June 2026

Powering Up

Building Climate Resilience into India’s Renewable Energy Future

Content

Executive summary

India is building its renewable energy future at extraordinary speed. However, the climate that these renewable assets face is already changing. Acting now – through smarter design, better site selection and targeted resilience measures – could protect them from the worst of the changes to come. A relatively modest investment of around USD 4.6bn, equivalent to 2% of the portfolio's replacement cost, has the potential to reduce the financial impact of climate risk on India's renewable energy assets from USD 55bn to USD 27bn. That is a 6x return on every dollar invested in resilience.

India became the world's third-largest renewable energy capacity generator in 2026, with installed non-fossil capacity reaching 283.5 Gigawatts (GW) by March. Renewable generation is expanding at around 11% annually, keeping consistent with the trajectory needed to meet the national 2030 target of 500 GW from non-fossil sources[1].

However, the climate these renewable generation assets will operate in is changing in ways that matter directly to anyone who owns, finances, insures or depends on them. Asia is warming nearly twice as fast as the global average and India is already experiencing the consequences with heatwaves becoming more intense, frequent and geographically widespread since the turn of the century.

According to the Global Energy Monitor, which is the lead data source for this report, there are 1020 planned renewable energy sites, encompassing solar PV, onshore wind and hydropower, spread across India. However, nearly 90% of this capacity, 871 assets, sits in just 10 states/union territories – Andhra Pradesh, Arunachal Pradesh, Gujarat, Karnataka, Ladakh, Madhya Pradesh, Maharashtra, Rajasthan, Uttar Pradesh and Uttarakhand. Therefore, for the purposes of this report, we have focused on the climate impacts in these 10 states/union territories.

We have used IPCC-aligned scenarios (SSP2-4.5) and our own insights of historic loss and damage to classify each of the 871 renewable energy generation assets, across 16 hazards, into five risk categories, as indicated by the chart on the right. For the purposes of this report, we have defined assets at category 3 as high risk and categories 4 and 5 as critical risk because at this level insurability will come into question.

Using this framework, the data tells a striking story. 729 renewable energy generation sites, accounting for approximately 239 GW, or 90%, of the total planned generation capacity is at high or critical risk of being adversely affected by climate risks by 2030. In more simple terms, this equates to the approximate annual power needs of 300 million households[2]. However, our modelling shows that there is a clear opportunity to materially reduce those risks, with investment in resilience capable of halving expected future losses - if done now.

Risk to Indian renewable generation pipeline capacity by 2030

27%	Category 5	Assets face **~30%** chance of experiencing a major, relevant climate event by 2030 and typically have **3** to **4** key climate hazards.
39%	Category 4	Assets face **~20%** chance of experiencing a major, relevant climate event by 2030 and typically have **2** to **3** key climate hazards.
23%	Category 3	Assets face **~15%** chance of experiencing a major, relevant climate event by 2030 and typically have **2** key climate hazards.
10%	Category 2	Assets face **~10%** chance of experiencing a major, relevant climate event by 2030 and typically have **1** to **2** key climate hazards.
0%	Category 1	Assets face **~5%** chance of experiencing a major, relevant climate event by 2030 and typically have maximum **1** key climate hazard.

1. India becomes World's third-largest renewable energy capacity holder, DD News, 8 April 2026
2. Derived from per-capita electricity consumption of ~1,331 kWh in FY2022–23 (Government of India) and an average household size of ~4.4–4.5 persons, implying ~6–7 MWh per household per year.

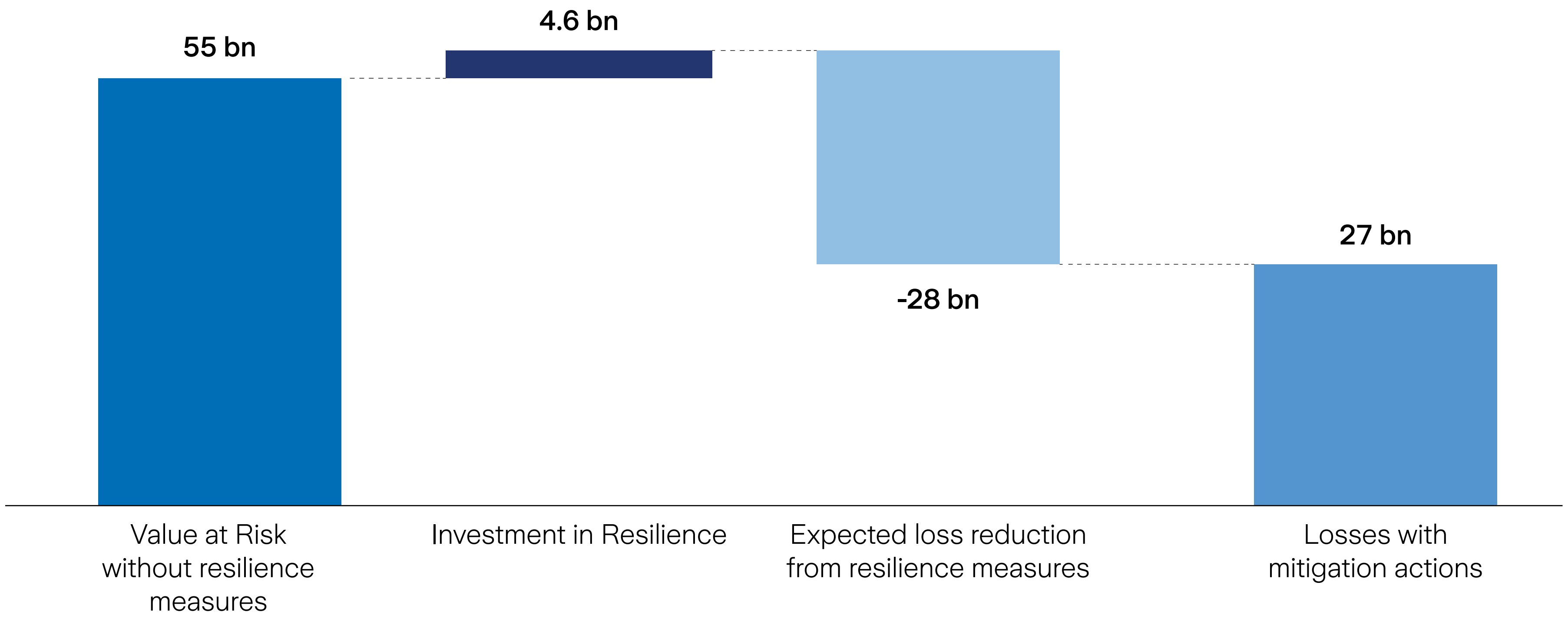
The financial case for resilience.

The financial case for acting now is both clear and compelling. Our analysis puts the Value at Risk (VaR) – the replacement cost across the assessed portfolio under a severe climate scenario – at approximately USD 55bn. That figure represents the exposure that asset owners, lenders and insurers face if climate risks go unaddressed.

Our experience across global energy portfolios shows that proactive resilience measures, embedded at design and construction stage when engineering flexibility is at its greatest and costs are lowest, can materially reduce that figure. An investment of approximately USD 4.6bn – around 2% of the portfolio's total replacement cost – could reduce losses to approximately USD 27bn. This is a potential reduction in losses of USD 28bn, delivering a return of approximately 6x on the resilience investment, with higher potential returns when planning-stage site selection is factored in.

