies that the article on loss and damage does not provide a basis for liability or compensation.

Regardless of litigation, climate change liability can also be established through indirect provisions e.g. a duty to report on climate risks and through commercial contracts.[108] In August 2015, France became the first country to introduce mandatory climate change-related reporting for companies (Article 173 of France's law on energy transition for green growth). In the EU, pension fund managers have to take into account ESG risks.[109] In the U.S., the Securities and Exchange Commission and state attorneys general are examining whether Exxon is adequately accounting for the plunge in petroleum prices and the prospect that governments might limit the use of fossil fuels to fight climate change.[110] According to the Task Force on Climate-Related Financial Disclosure (TCFD), in most G20 jurisdictions, companies with public debt or equity have a legal obligation to disclose material risks in their financial fillings. This also includes material climate-related risks. The task force view is that climate-related risks most likely are material risks for many organizations.

Consumers and investors are increasingly taking decisions based on green statements. Companies and their directors could therefore be held liable if they mislead about their green credentials. Climate liability also includes a duty to increase resiliency to climate change impacts based on best knowledge, but what this implies in practice is unclear. In Norway for example, there is a legal challenge on municipalities' liability for neglected pipes, questioning how to interpret liability for "inefficient maintenance", also in the light of future climate change impacts.[111]

108 Richard Lord QC (Editor) et al. Climate Change Liability: Transnational Law and Practice Paperback – January 16, 2012

109 Reuters

110 The Wall Street Journal, SEC Probes Exxon Over Accounting for Climate Change, 20 Sept. 2016 and Inside Climate News, Exxon's Big Bet on Oil Sands a Heavy Weight To Carry, 30 Sept. 2016.

111 Weather related damage in the Nordic countries; report by Participants from the Nordic insurance associations, June 27 2013

3.3 Technology Risk

Top Technology Risks		Regions most impacted [112]	Examples of sectors most impacted [113]	Potential impacts within next 5 years	Potential impacts towards 2050
Uncertainty in technological development and deployment (beyond what is driven by carbon pricing)	CCS may not be ready for full-scale deployment	All	Energy, Utilities, Industrials	Insignificant	To reach a 2°C target, it is critical that CCS for fossil fuel and industrial sources is available much before mid-century, and BECCS is operational around mid-century
	Renewable energy costs could continue to fall faster than expected	All	Energy, Utilities	Uncertain cost trajectories but unlikely to be an abrupt change	IEA wind projections range from 550- over 900 GW installed capacity in 2030 for wind, and 800-1300 GW for solar. Projections have been consistently underestimating renewables in past years.
	Vehicle fleet could continue to be electrified faster than expected	All	Transport, Energy	Uncertain penetration rate but unlikely to be an abrupt change	IEA and oil company scenarios show a range from less than 5% to over 60% electrification rate of light-duty vehicle fleets by 2040

Table 10: Top Technology Risks

CCS: Emission scenarios consistent with keeping global temperatures below 2°C above pre-industrial levels explore key uncertainties about the future, such as delayed implementation of climate policies and the availability of key technologies. A key message from these scenarios is that carbon capture and storage (CCS), particularly when combined with bioenergy (BECCS) to remove carbon from the atmosphere, is a critical technology required to reach aggressive mitigation targets in a cost-effective manner. CCS allows the continued use of fossil fuels in the short- to medium-term, could handle carbon dioxide from various industrial sources, and when combined with bioenergy, carbon dioxide removal (CDR) in the long-term to offset earlier emissions. There has been strong critique of the dominant use of CDR in emission scenarios. First, the pervasive use of CDR may represent a methodological limitation, where perfect foresight models simply shift mitigation to the future as the discounted costs are lower than the costs of earlier retirement of fossil infrastructure. Second, if CCS and CDR do not live up to expectations, as is currently the case, then the current lack of early mitigation in the expectation that CCS and CDR will come later will almost certainly guarantee that 2°C is infeasible. The challenges are compounded by scenarios that stop in 2040 (e.g., IEA), failing to show policy makers the pervasive risks that lie beyond 2040. A clear insight of the emission scenarios is that early deep mitigation is needed to limit the exposure to climate risks in the future in the event key technologies do not materialize as expected.

