May 2026

Powering Through

Building Climate Resilience into Southeast Asia's Energy Future

Content

Executive summary

Southeast Asia is building its renewable energy future at extraordinary speed. The climate is already changing the risks those assets face. Acting now through smarter design, better site selection and targeted measures could protect USD 83 billion in assets and deliver 6.5x return on every dollar invested in resilience.

Countries in Southeast Asia – from the archipelago of the Philippines to the Mekong corridors of Laos and Vietnam and from Singapore's urban grid to Indonesia's scattered islands – are investing in the largest clean energy build-out in their histories.

The ambition is for renewables to reach 45% of installed power capacity by 2030[1], up from around 33% today. The investment is substantial, political support is growing and the economics – particularly of solar and wind – have never been more compelling.

The build-out will strengthen economic growth and improve energy security at a time when that is more urgent than ever. It will also drive the region's long-term competitiveness with the rest of Asia as well as globally.

At the same time the climate these assets will operate in is changing in ways that matter to anyone who owns, finances, insures or depends on these facilities. Southeast Asia is one of the most climate-exposed regions on Earth. Typhoons, flooding, drought, hail and wildfire are not distant risks; they are present realities that shape the operating environment for every solar farm, wind project, hydropower facility and geothermal plant in the region.

Using proprietary climate risk modelling across 16 hazards, our data tells a striking story. Of 1,380 renewable energy generation sites across Southeast Asia, 927, accounting for approximately 181,000 MW of capacity, 75% of the total, are at very high risk of being adversely affected by climate risks by 2030. In more simple terms, this equates to the approximate annual power needs of 180 million households. Fortunately, 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.

1. ASEAN endorses action plan to increase renewable electricity share to 45% by 2030. Reuters. 16 October 2025

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.

Methodology

This report covers 10 Southeast Asian countries within the ASEAN bloc: Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam. The locations referenced utilise data from Global Energy Monitor as the base dataset. Timor-Leste is excluded from this analysis as it has only recently joined the bloc.

It focuses on solar PV, onshore wind, hydropower and geothermal assets that are announced, planned, or under construction. While this analysis of future climate risks highlights the cost of inaction, our modelling also shows that there is still an opportunity to help reduce those risks materially, with investment in resilience now capable of halving expected future losses.

That means there is still an opportunity to deliver resilience by design - by screening locations using forward-looking climate data, stress-testing the highest-risk projects and building resilience into procurement, engineering and construction decisions before vulnerabilities are locked in for decades.

This report uses IPCC-aligned scenarios (SSP2-4.5) and our own insights of historic loss and damage to classify energy generation assets into five risk categories. 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.

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

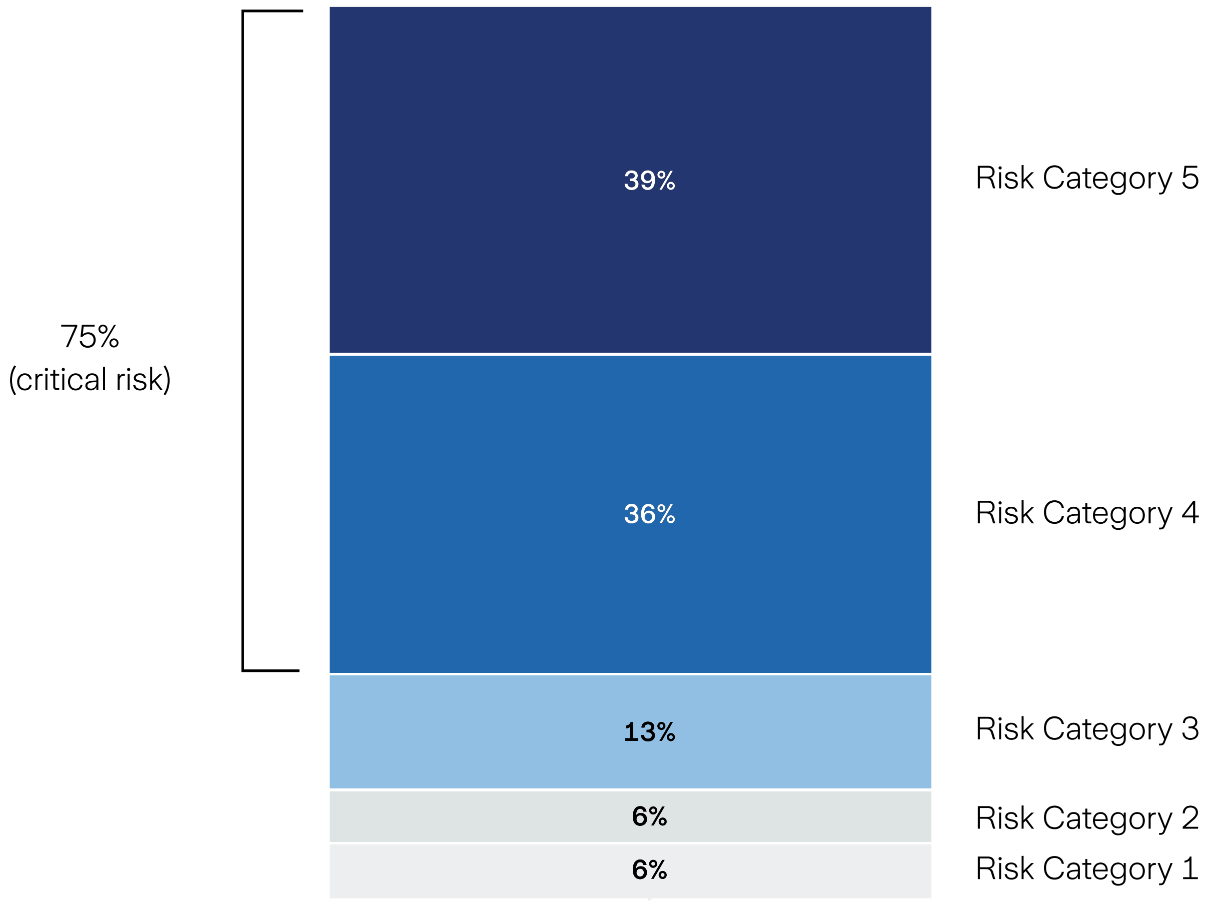
These are not hypotheticals. The hazards driving the highest scores: wind, flooding and wildfires are already occurring across the region.

This is not only a physical risk problem. Long-life renewable infrastructure depends on stable insurance to support financing, construction and operational continuity. Managing assets through a process that takes them from unmanaged risk to resilience will directly help enhance their insurability and bankability. Assets at critical risk – which stand at around 75% of planned capacity – face insurability hurdles without early resilience which in turn tightens financing and project economics. This will have material consequences for the region's energy transition pipeline.

It is more than simply avoided damage. In practice, resilient assets are easier to insure, easier to finance and more likely to deliver the operating performance assumed in modelling. For CEOs, resilience should be a question of competitiveness; for CFOs, it is a capital protection issue; for Heads of Sustainability, it is a transition quality issue; and for Heads of Risk, it is a way to move from static exposure awareness to active loss avoidance.