Value of proactive resilience for India's renewable energy pipeline

USD values (billions) are in present value terms (2026)



Unless otherwise stated, all asset counts, generation capacity and Value at Risk (VaR) references in this report relate to the assessed portfolio of announced, planned and under-construction renewable-energy assets and do not represent the total installed renewable-generation fleet in each country.

The good news is that the measures needed to protect these assets are already well understood and many of India's renewable projects are still at planning or construction stage. This means there is still time to build resilience in before design decisions become fixed.

This report shows that if we act now, we can protect India's renewable energy transition. To support this, we have identified five key actions that asset owners should take to move India's renewable portfolio from risk to resilience:

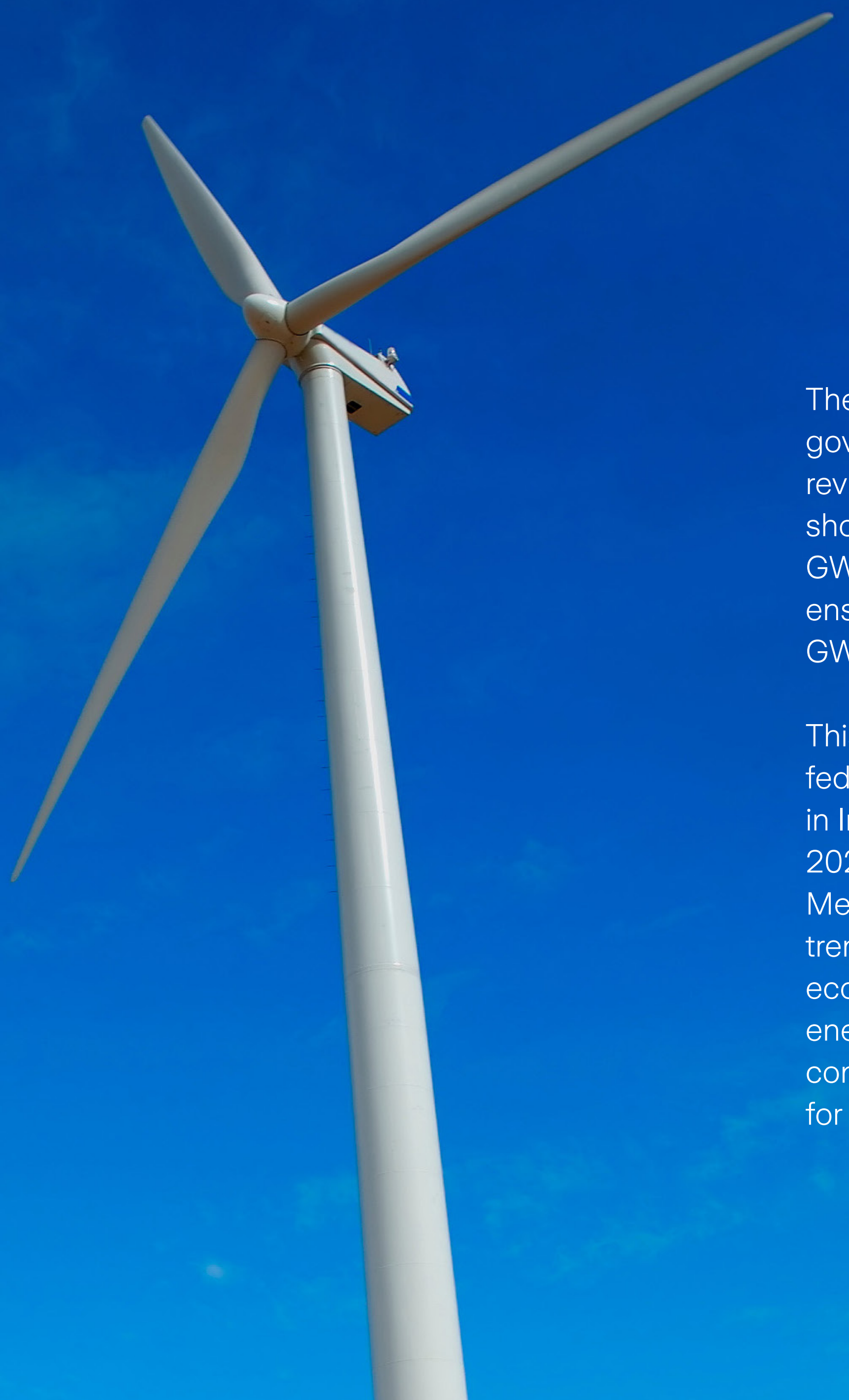
1. Make forward-looking climate screening standard at planning and permitting
2. Stress-test the highest-risk assets first while design choices are still flexible
3. Build hazard-specific resilience into procurement standards
4. Treat system resilience — substations, roads, grid connections, emergency response — as part of asset resilience
5. Use resilience quantification to strengthen the investment case with lenders, insurers and shareholders

None of these require a fundamental change in the economics of clean energy. They simply require earlier analysis, better design standards and a more integrated view of asset, operational and financial risk. For CEOs, building resilience is a question of competitiveness. For CFOs, it is a capital protection issue. For Heads of Sustainability, it is a transition quality issue. For Heads of Risk, it is the route from static exposure awareness to active loss avoidance

This report sets out how India's build-out fits into a rapidly changing regional and global energy landscape, what the data tells us about the risks those assets face, what good resilience practice looks like in action, and the five steps that will make the difference between an energy transition that is merely ambitious and one that is also durable.

India's energy moment

India's renewable build-out is one of the most important infrastructure stories in Asia Pacific. It is being driven by rising power demand, industrial growth, electrification, manufacturing policy and energy security concerns, all at a time when clean power has become more economically compelling. That combination explains the scale of ambition and why resilience must now be treated as a core design principle rather than a late-stage adjustment.



The pace of the energy transition is significant. The government's National Statistics Office[3] released its annual review of the energy sector in India in March 2026 which showed installed renewable capacity reached over 229.3 GW in 2025. This puts the annual growth rate at around 11%, ensuring the country is on track to meet its 2030 target of 500 GW from non-fossil fuel sources.

This trend is part of a wider regional shift. Data[4] from India's federal grid regulator shows that renewable power output in India grew more than 24% year-on-year in the first half of 2025, its fastest pace in three years. Meanwhile, the World Meteorological Organization has warned that Asia's warming trend is intensifying climate stress across economies, ecosystems and infrastructure. In other words, India's clean energy acceleration is happening at the same time as climate conditions across Asia Pacific are becoming more challenging for asset owners.