There are further physical and economic constraints on all these negative emission technologies. A recent study[114] finds that deployment of BECCS at a sufficient scale to meet a 2°C ceiling would require 7 - 25 % of total agricultural area globally, and 3 % of all fresh water supplies. Another study[115] on negative emission efforts in light of global carbon cycles, finds that carbon cycle feedbacks

112 Using IPCC WGII regions: Africa, Europe, Asia, Australasia, North America, Central and South America, Polar Regions, Small Islands, The Ocean (or more specific where possible)

113 Using MSCI Global Industry Classification Standard.

114 Smith, P. et al. (2016), Biophysical and economic limits to negative CO2 emissions, Nature Climate Change, Vol. 6, 42-50.

115 Jones, C.D. et al. (2016), Simulating the Earth system response to negative emissions, Environmental Research Letters, 11. doi:10.1088/1748-9326/11/9/095012.

can slow the effectiveness of negative emissions technologies. These dynamics may behave differently to past and future changes in climate and the composition of the atmosphere. However, more research and better understanding of carbon removal technologies and carbon cycle dynamics is needed.

Renewable energy: Scenarios that are available today, such as the IEA scenarios, have not captured the full range of the opportunity space e.g. faster deployment of renewable energy and electric cars. Renewable energy costs have fallen faster than expected due to improvements in efficiency of energy technologies and production technologies, as well as large-scale production, e.g. photovoltaics production in China. Thus, renewables' competitiveness to coal- and gas-based power production is steadily increasing. The de-centralized production of wind and solar energy causes challenges to the existing grid, which is designed according to large power production nodes with coal-fired, gas-fired, or nuclear power plants. A larger share of intermittent renewable energy production implies a larger need for local storage of heat or power, where one option is more battery storage. Another option is improved demand side management, which is intelligent management of power demand in private homes and industry. In any case, some base-load power from e.g. gas or biomass will be in demand. IEA scenarios show significant changes in projected renewable energy capacity year-on-year, reflecting how fast relative costs are shifting and how uncertain projections are[116].

Electric vehicles: According to IEA the worldwide stock of electric vehicles doubled from 2014 to 2015[117]. The cumulative sale passed 1.5 million in May 2016, roughly one third of this total in China, US and Europe each[118]. Vehicle fleet could be electrified faster than expected in most scenarios. Scenarios reviewed from IEA and several oil majors shows a range from less than 5% to over 60% electrification rate of light-duty vehicle fleets by 2040[119]. Demand for transport services will increase more slowly than population increase due to growth of compact and green cities, where the scope for public transportation is huge. Electrified public transportation on rail or buses running on hydrogen (fuel cells) and bio-fuels can remove greenhouse gas emissions from land transportation. There is substantial scope for reduced emissions from airplanes fueled by bio-fuels, and ships running on bio-fuels or batteries (short range). For public transportation in rural areas and private households, electric or hydrogen-fueled vehicles, as well as internet-based car-sharing services, can reduce transport-related emissions substantially.

In a recent study commissioned by Enova (a government agency to support more environmentally friendly consumption and generation of energy in Norway), CICERO developed a vision of a low-carbon and climate-robust society for Norway in 2050, based on interviews with representatives from industry, organizations, government, and research[120]. In this scenario, the respondents described an energy sector dominated by renewable energy, with only a small share for oil and gas, and all land based transportation is expected to be based on zero emission solutions in 2050 (mostly electric passenger cars and trucks running on hydrogen).

116 Kruitzwagen and Holmes, 2016
117 WEO 2016
118 https://en.wikipedia.org/wiki/Electric_car_use_by_country
119 Kruitwagen and Holmes, 2016
120 Torvanger, Bjørnæs, Francke Lund, van Oort (2016), Visjoner av lav-karbon Norge, CICERO Report.

