



# MEASURING PHYSICAL CLIMATE RISK IN EQUITY PORTFOLIOS

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# Executive summary

This white paper provides some of the tools that investors need to more accurately monitor and address the physical effects of climate change on investment portfolios. The objective is to satisfy institutional investors' growing desire for more climate resilient portfolios given the increasing frequency and intensity of natural disasters.

In 2017, the US Global Change Research Program Climate Science Special Report stated that it is extremely likely that human activities, especially emissions of greenhouse gases, are the dominant cause of the observed warming since the mid-20th century.<sup>1</sup> Thus far, investors' approach to boosting climate resilience has typically involved measuring the carbon emissions of issuers in their investment portfolios. This carbofoot-printing exercise helps assess the transition risk (i.e. the transition to a low-carbon economy) to a portfolio as global efforts to limit temperature rise below two degrees centigrade gather momentum. However, this strategy fails to take into account the physical risks of climate change, such as sea level rise, droughts, flooding, and cyclones. These, in our mind, pose a far more immediate threat to investment portfolios.

Addressing this gap, however, is far from easy. To do so, investors first need to identify the physical locations of the companies they invest in, a task made tricky by the generally poor corporate disclosure around these topics. Investors then need to master the increasingly

complex science around climate change to understand the vulnerability of these corporate production and retail sites. And finally, investors would need to account for the nature of the business activity being carried out in these locations to gauge the sensitivity to specific climate hazards. For instance, more energy and water intensive industries will be more directly affected by extreme heat and water scarcity while sectors such as construction, mining, retail, tourism and agriculture will be particularly sensitive to daily weather fluctuations.

We leverage data analytics from Four Twenty Seven, which maps the physical locations of corporate facilities around the world alongside climate models. Four Twenty Seven's scoring methodology identifies both the geographic exposure to climate hazards of individual companies, but, also the business sensitivity of facilities or companies to those hazards. In our view, this delivers powerful results since we can now identify over a million corporate sites and the risks to each site from heat stress, extreme rainfall, water stress and sea level rise.

This white paper has been written by Four Twenty Seven, the California based award-winning market intelligence and research firm specialized on the economic risk of climate change.



Asia is particularly vulnerable since five out of six people occupying the highest climate risk zones globally live there. The Asian Development Bank warned that, without mitigation action, Asia will experience temperature rise of six degrees centigrade by the end of the century.<sup>2</sup> Of extreme concern is the region's vulnerability to sea level rise. For example, China leads the world in terms of coastal risk with 145 million people and economic assets living on land ultimately threatened by rising seas.<sup>3</sup> Hence, Four Twenty Seven has mapped the physical climate risks for 500 large and mid-cap constituents of an Asia ex-Japan listed equity index.

We believe investors have no place to hide when it comes to the effects of physical climate change since even if emissions were cut to zero tomorrow, society will still face intensifying extreme weather events over the next several decades. We are keen to promote the disclosure by companies of annual and once in a lifetime climate risks so that we can manage these risks even more accurately going forward.

We hope you find this white paper informative and we very much look forward to discussing with you the ways to address the multitude of risks and opportunities physical climate risk presents to corporates, investors, and regulators around the world.



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<sup>1</sup> NUSGRCP (November 2017): Climate Science Special Report: Fourth National Climate Assessment, Volume I [Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 470 pp.

<sup>2</sup> Asian Development Bank and Potsdam Institute for Climate Impact Research (July 2017). A Region at Risk: The Human Dimensions of Climate Change in Asia and the Pacific.

<sup>3</sup> Climate Central (November 2015): Rising Seas Threaten Land Home to Half a Billion  
Whilst DWS makes reasonable efforts to check the accuracy of the scoring methodology and data from Four Twenty Seven, it cannot guarantee the accuracy of this information



## The wrath of climate change

In August and September 2017, for the first time in 166 years of weather records,<sup>1</sup> the United States saw three Category 4 hurricanes make landfall in the same year.<sup>2</sup> Estimates of the cost of destruction range from \$65 billion to \$190 billion, surpassing Hurricane Katrina's record of \$62 billion in 2005.<sup>3</sup> The storms caused a downward revision of economic growth estimates, as Goldman Sachs decreased its fourth quarter GDP growth forecast for the US by 0.8 percentage points due to Harvey and Irma.<sup>4</sup> This series of devastating hurricanes is a dire reminder that wealth is no protection from extreme weather events. The higher the value of assets, the greater the economic impact of climate-related events.

North America, however, is not the only region experiencing the wrath of climate change. In South Asia, the devastation from extreme storms and flooding throughout August 2017 affected over 16 million people, leaving more than 1,200 dead.<sup>5</sup> The city of Mumbai, India's financial capital, suffered its worst flooding since 2005. In Nepal, more than 20 per cent of the population was affected by severe flooding in the southern plains, known as Terai, which is also the most fertile region in the country. Around 80 per cent of the crops was damaged.<sup>6,7</sup>

Natural disasters have always been with us. However, they are now becoming more frequent, more intense, and importantly, more predictable. Climate science points to an increase in extreme weather events and long term climatic changes that will dramatically alter the environment upon which human societies and economic activity depends. Ignoring this extensive body of climate science and the unambiguous signals of long-term risks is a massive market failure.

# A major data gap

Yet today, investors lack the tools to anticipate, quantify, and respond to the oncoming impacts of extreme weather events on their equity portfolios.<sup>8</sup> Dozens of sophisticated climate models run by the world's leading academic institutions forecast changes in the earth's systems, but their outputs are extremely complex and require specialized programming skills and computers to access and process.<sup>9</sup> Raw climate data comes by the terabytes and comprises dozens of indicators that provide a detailed picture of forecasted changes to the planet's physical systems, but that do not speak to impacts on human and economic systems.

Compounding this issue, investors typically do not know the location of the corporate facilities of the corporations they invest in<sup>10</sup> and are thus unable to assess the risk to their portfolio companies.<sup>11</sup> Few corporations have performed their own climate risk assessments, and disclosure

from these companies is spotty at best.<sup>12, 13</sup> The lack of usable, relevant data on the projected impacts of climate change on publicly-traded companies and other underlying assets is a major concern to the financial system at large and hampers portfolio managers' abilities to devise a risk management strategy.<sup>14</sup>

To address this data gap, Four Twenty Seven, a market intelligence company specializing in analysis of the physical risk of climate change, has developed a model that leverages global climate data to provide asset-level risk assessments of corporations and score public equities' exposure to climate change impacts. Screening hundreds of thousands of corporate facilities around the globe using big data analytics technology, Four Twenty Seven provides a concise yet thorough view of each company's exposure to the physical impacts of climate change across its value chain.