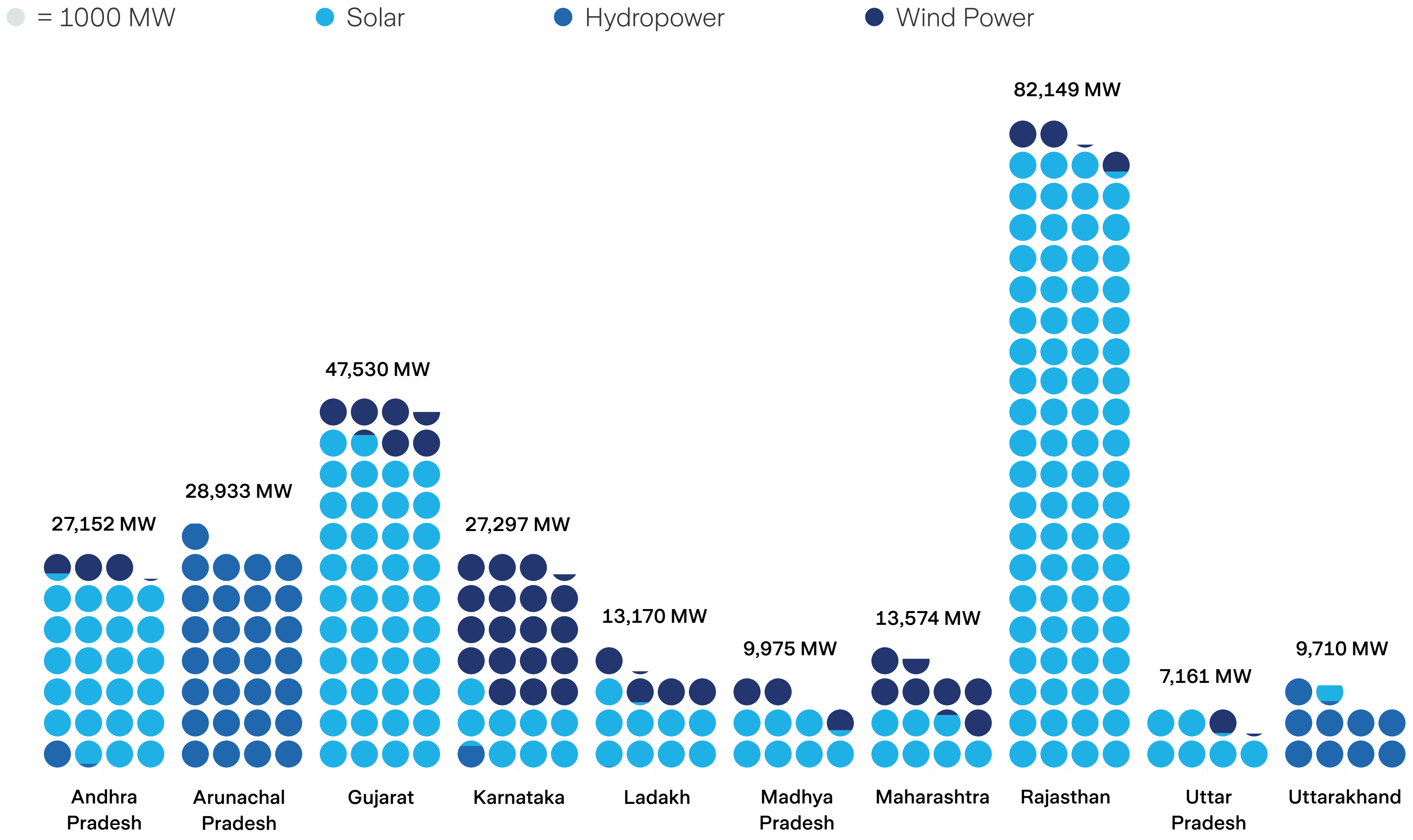
3. Energy Statistics 2026, Government of India, 27 March 2026
4. Renewable power output jumps 24%, Reuters, 2 July 2025

This is important because renewable projects are not simply expressions of sustainability intent. They are capital-intensive, long-life assets that influence financing, land use, procurement, operations, supply chains and corporate resilience simultaneously. For enterprise customers, especially in the renewable sector, the quality of the transition will increasingly depend on whether climate resilience is built into site selection, engineering standards and operating models from the outset.

India's state-level geography adds another layer of importance. The Indian government's Energy Statistics India 2026 report[5] highlights that renewable potential is heavily concentrated in a relatively small number of states. That concentration can support scale and efficiency, but it also means that hazard exposure in key geographies can have outsized implications for portfolios, lenders, insurers and supply chains.

To protect India's energy future, resilience must be treated as an enabler of growth, helping protect reliability, avoid avoidable losses and improve confidence among investors, insurers and enterprise customers.

Renewable pipeline capacity by state and technology



Source: Global Energy Monitor, February 2026

5. Energy Statistics 2026, Government of India, 27 March 2026

Climate risk is not a future problem

Climate risk is already reshaping the operating environment for infrastructure across India and the wider Asia Pacific region. The practical question for asset owners is no longer whether climate volatility matters, but how quickly organisations can adapt planning, engineering and investment decisions to conditions that are already changing.

The World Meteorological Organization's 'State of the Climate in Asia[6]' report points to widespread and prolonged heatwaves, record-high sea surface temperatures, destructive tropical cyclones, extreme rainfall, droughts and sea level rise in parts of the Pacific and Indian Oceans that exceeded the global average.

In India, this is resulting in heatwaves that have become more intense, frequent and spread more widely since the turn of the century[7] with parts of western India, the southeastern coast and the North Indian Plain most at risk. This changing weather pattern also affects energy demand as air conditioning is used more often.

At the same time, India received 8% more rain in 2025's monsoon season, the second consecutive year of increased rainfall. The data from the India Meteorological Department suggests that the trend is likely to continue with climate change rapidly impacting the country.

These trends affect infrastructure directly: flooding disrupts substations, roads, drainage, foundations, switchgear and access routes; drought changes generation reliability for hydropower and can affect wider cooling and water management assumptions; and heat creates ideal circumstances for wildfires.

6. State of the Climate in Asia 2024, World Meteorological Organization, 23 June 2025
7. Heatwaves become more intense, Nature, 12 February 2026

Wind, tornado, flood and hail are the most material hazards

Category	Asset Type	Wind	Flood	Storm Surge	Drought Duration	Drought Severity	Wildfire	Hail	Precipitation	Tornado	Earthquake	Cold Wave	Frost Days	Heatwaves	Hot Days	Sea Level Rise	Volcano
Generation	Solar	VH	VH	M	L	L	H	VH	L	VH	M	L	L	L	L	L	M
	Wind	VH	M	M	L	L	M	L	L	VH	M	L	M	L	L	L	M
	Hydropower	L	VH	L	H	H	L	L	L	M	H	H	H	L	L	L	H

The impact levels represent the generic potential for damage or operational disruption at portfolio level, considering asset generic characteristics, exposure of critical components, reliance on environmental conditions and likely recovery time. Very High (VH) and High (H) ratings are assigned where hazards can directly interrupt generation or lead to prolonged outages.

Our previous reports covering Southeast Asia, Europe and Canada all show the same underlying pattern: renewable and storage assets are often more climate-sensitive than they first appear, and much of the avoidable loss sits outside the core generating equipment itself.

This has clear commercial consequences. Climate risk influences operating continuity, maintenance needs, financing assumptions and insurance market confidence. As a result, asset resilience determines insurability and bankability.

In short, waiting carries a cost. Many of India's renewable projects are still in development, construction or early operating phases, which means a window of opportunity exists to improve site screening, strengthen design and align procurement with future climate conditions before vulnerabilities are locked in for decades. The question is not whether to act, but where the exposure is greatest.