4 Observed Impact Examples

Examples	Shade of Risk (applicable shade for physical risks from Section 2)	Potential financial impacts	Affected sectors	Affected regions
Heat stress threatens production in the Middle East	Heat stress Drought	Production/operation disruptions (power outages; worker unavailability); changes in resource/input prices (raising energy prices)	Energy (oil, gas and consumable fuels; energy equipment); health care; utilities; consumer staples (food products)	Middle East
Disruptions in global coffee and palm oil supply due to plant diseases	(Red or orange depdending on region) Heat stress Drought Flooding	Supply chain disruptions; production/operation disruptions; physical damage to assets; changes in resource/input prices; changes in demand	Consumer discretionary (retailing) ; consumer staples (food & beverage; retailing)	Africa; Central and South America; Asia
Coastal flooding threatens energy infrastructure in the US Gulf Coast region	Extreme weather (cyclones) Flooding	Physical damage to assets; production/operation disruptions	Energy (oil, gas & consumable fuels; energy equipment); industrials (transportation infrastructure); utilities	USA
Thailand flooding cuts global supply of electronic and car components	Flooding Extreme weather (tropical hurricanes)	Production/operation disruptions (power outages, worker unavailability; transport disruptions); supply chain disruptions; physical damage to assets; higher insurance costs; changes in demand	Industrials (transportation); consumer discretionary (automobiles & components; consumer electronics); information technology (electronic components; semiconductors)	South-East Asia

Flooding risk for European cities (and adaptation opportunities)		Flooding Extreme weather (precipitation)	Physical damage to assets; higher insurance costs; production/operation disruptions (worker unavailability; transport disruptions) POSITIVE TREND: changes in demand for products/services	Industrials, transportation	Northern Europe
US coal sector collapsing under market changes and environmental legislation		Policy Technology	Changes in resource prices; changes in demand	Energy (oil, gas & consumable fuels; energy equipment); utilities; financials (capital markets)	USA

Table 11: Observed impact examples

Key messages:

There are observed impacts for almost all risks today, some of which are the combined impact of multiple risks.

Financial impacts go beyond physical infrastructure damage to indirect impacts such as disrupted electricity, commutes, and worker time, and changes in demand.

Supply chains can be particularly vulnerable depending on the region. Via supply chains and multinational companies, sectoral impacts become global in nature, making it insufficient to study a sector in isolation.

Companies that are **early movers in adapting to climate change or developing and/or incorporating low-carbon technologies or risk-mitigating solutions can benefit**. In contrast, those that do not address climate risk may face rising insurance costs and other uncovered costs, and possibly stranded assets.

4.1 Heat stress threatens production in the Middle East

In Iraq, summer temperatures hit 53°C in 2016. The Iraqi GDP contracted by 10 to 20% during the summer heat in 2016 according to one estimate. Farmers have been struggling with wilting crops, and general workforce productivity has decreased. The government has declared multiple mandatory official holidays because of the heat. Yet many public employees turned up at work anyway because of the air conditioning available at government offices. Hospitals saw an increase in people suffering from dehydration and heat exhaustion.[121] In North Africa, record warm summer temperatures in 2015 and 2016, coupled with chronic shortages of energy and water, inflicted serious economic damage across different sectors.

Meanwhile, a recent study published in Nature Climate Change warns that by the end of this century[122], the oil heartlands of Abu Dhabi, Dubai, Doha and Iran's coast will experience higher temperatures and humidity than ever before on Earth, if the world fails to cut GHG emissions. Extreme T_{max} events exceeding 45 °C become the norm in most low-lying cities during summer, according to the study. Although it may be feasible to adapt indoor activities in the rich oil countries of the region, the relatively poor countries of Southwest Asia with limited financial resources and declining or non-existent oil production will probably suffer both indoors and outdoors.

BP energy outlook anticipates that increased air conditioning needs will push up energy consumption by 60% by 2035, with 96% of demand still met by fossil fuels.[123]

4.2 Disruptions in global coffee and palm oil supply

Coffee production, in particular the world's favourite coffee crop Arabica – comprising 70% of global consumption, is especially sensitive to a changing climate. In the Tanzanian highlands, yields have fallen by 46% over the past 50 years. This is mirrored by the other Arabica-growing nations including Brazil, Colombia, Costa Rica, Ethiopia and Kenya. The crops will need to move 300 to 500 meters further above sea level in order to survive. This may be feasible for producers in Ethiopia and Kenya, but will be difficult for market leaders like Brazil. A switch to Robusta is often discussed as an adaptation strategy, causing a shift in production to countries like Vietnam and Indonesia. Robusta is a higher-yield but lower-quality coffee variety used for instant coffee, and is able to withstand higher temperatures.[124]