Our research shows that acting now – screening risks early, stress-testing the most exposed projects, strengthening designs before they are fixed in place and using resilience analysis based on insurer risk insights and expertise – can avoid losses and improve project outcomes as well as access to capital.

Risk to renewable generation pipeline capacity by 2030



Southeast Asia's clean energy transition is worth protecting and if we act now, we can do exactly that.

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
Geothermal	• Earthquake • Volcanic hazards • Flood/extreme precipitation • Drought		• Seismic design • Flexible pipe supports • Slope stabilisation; drainage and erosion control • Volcanic hazard mapping

The financial case for resilience is strong.

Our experience of different loss scenarios over many years of working with customers, allows us to estimate the potential value at risk across the ASEAN renewable energy portfolio. Our analysis indicates that around USD 165 billion of value is at risk across the portfolio by 2030 in the absence of effective resilience measures. Putting those measures in place can reduce the financial risk from climate events by **40 to 50%.**

Our analysis shows that for the Southeast Asian countries in our study, an upfront investment of approximately USD 13 billion – or 2% of total asset value could help avoid over USD 83 billion of losses[2]. The return on that investment is approximately 6.5x, which is a conservative estimate based on physical hardening alone, but when planning-stage site selection is included, the returns are higher still.

2. Based on global climate-risk, infrastructure resilience and loss-modelling analysis undertaken between 2021 and 2026, combined with the ASEAN renewable asset portfolio assessment used in this report.

Southeast Asia's *energy moment*

The region's renewable build-out is one of Asia's most important infrastructure stories. It is being driven by rising electricity demand, energy security concerns, industrial growth and the increasing economic attractiveness of domestic renewable power. The scale of that opportunity is exactly why resilience now needs to move from the margins of project planning to the centre.

Southeast Asia's energy transition goes well beyond climate policy. It is linked to questions of competitiveness, industrial capacity and energy sovereignty. As demand rises across cities, manufacturing zones, transport systems, cooling networks and digital infrastructure, countries across the region are under pressure to secure reliable electricity that is both affordable and less exposed to imported fuel volatility.

That is the context for the region's ambitious plans for new energy infrastructure. In 2025, ASEAN announced a new action plan[3] aiming for renewables to make up 45% of installed power capacity by 2030, while also targeting 30% of total primary energy supply. Enerdata's subsequent analysis[4] made the same point: the region has moved beyond incremental target-setting and is now raising the ambition of the entire power system.

That ambition is being translated into action. The International Energy Agency has highlighted[5] how the region's renewables pipeline is growing with a sixfold increase in solar PV capacity between 2018 and 2024.

Clean energy investment requirements are also rising sharply. The ASEAN energy plan makes clear that countries will need to increase clean energy investment to around USD 190 billion by 2035, roughly five times current levels, if it is to meet climate goals.

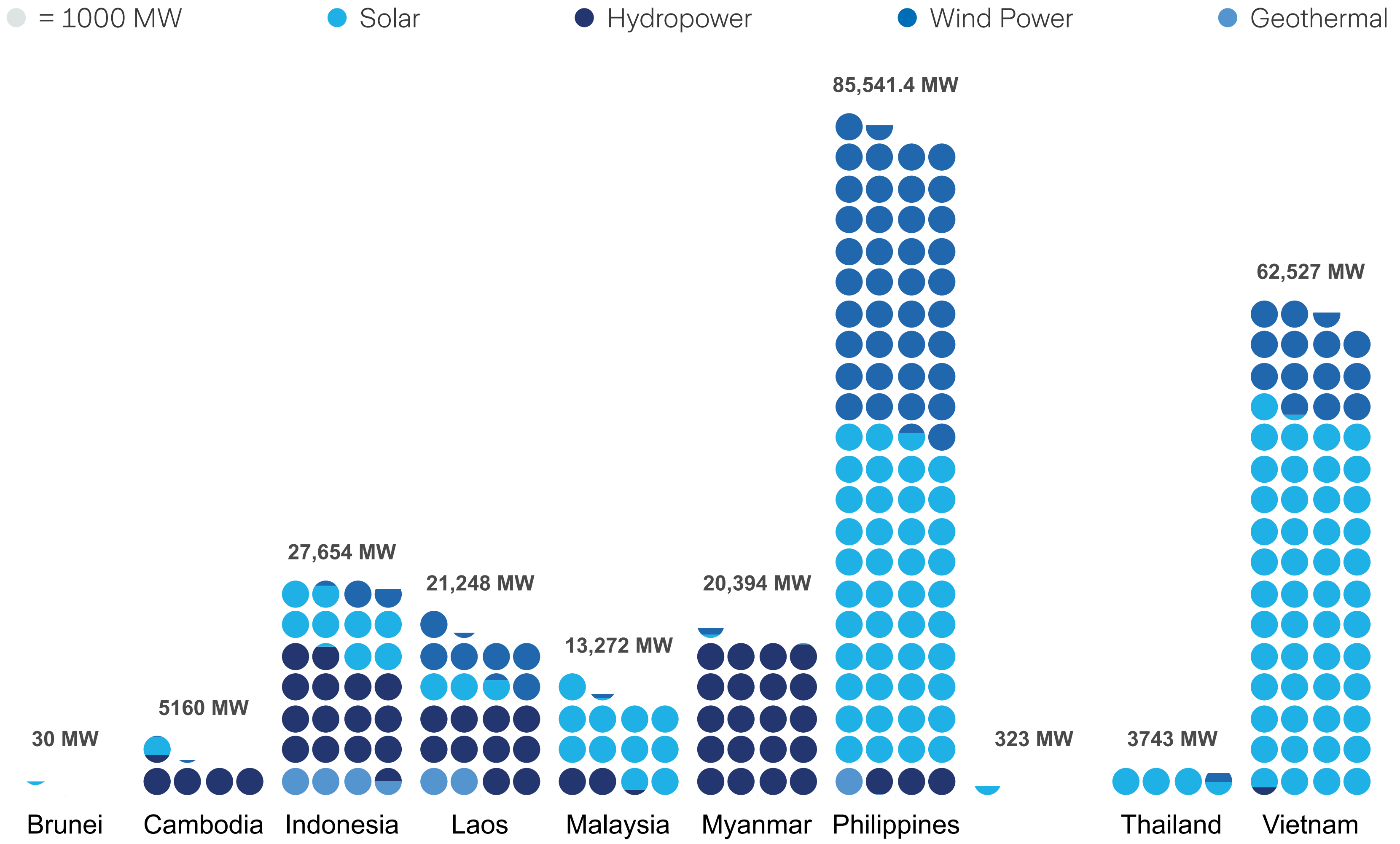
3. ASEAN Plan of Action for Energy Cooperation
4. ASEAN aims for 45% of power capacity from renewables by 2030, Enerdata, 17 October 2025
5. Accelerating Renewables Growth in ASEAN, International Energy Authority

Renewable projects are not simply expressions of sustainability intent; they are capital intensive, long-life infrastructure assets that will shape future earnings, operating resilience and strategic positioning. They affect procurement, land use, supply chains, finance, community trust and energy security simultaneously.