Protecting the portfolio at risk

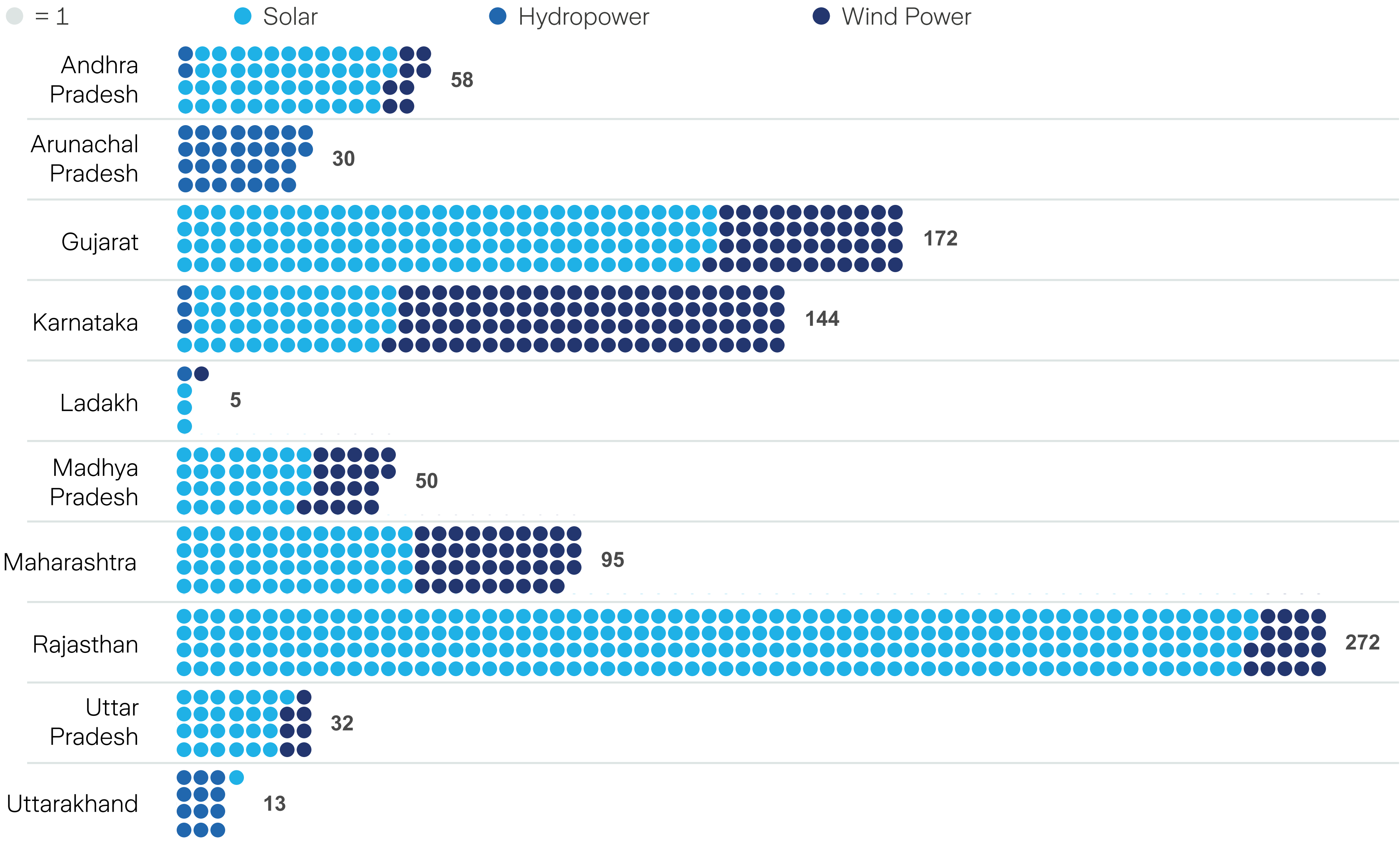
Our analysis of India's renewable energy portfolio shows a pipeline that is large, strategically important and materially exposed to physical climate risk.

Across 871 sites in the ten states with most renewable energy capacity, with a combined planned capacity of approximately 267 GW, the data highlights concentrated exposure to tornado, wildfire, flood and hail with 90% of assessed assets as high or critical risk, of which 66% are rated critical by 2030.

This is not a reason for alarm; it is a reason to act now, while many of these assets are still in planning or construction and resilience can still be built in at the lowest cost.

Solar dominates India's pipeline by both site count and capacity. Wind and hydropower contribute meaningfully but at smaller scale. The table overleaf summarises the assessed portfolio.

Number of planned renewable assets by technology and state / union territory



Source: Global Energy Monitor, February 2026

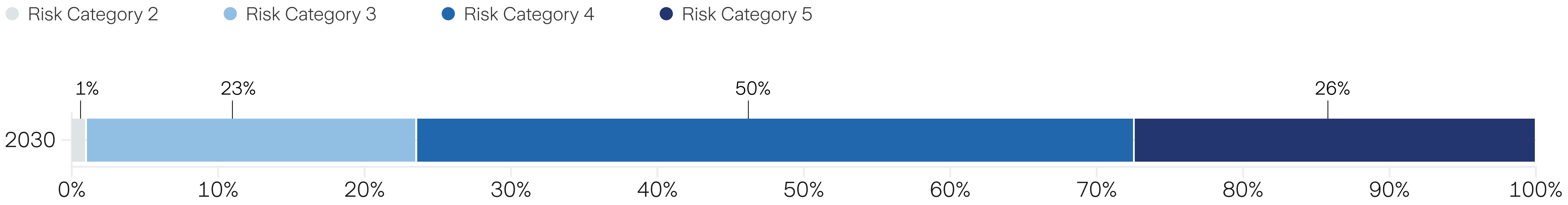
Solar PV

Solar is the defining technology in India's renewable pipeline, accounting for 593 of the 871 assessed sites and 182,286 MW – nearly 70% of total assessed capacity. Rajasthan alone holds 254 solar sites with 79,279 MW of planned capacity, followed by Gujarat (127 sites, 41,784 MW) and Andhra Pradesh (48 sites, 23,132 MW). This concentration of solar development in a small number of states means that state-level hazard conditions can affect a very large share of portfolio value.

For solar, the dominant hazards are tornado, hail, wildfire and flood. Hail creates both direct visible damage — shattering glass layers — and hidden defects that degrade performance over time and only appear later through reduced output. Wildfire smoke can reduce solar irradiance by as much as 70%, while wind and tornado events can damage tracking systems, mounting structures, inverters and wider balance-of-plant in ways that cause prolonged outages.

Many of these events are avoidable. Effective resilience starts with avoiding low-lying and poorly drained sites where possible and then building in stronger racking systems, elevated and waterproofed electrical equipment, better stormwater management and operating procedures for pre-event shutdown and post-event inspection. Hail resilience deserves particular attention in exposed locations, including glass specification, module choice and, where appropriate, tracker systems that allow panels to be moved into more protective positions.

Solar PV renewable generation pipeline capacity (%) by risk category (~2˚C warning scenario)



Wind power

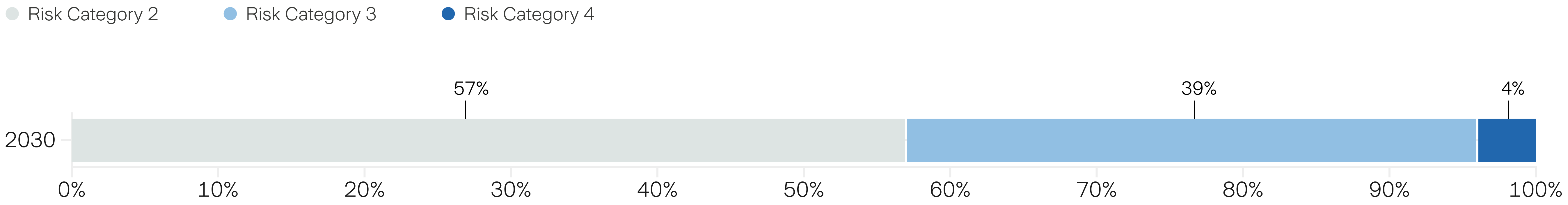
Wind is India's second-largest technology by capacity in this portfolio accounting for 230 of the 871 sites assessed in this report and accounts for approximately 44,177 MW of planned capacity. Karnataka dominates wind development with 93 sites and 18,223 MW, followed by Maharashtra (39 sites, 6,817 MW) and Gujarat (45 sites, 5,746 MW). These corridors span some of India's most productive wind resource zones, but they also sit in areas exposed to extreme wind events, flooding and the wider consequences of intensifying monsoon and cyclone patterns.