In parts of Central and South America, changes in rainfall patterns, as well as extreme rainfall and landslides are a significant challenge. Heavy rain in the first three months can significantly alter the growth pattern of coffee trees, with decreased fruit growth and smaller beans. It also increases vulnerability to pests and disease.[125]

Similar concerns exist for oil palms - one of the world's most rapidly expanding crops and a major source of vegetable fat used in foods, pharmaceuticals and cosmetics, for cooking and as biodiesel for vehicles, with Indonesia and Malaysia being the primary producers. The increasing frequency of

121 The Washington Post, An epic Middle East heat wave could be global warming's hellish curtain-raiser, 10 Aug. 2016.

122 The Guardian, Extreme heatwaves could push Gulf climate beyond human endurance, 26 Oct. 2015. Jeremy S. Pal & Elfatih A. B. Eltahir, Future temperature in southwest Asia projected to exceed a threshold for human adaptability, Nature Climate Change 6, 197–200 (2016), doi:10.1038/nclimate2833: "To predict impacts of future climate change towards the end of the century (2071–2100), two GHG concentration scenarios are assumed, based on the IPCC Representative Concentration Pathway (RCP) trajectories: RCP4.5 and RCP8.5. RCP8.5 represents a business-as-usual scenario, whereas RCP4.5 considers mitigation. Under RCP8.5, the area characterized by TWmax exceeding 31 °C expands to include most of the Southwest Asian coastal regions adjacent to the Gulf, Red Sea and Arabian Sea (Fig. 1). Furthermore, several regions over the Gulf and surrounding coasts exceed the 35 °C threshold."

123 BP Energy Outlook 2016, Middle East region.

124 The Guardian, Your morning espresso could be about to get a lot more expensive, 11 May 2015.

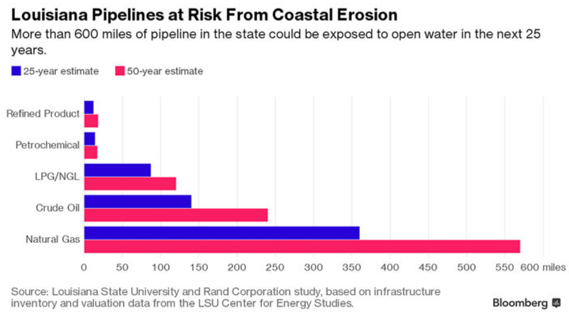
125 OXFAM Discussion papers, Climate change risks and supply chain responsibility, June 2012.

drought in South East Asia has caused declines of 10–30% in production. Scientific studies warn that temperature and precipitation changes might also lead to an increase in fungal diseases. [126]

4.3 Coastal flooding threatens low-lying energy infrastructure in the US Gulf Coast region

Summer 2016, flooding in Louisiana forced Exxon Mobil Corp. to shut units at its Baton Rouge refinery, the fourth-largest in the U.S. In Louisiana, marshes, swamps and barrier islands can mitigate flooding, soaking up rainfall like a sponge and reducing storm surge. But as the land erodes, storms advance without a buffer, and Louisiana's flood protection systems become less effective. The state estimates that damage from flooding could increase by $20 billion in coming years, if the coastline is not reinforced. Every year in Louisiana, more than 20 square miles of land is swallowed by the Gulf. At Port Fourchon, which services 90 percent of deepwater oil production, the shoreline recedes by three feet every month.[127]

Statewide, more than 610 miles of pipeline could be exposed over the next 25 years[128], under a moderate environmental scenario, according to Louisiana State University and the Rand Corporation. The oil and gas sector is already losing an average of $14 billion a year to environmental threats to its infrastructure, according to a study by America's Wetlands Foundation and Entergy Corp. By 2030, those losses could exceed $350 billion.[129]



A World Bank study[130] identifies New Orleans as one the world's cities that are most vulnerable to flooding in terms of the overall cost of damage. The IPCC writes in its Fifth Assessment Report[131] that more than half the area's major highways, almost half the rail miles, 29 airports, and virtually all the ports are subject to flooding with a storm surge of 7m.

