Uptime Institute® | RESEARCH

RISK & RESILIENCY

UI Intelligence report 20

A mission-critical industry unprepared for climate change

Operators advised to reassess their risks and strategies

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Most data center operators have failed to carry out an up-to-date risk assessment to prepare for hitherto unlikely events and gradual changes caused by climate change. As a result, their facilities and businesses may be vulnerable as the threat increases.

Uptime Institute is advising that data center operators review their resiliency and disaster recovery models and assumptions and conduct regular risk assessments.

This Uptime Institute Research report covers:

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SECTION 1:

Overview

Uptime Institute Research & methodology

Uptime Institute Research is an independent unit of Uptime Institute dedicated to identifying, analyzing, and clearly explaining the trends, technologies, operational practices, and changing business models of the mission-critical infrastructure industry, so that executives, investors, and operators may make considered, well-informed decisions, adopt best practices, explore new opportunities, and reduce their exposure to risk.

Uptime Institute Research has a dedicated team of experienced researchers, supported by a global network of data center and IT consultants from Uptime Institute. Uptime Institute Research conducts surveys, holds regular reviews, interviews industry experts and advisors, and draws on insights from research colleagues at its sister company 451 Research.

Uptime Institute Research delivers information and insights in the form of reports, consulting, conferences, online portals, roundtable discussions, and webinars. Full, premium reports are primarily available through the Uptime Institute Inside Track portal, by direct subscription (contact Uptime Institute sales), or, in certain cases, on Uptime Institute's web site.

KEY FINDINGS

• Many data centers are not built to withstand the most severe risks to be caused by climate change, including severe weather, flooding, and drought. Other risks, including higher ambient temperatures, can increase the costs of operation or even make a single data center uneconomical to operate.

• Many data center operators are confident that their facilities include features that will insulate them from climate change, at least in the near term. They may be correct, as 66% of respondents say their facilities are operating within their expected life and so might be replaced before some of the most extreme effects of climate change will be felt. But climate data is changing fast—they may not be correct.

• Climate change risks extend beyond data centers, to networks, colocation partners, utilities (power and water), transportation for resources and staff, and fuel suppliers.

• Climate change risks should be specifically added to resiliency reviews, which Uptime Institute recommends should be conducted regularly and should include a wide range of near- and long-term operational threats, both internal and external.

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- Data center operators should be able to reassure clients (internal and external) how risks from climate change (and any other material change affecting data center operations) may affect their IT operations.
- The climate change threat facing many data centers cannot necessarily be addressed by refurbishing, retrofitting, or renovating existing facilities. The nature and severity of the threat varies from location to location.
- Climate change may require organizations to adopt multi-site, or application, resiliency models to shift IT load as required or to increase the provision of active, out-of-region facilities.

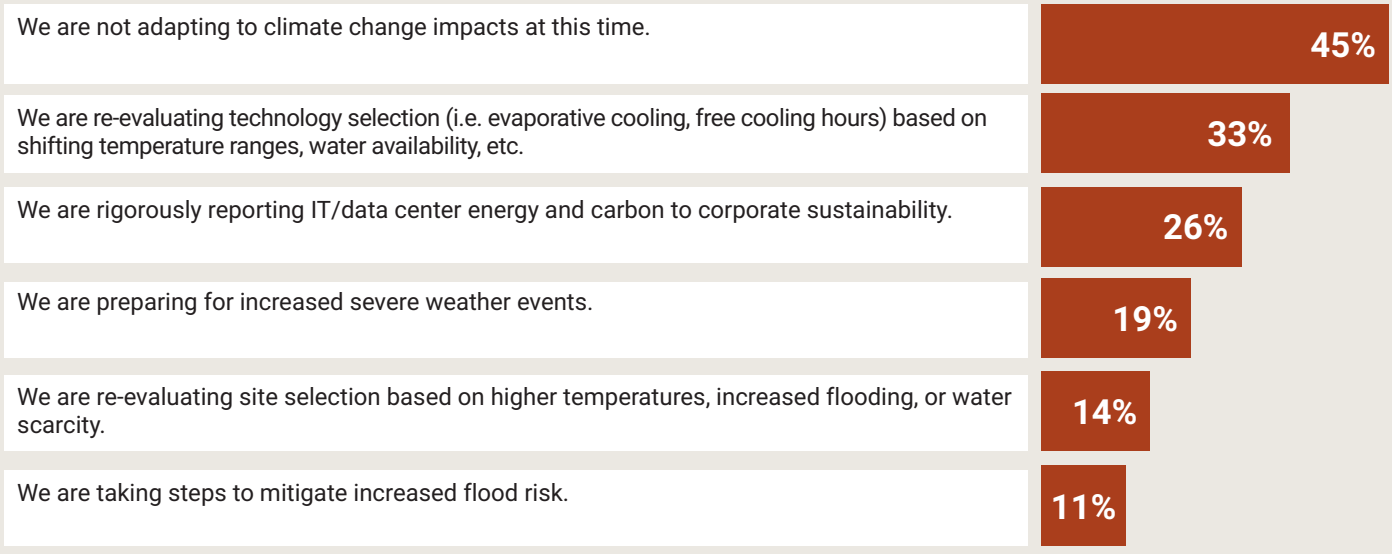
A relaxed industry?

Across the world, scientists and planners in many fields, and from many government agencies and industries, are planning for the impacts of climate change—some dramatic and life threatening, others subtle but costly. But the data center industry, which underpins so many critical activities, appears to be taking a relaxed approach; only detailed site-by-site analysis will reveal if it is complacent.

According to the Eighth Annual Uptime Institute Survey (See Appendix A), only a slight majority (55%) of data center operators is preparing for climate change. In addition, many fewer organizations reported preparing for increased flooding, more severe weather events, and higher temperatures or wider temperature ranges that are expected to result from climate change—even though risk assessment and risk management are a routine part of data center and business operations.

MANY DATA CENTERS ARE NOT PREPARING FOR CLIMATE CHANGE

Is your organization revising policies and/or planning to revise data center policies to adapt to climate change?