Good practice in wind resilience means starting well before turbine delivery: site selection informed by forward-looking climate projections rather than historical averages, and turbine class specification that reflects the full range of conditions the asset is likely to face over a 25–30-year life.

Just as importantly, resilience in wind projects is not only about turbines. Substations, switch rooms, collection systems, communications equipment and access routes often become critical points of failure during extreme events.

Stronger foundations, wider or deeper footings where needed, redundancy for yaw and braking systems, better drainage, slope stabilisation and clear post-event inspection protocols can all materially reduce loss and shorten recovery time.

Wind power renewable generation pipeline capacity (%) by risk category (~2˚C warning scenario)



Hydropower

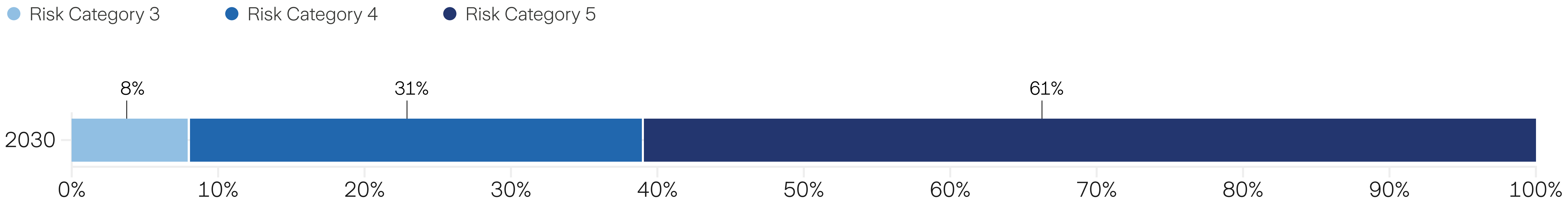
Hydropower represents the smallest share of the assessed portfolio by site count – just 48 sites – but contributes 40,188 MW of capacity and carries disproportionately high financial exposure due to the capital intensity of this type of civil infrastructure.

Two states account for almost all hydro capacity, with Arunachal Pradesh holding the largest portfolio in the assessed states (30 sites, 28,933 MW). Uttarakhand contributes most of the remaining capacity (12 sites, 9,210 MW) with Andhra Pradesh, Karnataka and Ladakh all having nominal capacity.

Hydropower resilience increasingly depends on recognising that historical hydrology is a weak guide to future performance. Changing flow patterns, drought, extreme rainfall, sedimentation and slope instability all affect generation reliability and asset condition and mean that operators who rely only on historical averages are likely to underestimate future variability.

Good practice therefore means using forward-looking hydrological scenarios, stress-testing both flood and drought conditions, understanding upstream catchment change and sediment dynamics and integrating climate-adjusted reservoir operations into project design and management. Spillway upgrades, sediment bypass or flushing systems, better monitoring and stronger emergency response arrangements can all deliver resilience benefits at a cost that is relatively modest to the long-term value of the asset.

Hydropower renewable generation pipeline capacity (%) by risk category (~2˚C warning scenario)



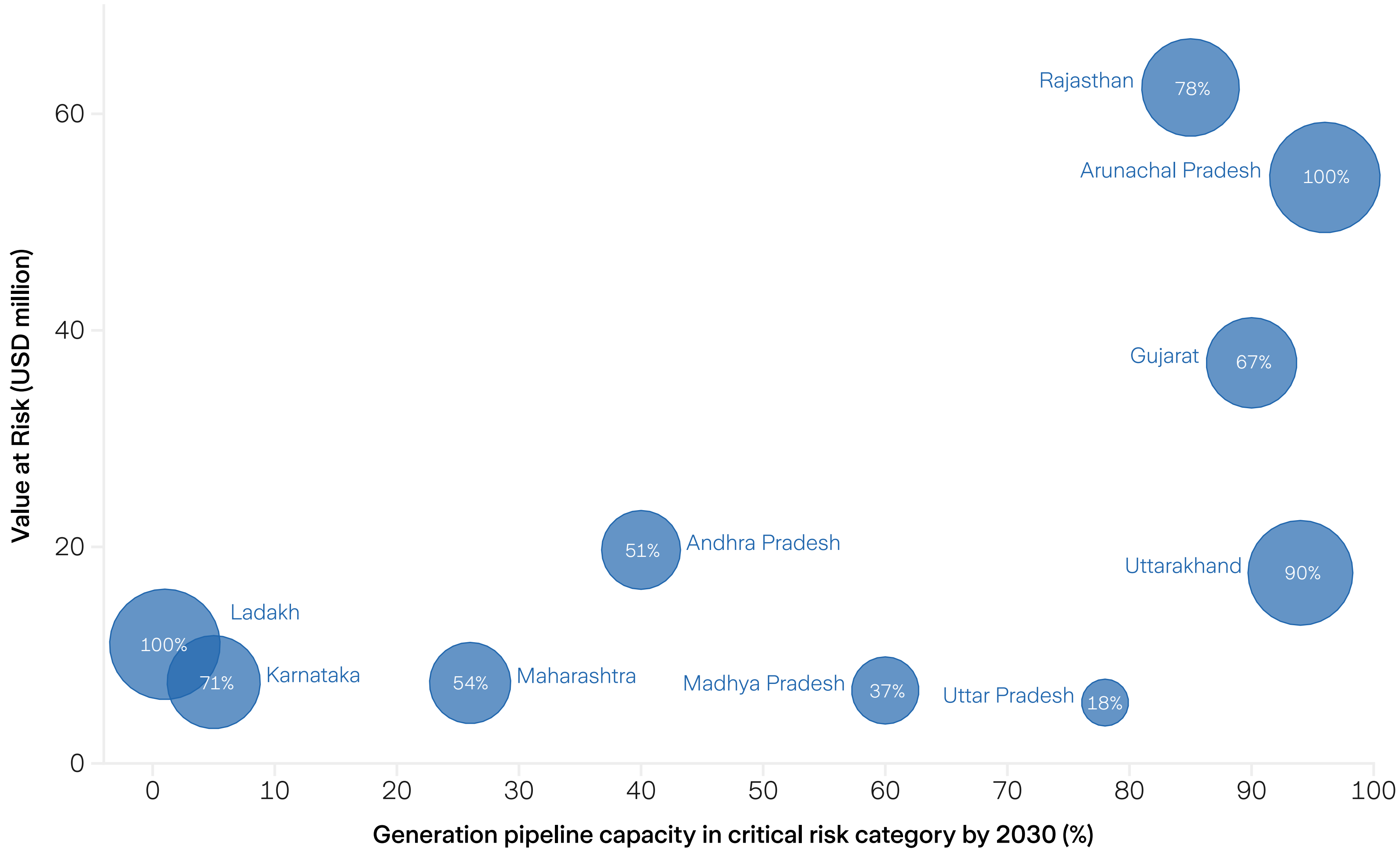
Risk by state / union territory

The analysis on the right compares Value at Risk (VaR) which reflects the total value of the renewable energy assets in each of the top 10 states, against the percentage of assets deemed to be at 'Critical Risk' in categories 4 and 5 by 2030. The bubble size reflects the forecast percentage of renewables in the overall energy mix of each state by 2030.