The region is not just adding renewable capacity, it is building energy systems for the future and the effectiveness of those systems will depend on whether resilience is treated a core design principle rather than an after thought.

As renewable power becomes a critical part of the economic backbone of Southeast Asia, then climate resilience must become a key element of mainstream asset stewardship.

Planned renewable pipeline capacity by country and technology



Source: Global Energy Monitor, February 2026

Climate risk is not a future problem

Climate risk is already reshaping the operating environment for infrastructure across Asia and Southeast Asia sits inside one of the world's most exposed regions. For long-life assets, the practical question is no longer whether climate volatility matters; it is how quickly organisations can adapt their planning, design and investment frameworks to it.

In 2025, Cyclone Senyar formed over the Strait of Malacca bringing widespread flooding across Thailand, Malaysia and Indonesia. It killed at least 1,500 and resulted in approximately USD 20 billion in damage.

This event illustrates the challenges facing Asia in general and Southeast Asia in particular.

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.

These trends matter directly to infrastructure. Flooding disrupts substations, roads, drainage, foundations, switchgear and access routes. Wind/tornado events damage turbines, panels, trackers and roofs. Hail can create direct shattering as well as hidden defects that only appear later through degraded performance. Drought changes generation reliability for hydropower and can affect wider cooling and water management assumptions.

6. State of the Climate in Asia 2024, World Meteorological Organization, 23 June 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
	Geothermal	L	M	L	L	L	L	L	L	L	H	L	L	L	L	L	H
	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.

The macroeconomic impact is also potentially more serious. The Asian Development Bank's (ADB) 2024 climate report[7] warns that climate change could reduce GDP across developing countries in Asia and the Pacific with the greatest impacts falling on lower income economies and highly exposed geographies.

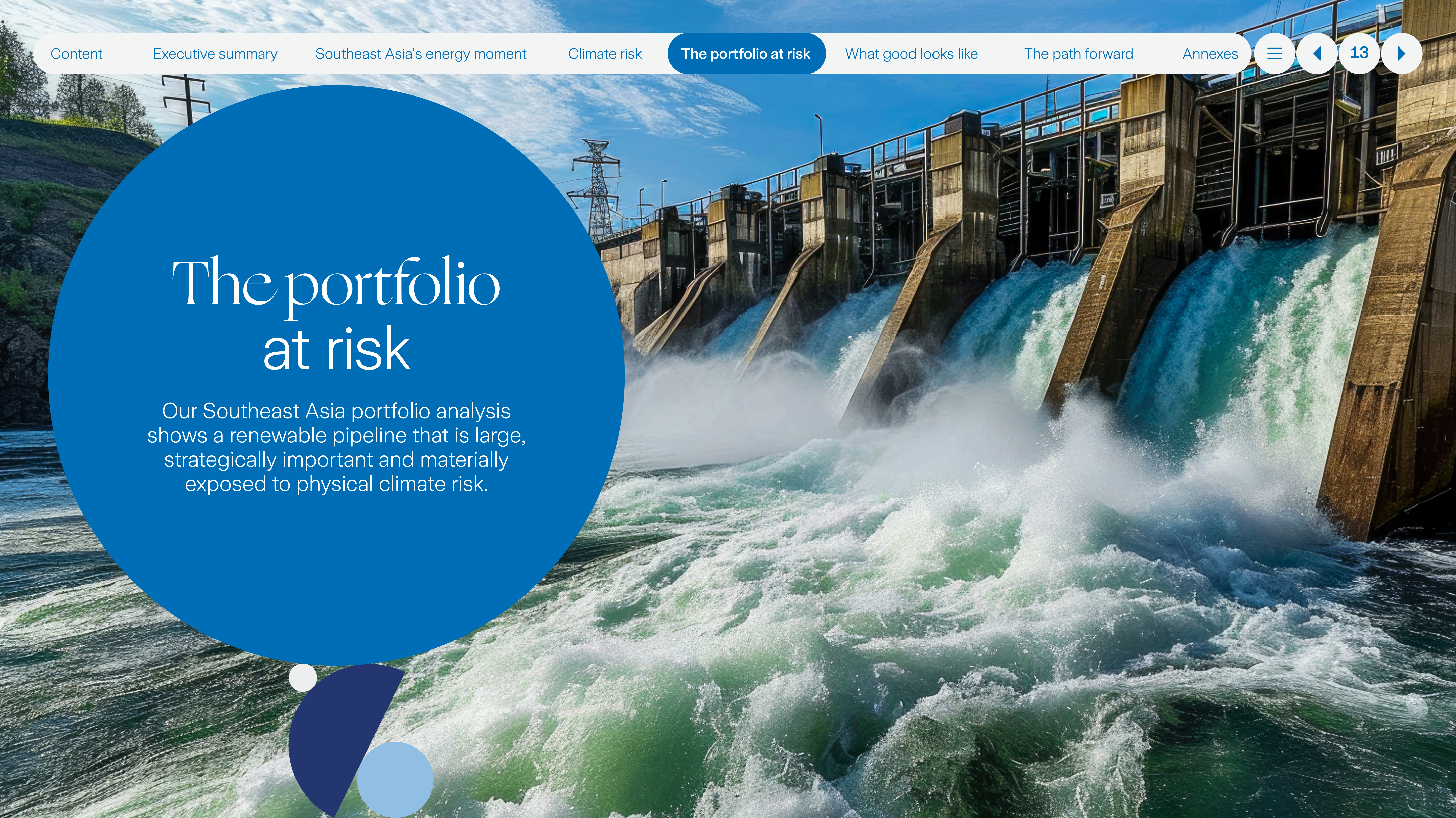
The ADB also estimates annual adaptation investment needs for the Asia region at USD 102–431 billion, while tracked adaptation finance in 2021–2022 was only about USD 34 billion.

That gap effectively measures how much resilience is still not being funded.

These numbers matter to the energy sector because costs do not stay at national scale. They filter down into higher operating risk, disrupted supply chains, pressure on public infrastructure, greater uncertainty in long-term project assumptions and a wider gap between resilient and non-resilient assets.

For renewable energy developers, owners and funders, the key point is that many of the region's assets are still in the planning or construction stages. That means there is still time to build in climate resilience while the cost of change is lower, the engineering flexibility is greater and the commercial benefits are larger.

7. ADB Says Climate Change Could Reduce GDP in Developing Asia and the Pacific by 17% by 2070, Asia Development Bank, 31 October 2024



The portfolio at risk

Our Southeast Asia portfolio analysis shows a renewable pipeline that is large, strategically important and materially exposed to physical climate risk.

Solar, which represents the largest single technology across the region (731 sites generating 117,884 MW), faces the steepest near-term exposure: 80% of solar generation capacity is in categories 4 or 5 by 2030.