4.4 Thailand flooding disrupts global supply of electronic and car components

In 2011, several industry parks, the airport as well as big parts of the capital Bangkok were inundated. The worst flooding in 70 years was a result of heavy rainfall, tropical storms, in combination with poor drainage. The industrial parks hosted 804 companies, more than half of which were owned or operated by Japanese companies. Roughly a quarter of global hard drive assembly facilities are located in Thailand, as well as producers of electronic components and car manufacturers. It took one to two months to complete discharging from the inundated industrial complexes, causing supply chain

126 R.R.M. Paterson et al., Future climate effects on suitability for growth of oil palms in Malaysia and Indonesia. Scientific Reports 5, Article number: 14457 (2015), doi:10.1038/srep14457 and R.R.M. Paterson et al., How will climate change affect oil palm fungal diseases? Crop Protection Volume 46, April 2013, Pages 113–120.

127 Bloomberg, Louisiana's Sinking Coast Is a $100 Billion Nightmare for Big Oil, 17 Aug. 2016.

128 Economic evaluation of coastal land loss in Louisiana. Louisiana State University & the Rand Corporation, Dec. 2015. For more information on the Coastal Louisiana Risk Assessment (CLARA) Model, see 2012 Coastal Master Plan Appendix D-25: Risk Assessment (CLARA) Model Technical Report, or Fischbach, et al. (2012). The study compared two environmental scenarios - a moderate one and a less optimistic one, for two time horizons – 25 years ahead and 50 years ahead. The figure cited here is from the moderate scenario.

129 Bloomberg, Louisiana's Sinking Coast Is a $100 Billion Nightmare for Big Oil, 17 Aug. 2016.

130 Which Coastal Cities Are at Highest Risk of Damaging Floods? The World Bank, 19 Aug. 2013.

131 IPCC AR5 WGII chapter 8.

and production interruptions[132] for big global computer brands like Acer, Samsung, Lenovo, Apple and car manufacturers like Toyota and Honda. The economic damage of the 2011 flooding in Thailand and globally was estimated at nearly 44 billion USD.[133]

A combination of management and physical constraints conspired to create the flood impacts. Draining or lowering the water reservoirs in anticipation of the floods could have avoided some of the damage. Accurate climate forecasts could have averted the situation or reduced the impact. After the 2011 flooding, the government announced measures to prevent future floods, among others flood tunnels under Bangkok to discharge surplus water. According to the climate change agency of the Thai home department, none of these have been implemented, while it also warns for a repetition of the 2011 floods.[134] In early 2017, Southern Thailand was again hit by unseasonably heavy rain and flooding, causing dozens of victims, shutting down infrastructure and hitting rubber production.[135]

Surveys show that most of the affected companies want to operate in the same locations. Costs might increase when manufactures ask their suppliers to diversify risk and procurement sources.[136]

4.5 Flooding risk for European cities (and adaptation opportunities)

Several big European cities are particularly prone to flooding, due to their location and an increased risk for heavy rainfall. Copenhagen, for example, has experienced four major rainfall events in the past six years. The largest, in 2011, caused damage totaling nearly 900 million USD. This does not include direct costs of repairing municipal infrastructure or indirect costs such as loss of earnings, loss of business operation, rising insurance premiums or companies choosing to move away. The Copenhagen Adaptation Plan points out that the intensity of rain with a 10-year return will increase around 30% by 2100.[137]

City governments in Copenhagen and Rotterdam have heavily invested in adapting to the increased flooding risk, turning this into an opportunity for developing new products and services. Copenhagen's cloudburst plan will update the city's sewage system and make structural changes to the city's infrastructure, delaying the infiltration of the water by adding green areas and water basis and by leading the water away from the sewerage system. Total employment of more than 13,000 full-time equivalents with over 230 million USD (DKK 1.6bn) in tax revenues can be created in the construction phase.[138]

Building on its own experiences in fighting water, Rotterdam is promoting new products and services across the world, including sea walls, water storage in urban squares and underground parking garages, floating neighbourhoods and pavilions. At present, there are approximately 3600 jobs in the region that are directly linked to climate adaptation. In particular, businesses in the maritime, engineering and delta technology sectors in the Rotterdam region benefit from the increased focus on urban adaptation.[139]

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132 Financial Times, Computer makers caught in wake of Thai floods, 28 Oct. 2011. Bloomberg, Worst Thai floods in 50 years hit Apple and Toyota supply chains, 20 Oct. 2011.