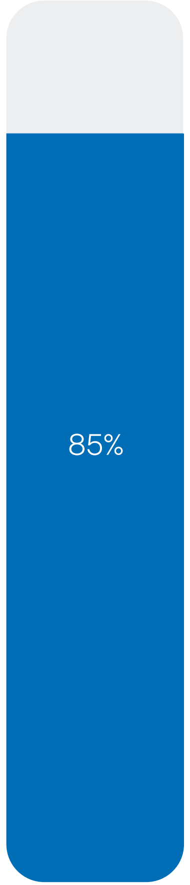
While the chart gives an indication of the relative exposure, each state has its own combination of climate hazards, demand pressures and economic dynamics.

The snapshots that follow look at those factors in more detail — setting out what is driving energy consumption upward and what climate conditions are making the generation of that energy more challenging.

Comparison of states / union territories according to Value at Risk, Risk Profile and % of Renewables as Proportion of Planned Energy Mix by 2030



State Snapshots



Rajasthan - 272 sites

82,149 MW Capacity · VaR USD 16.4bn · 85% at Critical Risk (4/5)

India's largest renewable energy generating state by a considerable margin, Rajasthan holds 272 assessed sites spanning 82,149 MW of planned capacity and carries the highest absolute Value at Risk in the portfolio at USD 16.4bn. Solar dominates the mix, making Rajasthan central to India's 500 GW non-fossil target.

Temperatures regularly exceed 50°C in the state, simultaneously stressing solar panels and the balance-of-plant they depend on. That heat also drives some of India's highest per-capita cooling loads while the rapid urbanisation of Jaipur and Jodhpur will push electricity consumption higher still in the decades ahead.

Gujarat - 172 sites

47,530 MW Capacity · VaR USD 8.6bn · 90% at Critical Risk (4/5)

Gujarat's 172 assessed sites span 47,530 MW across both solar and wind technologies, placing it second in the portfolio by capacity. With 90% of assets in categories 4 or 5 it carries a VaR of USD 8.6bn. The hazard profile is particularly complex: in addition to the hail and tornado exposure it shares with Rajasthan, Gujarat's long coastline introduces cyclone and storm surge risks that affect coastal solar and wind assets.

On the demand side, Gujarat is one of India's most industrially dynamic states. Its expanding EV manufacturing base and growing green hydrogen ambitions will drive sustained power consumption growth over the next decade, making resilient generation a genuine economic necessity.

State Snapshots

96%

Arunachal Pradesh - 30 sites

28,933 MW Capacity · VaR USD 13.1bn · 96% at Critical Risk (4/5)

Arunachal Pradesh presents the most striking risk profile in the portfolio. Just 30 assessed sites carry a VaR of USD 13.1bn and 96% of those assets sit in the critical risk categories 4 and 5. The portfolio is almost entirely hydropower, concentrated in the eastern Himalayan foothills where high precipitation, slope instability, seismic activity and flood risk create a severe and compound hazard environment. Energy generated here flows into India's northeast grid, serving a region with limited alternative supply, which means any climate-driven disruption carries system-level consequences well beyond the state itself. Given the scale of financial exposure and the difficulty of post-event access, climate-informed siting and robust engineering are fundamental requirements.

5%

Karnataka - 144 sites

27,297 MW Capacity · VaR USD 1.9bn · 5% at Critical Risk (4/5)

Karnataka is a relative outlier, with 144 assessed sites and 27,297 MW of planned capacity – predominantly wind, with 93 sites and 18 GW concentrated in the state's southern corridors. At just 5% in categories 4 or 5, it has the lowest critical-risk rate in our analysis, reflecting a more moderate hazard environment overall. Flood risk during intense monsoon events and slope instability in the Western Ghats remain relevant considerations for planners.

Karnataka faces some of India's fastest-growing industrial electricity consumption: Bengaluru's technology sector is already one of the country's largest commercial power users and rising urban cooling loads will add further pressure.

State Snapshots

40%

Andhra Pradesh - 58 sites

27,152 MW Capacity · VaR USD 4.4bn · 40% at Critical Risk (4/5)

Andhra Pradesh's 58 assessed sites span 27,152 MW across a mix of hydro, solar and wind technologies, producing a VaR of USD 4.4bn with 40% of assets in the highest two risk categories. The dominant hazard driver is the Bay of Bengal coastline, which channels some of India's most active cyclone tracks and associated flood risk directly into areas where much of the generation is planned. This coastal exposure combines with broader heat stress across the state's interior.

Rising industrial activity from ports, manufacturing clusters and expanding data infrastructure is making the state's power needs increasingly acute. The combination of high demand growth and significant climate exposure makes Andhra Pradesh a state where early resilience investment could deliver particularly strong operational and economic returns.

26%

Maharashtra - 95 sites

13,574 MW Capacity · VaR USD 1.6bn · 26% at Critical Risk (4/5)

Maharashtra's 95-site portfolio spans 13,574 MW across solar and wind technologies, carrying a relatively contained risk profile, with 26% of assets in categories 4 or 5 and a VaR of USD 1.6bn – the second lowest of the ten states. Along the Konkan coast, cyclones and floods are a real danger, but the immediate impact of these risks can get lost when data is averaged across the whole state, however, and warrant careful attention in coastal project siting.

From a demand point of view, Mumbai's urban heat island is intensifying, data centre investment is accelerating and industrial electrification is pushing baseline consumption sharply upward across the state's manufacturing corridors. Maharashtra's manageable risk profile is an asset but there is a risk it could breed complacency at a time when increasing energy demand is making reliable generation critical.

State Snapshots

1%

Ladakh - 5 sites

13,170 MW Capacity · VaR USD 2.8bn · 1% at Critical Risk (4/5)

Ladakh is a small but significant part of India's renewable portfolio, with five sites and 13,170 MW of planned capacity, much of it tied to capital-intensive hydropower. Just 1% of assets sit in categories 4 or 5, yet the portfolio still carries a VaR of USD 2.8bn, reflecting the high replacement cost of large hydro infrastructure. The hazard environment is shaped by steep terrain, freeze-thaw cycles, glacier-fed hydrology and growing variability in high-altitude weather patterns. Access constraints mean that recovery from an extreme event can be slow and costly.

Ladakh's own consumption is modest, but the strategic value of its generation to the wider northern grid gives each site an importance that extends far beyond its immediate geography.

60%

Madhya Pradesh - 50 sites

9,975 MW Capacity · VaR USD 1.6bn · 60% at Critical Risk (4/5)

India's largest state by area, Madhya Pradesh holds 50 assessed sites and 9,975 MW of planned capacity in a heavily solar weighted portfolio, carrying a VaR of USD 1.6bn with 60% of assets in the highest risk categories. As a predominantly inland state, its hazard profile is driven by heat stress, wildfire risk and drought, with drought conditions accelerating dust accumulation on solar panels which gradually degrades output between cleaning cycles – a compounding challenge for large-scale installations.

Rising temperatures across its major cities are increasing demand for air conditioning while agricultural electrification continues to drive rural demand growth across a large and dispersed population.