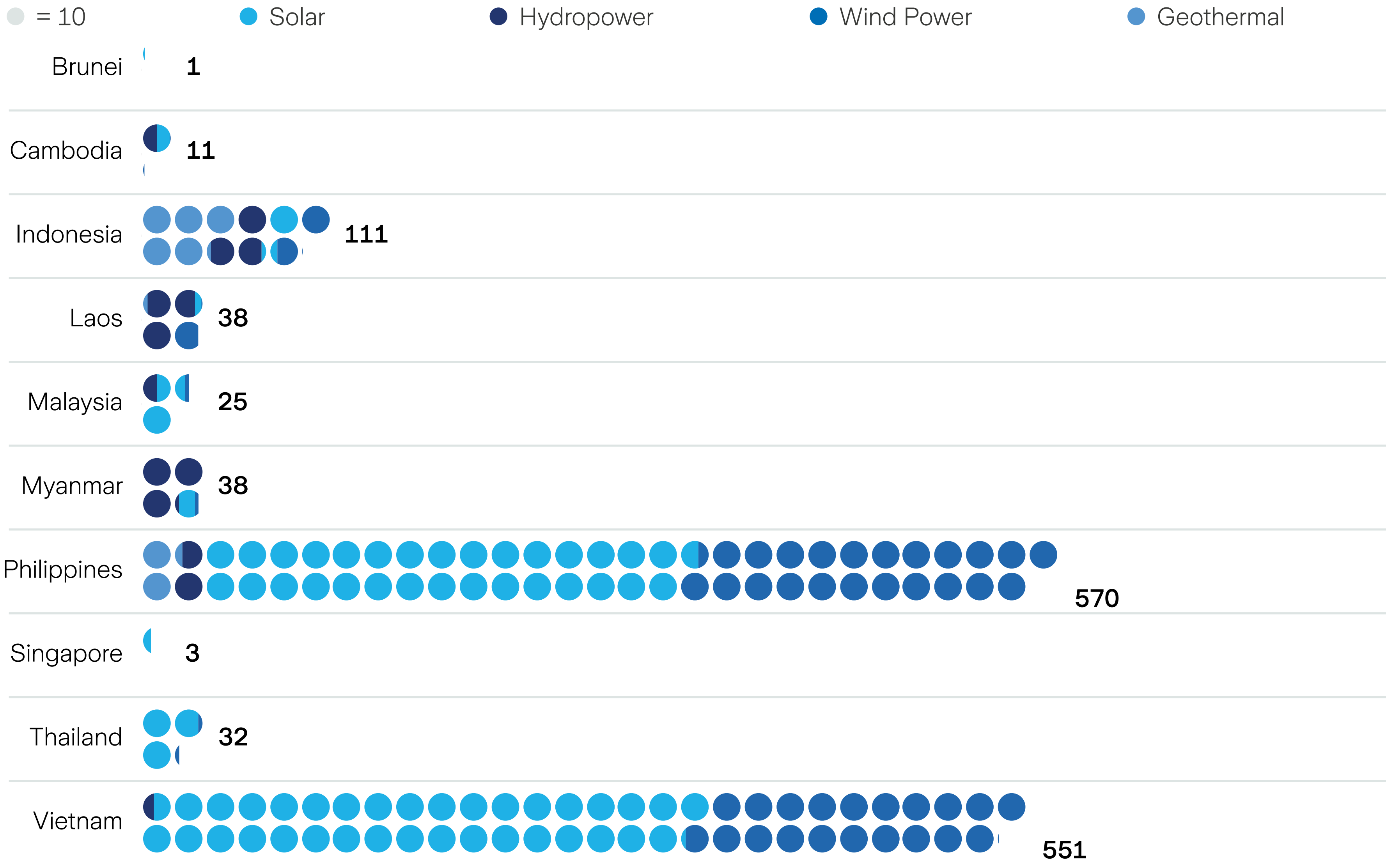
Wind power comprises 459 pipeline assets across the region, with approximately 61 GW of planned capacity across the portfolio. By 2030, around 56% of this capacity is expected to fall within risk categories 4 or 5, primarily due to exposure to typhoon, flood and coastal hazards. This indicates a significant concentration of climate risk across key wind development corridors. Given the volume of planned Solar and Wind assets in the Philippines and Vietnam, these countries face a potentially high level of risk exposure.

Hydropower, accounts for a significantly smaller number of assets across the region, with 114 currently planned. However, the disproportionate high financial exposure due to the scale and capital intensity of civil infrastructure means these represent high impact losses.

Approximately 55% of capacity is projected to fall within risk categories 4 or 5 by 2030, highlighting material vulnerability within future large-scale developments.

Geothermal assets across the region show comparatively lower concentrations of high-risk exposure. However, localised hazards, including flooding, slope instability and disruption to distributed steam field infrastructure, remain material hazards and may affect operational reliability at site level once commissioned.

Planned renewable energy assets by country



Source: Global Energy Monitor, February 2026

The main hazards affecting this portfolio are wind, tornado, wildfire, flood, hail and drought. These are important as they are directly linked to key loss drivers and contribute to the overall risk.