Source: Uptime Institute 2018 Data Center Survey (n=709)

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An apparent lack of diligence and action by many data center operators contrasts with the near-universal acknowledgement that global warming (either anthropogenic or non-anthropogenic) has increased the likelihood and severity of flooding or drought, changed major storm patterns, and warmed the outside air that many data centers use for cooling. There are also secondary changes, such as the increased likelihood of fire, reduced water quality, and more frequent lightning strikes, among others. Any of these effects can in turn affect water and power availability and pricing.

A low PUE will be of little help to a flooded data center

Our most recent survey findings are at odds with a previous Uptime Institute research paper (*Advisory: Integrating Corporate Sustainability and IT Operations*), which detailed the importance of environmental/sustainability/governance (ESG) offices to address climate change and other sustainability concerns. Corporate boards and large institutional investors increasingly see climate change as a major threat to operations and business continuity, which has had an effect on share price and market capitalization at publicly traded companies.

ESG offices can have a far-ranging impact on organizations, and they also often also oversee diversity and environmental stewardship programs. ESG offices ensure that a company meets the supply chain requirements of its industry, increases its resource efficiency, and reduces environmental waste, all of which can lower a company's expenses, improve its profitability, and enhance its reputation. But it does not necessarily make them more resilient.

Despite the broad mandate of ESG offices, our research indicates that sustainability initiatives (in the IT/data center sector, at least) often focus on reducing and reporting the impact of the business on the environment rather than on the impact of a changing environment on the business.

Reducing PUE, reducing energy use, and eliminating waste are ways that organizations can support efforts to become efficient and therefore mitigate climate change. A low PUE, however, will be of little help to a data center that finds itself with insufficient redundancy or cooling or is surrounded or even inundated by water because of climate change.

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Climate change effects

Climate change means much more than just hotter weather. Increases in ocean and freshwater temperatures, frost-free days, and heavy downpours have all been documented. Global sea levels have risen, and there have been large reductions in snow cover, glaciers, and sea ice. Storms and related extreme weather events are both more frequent and more intense. These and other climate changes have affected and will continue to affect human health, water supply, agriculture, transportation, energy, coastal areas, and many other sectors of society around the world. All of these changes have been recorded and measured by many scientists and governments.

Storms and extreme weather events are both more frequent and more intense

Some of the changes are common to many regions. In the U.S., the Northeast, Midwest, and Great Plains states have experienced large increases in heavy precipitation and runoff that exceeds the capacity of storm drains and levees, causing flooding events and accelerated erosion. Other impacts, such as those associated with the rapid thawing of permafrost in the arctic, are unique to that part of the globe. However, changes in precipitation patterns have been recorded on all continents.

Water quality and availability are being affected by climate change. Changes in precipitation and runoff, combined with changes in consumption and withdrawal, have reduced surface and groundwater supplies in many areas. These trends are expected to continue, increasing the likelihood of water shortages. Water quality is also lessened in many areas, particularly due to sediment and contaminant concentrations after heavy downpours. Sea level rise, storms and storm surges, and changes in surface and groundwater use patterns are expected to compromise the sustainability of coastal freshwater aquifers and wetlands. In most regions, water resources managers and planners will encounter new risks, vulnerabilities, and opportunities that may not be properly managed with existing practices.

Each of the changes due to changing weather patterns can affect data center operations, some in multiple ways. The risk to equipment from flooding is obvious. Floods can also damage engine generators or foul diesel tanks. Less obviously, flooding can damage telecom equipment in the surrounding area, block roads and fuel deliveries, and cause staffing problems during an emergency. For these reasons, mitigation planning needs to extend beyond the data center itself.

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Climate change and mission critical infrastructure

Most data centers are built as resilient facilities and are run to maintain high availability. The risks of losing power, cooling, connectivity, or other resources are well understood and mostly mitigated successfully. Similarly, most IT service operators invest heavily to reduce risks of downtime caused by failures in IT equipment or software and by security breaches or corruption of data.

The risks arising from climate change are mostly familiar to data center operators and have been to a large extent addressed during site selection and design and construction. But other risks are new in scale or type, including the following:

• *Regional and local infrastructure risks.* As one of Uptime Institute's senior consultants noted, in the case of severe flooding and extreme storms, the resiliency of a single data center is almost beside the point, because all data centers depend on the availability of staff and local infrastructure including water and power utilities, telecommunications systems, and fuel delivery. Some, or all, of these resources are almost always unavailable in the worst cases. While these are generally site selection issues, climate change means the threat levels are changing fast in some areas.

Mitigation planning needs to extend beyond the data center

• *Connectivity.* A recent report from University of Wisconsin-Madison and University of Oregon researchers documented the vulnerability of fiberoptic cable to rising sea levels. They noted that a significant amount of digital infrastructure will be impacted over the coming years and cautioned that mitigation planning should begin immediately. According to the study, more than 3,600 miles of fiber in densely populated coastal regions of the U.S. will be underwater in less than 15 years, excluding the impact of storm surges.

• *Design changes.* Current maps for estimating economizer or free-cooling hours may slowly become less accurate, which could in turn change the availability and usability of some technology as well as the ROI on equipment and require a review of design decisions. Warmer air temperatures could increase the use of indirect cooling systems compared to direct cooling systems because of air quality or fire concerns. Threats such as higher winds would require more durable building shells and higher wind ratings or enclosures on outside structures and warmer temperatures would require greater cooling capacities. The costs of protecting redundant on-site power and telecommunication paths and infrastructure might also increase.

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• *Site changes.* While it is not possible to anticipate all the ways that climate change might influence site selection, it is logical to surmise that new data centers will have different risk profiles. Data centers may move even further outside of flood plains and storm paths and nearer plentiful resources like water or electricity. The changing risk profile might cause some operators to increase their appetite for risk found in sites near congested areas or near airports and other high-priority facilities, as long as the local infrastructure was found to be resilient. A change in risk assessment could lead to increased land acquisition costs for new facilities, which would cost more to build.