## Investors and regulators call for disclosure

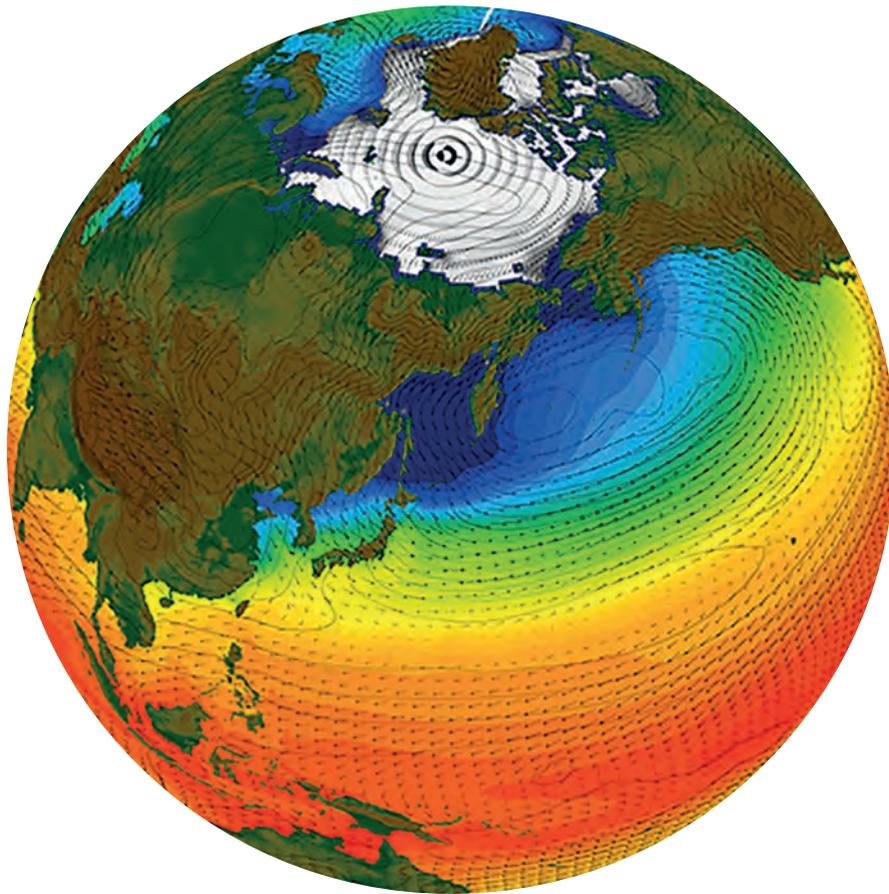
Global asset management firms including DWS,<sup>15</sup> BlackRock,<sup>16</sup> State Street,<sup>17</sup> Vanguard,<sup>18</sup> Amundi,<sup>19</sup> and Schroders,<sup>20</sup> as well as institutional investors in Europe and in the US, are acutely aware of climate risks and are raising the alarm with their investors and portfolio companies. Financial regulators are also stepping up their efforts to address the "Tragedy of the Horizon" – an expression coined by Mark Carney, Governor of the Bank of England and Chair of the G20 Financial Stability Board (FSB).<sup>21</sup> Carney cites outcomes like the impact of rising seas on the world's coastlines and infrastructure as one of the largest risks to financial stability around the world.

Under Carney's leadership, the FSB created an industry Taskforce on Climate-related Financial Disclosures (TCFD) led by Michael Bloomberg.

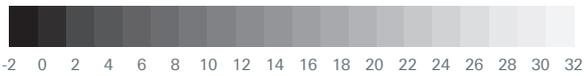
In June 2017, the Taskforce released its guidance for investors and corporations on better assessing and disclosing climate risk.<sup>22</sup> The TCFD breaks down climate risk into two distinct categories: Energy Transition risk and Physical risk. Energy Transition risk refers to the potential large-scale impacts of rapidly decarbonizing our economies and energy systems. Physical climate risk includes both shocks and stresses from climate impacts. The TCFD recommendations come among growing regulatory pressures in Europe. Article 173, part of the French Energy Transition for Green Growth Law, pioneered the field by requiring institutional investors to disclose climate risk in their portfolio, including both transition and physical risk.<sup>23</sup>

Figure 1. Climate models simulate earth's systems

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Sea ice concentration (%)



Sea surface temperatur (C°)



Source: National Center for Atmospheric Research

## SECTION I - PHYSICAL CLIMATE RISK SCORES

# Modelling a complex reality

The effects of climate change will be ubiquitous but uneven, ranging from those that disrupt daily life, such as damaged or flooded infrastructure, to more gradual impacts like declines in labor productivity<sup>24</sup> and widespread threats to global welfare through decreased crop yields.<sup>25</sup>

These changes in the natural environment affect economic activity through disruptive events, changes in resource availability (freshwater, coastal real estate), commodity price volatility, and reduced human health.<sup>26</sup> Further, climate change and extreme weather events increase environmental and socioeconomic vulnerability, exacerbating poverty, and driving new migration patterns.<sup>27</sup>

Different industries and sectors will experience different impacts, depending on their sensitivity to factors such as weather and natural resource availability. Resource-intensive sectors that consume a lot of energy and water in their production processes will be more directly affected by extreme heat and water scarcity than sectors that do not, such as service-based industries. Similarly, those sectors most sensitive to daily weather fluctuations – such as construction, mining, retail, tourism and recreation, and agriculture – are more likely to experience a reshaping of their markets, seeing new risk but also opportunities arise in response to shifts in demand.

To capture the nuance and diversity of these risk and opportunity drivers, Four Twenty Seven's scoring methodology includes an array of indicators, each focused on a distinct driver of climate risk. Company scores include both geographic exposure to climate hazards and business sensitivity of facilities or companies to those hazards. Four Twenty Seven's methodology was developed with a focus on the business-climate nexus, based on published research of how climate risks affect companies.

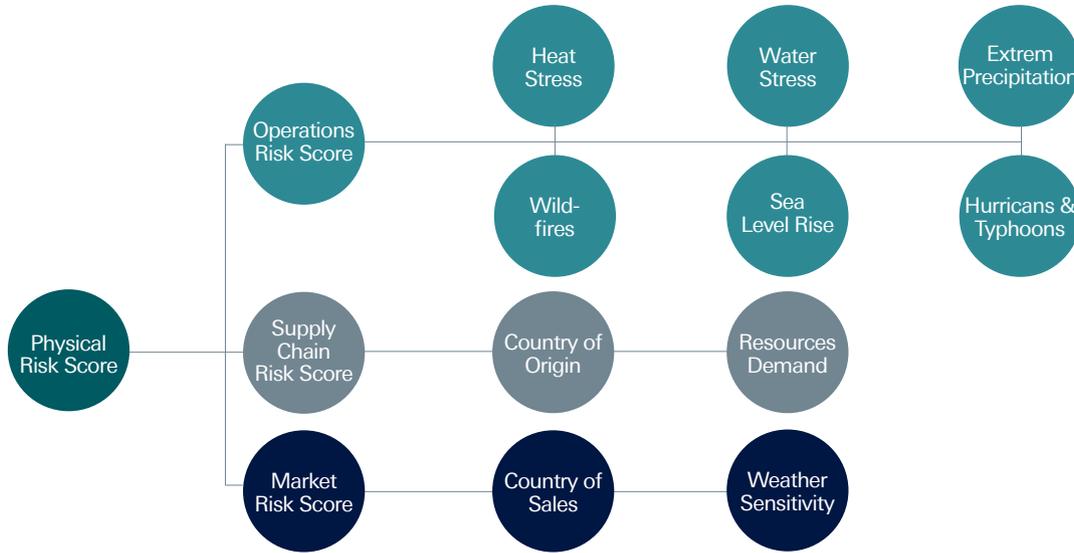
Four Twenty Seven's physical risk score comprises three key components: Operations Risk, Supply Chain Risk, Market Risk (Figure 2).

Operations Risk is assessed at the facility-level, whereby thousands of corporate facilities are screened individually for their exposure to climate risk, accounting for the fact that different facilities have different sensitivity to specific hazards. Each company receives a composite Operations Risk score that is an aggregate of facility scores, reflecting both exposure and sensitivity to climate hazards. The other components, Supply Chain Risk and Market Risk, are scored using company financial data on production, revenues, and other fundamentals.

Each dimension of risk is scored on a scale of 0 to 100, from the most exposed (low score) to the least exposed (high score). Scores are normalized so companies' climate risk can be compared across diverse portfolios. This approach enables the quantification of the many factors and risks that may affect the future value of a company, providing investors with a concise, standardized measure of physical climate risk. This integrated measure provides a point of entry to understand and address climate risk, engage with corporations, and identify risk mitigation strategies.

Figure 3 provides an example of the relative performance of France's 40 largest companies from the benchmark index CAC40. Market and supply chain risk score is shown the X-axis and operations risk score on the Y-axis.

Figure 2. Four Twenty Seven’s climate risk indicators



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Figure 3. Best and worst-in-class in France’s CAC40



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## Operations risk

Perhaps the most telling metric of a company's climate risk is the location of its assets and their exposure to changing extreme weather patterns. The geographic areas on which a company depends to produce, manufacture, deliver, and sell goods, are a powerful indicator of its fundamental exposure to future climate risks.

Operations Risk indicators measure the exposure and sensitivity of a company's assets to physical climate risks. The company level score is based on the level of exposure of its assets (manufacturing plant, distribution center, warehouse, offices, other investments such as real estate, etc.). A facility's individual score is a combination of the local exposure to climate hazards and the

facility's own sensitivity to that hazard. For example, a water-intensive facility in a drought-prone region will have a higher Water Stress score than another facility in the same region that does not rely as heavily on fresh water.