Wind/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

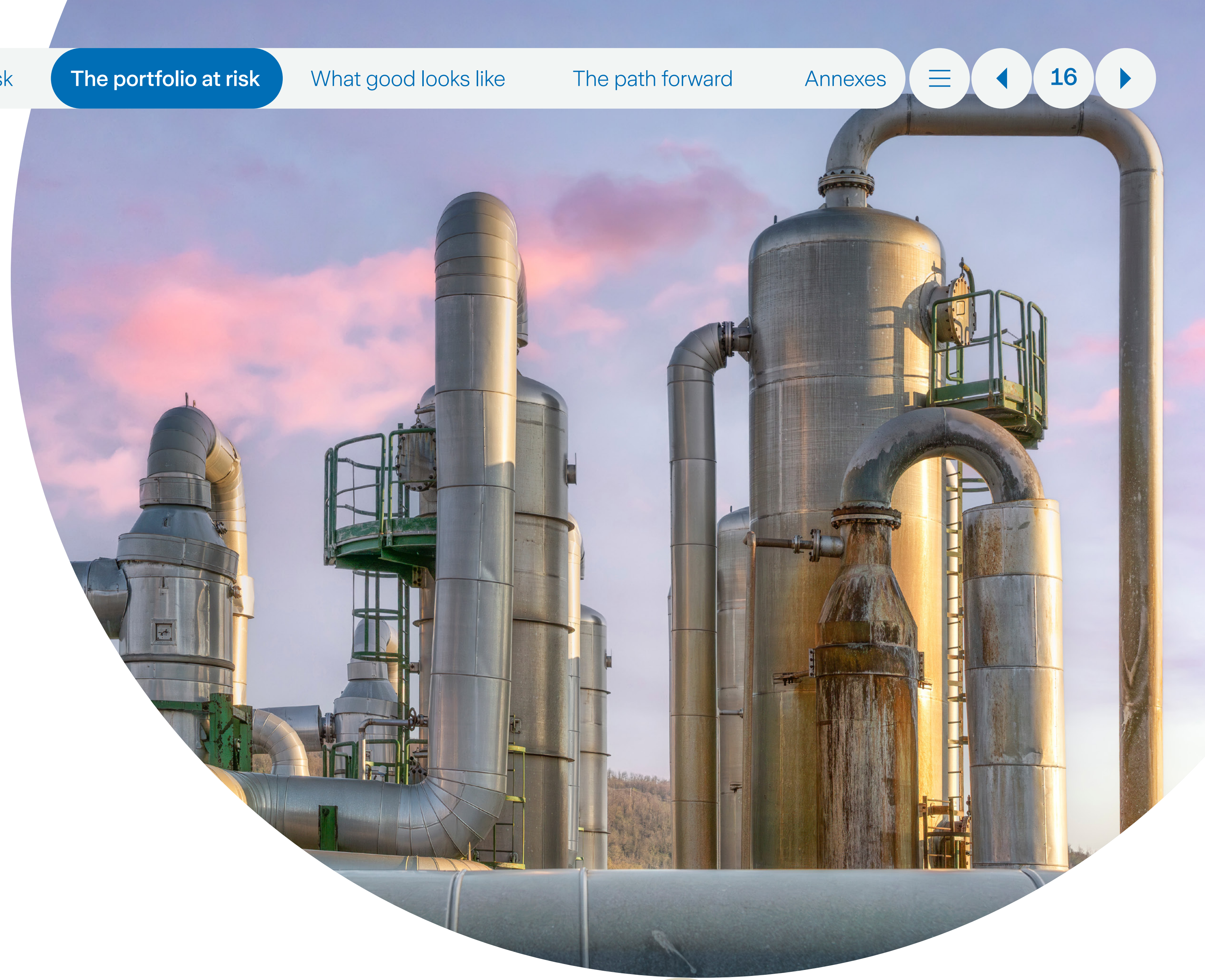
Flooding damages civil works, substations, roads, drainage systems and electrical equipment, leading to operational disruptions.

Hail

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

Drought

Drought reduces water availability, affecting hydropower generation and cooling processes and can also increase dust accumulation, reducing solar panel efficiency.



To fully understand the impact of these hazards, we need to not only look at risk exposure but also at the Value at Risk (VaR) and put that in the context of each country's GDP.

Value at Risk (VaR) is an indication of financial exposure caused by climate hazards, including property damage and business interruption. Investing in resilience materially reduces severe-loss exposure and supports insurability and bankability.[9]

Our analysis suggests that Vietnam and the Philippines are most vulnerable to an economic shock resulting from climate impacts on renewable energy infrastructure. Their relatively sizeable economies (USD 476 billion and USD 461 billion respectively[10]) are supported by grids that rely on renewable energy to a greater extent than their Southeast Asia peers. Planned hydro, solar, wind and geothermal make up over 43% of Vietnam's grid while in the Philippines the figure is just over 20%.

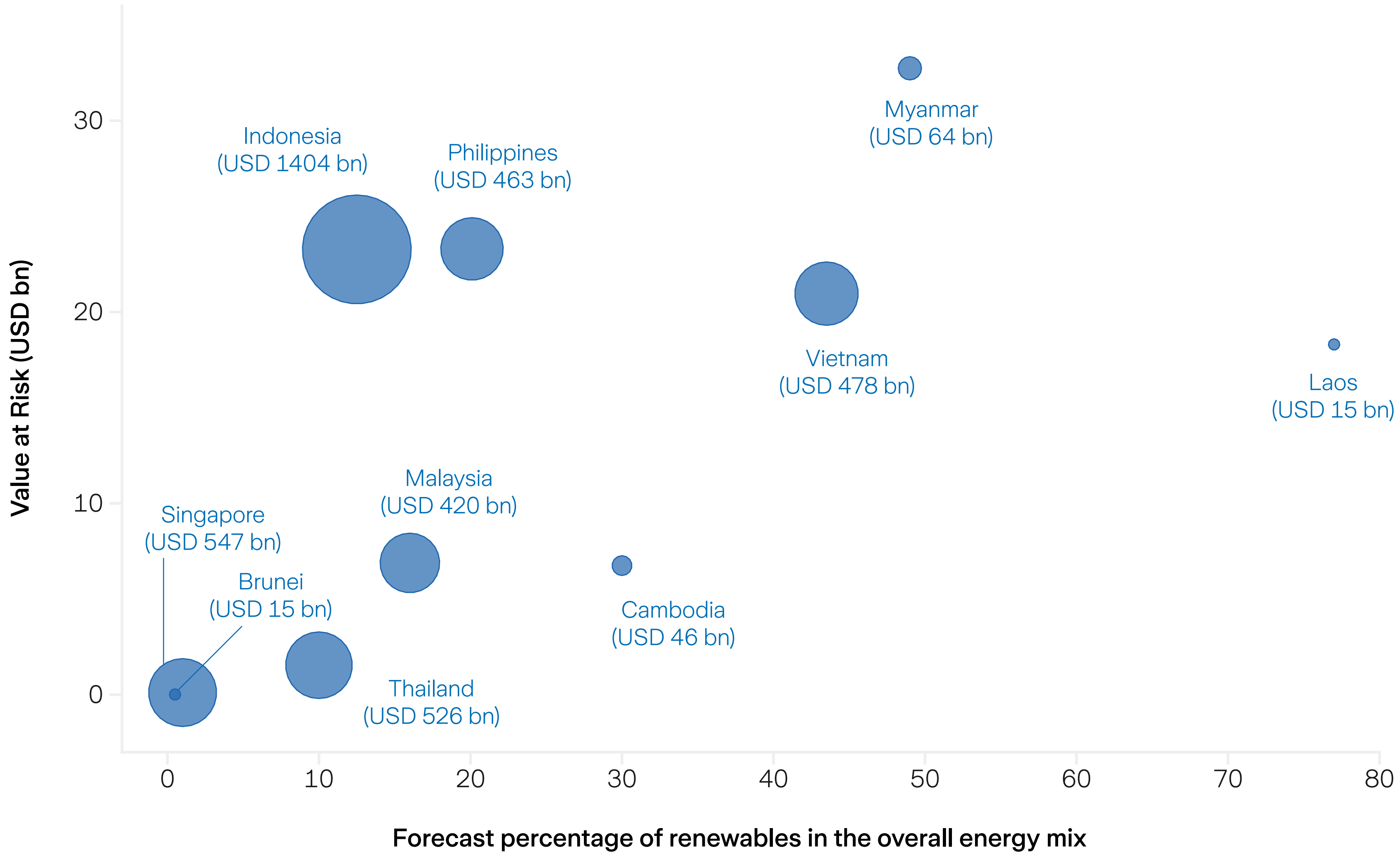
While protecting energy infrastructure should be high on the agenda for all countries, it is particularly important when economies are underpinned by reliance on renewable assets that are under threat from climate change.