A change in risk assessment could lead to increased land acquisition costs for new facilities

• *Operational resources and costs.* A migration to climate-change resistant sites would tend to put data centers in price competition for resources and labor with other facility types, causing higher operating costs. Uptime Institute has already seen anecdotal reports that insurance companies are reassessing their policies and premiums in the face of climate change. We assume that costs such taxes, and even security, would rise too, with the migration of facilities to more built up areas.

• *Water shortages.* Precipitation changes will result in drought and water shortages in some areas, making evaporative cooling options untenable. Even small changes in temperature for a certain number of days a year can make economization and free cooling strategies more expensive or unviable.

• *Legal and governance.* Organizations in every region should expect increased scrutiny of data center carbon emissions. Many governments are imposing or entertaining new rules, so the long-term trend is clear: new and expanded regulations are highly likely across the globe. At the same time, many organizations are responding to shareholder and customer pressure to conform to sustainability requirements. Non-conforming organizations may lose sales and/or investment opportunities, or be excluded from supply chains.

• *Fuel costs.* Producing energy from fossil fuels (coal, oil, and natural gas), nuclear power, biofuels, hydropower, and some solar power systems often requires adequate and sustainable supplies of water. Issues related to water, including availability and restrictions on the temperature of cooling water returned to streams, already pose challenges to production from existing power plants and the ability to obtain permits to build new facilities.

The effects of climate change vary from region to region and even from site to site. Each data operator must evaluate every facility individually after first determining what the expected risks are a given site.

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Table 1: Climate change and risk assessment

The recently released UK Climate Change Risk Assessment 2017 came to similar conclusions as Uptime Institute. The table below, reproduced with the permission of techUK, shows how climate events can damage data centers and fixed-line and mobile telecom providers (see Appendix F). This table is useful for all data centers, although the original analysis applied to UK sites specifically.

Table 1: Impacts	Data Centers	Fixed Line Telecoms	Mobile Telecoms
Coastal flooding erosion, inundation by salt water, increase in salt spray	Flooding of exposed infrastructure, damage to cabling, scour damage to foundations, subsidence, cabling exposed or damaged, salt damage to materials. Problems with emergency access for engineers.	Flooding of exposed infrastructure, damage to cabling, scour damage to foundations, subsidence, cabling exposed or damaged, salt damage to materials and equipment. Problems with staff access and safety.	Flooding and salt water damage to expose infrastructure—cabling and underground ducting and cabling. (Masts and base stations usually positioned on high ground but base stations may be occassionally flooded. Problems with staff access and safety.
Fluvial flooding (erosion, inundation by fresh water, silt and sewage deposit)	Flooding, silt and sewage, water ingress and/or damage to heavy plant and switchgear, erosion and scour of cabling and buildings. Problems with emergency access for engineers.	Scour of cabling, flooding of ducting, underground cables, cabinets and access points. Water damage to assets, silt damage, disruption to fleet operations. Problems with fleet operation and emergency access.	Flooding of ducting, water damage to cabling and hardware, scour damage to buildings, exposed cabling. Occasional flooding to base stations, silt and sewage despost. Problems with fleet operation and emergency access.
Pluvial flooding (flash floods, inundation of localised area	Flooding of facilities. Heavy plant and switchgear disabled, damage to cabling, water damage to other hardware. Problems with emergency access for engineers.	Water damage and flooding to exchanges, cabinets, ducts, exposed infrastructure below and above ground. Disruption to fleet operation and emergency crew access.	Flooding and water damage in exchanges, ducts, exposed infrastructure below and above ground. Disruption to fleet operation and emergency crew access.
More rain, heavier rain, larger droplets	Not significant, no known incidences	Greater penetration into cabinets, damage to connection points such as tops of poles. Higher groundwater may change shear strength of substrate and reduce pole stability.	Mobile signal can be affected by rain (rain shading). Mainly a problem above 10GHz. Connectivity may be reduced. Possible penetration into exposed base stations. Higher groundwater may change shear strength of substrate and reduce mast stability.

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Table 1: Impacts	Data Centers	Fixed Line Telecoms	Mobile Telecoms
Sustained high summer temperature	Poor working conditions for staff. Some legacy sites may struggle to maintain required temperature to avoid hot spots. May compromise some activity if sooling cannot be maintained. Cooling costs may increase for other facilities.	Maintaining safe working conditions in exchanges, etc. Component failure, ICT equipment failure, especially legacy kit (NB: Newer equipment has higher temperature and humidity tolerances)	Maintaining safe working conditions in exchanges, component and equipment failure in base stations.
Increased rapidity of temperature change	Higher HVAC (Heating, Ventilation, Air Conditioning) costs. Stress on components and hardware.	Stress on components and hardware. Shorter in-service life.	Stress on components and hardware. Shorter in-service life.
Increased humidity	More active humidity management required. Higher risk of damage to hardware, may affect reliability and life expectancy.	Damage to exposed assets. Shorter in-service life.	Damage to components and ICT hardware and supporting equipment. Can speed up degredation and affect reliability.
Increased storminess - wind and lightning	Not significant unless power, comms or transport links affected - second tier effects.	Cable heave (tree, roots, etc.) scour, aerial parts of network at risk–poles particularly and wires.	Cable heave, cables exposed from scour, aerial parts exposed, towers and masts subject to damage, microwave dishes displaced or misaligned.
Drought	Access ot cooling water for water cooled facilities. Subsidence.	Subsidence of fixed assets, fractured ducts.	Subsidence, fractured ducts.

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SECTION 2:

What to do

Who is best prepared?

Further research by Uptime Institute reveals that some data center operators report confidence that their facilities include features that will insulate them from climate change. They may be correct, as 66% of respondents say their facilities are operating within its expected life. These facilities may have been sited and built to minimize the effects of climate change, or at least these data center operators believe they were.