Specific climate hazards included in the Operations Risk scores include heat stress, water stress, extreme precipitation, sea level rise, hurricanes, and wildfires. Operations Risk also includes a measure of socioeconomic risk to each asset based on the country where it is located. This measure is based on a subset of indicators from the 427 Country Climate Risk Index.

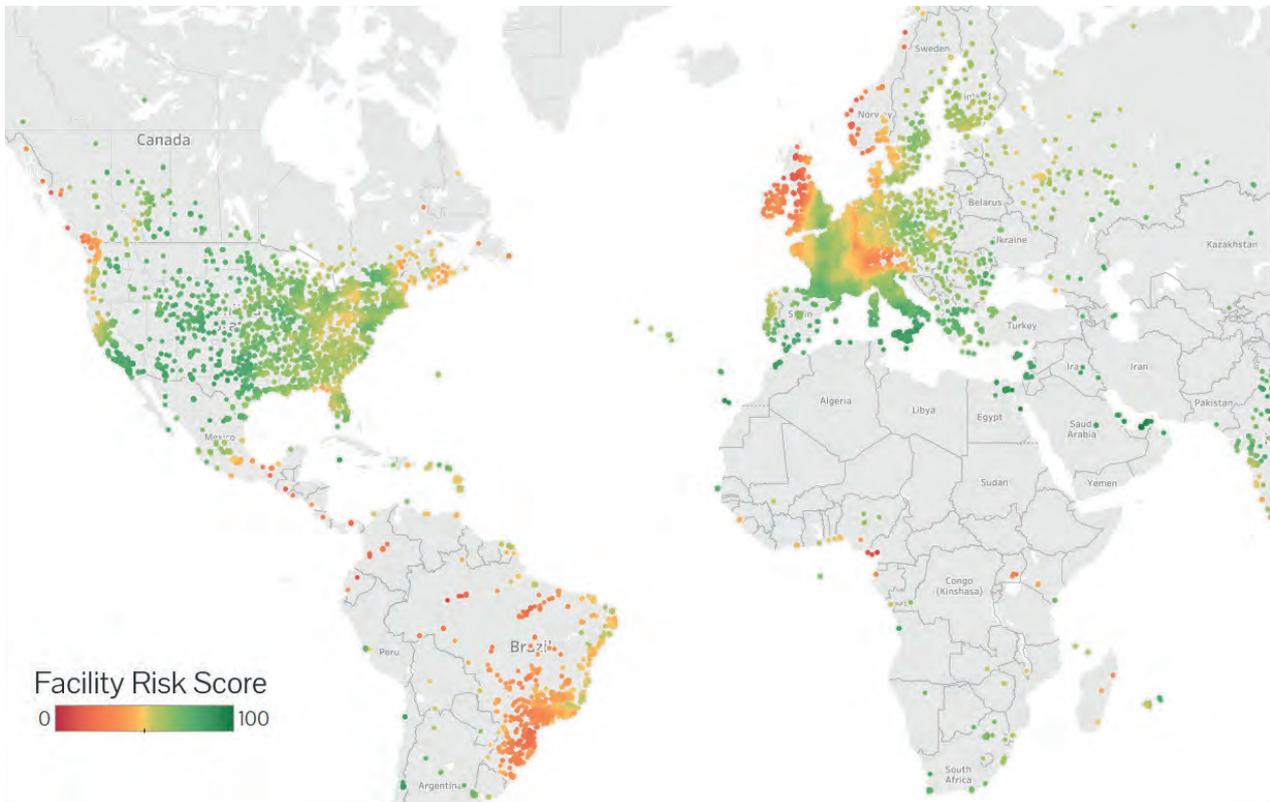
### Operations risk indicators

CLIMATE HAZARD	DESCRIPTION	POTENTIAL BUSINESS IMPACTS
Heat Stress	Increase in temperature	<ul style="list-style-type: none"> <li>– Increased energy costs</li> <li>– Heightened risk of brownouts/power outages</li> <li>– Stress on human health/ labor force</li> </ul>
Water Stress	Change in water supply and demand	<ul style="list-style-type: none"> <li>– Reduced water supply</li> <li>– Increased water costs</li> <li>– Social license to operate/reputation</li> </ul>
Extreme Precipitation	Intense rainfall events	<ul style="list-style-type: none"> <li>– Property and building damage</li> <li>– Compromised infrastructure</li> <li>– Business interruptions</li> </ul>
Wildfire	Change in fire conditions	<ul style="list-style-type: none"> <li>– Permanent loss of property value</li> <li>– Relocation costs</li> </ul>
Sea level rise	Heightened storm surge, augmented by sea level rise	<ul style="list-style-type: none"> <li>– Nuisance floods, property damage</li> <li>– Permanent loss of property value</li> <li>– Relocation costs</li> </ul>
Cyclones, Hurricanes, Typhoons	Exposure to past cyclones	<ul style="list-style-type: none"> <li>– Severe property damage</li> <li>– Permanent loss of property value</li> <li>– Relocation costs</li> </ul>
Socio-economic vulnerability	Social unrest, migration or economic disruption exacerbated or induced by climate change	<ul style="list-style-type: none"> <li>– Business interruptions, property damages</li> <li>– Impact on workforce</li> <li>– Social license to operate</li> </ul>

Developing the Operations Risk scores for the French 40 multinational companies displayed below involved mapping over 68,000 sites and gathered information specific to each facility: geographic location and primary function. Four Twenty Seven performs a climate risk assessment of each unique facility using global climate models statistically downscaled by the U.S. National Air and Space Agency (NASA) to a 25km<sup>2</sup> precision. We evaluate site risk by comparing projected changes to current conditions.

Figure 4 maps CAC40 sites and shows their relative exposure to extreme precipitation. Facilities in red or orange have the highest exposure to extreme precipitation and conditions that might lead to flooding. Overall, Four Twenty Seven's global facility database contains over a million corporate sites.

Figure 4. CAC40 facilities and extreme precipitation risk



## Supply chain risk

Climate change risks can multiply through global supply chains. Disruption may stem from extreme weather events, but also from climatic changes to regions for crop farming, mineral extraction, or fluctuation of production or transportation costs. Four Twenty Seven evaluates the level of climate risk in a company's supply chain with two indicators. The Country of Origin indicator is a measure of the risk in countries that export the commodities a company depends on. The Natural Resources indicator measures the level of the industry's dependency on climate-sensitive resources such as water, land, and energy across the supply chain.

This industry-based approach offers insight into likely upstream risks for a company without directly identifying a company's suppliers. Using detailed trade flow data, Four Twenty Seven maps the network of countries contributing to each industry's supply chain and combines it with the relative climate risk for each of those countries. Countries individual exposure is scored using the 427 Country Climate Risk Index (see below).

## Supply chain indicators

INDICATORS	DEFINITION	POTENTIAL BUSINESS IMPACTS
Country of Origin	Measures current and future levels of climate risk in countries that contribute to sector production and re-export activities	<ul style="list-style-type: none"> <li>– Distribution delays and disruption</li> <li>– Supply shortages</li> <li>– Maladaptation or resource mismanagement</li> <li>– High price sensitivity</li> <li>– Susceptibility to hazards and climate risks</li> </ul>
Resource Demand	Measures sector dependence on natural resources: water, energy and land	<ul style="list-style-type: none"> <li>– Supply shortages</li> <li>– High input costs</li> <li>– Social license to operate</li> <li>– Reputation risks</li> </ul>

## Market risk

Market Risk scores provide insights into the heart of a business' concern: its primary customers, markets, and sales. The metric estimates how patterns of purchasing and consumption may fluctuate because of climate change. Indeed, shifts in markets, economic welfare, and consumer preferences follow changes in weather patterns for a number of commodities. The macroeconomic impact of climate change on regional economies and productive capacity becomes an indirect driver of risk and opportunities for companies that operate in that market.

Each company is evaluated for Market Risk according to two measures: where it generates its sales and how its industry has historically responded to weather variability. For Country of Sales Risk, we use reported and modeled company revenue data and apply scores for the 427 Country Climate Risk Index to countries that contribute to a company's revenues. For Weather Sensitivity, we analyze the elasticity of consumption and production to historical variability in temperature and precipitation patterns. These two measures are combined to constitute Market Risk and reflect the degree to which a company's sales may fluctuate following regional climate impacts or prolonged stresses originating from changes in weather patterns.