133 Masahiko Haraguchi & Upmanu Lall, Flood risks and impacts: A case study of Thailand's floods in 2011 and research questions for supply chain decision making, Background Paper for the Global Assessment Report on Disaster Risk Reduction 2013.

134 Dagens Næringsliv, Økt flomfare i Thailand, 6 Oct. 2016.

135 Reuters, Thai floods kill 21 and hit rubber production, 9 January 2017.

136 Masahiko Haraguchi & Upmanu Lall. See xiii.

137 The economics of managing heavy rains and stormwater in Copenhagen – The Cloudburst Management Plan (2016). European Commission, Climate Adapt.

138 European Commission, Climate Adapt. The economics of managing heavy rains and stormwater in Copenhagen – The Cloudburst Management Plan (2016).

139 The Guardian, Rotterdam: designing a flood-proof city to withstand climate change, 18 Nov. 2013. Connecting Delta cities –a C40 network.

4.6 US coal sector collapsing under market changes and environmental legislation

Peabody, the world's largest private sector publicly traded coal company was forced to seek bankruptcy protection in April 2016, under competition from cheap natural gas. Recent years have seen at least 26 US coal companies go into bankruptcy.[140]

EIA forecasts U.S. coal exports will decline by 26% in 2016 to 55 Mt, the lowest level since 2006. Exports are expected to decline by an additional 5% in 2017, reflecting an historic shift in both the coal industry and the electric power sector it serves.[141]

In 2016, for the first time in history, more electricity is produced using natural gas than with coal, while solar generation capacity is growing rapidly with an average annual growth rate of 39%.[142] The US saw investment in renewable energy pick up in the last two years to reach its highest since the peak of "green stimulus" spending in 2011.[143]

Increasingly stringent Environmental Protection Agency (EPA) regulations also have played a significant role in the decline of the US coal sector. According to an analysis by Carbon Tracker Initiative[144], only two of seven influential EPA regulations were designed to tackle climate change, while the other five sought to mitigate other forms of hazardous pollution. Whether these regulations will be upheld by Trump's EPA is an open question.

140 Carbon Tracker Initiative, The US Coal Crash report, March 2015.
141 US Energy Information Administration, Short-term energy outlook, Oct 2016.
142 Climate Central, U.S. Energy Shakeup Continues as Solar Capacity Triples, 20 Oct. 2016.
143 Frankfurt School-UNEP-Bloomberg New Energy Finance, Global trends in renewable energy investment 2016.
144 Carbon Tracker Initiative, The US Coal Crash report, March 2015.

5 Investor Approaches and Information Gap Analysis

Key messages:

CO_2 footprint reporting does not reflect how well a company is prepared for changes in transitional or physical risk. Current company-level reporting provides a snapshot that is immediately out-of-date, and largely omits exposure to physical impacts.[145] In general, there is limited transparency on exposure to physical climate risk, and water footprints don't capture future risk preparedness.

Companies do not know what to report or how to report it.[146] There is a lack of consistent company level data on climate risk such as scenario and planning information that draws links to company financials.

A list of useful references for physical impacts at the global and regional level are provided on our website at www.cicero.uio.no/en/climateriskreport

145 Caldecott, B. and L. Kruitwagen (2016). "How asset level date can improve the assessment of environmental risk in credit analysis", Guest Opinion, S&P Global Ratings, 3 October 2016.
146 Carney, M. (2016). "Resolving the Climate Paradox", Speech given by Mark Carney, Governor of the Bank of England, Chair of the Financial Stability Board, Arthur Burns Memorial Lecture, Berlin, 22 September 2016. http://www.bankofengland.co.uk/publications/Pages/speeches/2016/923.aspx