Respondents who view climate change as a crisis may be planning to weather its impact by migrating to a colocation/cloud service or building an entirely new facility. New facilities can be built to withstand higher winds and storm surges, on a higher plain away from the threat of floods, or near more plentiful water resources. New facilities can also be designed to operate efficiently at higher outdoor temperatures. In these circumstances, hardening or improving an existing data center may be deemed futile, as local infrastructure failures would isolate even the hardest of single data center facilities.

The level of awareness of climate change, and the level of preparedness, depends in part on the level of the threat. But it also depends on what your business is, where you are, and what your job is.

AMONG VERTICALS: COLOS REPORT BETTER LEVELS OF CLIMATE PREPARATION

Is your organization revising policies and/or planning to revise data center policies to adapt to climate change? Select all that apply:

	Colocation (%)	Telecom-munications (%)	Financial (%)	Software/Cloud Services (%)	Industry Average (%)
Preparing for climate change	**81**	**60**	**61**	**57**	**55**
Willingness to re-evaluate techngology selection	**54**	**33**	**33**	**32**	**33**

Source: Uptime Institute 2018 Data Center Survey (n=709)

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In our survey, by job category, for example, C-level executives were slightly more likely than facility or IT managers to report that their IT organizations were preparing for climate change in some way. Geography made little difference: Europe (37% reported not adapting to climate change) and Africa and the Middle East (34% not adapting) were only slightly more likely to be preparing for climate change than the world as a whole (45% not adapting). Europe (41%) and Africa and the Middle East (29%) also said they were more likely to be rigorously reporting IT/data center energy and carbon to corporate sustainability than the world as a whole (26%).

Newer facilities may withstand the effects of climate change

Ultimately, colocation providers proved most cognizant of the risk of climate change. Compared to other sectors, 81% of colo operators said they were preparing for climate change. Telecommunications (60%), financial (61%), and software and/or cloud services (57%) made up the remainder of the top four, with the industry average being 55%. Colos were also far more like to express willingness to re-evaluate technology selection (54%), far ahead of finance (33%), telecom (33%), and manufacturing (32%). And by small margins, colos were also more likely to report rigorous participation in corporate sustainability (36%) and to say they were re-evaluating site selection (19%) than other verticals.

Uptime Institute attributes some of these survey results to the nature of the colocation business. Our 2017 Uptime Institute survey found that colocation providers were far more likely than any other sector to report building or planning new space, which means that these firms are also re-evaluating much of what they build on a regular basis.

Evaluate resiliency early and often

Uptime Institute advises that organizations seeking to mitigate the most severe effects of climate change should implement a form of application resiliency, in which two or more data centers share workloads back and forth. Optimally, the two data centers should be located in two different regions but close enough so that latency does not become a concern.

Data centers should re-evaluate their resiliency and data center plans regularly. When kept up to date, these plans provide the basis for operational resiliency in the face of emergencies, including weather-related disasters likely to become more frequent as a result of climate change.

It is true that climate change preparations begin with site selection, but data center operators should know that new storm patterns, warmer temperatures, and increased flooding will vary on a region by region or facility by facility basis, meaning that assumptions made during design and site selection may become obsolete.

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Preparing for outages caused or exacerbated by climate change can be difficult because of the variety of new threats and because it is nearly impossible to judge the potential severity of some threats. While efficiency metrics such as PUE give the industry a fixed, and therefore relatively easy target to hit, climate change-related threats can be region wide and involve unforeseen elements.

Conversely, distributed IT architectures can protect IT operations against local data center outages. Reducing the number and severity of outages as the IT environment becomes more complex is effective, but distributed IT architectures can also be so complex that failures, recovery times, and costs are difficult to calculate.

As region-wide disasters become more common or more severe, planning an organization's IT resiliency becomes more complicated. Uptime Institute advises that disaster and emergency planning can no longer be isolated to equipment testing and emergency drills and procedures but instead must be conducted in the context of an organization's broader emergency and business-continuity plans.

At some point, every data center operator must justify the cost of every decision and hope that the facility is built to withstand the challenges it eventually meets. The relatively slow pace of climate change (relative to the expected life of a data center) makes this task more difficult.

Uptime Institute believes that data center operators should identify possible vulnerabilities and perform a cost-benefit analysis that may enable them to remain operational during severe conditions, as required to meet business objectives.

techUK, a UK-based industry group, has put forward a simple matrix approach, with the likelihood an event (1-5) multiplied by the severity of its impact on a data center (1-5).

The Matrix can be used to determine "RAG" ratings associated with risk scores generated during the risk assessment.

Impact					
5	10	15	20	25	
4	8	12	16	20	
3	6	9	12	15	
2	4	6	8	10	
1	2	3	4	5	
		Likelihood			

A simple matrix developed by techUK can be used to rank and prioritize risks revealed during a facility assessment. Source: techUK, 2018.

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While clearly illustrative, the matrix suggests 25 different possible risk profiles, with many requiring action to reduce either the likelihood of an event or to reduce its effect on the business. Conversely events that can be deemed improbable or unlikely to have a material effect on the data center can be disregarded. This approach can be seen as a high-level management tool for parsing problems.

Uptime Institute developed FORCSS to help organizations evaluate options to meet this sort of challenge. In a FORCSS engagement, Uptime Institute facilitators help organizations weigh IT options against each other, according to business objectives.

Assumptions made during site selection may be obsolete

Conducting a resiliency analysis is the first step. A resiliency assessment identifies a facility's strengths and vulnerabilities. Identifying and clarifying these qualities makes it possible for IT staff to build comprehensive and holistic solutions that make use of a facility's strengths and mitigate its weaknesses. In this step, Uptime Institute advises that organizations incorporate projections of environmental conditions produced by climate change. In this way, the results of the resiliency assessment will remain valid for a period of time.

Uptime Institute's Hybrid Resiliency Assessment provides operators with results that extend beyond the single facility. It is designed to reduce the risks associated with business service delivery when the underlying infrastructure spans multiple data centers, co-location sites, and clouds. It is an independent evaluation of an organization's hybrid infrastructure and ability to deliver specific IT services over the expected range of operating conditions.