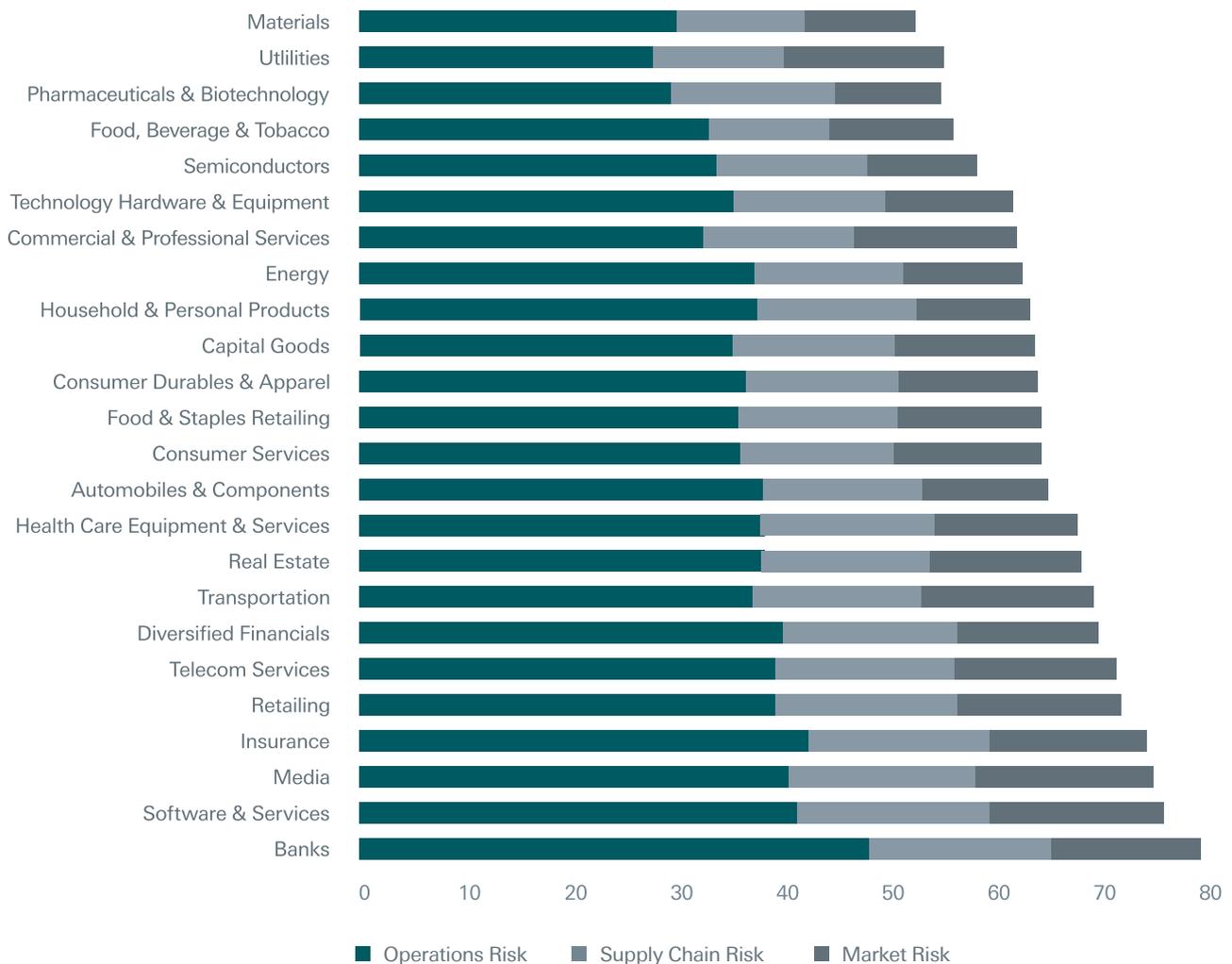
### Market risk indicators

INDICATORS	DEFINITION	POTENTIAL BUSINESS IMPACTS
Country of Sales	Measures current and future levels of climate risk in countries that contribute to company revenues	<ul style="list-style-type: none"> <li>– Interruptions at points of sale</li> <li>– Change in customer welfare and economic conditions</li> <li>– Changes in customer preferences and market opportunities</li> <li>– Migrations, conflicts, and risk of political disruption</li> </ul>
Weather Sensitivity	Measures the sensitivity of a sector to weather variability	<ul style="list-style-type: none"> <li>– Volatility in sales and revenues</li> <li>– Higher inventory costs</li> <li>– Changing consumer preferences</li> </ul>

Figure 5 shows the relative breakdown between Operations, Supply Chain, and Market Risk scores for a subset of 500 companies in Asia. Low scores indicate a greater vulnerability to climate change risk. Companies most vulnerable to climate change combine low scores in each category: a complex supply chain that depends on resource-intensive commodities, production facilities

concentrated in sites exposed to climate hazards, and a propensity to serve primarily a local market. Materials, Utilities, Food & Beverage, Pharmaceutical, and Hardware Manufacturing top the list. Service industries exhibit higher scores, although the data limitations prevent a full risk assessment for Insurance, Financial Services, and Real Estate sectors.

Figure 5. Industries exhibit different vulnerability profiles



## Modeling climate risk at the country level

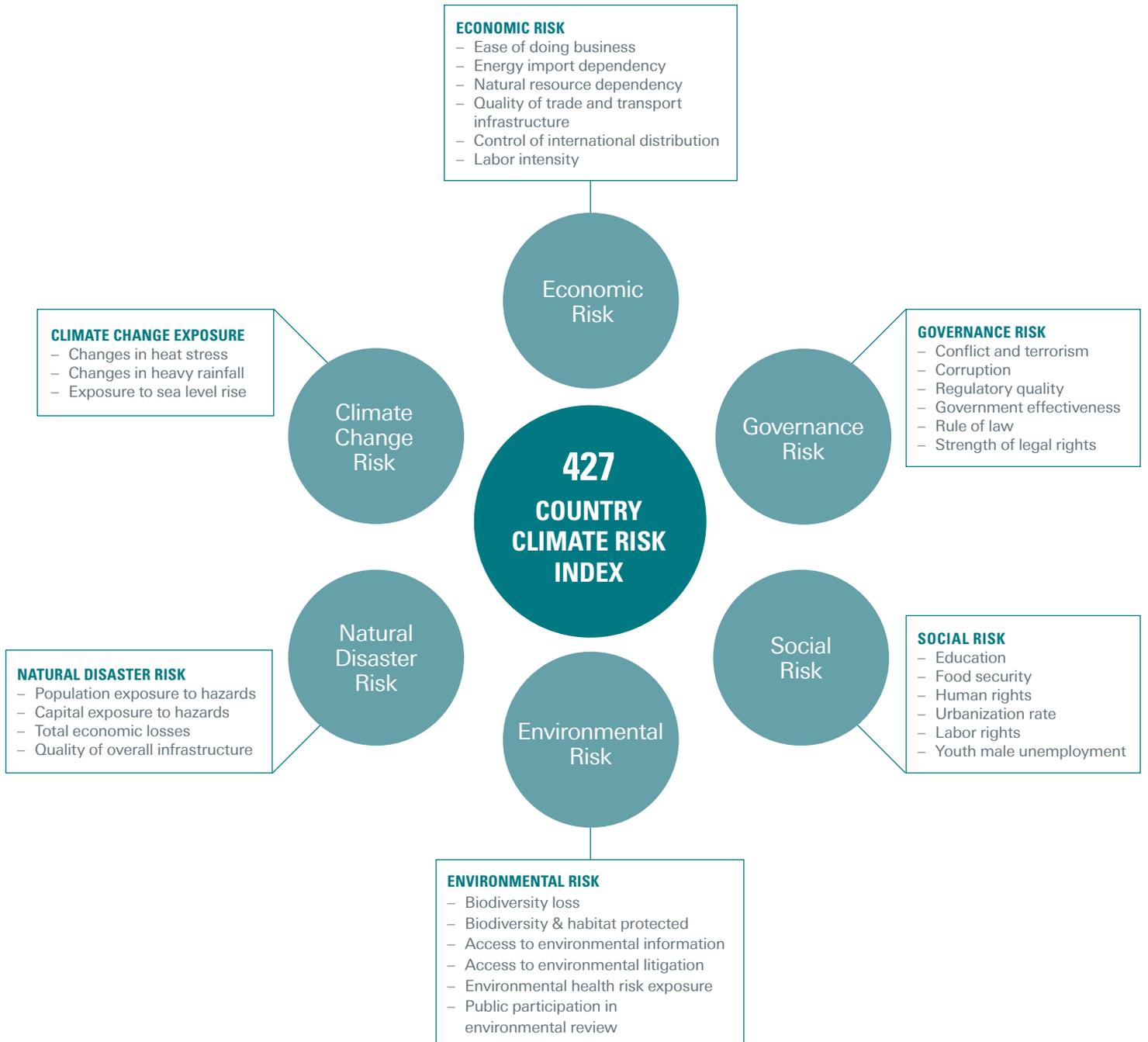
The impacts of climate change can lead to costly business interruptions anywhere in the world, though the size and extent of impact will vary widely. The Four Twenty Seven Country Climate Risk Index<sup>®</sup> evaluates the risk of doing business in a changing climate at the country level (Figure 6 on next page). This index includes both forward-looking and historical measures of risk and resilience. It overweighs climate risk exposure indicators that measure the relative change between historical conditions and projected climate change for key physical risk measures, including heat stress, extreme rainfall, water stress, and sea level rise, each of which is composed of several underlying metrics.<sup>28</sup>