State Snapshots

94%

Uttarakhand - 13 sites

9,710 MW Capacity · VaR USD 3.1bn · 94% at Critical Risk (4/5)

Uttarakhand's 13 sites hold 9,710 MW of planned capacity, almost entirely in capital-intensive hydropower, and carry a VaR of USD 3.1bn with 94% of assets in the highest risk categories. It makes the state one of the clearest examples of how a small number of sites carry outsized financial exposure due to its hazard profile being driven by extremes in Himalayan precipitation - flood risk, slope instability and changing hydrology. These factors threaten both generation reliability and physical asset integrity across the state's river systems.

Demand in Uttarakhand itself is growing steadily through urbanisation and tourism, but the greater significance of this portfolio lies in its contribution to the northern grid. Spillway upgrades, sediment management, stronger monitoring and robust emergency response arrangements are particularly valuable in this challenging operating environment.

78%

Uttar Pradesh - 32 sites

7,161 MW Capacity · VaR USD 1.3bn · 78% at Critical Risk (4/5)

Uttar Pradesh's 32 sites deliver 7,161 MW of planned capacity and a VaR of USD 1.3bn, with 78% of assets in the highest risk categories. The portfolio is relatively small for India's most populous state, which is home to around 241 million people, reflecting its comparatively late start in the renewable transition. Flood exposure from the Ganga river system and extreme heat events are the dominant hazards for its solar and wind assets.

There is significant pressure on these assets: Agra, Lucknow and Varanasi are all expanding rapidly and urban heat intensification is pushing air conditioning loads to new peaks each summer. Uttar Pradesh's combination of high demand and material climate exposure makes resilience an urgent priority for the state.

What good looks like: Adaptation in practice

Understanding the risk is the first step. Knowing what to do is the second. Zurich Resilience Solutions works with clients around the world to identify where physical climate risks are greatest and to design practical measures that reduce them — before a loss event occurs. The following case study illustrates what that looks like in practice and why acting at the design stage makes such a decisive difference.

Case study

The project is a utility-scale solar PV development of approximately 2.5 GW, designed using reputable original equipment manufacturers and following established design-by-code principles.

It was designed using reputable original equipment manufacturers and following established design-by-code principles, demonstrating strong engineering is not the same as climate resilience. Even a well-designed asset can remain vulnerable if it does not fully account for the specific hazards it will face over its operational lifetime. In this case, severe hail exposure was identified as the critical risk, capable of causing significant damage to PV modules and affecting both generation capacity and recovery timelines.

This is a useful case study because it shows how a fundamentally sound asset can be strengthened through targeted design improvements before a loss event occurs. It also illustrates why developers, investors and insurers should think about resilience early — while engineering configurations, procurement strategies and design choices are still flexible.

Our risk assessment identified the potential for loss as being very high, driven by module vulnerability to weather events. Without resilience measures in place, the Value at Risk (VaR) was approximately USD 178.5 million while with the hail-stow tracker the loss was reduced to USD 43 million. This reduction demonstrates how design-stage resilience measures can materially reduce severe loss exposure, improve operational continuity and help safeguard long-term asset value.

Our engineers evaluated design alternatives and identified the adoption of a single-axis tracker system with a ‘hail stow’ function as the key mitigation measure. This allows panels to be repositioned to a protective angle automatically during hail, reducing direct impact forces and limiting damage severity. The incremental capital investment required was approximately USD 34 million, or a 30% increase relative to a fixed-tilt system.

This represents a step-change improvement in the asset's risk profile, moving from a high-vulnerability configuration to a more controlled and predictable outcome. Such improvements are critical in aligning projects with insurance market expectations and financing requirements.

Resilience, embedded at the design stage, is not an additional cost. It is a practical enabler of bankable, insurable and sustainable energy infrastructure. The case study shows what one well-targeted intervention can achieve. The next section sets out the five actions that, taken together, will move India's entire renewable portfolio from exposure to resilience.

~75% reduction
in severe loss exposure through design-stage resilience integration

~20% increase
in generation output through tracker optimisation

~12x +
indicative resilience value multiple combining severe-loss exposure reduction and operational performance improvement[8]

~USD 136m
reduction in potential severe-loss exposure under a defined extreme-event scenario.

~21 to ~12 months
reduction in recovery time, significantly reducing downtime, supporting faster return to generation, and limiting BI exposure.

8. Outcome includes avoided severe-loss exposure and indicative operational performance improvements under scenario-specific assumptions. Loss exposure comparisons are scenario-based engineering estimates illustrating relative changes in severe-loss exposure under a defined hazard scenario. They are not probability-weighted expected loss calculations.

Opportunities to Protect India's Renewable Energy Mix

The below chart shows the type of mitigation measures, by technology, that can help protect India's energy transition.

Asset Type	Key Hazards	Mitigation in Action	Possible Climate Resilience Measures
Solar	• Wind • Flood • Heat and wildfire • Hail		• Elevate inverters/substations • Strengthen drainage • Specify wind-rated mounting • Improve vegetation management
Wind	• Wind • Lightning • Flood/extreme precipitation • Earthquake		• Specify typhoon-class turbines • Improve yaw/braking redundancy • Lightning protection • Slope stabilisation and resilient access roads
Hydropower	• Drought • Flood/extreme precipitation • Earthquake • Volcano		• Climate-adjusted hydrological modelling • Drought operating rules • Sediment flushing/bypass • Flood-protected electrical systems and emergency response planning

Five practical steps forward

India's renewable future is a story of opportunity. The country's scale, policy momentum and growing role in the global clean energy economy are real strengths, and the data in this report shows that the risks facing the portfolio are not inevitable – they are manageable, provided action is taken now. The task is to move from awareness to action: to make resilience a standard part of how India's clean energy infrastructure is planned, designed, financed and operated.

1. Make climate risk screening mandatory at planning and permitting

Forward-looking climate screening should be a standard requirement in site selection, project approval and permitting. Historical baselines are no longer enough for assets, many of which will operate well into the 2050s and beyond. Screening is also where resilience can often be introduced at the lowest cost and with the greatest design flexibility.

2. Stress-test the highest-risk assets first

With 66% of the assessed portfolio sitting in Categories 4 and 5 by 2030, prioritisation matters. Multi-hazard stress-testing of the most exposed projects helps quantify the difference between the Value at Risk (VaR) and the losses with mitigation actions, and produce an investment roadmap for resilience action.

3. Build hazard-specific resilience into procurement

Many of the decisions that determine long-term asset resilience are made before the project is built. Wind loading, hail resistance, flood elevation, drainage, fire protection, corrosion resistance and redundancy should be written into design and procurement standards rather than treated as optional upgrades.

4. Treat system resilience as part of asset resilience

Even well-designed assets depend on the resilience of the wider network around them. Grid infrastructure, interconnection, access roads, water systems, communications, and emergency response all influence how quickly a project can recover from a severe event. Resilience therefore needs to extend beyond the fence line.

5. Use resilience quantification to unlock capital

One of the strongest arguments for resilience is that it can be translated directly into financial terms. An indicative resilience investment of around 2% of CAPEX could reduce severe-loss exposure by as much as 75% under our assumptions. This corresponds to an avoided-loss multiple of approximately 38x and supports stronger insurability and bankability outcomes.

India's Leadership Opportunity

India's case matters beyond its borders. As the world's third-largest renewable energy capacity holder and one of Asia Pacific's most important growth markets, its approach to climate resilience will shape how investors and risk professionals think about clean infrastructure across the region. In that sense, the Indian market is both national and global: a proving ground for how to build renewable portfolios that are not only larger, but stronger.