Know the weather

Most businesses understand how an event involving a data center will affect the business. Calculating the likelihood and shape of a weather-related event can be more difficult. However, international organizations, insurance companies, and governments have created tools to help calculate the likelihood of natural disaster or temperature rise.

Some of these can be used to determine whether an event is a hundred-year flood or a thousand-year flood (see Appendix E: Hundred Year flood).

There is a variety of other tools available. For example, CatNet is an interactive map tool from the insurance company Swiss RE. It contains information on a number of natural hazards, including tornados, earthquakes, 'European winterstorm peak gust', hail, volcanoes, etc., and also flood risk. Swiss Re regards CatNet as a first attempt at a Worldwide Natural Hazard Atlas. The CatNet (http://ec.europa.eu/environment/water/flood_risk/flood_atlas/pdf/flood_maps_ch6.pdf) is accessible for external users who register, but only for a trial period of 8 weeks, after which it is a commercial service.

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Similarly, FM Global offers a global flood map (https://www.fmglobal.com/research-and-resources/global-flood-map). In the UK, the Environment Agency publishes a comprehensive map of all areas at risk of a one-in-100 year flood.

Using projections of environmental conditions extends the validity of a resiliency assessment

The Green Grid offers temperature maps and isometric charts that demonstrate the suitability of free cooling in certain geographies; these have been updated to reflect changing temperatures.

There are, of course, many real time, detailed weather services, some of which are designed specifically for utilities, energy providers, and other large-scale providers of infrastructure. One example is Schneider Electric (https://www.schneider-electric.ca/en/work/services/cloud/weather/energy/). Others include:

- National Weather Service (https://www.weather.gov/iwx/realtimespotter)
- The National Center for Atmospheric Research (http://weather.rap.ucar.edu/)
- The National Oceanic and Atmospheric Administration (https://nowcoast.noaa.gov/)
- PGASA (https://www1.pagasa.dost.gov.ph/index.php/20-weather/3653-daily-weather-forecast-2) Phillipines
- Hong Kong Observatory (https://www.hko.gov.hk/wxinfo/intersat/satellite/sate.htm) Hong Kong
- Sat24 (https://en.sat24.com/) Europe

Some of these services can be delivered via an API, so that the data can be integrated into a DCIM dashboard.

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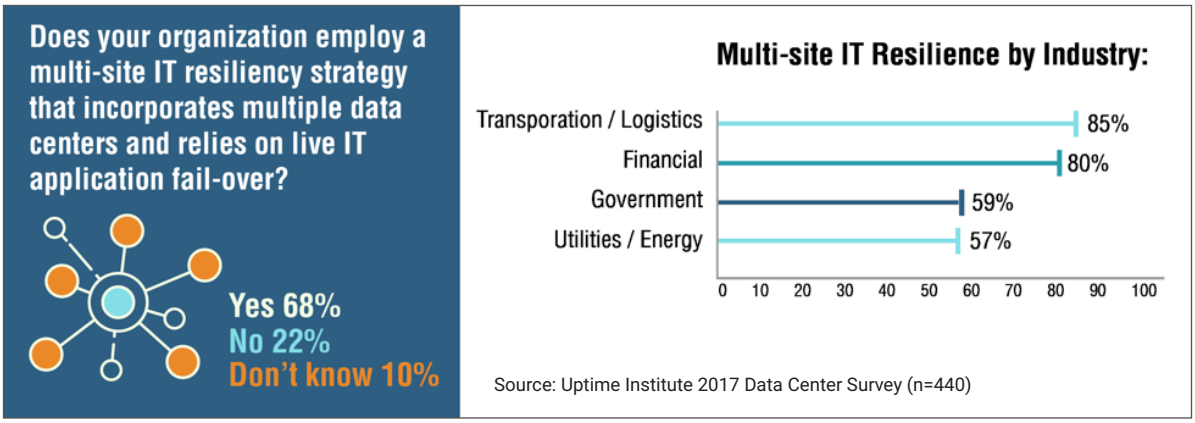
Distributing Risk: Application Resiliency

Throughout this report, reference has been made to the fact that climate change related events can be region wide, affecting not just a single site, but all surrounding infrastructure, nearby sites, local suppliers, and staff. For this reason, most operators wishing to ensure high levels of resiliency will adopt a multi-site resiliency model. This can range from out-of-region and off-line back up to rapid disaster recovery and near real-time, active-active out-of-region load shifting. Climate change type events make this method more attractive, notwithstanding its complexity.

In 2017, 68% of respondents to Uptime Institute's annual survey reported employing a multi-site IT strategy. In the 2018 survey, 61% of respondents say having workloads spread across on-premises, colo, and cloud data centers has made their organizations more resilient.



In recent years, distributed resiliency as pioneered by the larger hyperscales has evolved into a clear architecture of availability zones, some regional, some global, that distribute loads to increase resiliency and eliminate single site failures. This approach is variously called application resiliency, software-level resiliency, hybrid resiliency, network-level resiliency, and cloud-level resiliency. This is described in detail in our report Next Generation Resiliency (Appendix G).

OVERALL INDUSTRY ADOPTION OF RESILIENCY STRATEGIES

Which of the following do you deploy to achieve or enhance resiliency (Select all that apply)

Source: Uptime Institute 2018 Data Center Survey (n=467)

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Over time, the need for resiliency and how it is achieved at both the data center and application level will change significantly as the world gradually moves to more cloud-based, hybrid, and distributed architectures. Advances in hybrid and cloud computing, containers and virtualization, DevOps, replication, distributed databases, and global traffic management are coinciding with huge investments in data center and network capacity and a move towards greater use of software to intelligently manage workloads, traffic, and resiliency. All of these are combining to form an architectural shift, from single-site, vertical resiliency to distributed, replicated resiliency.

In the purest versions of this new resilience paradigm, applications and data can be spread across racks, data centers, and regions and may be blind to underlying data center or component failure—meaning that failures will have little impact and can be allowed to happen.