Investors’ Climate Risk Approaches (based on survey results from CICERO Climate Finance Advisory Board)[147]		Information Gaps & Challenges
Portfolio level	Climate risk analysis • Portfolio or fund carbon foot-printing • Carbon intensity of revenue • Risk/opportunity analysis with scenarios for next 10-15 years	• No standard method for foot-printing funds, access to data varies and suppliers use different methods
	• Green investment products • Dedicated green bond portfolio or fund • Issuing and underwriting green bonds • Offering green investment products e.g. renewable energy mutual fund, green car loans • Dedicated investments to green technologies • Fossil-free and sustainably-optimized investment products (e.g. excluding companies with significant revenue from oil, gas and coal in addition to wider exclusion policy)	• Valuing environmental impacts is a challenge • Comparing across different green products is challenging
Company or asset level	ESG analysis • In-house sustainability ratings including climate change: business practice profile and indicators for positioning on climate (physical and regulatory) trends by sector • Physical climate change assessment for agriculture and forestry • Technology-Policy-Energy substitution dynamics for energy sector • Policy, water, and climate change risk analysis for utilities, oil and gas, mining • Water scarcity risk mapping where geographic information is available • Forecasts for extreme weather events and temperature change inform state economic and productivity forecasts • Post-investment ESG analysis	• Difficult to determine which are the most credible information sources • GHG emissions not sufficient for investment decisions on climate risk • Lack of asset-level data on climate risks, e.g. need more information on connection between companies earnings and climate risk • Lack of disclosure on company planning for low carbon future • Lack of scenario information for sector/company/country impacts • Lack of country-by-country reporting from companies on water risk and more granular data on water stress areas • Challenging to interpret which scenarios to use
	Active ownership and engagement • Questions and expectations for companies on climate change and water management • Dialogue with companies on ESG strategies • Exercising voting rights and shareholder resolutions based on 2 degree target and to end oil sands activities in Canada • Letters sent to external fund managers encouraging carbon footprint reporting • Participation in initiatives to accelerate companies progress towards government target	
	Divestment and exclusions • Divestment from companies with substantial climate risk in coal, oil, gas, utilities sectors • Based on ethical criteria of unacceptable levels of GHG emissions • Sustainability and climate related exclusions e.g. 30 % threshold on revenues from coal: palm oil and oil sands exclusions	

Table 12: Investor climate risk approaches and information gaps

147 See list of Advisory Board members here: http://www.cicero.uio.no/en/cicero-climate-finance/advisory-board

The CICERO survey results presented in table 12 reflect a range of different investor types (pension funds, asset managers, and banks) and mandates. At the portfolio level, investors employ carbon foot-printing and offering/seeking green investment products such as green bonds. At the company or asset level, analysis of different climate change factors is performed for specific sectors, e.g. focusing on policy risk for mining, oil and gas, and utilities.

The most common information gap cited was a lack of consistent company level data on climate risk such as scenario and planning information and links between climate risk and company financials. This fits well with the top ESG information challenges cited by Blackrock: 1) reliance on self-reported data, 2) inconsistent collection, management and distribution of ESG data, and 3) disparate approaches to measure and report ESG information to investors[148]. The initial stocktaking of the Financial Stability Board's TCFD reported that current disclosure based in static carbon footprints is incomplete and fragmented[149].

For physical impacts, information gaps were noted in our survey on company-level water risk and granular information on water stress areas. To highlight the importance of improving granular information on physical climate risk, material impacts from physical climate change are reported by 75% of the 2,449[150] companies through the Climate Disclosure Project (CDP) disclosure system in 2016. Of these companies, 45% reported material risk from physical climate change from change in precipitation extremes and droughts (**Figure 7**).