For anyone in energy generation, the conclusion is practical. The climate is already changing the way renewable assets perform and the situation is getting more challenging, not easier. But that does not weigh in favour of retreat; it argues for earlier analysis, better design, stronger resilience standards and a more integrated view of asset, operational and financial risk. That is how the energy transition remains optimistic, investable and durable.

Annexes

Scope

The analysis in this report covers announced, planned, pre-construction, and under-construction renewable energy assets in India. The entire data set covers 1,020 sites across India's states and union territories:

State/Union territory	Sites	State/Union territory	Sites
Andaman and Nicobar Islands	1	Madhya Pradesh	50
Andhra Pradesh	58	Maharashtra	95
Arunachal Pradesh	30	Meghalaya	4
Assam	11	Mizoram	1
Bihar	7	Nagaland	1
Chhattisgarh	4	Odisha	11
Gujarat	172	Punjab	9
Haryana	4	Rajasthan	272
Himachal Pradesh	24	Sikkim	3
Jammu and Kashmir	9	Tamil Nadu	28
Jharkhand	11	Telangana	6
Karnataka	144	Uttar Pradesh	32
Kerala	8	Uttarakhand	13
Ladakh	5	West Bengal	6
Lakshadweep	1	Grand Total	1020

It assesses solar PV, onshore wind, and hydropower generation sites.

We have used open-source data (Global Energy Monitor) to create a dataset for this analysis covering 1,020 energy generation assets across India. This captured details on location, status, capacity and technology.

For the financial framing, value at risk is estimated using replacement-cost assumptions by megawatt (MW) together with dominant-hazard loss factors. Value at Risk without resilience measures represents severe loss outcomes without effective resilience measures. Loss with mitigation actions represents more controlled outcomes where resilience measures are in place and function as intended. The difference between the two provides a practical way to express the value of resilience in commercial terms.

The difference between the two provides a practical way to express the value of resilience in commercial terms.

For the hazard impact assessment, risk scores were derived for each asset based on the modelled impact of multiple hazards. These scores were then classified into five risk categories using a z-score approach. The categorisation thresholds are calibrated based on a broader reference portfolio of approximately 11,440 locations across Asia, ensuring regional consistency.

The chart on the next page illustrates the methodology we have used to calculate risk score and categorisation.

Methodology

Zurich Resilience Solutions' geospatial climate risk modeling was used to assess physical climate risks to generation assets

Physical climate risk refers to the risk of physical damage or service disruption to a generation or storage facility from a climate hazard (e.g., flood, drought), determined by the severity of the hazard and the materiality (impact) on the technology.

1 Asset data collection

- We created a dataset of more than 11,440 energy generation assets across Asia using open source data from Global Energy Monitor. And then develop the analysed portfolio of 1,020 energy generation assets in India.
- This dataset consisted of the location of each asset, its operational status (e.g., announced, in construction), capacity and the generation/storage technology (e.g., wind, solar).
- The analysis in this report is based on energy asset data available as of February 2026.

2 Mapping Data to Zurich Climate Modeling

- ZRS's proprietary climate data was used to determine the climate risk faced by each asset, based on IPCC definitions of climate scenarios, scaled to the asset-level under a range of time horizons.
- ZRS' Climate Spotlight digital platform was used to analyze and visualize the combination of climate and asset datasets. The hazard ratings were expressed qualitatively from low to very high, for 16 hazards.
- The most likely climate scenario of SSP2-4.5 (2°C warming by 2030) with near-time horizon was selected as it aligns with current emission trends and typical renewable asset lifespans.

3 Impact Assessment

- In coordination with ZRS energy and climate specialists, an impact assessment was developed that determined the materiality of each climate hazard on technology types
- The potential impact of each hazard type was assigned a value of 'low' to 'very high', reflecting the impact a particular climate hazard would have on an asset. This was to ensure that assessment of climate risk would reflect the probable likely impact on an asset.

4 Total hazard-impact score

- A total score was then developed for each asset site in the database. This calculation converted the ratings of hazard and impact, which were categorised as low to very high, to a 1 to 4 scale.
- The value of the hazard and impact for each asset was then multiplied.
- For example, if a solar farm has a 'very high' hazard level for hail (a value of 4) and a hail impact score of very high (a value of 4), the total hazard-impact score for that solar farm would be 16.

5 Risk categorization

- Assets are grouped into five categories (1 to 5) using z-scores, where 1 represents less risky assets and 5 represents highly risky assets. Z-scores measure how far each asset's hazard-impact value deviates from the mean.
- The impact of risk in categories 3 and above are significant and, for the purpose of this analysis, we have therefore defined those assets above category 3 as high risk and those falling into categories 4 and 5 as critical risk.
- The probability of experiencing a climate event is calculated using the return period for each asset and then averaged across all assets within each category.

Note: Shared Socioeconomic Pathways (SSPs) are climate change scenarios of projected socioeconomic global changes by the UN Intergovernmental Panel on Climate Change
Source: Zurich Resilience Solutions (ZRS)

We have used the following process to calculate the probability of climate hazards at an asset location:

First statistical step: Converting return periods to probability

Extract return period for each climate hazard from ZRS' data → Use the probability mass function for Poisson's distribution to calculate the probability of the hazard not **taking place** in the next five years

Example: If the return period of occurrence for a wind gust hazard is 100 years (μ = 0.01), then the probability of no occurrences in five years is:

$$P(r;t) = \frac{(\mu t)^r}{r!}e^{-\mu t} \longrightarrow P(r=0;t=5) = \frac{(5/100)^0}{0!}e^{-5/100} \approx 95.12\%$$

Intermediate step: Finding the cumulative probability of a climate event NOT taking place at an asset location in the next five years

When both the hazard level from ZRS' database and the risk impact score from the impact matrix exceed threshold 'L', the 5-year non-occurrence probability becomes one of the factors multiplied together in the cumulative probability calculation.

Note: This multiplication approach assumes all climate hazards are statistically independent events, providing a simplified but practical basis to determine probability of climate events taking place

Probability any climate hazard **does not** take place at that asset location in the next 5 years = Probability that **climate hazard A** does not take place in the next 5 years × Probability that **climate hazard B** does not take place in the next 5 years × Probability that **climate hazard C** does not take place in the next 5 years × Probability that **climate hazard...** does not take place in the next 5 years

Final probability: Finding the probability that a climate event DOES take place at an asset location in the next five years

Probability a climate hazard **does** take place at that asset location in the next 5 years = 1 - Probability that climate hazard A does not take place in the next 5 years

Key:

Intermediate output

Calculated output

The main hazards affecting the portfolio

The four hazards that drive the highest scores across the India portfolio are tornado, wildfire, flood and hail. Each has direct relevance to generation continuity and asset value.

Tornado

Tornado-scale and extreme wind events can damage turbines, blades, mounting structures and the wider balance of plant.

Wildfire

Wildfires can damage solar panels, cabling and substations, while also disrupting grid connections and causing temporary shutdowns of generation assets.

Flood

Flooding damages civil works, substations, roads, drainage systems and electrical equipment, leading to operational disruptions.

Hail

Hail creates severe direct losses in solar assets and can also introduce hidden defects that affect performance over time.

Acknowledgements and disclaimer

This report is intended as a thought-leadership and decision-support document for enterprise audiences. It combines our India portfolio analysis and risk engineering work with external contextual sources.

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