In the extreme case of the failure of a data center, or the isolation of one due to connectivity issues, this change means that IT resiliency can be achieved through rapid handover of workloads to alternate data centers, all under automated software control. Uptime Institute advocates investing in these models but strongly cautions that highly available and maintainable infrastructure will still be required.

Technology and process

Given the intractable problems posed by climate change, it would be little wonder if data center operators see themselves as having few good short-term options for dealing with the most extreme consequences of climate change.

This is not the case: some technologies and certainly good practice can reduce risks. For example, roughly one third of all respondents to our most recent Uptime Institute survey say they are re-evaluating technology selection based on shifting temperature ranges and water availability. This re-evaluation is in line with Uptime Institute's recommendations regarding how data centers should prepare for emergency weather conditions.

Many of the effects of global warming (rising sea levels and temperatures) will be incremental, and not all changes will be extreme. It will be important that data center operators prepare for these effects as well. Evaluating facilities for vulnerabilities can lead to simple changes such as:

- Elevating generators, moving pumps, or raising temperatures or contracting for supplies from out of region
- Developing and rehearsing operating procedures for emergencies
- Scheduling out of town workers for true emergencies
- Reducing energy and water consumption
- Improved lightning protection

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A thoughtful evaluation of facilities, even Tier III and Tier IV facilities, can reveal weaknesses, some of which might be fixed relatively easily. In one highly publicized example, a data center operator in New York City was forced to use a "fuel bucket brigade," moving fuel by hand up 18 stories for 48 hours in the aftermath of Superstorm Sandy. The brigade's heroics kept the data center online, but a better designed fuel system would have led to better operational sustainability (https://insidetrack.uptimeinstitute.com/member/resource/show/22107).

Data centers may become to blind to underlying failures

Similarly, Microsoft Azure recently suffered an outage in southwest Texas, which has been attributed to lightning strikes that were part of a strong storm. While these types of outages are rare, similar outages have affected Fujitsu, the Singapore Exchange, AT&T, Google, and other facilities in various places across the globe. Operators should include lightning protection as part of their resiliency assessments. However, in this and many other situations, public cloud users can take a different path; rather than evaluating lightning protection schemes and a laundry list of other issues, they can assess the provider's overall resiliency.

Every site and geographical location is different, so each operator should consider conducting a local analysis. The table below lists some of the areas of concerns, and some possible technologies and process changes that may reduce risk.

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STRATEGIES FOR MITIGATING CLIMATE CHANGE

Climate Change Condition	Local Condition	Potential Mitigation
Increased rain/rising ocean levels	Long term, recurrent, and higher flooding	• Check local flood maps • Confer with local authorities about infrastructure availability, including connectivity, utility power, and roads • Stock sandbags • Confer with local authorities about evacuation plans • Evaluate site: Elevate the entire data center, if possible. Elevate data halls, generators, diesel tanks and pumps, and electric conduit and cable where possible, especially in existing data centers • Harden exteriors, including any penetrations such as windows and doors Re-evaluate independence of utility power paths, connectivity, and emergency power systems, including the utility substation • Investigate load shifting
Drought	Water shortage	• Investigate ability to increase cooling capacity. Consider DX solutions • Investigate ability to operate at warmer temperatures • Investigate load shifting • Budget for higher cooling costs
Extreme Storm	High winds, increased and more frequent storms, increased lightning strikes	• Evaluate building shell • Enclose exterior structures, if possible • Eliminate on-site exterior storage • Re-evaluate independence of utility power paths, connectivity, and emergency power systems • Check lightning protection
Warmer global temperatures	Warmer local ambient air, greater temperature variation, colder local ambient air	• Investigate ability to increase cooling capacity • Investigate ability to operate at warmer temperatures • Increase building insulation to reduce solar loads • Check whether cooling and power systems that use outdoor air for cooling their own internal components, including engine generators, are rated to operate at the same capacity at the same capacity at the new extreme temperatures • Protect against freezing
Fire	Smoke and pollutants in air	• Investigate indirect cooling • Investigate additional filtration • Evaluate building shell
Other	Business interruption	• Review vendor SLAs, especially fuel • Investigate load shifting • Prepare for civil unrest • Review insurance policies • Review staffing requirements and availability

Source: Uptime Institute Research 2018

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Summary

In the wake of Superstorm Sandy in the US in late 2012, Uptime Institute found that only a couple of data centers followed industry best practices and went to engine generators before losing utility power (https://insidetrack.uptimeinstitute.com/member/resource/show/21637). These facilities were able to conduct a more orderly transition to backup power. Of the data centers surveyed at the time, 75% remained operational, with the key factor being reliable fuel supply.

Climate change will eventually raise the cost of power

The impact of that storm demonstrated that infrastructure and supplies are not the only key element in remaining operational in the wake of an expected storm. For example, in 2014 Uptime Institute recognized Morgan Stanley for the effectiveness of its storm planning. Their plan included provisioning data centers with food and comfortable resting places, as well as bringing staff in from out of town. The out-of-town staff performed effectively while those who lived in areas affected by the storm cared for their families and homes. Of course, Morgan Stanley had taken steps to familiarize its out-of-town staff with the affected facilities.

In an emergency, making efficient use of resources is not just a cost issue; it can be the difference between remaining operational and shutting down. A data center that uses the minimal required fuel and water during normal operation will find it easier to obtain adequate supplies in an emergency. It is still likely that some loads will be shifted but only as a way to stretch the supplies on hand and not because of waste. Additionally, the U.S. government expects that climate change will eventually raise the cost of power because of the amounts of water needed for fuel extraction and power generation.

Uptime Institute advises that data center operators prepare by analyzing current emergency weather plans, as climate change will manifest locally as extreme weather events. Updating and revising disaster preparation plans and procedures will provide a degree of resiliency.