In each country, we focus our analysis of climate data on densely populated locations, which are typically correlated with areas of higher economic activity (e.g. cities, ports, industrial areas, critical transportation infrastructure). In effect, this eliminates from our scoring rural areas which are less likely to be economic hubs or contain critical infrastructure. When examining climate hazards, we focus on the tail risks (90th percentile), to capture the conditions that could lead to climate “shocks” in centers of economic activity.

The time to recover from extreme events also varies widely by country. Businesses rely not only on the resilience of their own infrastructure and systems, but also on those of the country within which they operate. That is why we have obtained indicators that approximate a country’s ability to withstand, prevent, or otherwise recover from climate impacts based on their political, environmental, social, and economic stability.

Lastly, the index includes measures of historical occurrence of major hazards and the relative economic impact due to major climatological, geophysical, hydrological, and meteorological events in the recent past. Each of these indicators are screened for relevance and quality, and obtained from open-source databases provided by leading multi-national research organizations such as the World Bank, the Food and Agriculture Organization, and the United Nations, among others.<sup>29</sup>

Figure 6. The many dimensions of country climate risk



## The next frontier: Corporate resilience indicators

The impacts of climate change span much more than a company's physical assets, ranging from its finances to its reputation.

- **Financial risk** can go beyond recovering from an extreme weather event. Even a company that was not directly affected might be financially impacted. For example, through a gradual increase in its operational expenses due to rising insurance costs, a default in bank loans or other debt, or at a more macro-level, lower consumption levels.
- Climate change can trigger **regulatory risk** as governments prepare to deal with the potential hazards from climate change. Changes to zoning laws due to sea level rise, for example, could dramatically impact real estate prices.
- **Litigation risk** might also arise as climate change sparks breaches of fiduciary duty around improper or insufficient disclosure, negligence in allowing exposure to climate change, or breaches of contracts with suppliers (e.g., due to non-delivery of goods) or insurers (e.g., disagreement around the meteorological definition of an event or improperly denied claims).<sup>30</sup>
- There may be **reputational risks** for companies whose preparation and responses to climate change events will be scrutinized by the public.<sup>31</sup> Conversely, some companies are concerned over first mover's disadvantage and triggering a backlash as they provide more information on their exposure than their competitors.
- Lastly, an assessment of **corporate resilience** is critical to gaining a full picture of risk in a portfolio. A robust risk management process, a management style that enables companies to better process and assimilate new information, a culture of innovation, and proactive engagement in responsible corporate adaptation will be a key driver of success in a changing climate.<sup>32</sup>

These drivers of risk are not currently included in our set of indicators, but constitute the next frontier to gain a more comprehensive and nuanced understanding of all facets of company vulnerability to climate change. The disclosures called for by the TCFD may help bring some of these dimensions to light.

## SECTION II – EXPLORING CLIMATE RISK IN FAR EAST ASIA

# A regional focus

DWS and Four Twenty Seven have partnered to develop a climate-optimized passive investment strategy.

DWS leverages Four Twenty Seven’s physical climate risk scores so that we can create a series of indexes titled to seek to minimize exposure to climate risk while maintaining performance comparable to that of the benchmark index. This section explores more detailed findings over a set of 500 large and mid-cap companies in emerging economies in Far East Asia (China, South Korea, Indonesia, Malaysia, the Philippines, Thailand, etc.) to highlight vulnerabilities specific to the region.

The International Monetary Fund’s October 2017 World Economic Outlook emphasizes that adverse economic

impacts of rising temperature will affect low-income countries most.<sup>33</sup> The Asian Development Bank also recently warned of Asia’s acute vulnerability to climate change: without mitigation action, the temperature in Asia is expected to increase by 6 degrees Celsius by the end of the century, which will coincide with more extreme tropical storms, increasing pollution, more frequent and severe flooding, and decreased agriculture productivity.<sup>34</sup> Understanding which Asian company is most exposed to these looming hazards is the first step to mitigating risk exposure in an equity portfolio.

## The science of sea level rise

DR. BENJAMIN STRAUSS  
PhD, Climate Central

Global sea level rise is driven by two main factors: first, rising global temperatures are causing water to expand as it warms; and second, warmer temperatures are eating away at ice previously locked in land-based glaciers and ice sheets, sending meltwater and icebergs into the ocean. Both phenomena are well documented, and over the past century or so, oceans all over the world have been creeping steadily higher — about 20 cm (8 in.), on average, since around 1900.

Globally, under business as usual emissions, the seas are likely to rise between 0.6 and 1.0 m (2-3.3 ft.) by century’s end, although rise as high as 2.5 m is plausible.<sup>39</sup> However, local increases can vary widely from the global change due to factors such as differences in land subsidence rates, oceanic current shifts and local ocean tem-

perature changes. A complete picture of coastal vulnerability requires developing local sea level projections, integrating them with local flood risks from tides and storms, and comparing projected flood heights against land elevations.

Problematically, however, the widely-used global elevation dataset from NASA averages two meters too high in coastal areas. This overestimation of land elevation means past coastal assessments have been biased toward underestimation of risk. Climate Central has developed a new global coastal elevation dataset, CoastalDEM™; nearly eliminating this bias and setting up uniquely accurate regional and global coastal assessments. Climate Central integrates local sea level projections with local flood height-probability relationships to quantify the expected number of local floods exceeding critical elevations over a fixed period. These results, combined with facility locations, feed into Four Twenty Seven’s Operations Risk scores for sea level rise.

## Sea level rise in the Pearl River Delta

Increased coastal flooding driven by sea level rise is a current climate change impact and an accelerating threat. Five out of six people occupying the highest risk zones globally live in Asia, and delta regions are both economically important and particularly vulnerable in Asia. Princeton, New Jersey-based think tank Climate Central showed that business-as-usual emissions and a 4 degrees Celsius increase in global temperatures could lock in enough sea level rise to submerge land currently home to 470 to 760 million people, with unstoppable rise unfolding over centuries. China leads the world in coastal risk with 145 million people living on land ultimately threatened by rising seas if emission levels are not reduced.<sup>35</sup>