9. See Annexes for a more detailed explanation.
10. Source: International Monetary Fund 2024

The analysis on the right compares indicative Value at Risk (VaR) exposure against the forecast percentage of renewables in the overall energy mix of each country in 2030, while the bubble sizes reflect the GDP of each country. It highlights the cumulative financial impact that climate hazard exposures present to each country.

Placed in a wider context, Southeast Asia's portfolio exposure is more severe than in our comparable analyses of European and Canadian energy resilience. It also underscores an important commercial point: resilience should be treated as a core design requirement, not as a nice-to-have enhancement once projects are operational.

Country comparison of relative financial exposure to climate risks



If we apply that logic to the renewable energy pipeline in the ASEAN region, the total value at risk, without resilience measures, is USD 165 billion. This is referred, in risk engineering terms, as the Estimated Maximum Loss (EML) which is indicative of a severe loss scenario.

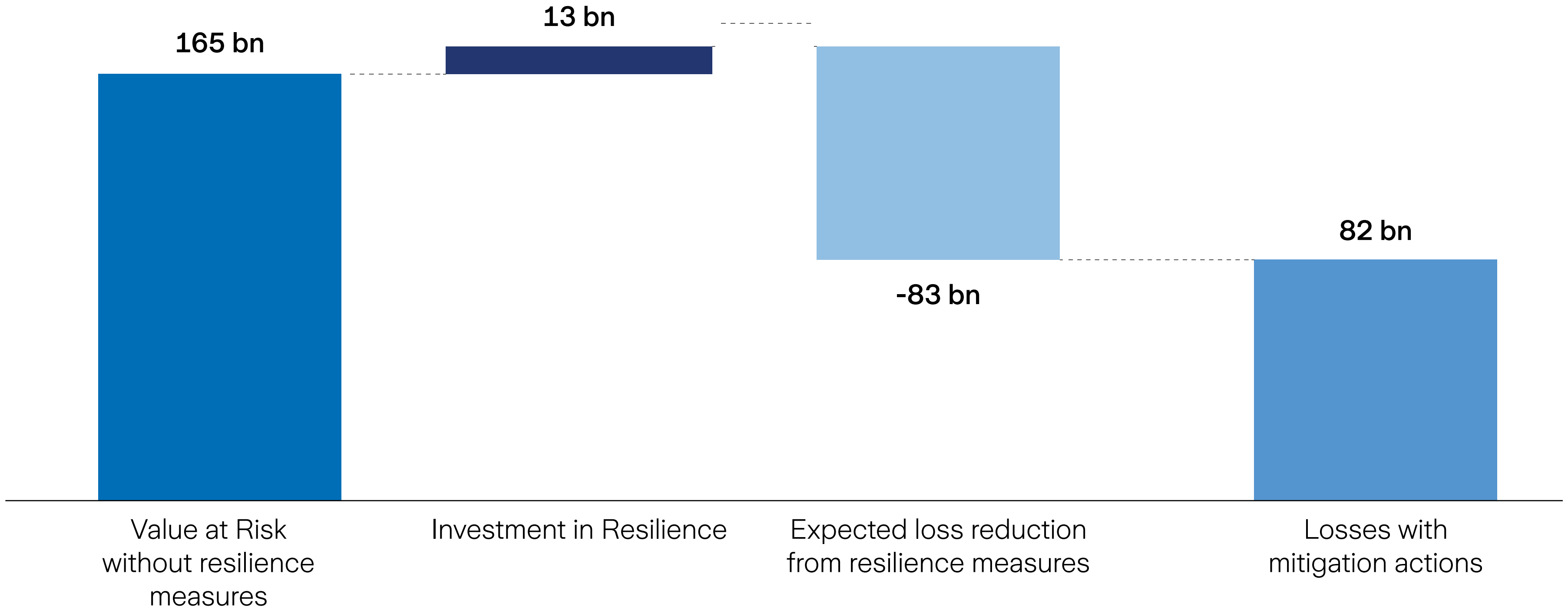
Our experience over decades of work with hundreds of clients has shown that proactive resilience typically adds between 2-10% to upfront CAPEX when embedded at the design or construction phase. At this stage, many resilience measures are design optimisations, rather than additional systems.

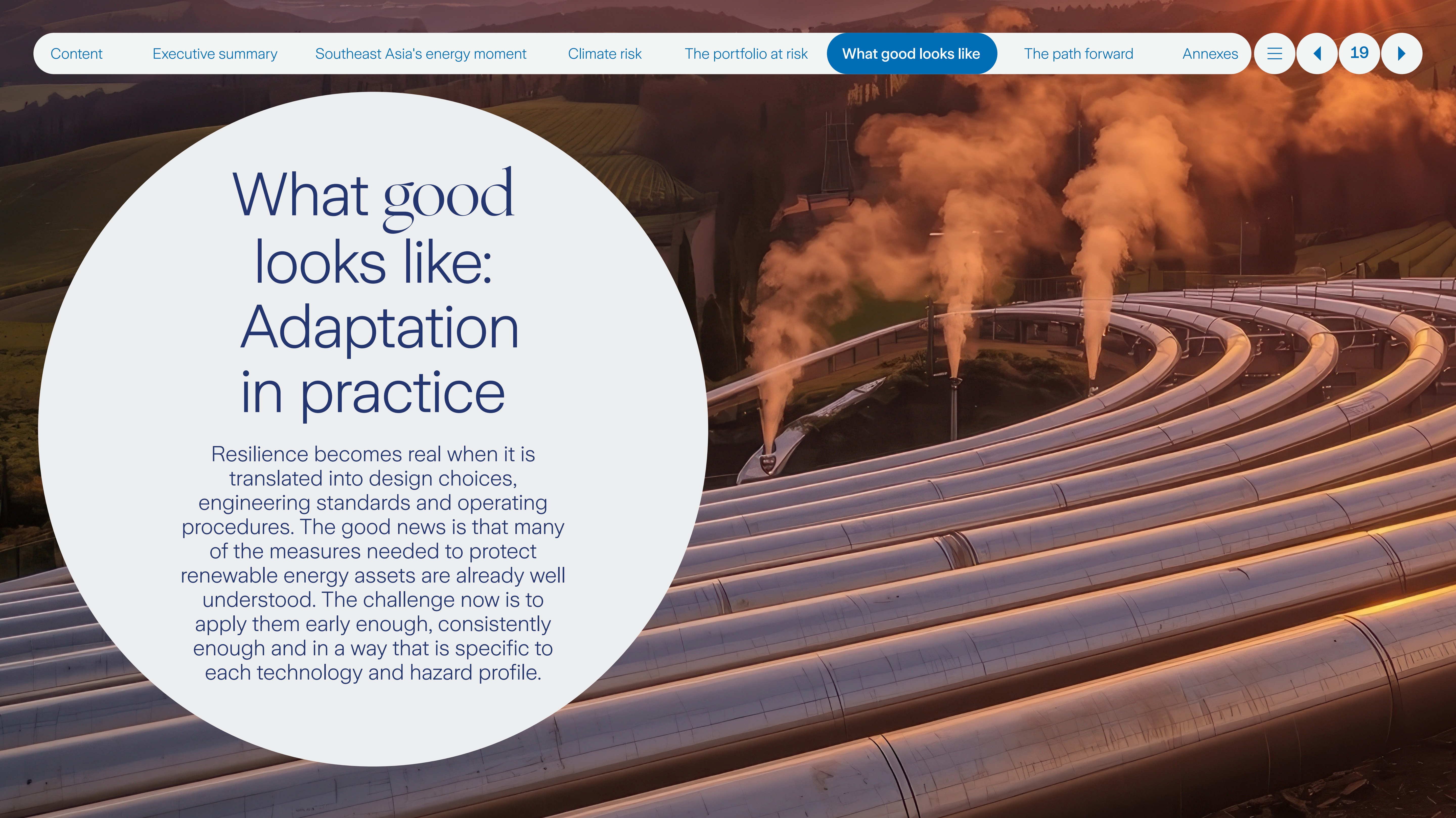
By investing in resilience measures early in the project lifecycle, the amount of potential loss can be reduced materially, through less severe loss exposure, improved operational continuity and enhanced insurability.