However, preparing for the status quo will not be sufficient. Climate change will drive more frequent and more severe events, so Uptime Institute advises data center operators to continually review these plans as part of resiliency planning. The frequency and severity of change will vary by location, so data center operators must conduct these assessments facility by facility.

Climate change is already driving change that has made data centers more vulnerable to external threats. In this new environment, data center operators must conduct regular site resiliency assessments in the near term and evaluate distributed and out of region resiliency plans to remain operational as the effects of climate change become even greater. Data center operators must be sure to remain informed about regional disaster plans and vulnerabilities in local infrastructure that could impair viable operation.

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ABOUT THE LEAD ANALYST

Kevin Heslin is chief editor and director or Ancillary Projects, Uptime Institute. As chief editor, Kevin helped launch two new Uptime Institute information projects, Inside Track and The Uptime Institute Journal. At Uptime Institute, he has authored and co-authored numerous papers and case studies. Kevin has a more than 30-year career examining energy and sustainability issues from the end-user perspective. He has worked in academic, non-profit, and standards organizations, in addition to serving as editor of various print publications.

Uptime Institute is an unbiased advisory organization focused on improving the performance, efficiency, and reliability of business critical infrastructure through innovation, collaboration, and independent certifications. Uptime Institute serves all stakeholders responsible for IT service availability through industry leading standards, education, peer-to-peer networking, consulting, and award programs delivered to enterprise organizations and third-party operators, manufacturers, and providers. Uptime Institute is recognized globally for the creation and administration of the Tier Standards & Certifications for Data Center Design, Construction, and Operations, along with its Management & Operations (M&O) Stamp of Approval, FORCSS® methodology, and Efficient IT Stamp of Approval.

Uptime Institute – The Global Data Center Authority®, a division of The 451 Group, has office locations in the U.S., Mexico, Costa Rica, Brazil, U.K., Spain, U.A.E., Russia, Taiwan, Singapore, and Malaysia.
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SECTION 3:

Appendices

Appendix A. The Eighth Annual Uptime Institute Data Center Survey: Operators struggle with constraints, change, and complexity This report draws on the results of the Eighth Annual Uptime Institute Data Center Survey, which provides an overview of the major trends shaping IT infrastructure delivery and strategy. The survey was conducted via email between February and May 2018. It includes responses from 867 data center operators and IT practitioners globally from enterprise and service provider facilities. For further analysis of the survey results, see https://insidetrack.uptimeinstitute.com/member/resource/show/24664.

Appendix B. Advisory: Integrating Corporate Sustainability and IT Operations. Inside Track. https://insidetrack.uptimeinstitute.com/member/resource/show/24042.

Appendix C. Uptime Institute data shows outages are common, costly, and preventable. https://insidetrack.uptimeinstitute.com/member/resource/show/24628.

Appendix D. Outside pressure, environmental sustainability, and data centers

To date, the investor community has applied significant pressure on data centers to prepare for the impacts of climate change. Almost without exception, industry groups and government have focused their attention on carbon and energy. Efforts such as LEED, PUE, and even Uptime Institute programs such as Efficient IT can be fairly described as efforts to control or limit energy waste and carbon emissions. These tools can mitigate or even help partially avoid climate change but do not help an organization meet the effects of climate change. Many would argue that the government and other private authorities are rightly focused on minimizing the effects of climate change, especially on human life, and that operators of data centers and large corporations are well positioned to fend for themselves, even in worst-case scenarios.

In the UK, for example, a highly regarded Climate Change Agreement disbursed £21 million annually to compile measured energy use data and establish energy efficiency (PUE) reductions. As a result, the UK claims to be the only country in the world to have collected site-level energy use data for its data centers. Collecting this data is a good thing, as is establishing a regional goal to reduce average PUE by 15% between 2011 and 2020, but it hardly constitutes preparing for the effects of climate change.

Not all sustainability offices reference data center or even IT operations. Instead many of these offices encourage, track, and report key performance initiatives, including energy, water, and carbon use across the entire company, with IT performance being just a component. These sustainability offices, especially when led by a C-suite executive, address investor demands related to market capitalization, financial returns, and long-term risk management. They also enable companies to meet the sustainability demands of end use customers and to remain active in supply chains in their own verticals. In addition, companies that proactively manage their environmental footprint should have reduced exposure to negative media attention or from non-governmental organizations like Greenpeace.

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These demands are typified by Laurence Fink, CEO of Blackrock, one of the world's largest global investment managers, who wrote an open letter to CEOs in February 2016. He said, "Generating sustainable returns over time requires a sharper focus not only on governance, but also on environmental and social factors facing companies today.

100-year floods and storms involve more rain and greater levels of flooding.

"Over the long-term, environmental, social, and governance (ESG) issues—ranging from climate change to diversity to board effectiveness—have real and quantifiable financial impacts. At companies where ESG issues are handled well, they are often a signal of operational excellence. BlackRock has been undertaking a multi-year effort to integrate ESG considerations into our investment processes, and we expect companies to have strategies to manage these issues. Recent action from the U.S. Department of Labor makes clear that pension fund fiduciaries can include ESG factors in their decision making as well."

Fink has continued his pressure campaign, joined by other active investors and more recently by index funds Vanguard and State Street, which jointly control many trillions of investment dollars. "Last year, BlackRock, Vanguard, and State Street made the news when, for the first time, they voted in favor of a resolution that required Exxon to report on the financial impact that climate change could have on the company," wrote Janet Brown, CEO of FundX Investment Group on ThinkAdvisor (https://www.thinkadvisor.com/2018/06/27/can-governance-impact-investing-make-a-difference/?slreturn=20180617102602).

These activities are significant as they affect the overall profitability of a company, its market cap, its share prices, its investment outlook, and its costs of borrowing. Previous Uptime Institute research has identified a number of studies that suggest that responsible ESG companies outperform other firms in these key areas.

In order to further their transparency and credibility, many companies go a step further by following Carbon Disclosure Project (CDP) or Global Reporting Initiative (GRI) reporting protocols, with some adhering to both. GRI and CDP are the primary organizations that drive most of sustainability reporting worldwide, and fifteen of the 24 sustainability reports examined by Uptime Institute made mention of one or both of these reporting formats; seven reported using both.