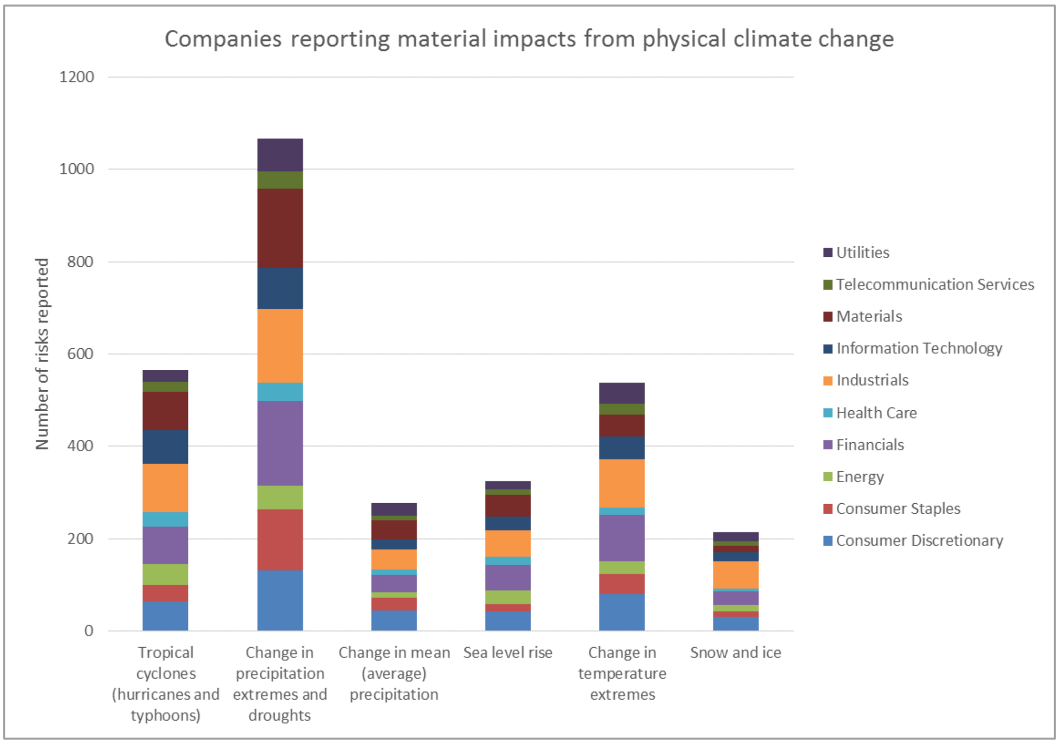

Figure 7: Companies by sector reporting material impacts from physical climate change
Notes: Data provided by CDP based on CDP 2016 Company Reports, based on 2,449 companies reporting. Companies can report on more than one risk

148BlackRock (2016). "Exploring ESG: A Practitioner's Perspective", June 2016.
149 Carney, M. (2016). "Resolving the Climate Paradox", Speech given by Mark Carney, Governor of the Bank of England, Chair of the Financial Stability Board, Arthur Burns Memorial Lecture, Berlin, 22 September 2016.
150 Reporting to institutional investors

CICERO is Norway's foremost institute for interdisciplinary climate research. We help to solve the climate problem and strengthen international climate cooperation by predicting and responding to society's climate challenges through research and dissemination of a high international standard.

CICERO has garnered attention for its research on the effects of manmade emissions on the climate, society's response to climate change, and the formulation of international agreements. We have played an active role in the IPCC since 1995 and eleven of our scientists contributed the IPCC's Fifth Assessment Report.

- We deliver important contributions to the design of international agreements, most notably under the UNFCCC, on topics such as burden sharing, and on how different climate gases affect the climate and emissions trading.
- We help design effective climate policies and study how different measures should be designed to reach climate goals.
- We house some of the world's foremost researchers in atmospheric chemistry and we are at the forefront in understanding how greenhouse gas emissions alter Earth's temperature.
- We help local communities and municipalities in Norway and abroad adapt to climate change and in making the green transition to a low carbon society.
- We help key stakeholders understand how they can reduce the climate footprint of food production and food waste, and the socioeconomic benefits of reducing deforestation and forest degradation.
- We have long experience in studying effective measures and strategies for sustainable energy production, feasible renewable policies and the power sector in Europe, and how a changing climate affects global energy production.
- We are the world's largest provider of second opinions on green bonds, and help international development banks, municipalities, export organisations and private companies throughout the world make green investments.
- We are an internationally recognised driving force for innovative climate communication, and are in constant dialogue about the responses to climate change with governments, civil society and private companies.

CICERO was founded by Prime Minister Syse in 1990 after initiative from his predecessor, Gro Harlem Brundtland. CICERO's Director is Kristin Halvorsen, former Finance Minister (2005-2009) and Education Minister (2009-2013). Jens Ulltveit-Moe, CEO of the industrial investment company UMOE is the chair of CICERO's Board of Directors. We are located in the Oslo Science Park, adjacent to the campus of the University of Oslo.

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