If we work this through against the USD 165 billion portfolio, there is the potential to avoid ~USD 83 billion in losses for ~USD 13 billion in investment which is a ~6.5x return.

Value of proactive resilience for ASEAN's renewable energy pipeline

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





What good looks like: Adaptation in practice

Resilience becomes real when it is translated into design choices, engineering standards and operating procedures. The good news is that many of the measures needed to protect renewable energy assets are already well understood. The challenge now is to apply them early enough, consistently enough and in a way that is specific to each technology and hazard profile.

Our analysis shows that solar is the largest renewable energy generation technology, with sites in almost every one of the countries in our study. That makes it particularly important to understand the challenges facing this technology as our climate changes given that 80% of all pipeline solar capacity is at category 4 or 5 risk of damage by 2030.

This is a significant challenge for both Vietnam and Philippines, as both countries rely heavily on this form of renewable energy.

Hydropower has most value at risk at just over USD 83 billion in category 4 or 5 by 2030, due to the high build costs associated with this technology. Additionally, the high energy output potential of hydropower also means that the loss impact is heavily pronounced in case of natural catastrophe.

With this in mind, what steps can asset owners take to mitigate the risk that climate change poses?

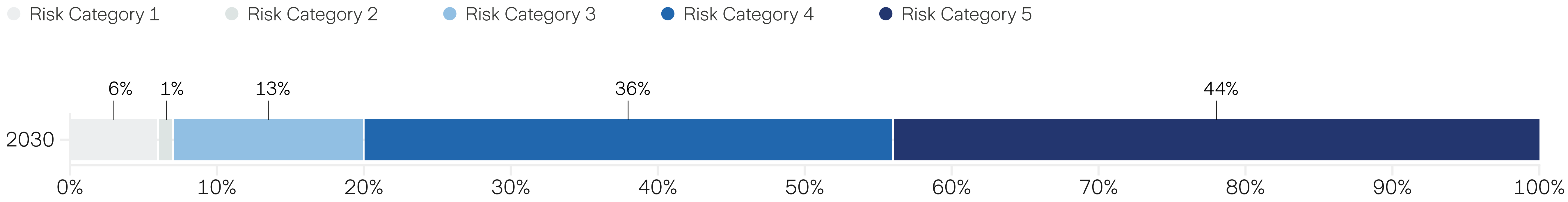
Solar PV

Solar assets are often be treated as simple and modular, but their climate vulnerability can be complex. In the region, high winds, flooding, intense rainfall, hail, heat, humidity, wildfire and corrosion all matter. A substantial share of avoidable losses can sit outside the module itself, in mounting systems, inverters, transformers, combiner boxes, drainage and wider balance-of-plant design.

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 capacity (%) by risk category (2˚C warning scenario)



Wind power

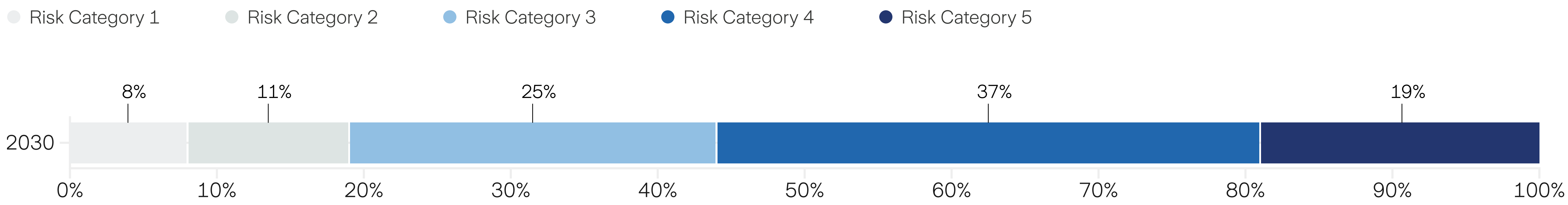
Wind assets in Southeast Asia face a mix of tropical cyclones, extreme gusts, lightning, flooding, slope instability, wildfire and coastal corrosion.

Good practice begins well before turbine delivery. It starts with site selection informed by forward-looking climate data rather than historical averages alone and with turbine class specification that reflects the conditions the asset is likely to experience over its actual operating 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 capacity (%) by risk category (2˚C warning scenario)



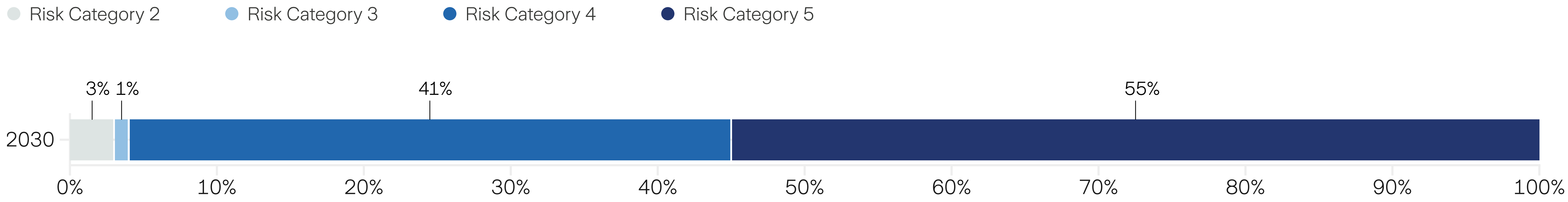
Hydropower

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 capacity (%) by risk category (2˚C warning scenario)



Geothermal

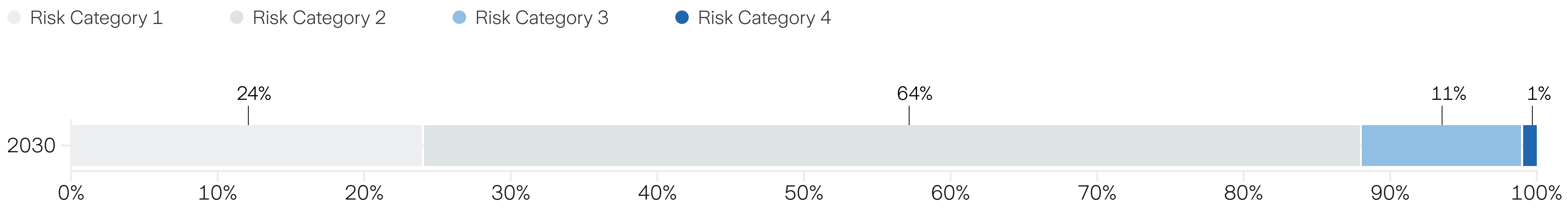
Geothermal assets are often robust at plant level but vulnerable across the wider field. Extreme rainfall, flooding, erosion, slope instability, water constraints and damage to wells, pipelines, access roads and supporting electrical systems can all create prolonged outages.