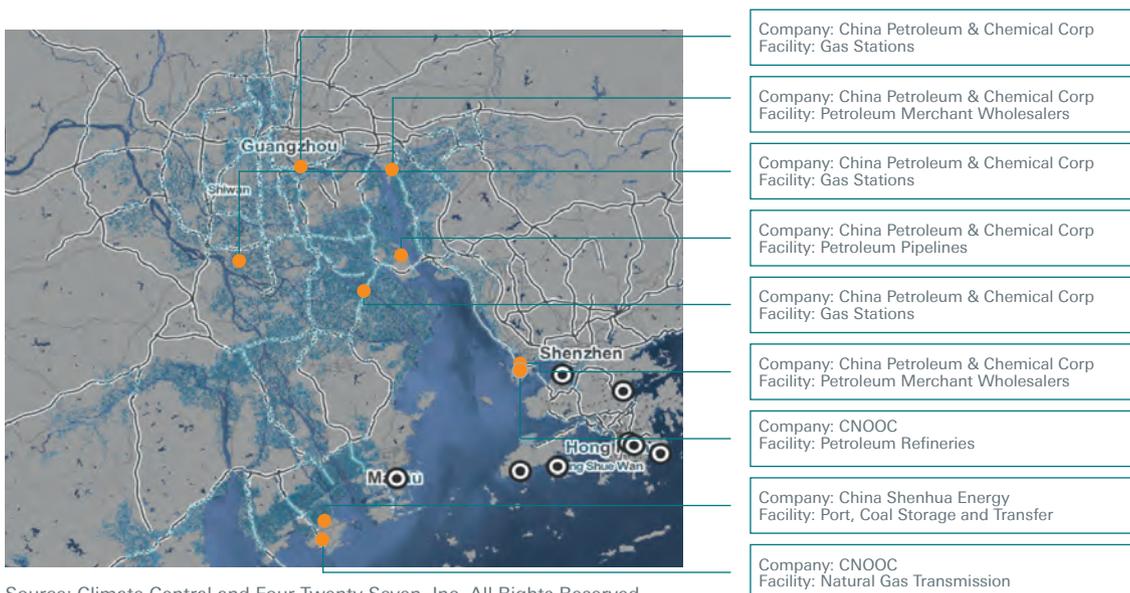
The Guangzhou region in southeast China is one such example of acute concentration of human populations and economic assets in a region prone to floods and vulnerable to sea level rise. Guangzhou and its cluster of cities, including Shenzhen, had a municipal GDP of 2 trillion yuan (280 billion \$) in 2016,<sup>36</sup> driven by a high concentration of commercial and manufacturing assets. Floods along the Yangtze are frequent and threaten manufacturing, transportation, and supply chains both in China and internationally.<sup>37</sup>

Four Twenty Seven data for the Oil and Gas sector near Guangzhou and Shenzhen shows a number of high value, long-lived capital assets at high risk of flooding due to combined sea level rise and storm surge.

The Pearl River Delta is already experiencing a higher than average rate of sea level rise, with research suggesting that a 30 cm rise in relative sea level at the mouth of the estuary is possible by 2030 (against an average 8 cm globally).<sup>38</sup> In addition, tidal variability and storm surge are relatively high. Figure 7 illustrates the number of assets exposed to flood risk in the region under a two-meter flood scenario (which could represent any combination of sea level rise, tide, and storm surge).

Energy assets are long-lived, high value capital assets that cannot be easily moved. Oil platforms and exploration wells, power plants, and other energy infrastructure will require protection from rising seas, or will be decommissioned or moved well before the water reaches the facilities. This creates, at the very least, uncertainty over the long-term viability of such assets, and signals a risk of costly relocation or decommission efforts for the parent companies.

Figure 7. Oil infrastructure in the Guangzhou region is exposed to sea level rise and flood risk.



Source: Climate Central and Four Twenty Seven, Inc. All Rights Reserved (November 2017).

## Impacts of heat on worker productivity

One of the largest measurable impacts of climate change on the global economy is the expected decline in labor productivity as temperatures increase, particularly in less developed economies that rely more heavily on outdoor industries.<sup>40</sup> Even in developed economies, labor productivity improvements have been historically important, and even small percentage reductions in GDP translate into large monetary declines. Research shows that workers subjected to hotter environmental conditions show reduced cognitive capacity and endurance, resulting in diminished work intensity and duration.<sup>41,42,43</sup> Further, higher temperatures reduce the amount of time that individuals allocate towards labor, reducing available labor supply.<sup>44</sup>

Industries such as agriculture, construction, utilities, and manufacturing have a higher risk of declining labor performance due to heat, but even industries where the workforce is primarily indoors in climate-controlled conditions have been found to suffer diminished performance during periods of high outdoor temperature.<sup>45</sup> Unlike acute weather events that grab headlines, these damages are not always immediately recognized, but this chronic stressor represents a measurable and significant drain on financial performance.

Many of the worst performers in the Far East ex Japan Climate index developed by DWS score low on our Heat Stress indicator, in particular companies in the Food and Beverage industry as well as Materials companies.

## Extreme precipitation and the 2011 Thailand floods

Annual precipitation in Asia is expected to increase by up to 50 per cent over most land areas in the region, putting coastal and low-lying areas at an increased risk of flooding. Bangkok, along with 12 other Asian cities, is in the top 20 cities globally forecasted to experience the largest growth of annual flood losses from 2005-2050.<sup>46</sup> Bangkok is no stranger to flooding, as the 2011 floods were the worst the country had experienced in 50 years.<sup>47</sup> The heavy monsoon inundated many industrial parks, which hosted over 800 companies.

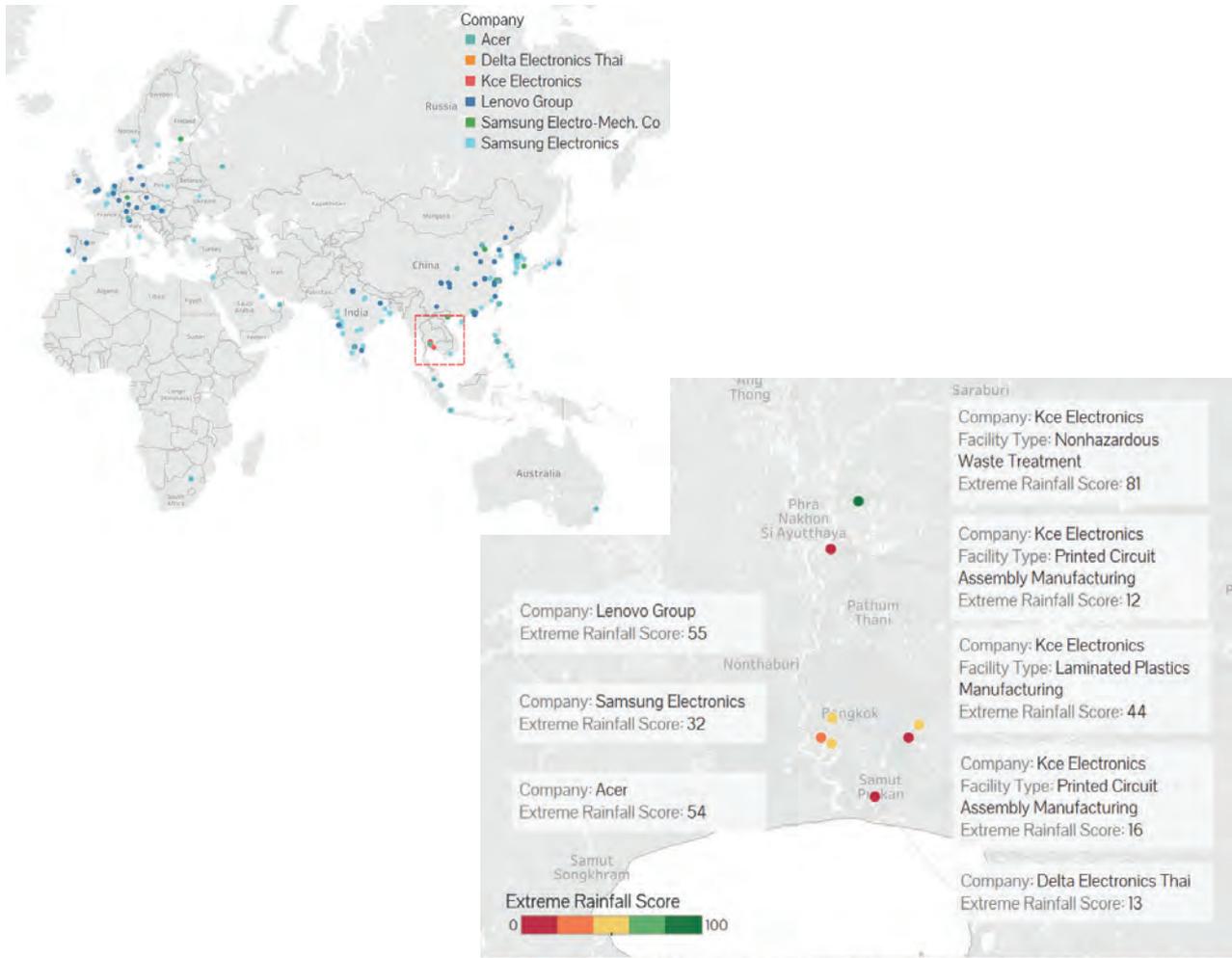
The economic fallouts of the floods were felt across industries ranging from car manufacturers such as Honda, Toyota, and Ford,<sup>48</sup> to companies such as Goodyear and Sony,<sup>49</sup> to Thailand's rice industry, one of the largest exporters in the world.<sup>50</sup> Even tourism revenue declined, partially due to the closing of Don Mueang airport, one of the two international airports serving Greater Bangkok.<sup>51</sup> The ripples were also felt worldwide and further up the value chain in the operations of hard drive manufacturers like Western Digital and Toshiba<sup>52</sup> impacting

companies that rely on these parts such as Lenovo.<sup>53</sup> The total economic damages ensuing from the Thai floods, both locally and globally, were totaled at almost 44 billion \$.<sup>54</sup>