From the CDP website: "CDP investor initiatives—backed in 2015 by more than 827 institutional investors representing an excess of US$100 trillion in assets—give investors access to a global source of year-on-year information that supports long-term objective analysis. This includes evidence and insight into companies' greenhouse gas emissions, water usage, and strategies for managing climate change, water, and deforestation risks."

In addition to meeting the growing demands from the investor community, CDP and GRI reports help companies meet consumer and business to business demands for environmentally responsible products and also enable the organizations to participate in supply chains where sustainability is a requirement.

Contrary to Uptime Institute's expectations based on prior research, critical facilities management (33%) was more likely to say their organization was rigorously reporting to corporate sustainability than either C-level (18%) or IT management (23%). All these findings are lower than results from the 2017 survey in which 76% of all respondents (IT involvement=70%) said they had a defined and funded corporate sustainability program. They also said they reported an extensive list of KPIs.

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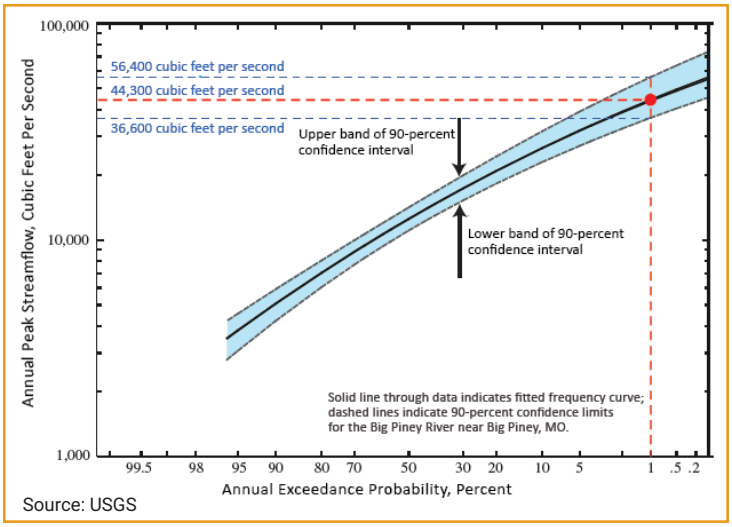

Source: USGS

Appendix E: 100-year weather events

According to the USGS (https://water.usgs.gov/edu/100yearflood-basic.html), the U.S. government adopted the 1% annual exceedance probability (AEP) flood as the basis for its National Flood Insurance Program in the 1960s, seeing it as a fair balance between protecting the public and overly stringent regulation. Because the 1% AEP flood has a 1 in 100 chance of being equaled or exceeded in any single year and it has an average recurrence interval of 100 years, it has come to be known as the "100-year flood." More recently, the 100-year terminology has been applied to events such as storms, droughts, hurricanes, and tsunamis.

Scientists and engineers frequently use statistical probability (chance) to put a context to floods and their occurrence.

If the probability of a particular flood magnitude being equaled or exceeded is known, then risk can be assessed. To determine these probabilities, the U.S. Geological Survey (USGS) operates more than 7,500 stream gages nationwide where the height of the water and the quantity of flow (streamflow) of a river are recorded. Examining all the annual peak streamflow values with time allows us the USGS to estimate the AEP for various flood magnitudes. For example, we can say there is a 1 in 100 chance that next year's flood will equal or exceed the 1% AEP flood.

More recently, people talk about larger floods, such as the "500-year flood," as tolerance for risk is reduced and increased protection from flooding is desired. The "500-year flood" corresponds to an AEP of 0.2%, which means a flood of that size or greater has a 0.2% chance (or 1 in 500 chance) of occurring in a given year. Rather, a 500-year flood is an event that has a 1 in 500 chance of occurring in any given year. "For a 500-year flood, there is a 0.2% chance of having a flood of that magnitude occurring" in any given year, according to the National Weather Service.

The 1% AEP flood has a 1% chance of occurring in any given year; however, a building in the 100-year floodplain and having an expected life has a 26% chance of being flooded at least once. The value of 26% is based on probability theory that accounts for each of the 30 years having a 1% chance of flooding.

The USGS does not talk about increasing frequency of 100-year floods or other events. However, climate change has brought a recognition that 100-year floods and storms involve more rain and greater levels of flooding, thus 100-year flood plains can be seen as larger. In Houston, Texas, for example, the high-water mark of a 100-year flood is 3.5 feet higher than it was in recent years, and that level is now reached every 30 years.

Similarly, Coupled Model Intercomparison Project Phase 5 (CMIP5) models from the World Climate Research program indicate that storm-surge heights in New York City will increase only slightly from 2010 to 2100 or 2300, because the predicted strengthening of the strongest storms will be compensated by storm tracks moving offshore. However, the projected sea-level rise will cause overall flood heights associated with tropical cyclones in New York City increase greatly compared with modern flood heights. The CIMP5 predicts the 1-in-500-year flood event will increase from 3.4 meters above mean tidal level (1970–2005) to 4.0–5.1 meters by the end of this century. CIMP5 predicts the frequency of

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heights. The CIMP5 predicts the 1-in-500-year flood event will increase from 3.4 meters above mean tidal level (1970–2005) to 4.0–5.1 meters by the end of this century. CIMP5 predicts the frequency of a 2.25-meter flood will increase from ~500 years before 1800 to ~25 years from 1970–2005 and to ~5 years by 2030–2045. For more information about these projections, visit: http://www.pnas.org/content/early/2017/10/03/1703568114

Appendix F. The UK'S Core Digital Infrastructure: Data Centres. Climate Change Adaptation and Resilience. http://www.techuk.org/images/ICT_ARP_response_to_DEFRA_2016.pdf

Appendix G. Next Generation Resiliency. https://insidetrack.uptimeinstitute.com/member/resource/show/24194

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