The technology hardware sector was particularly hit by the floods, as Thailand is home to about a quarter of the world's manufacturing capacity for hard disk drives.<sup>55</sup> The impacts were felt all the way up the stock market: by November 30th, 2011, Thailand's Stock Exchange Index, the SET, was down by 17 per cent from its July 29th high point, hitting its low for that period a few weeks after, on October 4th, with a drop of 28 per cent.

Using Four Twenty Seven facility maps, we were able to identify precisely which Asian hardware manufacturing companies were most affected by the floods: Acer, Lenovo, and Samsung Electro-Mechanics all have facilities in the Bangkok region, as do two smaller Thai firms, KCE and Delta Electronics (see [Figure 8](#)).

Figure 8. Identifying hardware manufacturers affected by 2011 Thai floods



1. At the time of the floods, KCE Electronics only had 3 manufacturing facilities, all in Thailand, and all located within the areas affected by the floods.

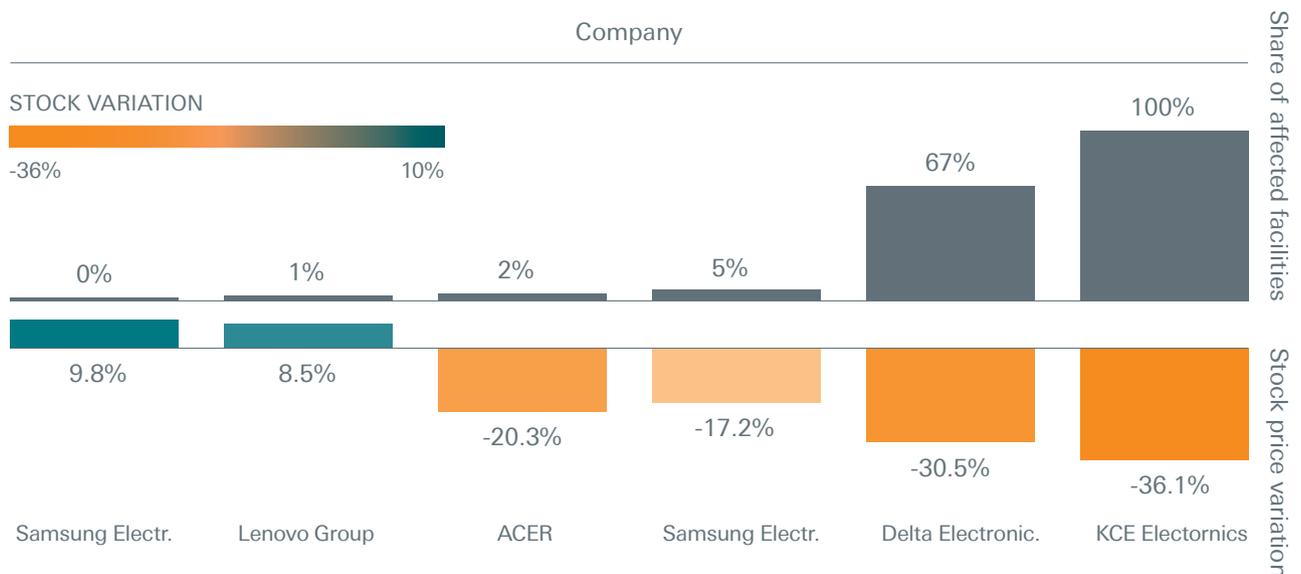
Acer, Samsung Electro-mechanics, Delta, and KCE all reported drops in share prices in that same period; the largest being that of KCE, a Thai manufacturer of printed circuit boards,<sup>56</sup> whose shares fell by 35 per cent in that period. Yet not all of the stock prices of technology manufacturing companies with facilities in Thailand's affected regions were negatively impacted. Samsung Electronics and the Lenovo Group both saw their shares go up within the same period, by 10 and 9 per cent respectively (Figure 9).

A closer look at corporate facilities reveals that geographic concentration of facilities may be a key driver: Lenovo and Samsung Electronics both have over 100 company sites worldwide, of which only one is located within the area affected by the floods. In contrast, KCE Electronics had, at the time, only 3 manufacturing facilities,<sup>57</sup> all in Thailand, and all located within the areas affected by the floods.

Indeed, KCE reported in its fourth quarter 2011 Earning Release that the floods stranded nearly 50 percent of KCE Ayutthaya plant's production capacity<sup>58</sup> and resulted in lower production at other KCE plants that use KCET's semi-processes products. Production did not restart until the next year, and even by February 20th, production capacity was only 60 per cent of normal.<sup>59</sup> The damages from the flooding to KCE were estimated at nearly \$60 million dollars, of which over \$36 million was for damages to fixed assets and \$14 million by damages to inventory.<sup>60</sup> The loss was mostly covered by insurance to property damage and business interruption. In 2012, KCE registered nearly \$50 million in capital expenditure (22 per cent of sales), mostly to replace KCET machinery.<sup>61</sup>

This concentration of assets in a region prone to extreme precipitation and flooding is captured in the companies' scores for Extreme Rainfall (and overall Risk Scores), enabling investors to understand the different risk profiles of their portfolio companies.

Figure 9. Financial impact is correlated to asset geographic concentration



Companies within the MSCI AC Far East ex-Jap Index, and the Technology hardware & Equipment Global Industry Classification Standard (GICS). Percentage of affected facilities computed per number of sites identified by Four Twenty Seven, Inc. Stock variation from 7/29/2011 to 11/30/2011.

## Does climate change cause extreme weather events? Climate science and extreme event attribution

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Until recently, when scientists were asked whether climate change was the cause of an extreme weather event such as a heat wave or large flood, the reply would be “We can’t say anything about individual events but this event was consistent (or not) with climate change.” However, new techniques now shed light on how the human interference in the climate system has influenced specific, individual weather events. These “event attribution” techniques rely heavily on climate models to simulate both the actual world that the event occurred in as well as a counterfactual world to explicitly model the human-driven changes to the climate system. There are a number of methods available to make quantified assessments and scientists are extremely careful in choosing models capable of providing credible simulations.<sup>62</sup>

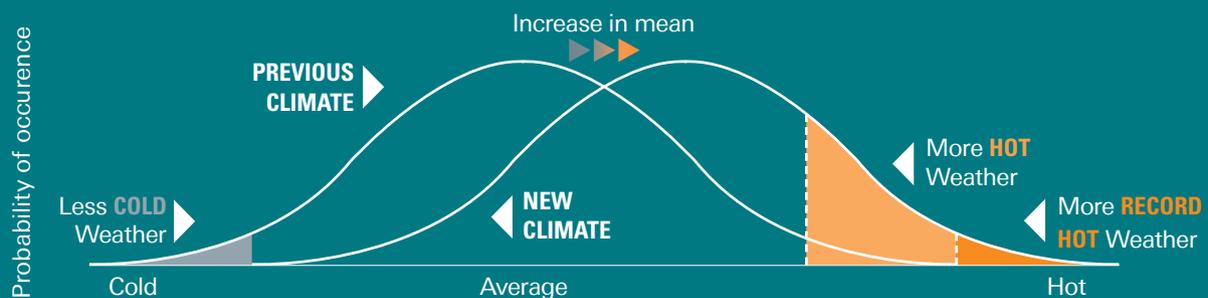
Two general types of statements can be made about whether a specific weather event might be attributed to climate change: did climate change affect the probability of occurrence of this event, and was this event more intense or of greater magnitude because of climate change. The degree of confidence for these statements can vary for a single event. The current state of science does not allow scientists to establish

full causality, i.e. to state with certainty that a specific event would not have happened without climate change. No such event has yet been documented in the literature, but they are certainly plausible in the warmer future scenarios examined by the Intergovernmental Panel on Climate Change.

Currently, confidence in probabilistic event attribution statements is highest for temperature extremes, both hot (increasing probability and magnitude) and cold (decreasing probability and magnitude). Intense storms and resultant flooding can be problematic as current generation climate models may not be able to reproduce precipitation amounts close to observations due to limitations in model fidelity. Recently, more refined approaches involving high-resolution forecast models have proved useful in quantifying the human influence on intense storms, albeit with more conditions invoked.<sup>63</sup>

Event attribution is a rapidly developing science, and attribution of select events for the past year is now systematically assessed in the Supplement to the State of the Climate Reports, published annually since 2013 in the Bulletin of the American Meteorological Society. It is likely that confidence in extreme event attribution will continue to improve in the near future.<sup>64</sup>

Figure 10. Climate change shifts the odds for extreme weather events



Source: IPCC

## Macroeconomic impacts and market risk

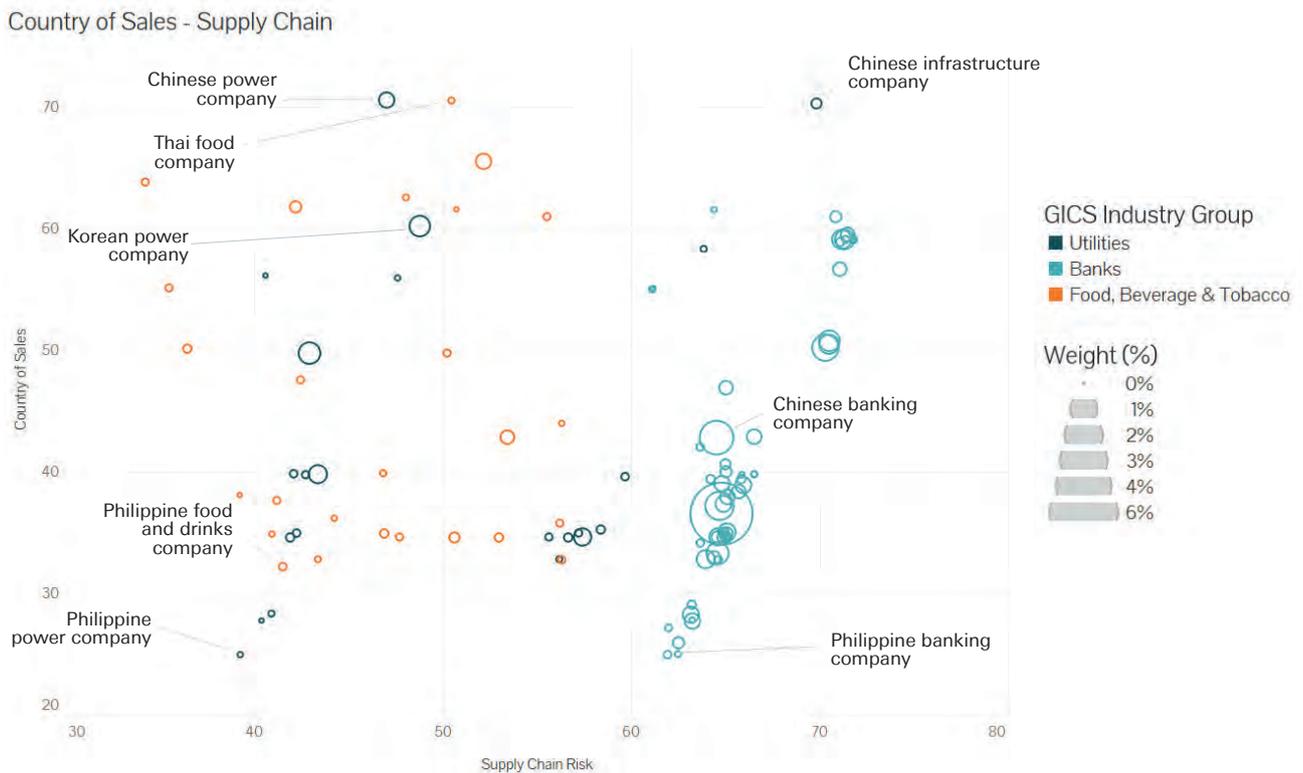
Unabated climate change could severely affect Asia's future growth, reverse current development gains, and degrade quality of life.<sup>65</sup> Such sweeping impacts on socio-economic development means companies are also exposed to diffuse risk to their markets and customers, in addition to localized, site-specific operational risk. Four Twenty Seven's Country of Sales risk indicator is designed to capture this market risk. **Figure 11** illustrates our findings for three sectors: Banks, Utilities, and Food.

Banks tend to be high performers on all metrics but one: Country of Sales. Banks don't have much of a supply chain, and operate numerous branches across their markets, with high redundancies and therefore limited business impacts from local hazards. However, many banks serve only their domestic market, such that banks

in Thailand, the Philippines, China, and Indonesia rank as lowest performers on the Country of Sales indicator, as they are vulnerable to shocks in their home country.

Utilities, in contrast, also don't have a deep supply chain but they tend to be much more exposed to Operation Risk, especially as they operate water and energy intensive power plants. Just like banks, they depend on the market they serve – **Figure 11** shows Kepeco, the Korean utility scoring well above local utilities in Thailand and the Philippines. Lastly, companies in the food industry score consistently low for supply chain risk due to their dependency on agricultural supply chains, but show a wide range of market risk, depending on whether they cater to their domestic market like Robina Corp., or are focused on export agricultural goods like Thai Union Group.

**Figure 11. Market risk (Country of Sales Indicator) varies widely within each sector**



# Conclusion

Climate change has become a driver of risk and performance in financial markets, and the need to integrate company climate risk into investment decisions will only grow over time. Gaining greater visibility into these risks, which are currently not priced by financial markets, is a duty for all investors and corporate directors. Four Twenty Seven's climate risk analytics open a unique window into the many dimensions of climate change impacts on value chains, empowering corporations, and investors alike to take action to mitigate risk and seize opportunities.

As regulators and institutional investors continue to exert pressure on portfolio companies for more disclosure, this dataset on corporate climate risk will gain nuance and granularity. Are companies properly insured for climate losses? What is the maximum potential loss from an extreme weather event on their top five facilities? Are they proactively assessing their long-term risk to build resilience at the company and site level?

Solutions exist. Leading companies are already engaging closely with local authorities to support local adaptation measures and foster resilience for their facilities, their employees, and the broader community.<sup>66</sup> Better understanding these risks need not be a driver of divestment and exclusion. Rather, it is the starting point to investing in resilience, supporting companies with stronger climate risk management approaches, and ensuring our broader economic system is protected from the worst impacts of climate change.

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### About Four Twenty Seven

Four Twenty Seven ([www.427mt.com](http://www.427mt.com)) is an award-winning market intelligence and research firm specialized on the economic risk of climate change. Four Twenty Seven's data analytics solutions bring climate intelligence to economic and financial decision-makers. Four Twenty Seven provides financial portfolio climate risk assessments, development of climate resilience strategies, quantification of metrics and indices for benchmarking, monitoring and evaluation, and training and stakeholder engagement to Fortune 500 corporations and governments worldwide.

Four Twenty Seven was a finalist for the prestigious Cartier Women's Initiative Award (2014), earned Climate Change Business Journal Awards for Climate Risk Management and Adaptation (2014 and 2015), took first prize in the ESRI Human Health and Climate Change Challenge 2015, and won the Verdantix Environment, Health and Safety Information Management Award (2016). Its founder, Emilie Mazzacurati, was awarded the Berkeley Visionary Awards in 2016. The company was founded in 2012 and is headquartered in Berkeley, California with offices in Washington, DC and Paris, France.

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