The lesson is that resilience is often determined by distributed infrastructure rather than the turbine hall alone.

Robust resilience is therefore more ‘system wide.’ It includes geotechnical screening, careful siting of wells and ancillary infrastructure, resilient access design, slope stabilisation, drainage, corrosion-resistant materials, flood protection for pipelines and electrical systems and integrity monitoring across the field.

For owners and lenders, that broader view is essential to understanding true operating resilience.

Geothermal renewable generation capacity (%) by risk category (2˚C warning scenario)



The cost argument

The commercial logic for early action is compelling. Most resilience measures can be embedded efficiently at design and construction stage, when engineering flexibility is at its peak and changes are less expensive.

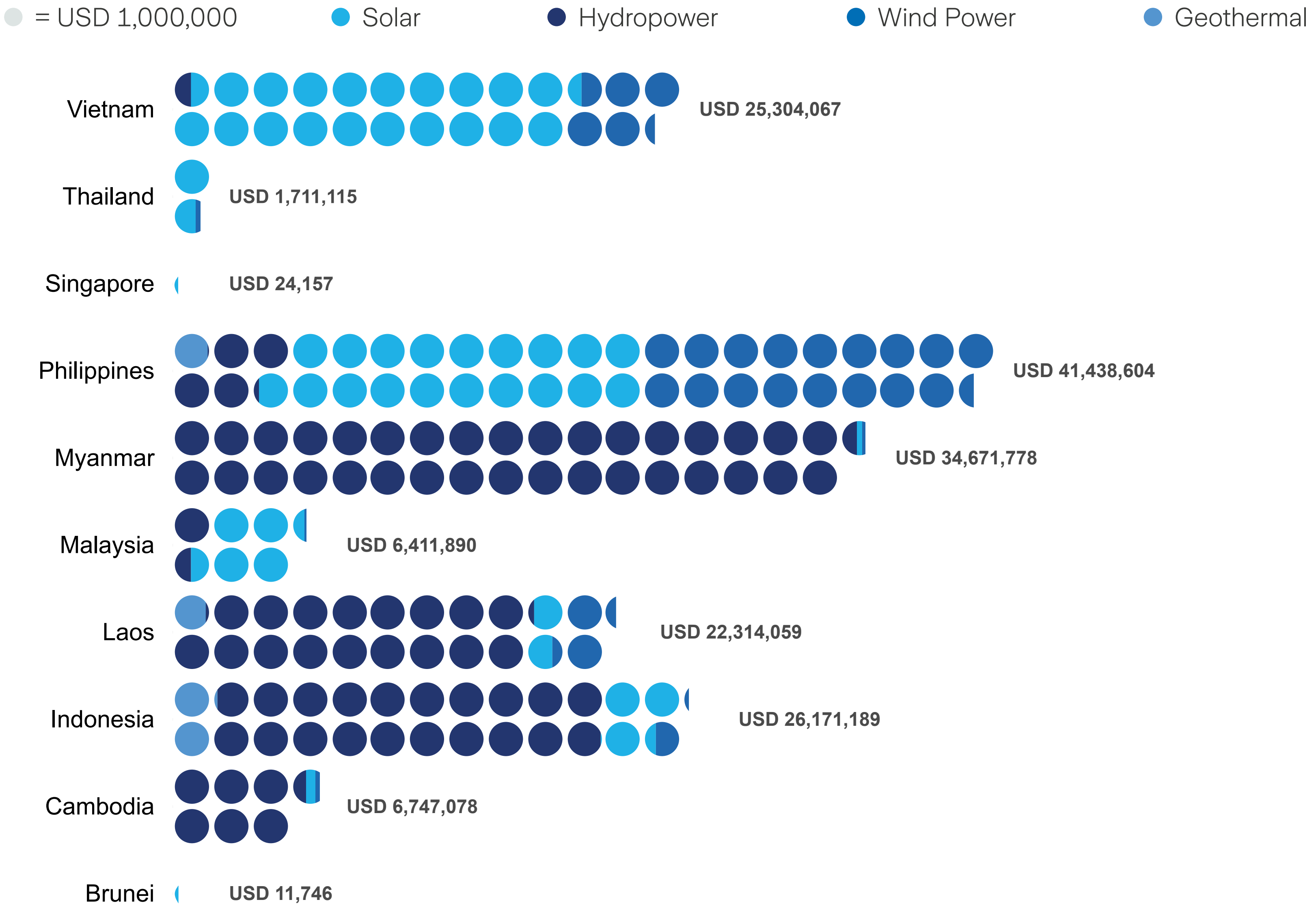
On the portfolio framing used in this report, resilience investment equivalent to around 2% of CAPEX will materially reduce the value of assets at risk. This means resilience is not a luxury but a practical and cost effective way to protect long-term asset performance.

External reporting supports this broader direction of travel. The ADB's climate work has made clear that climate adaptation finance across the region remains far below what is needed while Reuters' reporting on Southeast Asia's energy investment[11] needs shows how much capital still needs to be mobilised if climate and energy goals are to be met. In that context, better resilience is not only about risk reduction. It is also about helping make large infrastructure projects more investable in a market where capital increasingly favours quality, durability and credible adaptation planning.

Taken together, these measures show that "good" does not mean over-engineering every asset. It means matching the design to the hazard, spending where the loss-reduction value is highest, and recognising that the best time to do that is usually before the asset enters operation.

11. Energy majors lock onto Southeast Asia in race for more gas for AI power demand | Reuters, 18 June, 2025

Value at risk by country per generation type



Zurich Resilience Solutions works with clients around the world to reduce their exposure to physical climate risks. One example of how this works in practice is a utility-scale solar PV development of approximately 2.5 GW which we are advising on in the ASEAN region.

The project was designed using reputable original equipment manufacturers and following established design-by-code principles. That matters because 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.

The project 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, Estimated Maximum Loss (EML) was approximately USD 178.5 million while with the hail-stow tracker the Probable Maximum Loss (PML) was estimated at 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.

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

~20% increase
in generation output through tracker optimisation

~12x +
resilience value multiple combining avoided losses and operational performance improvement[12]

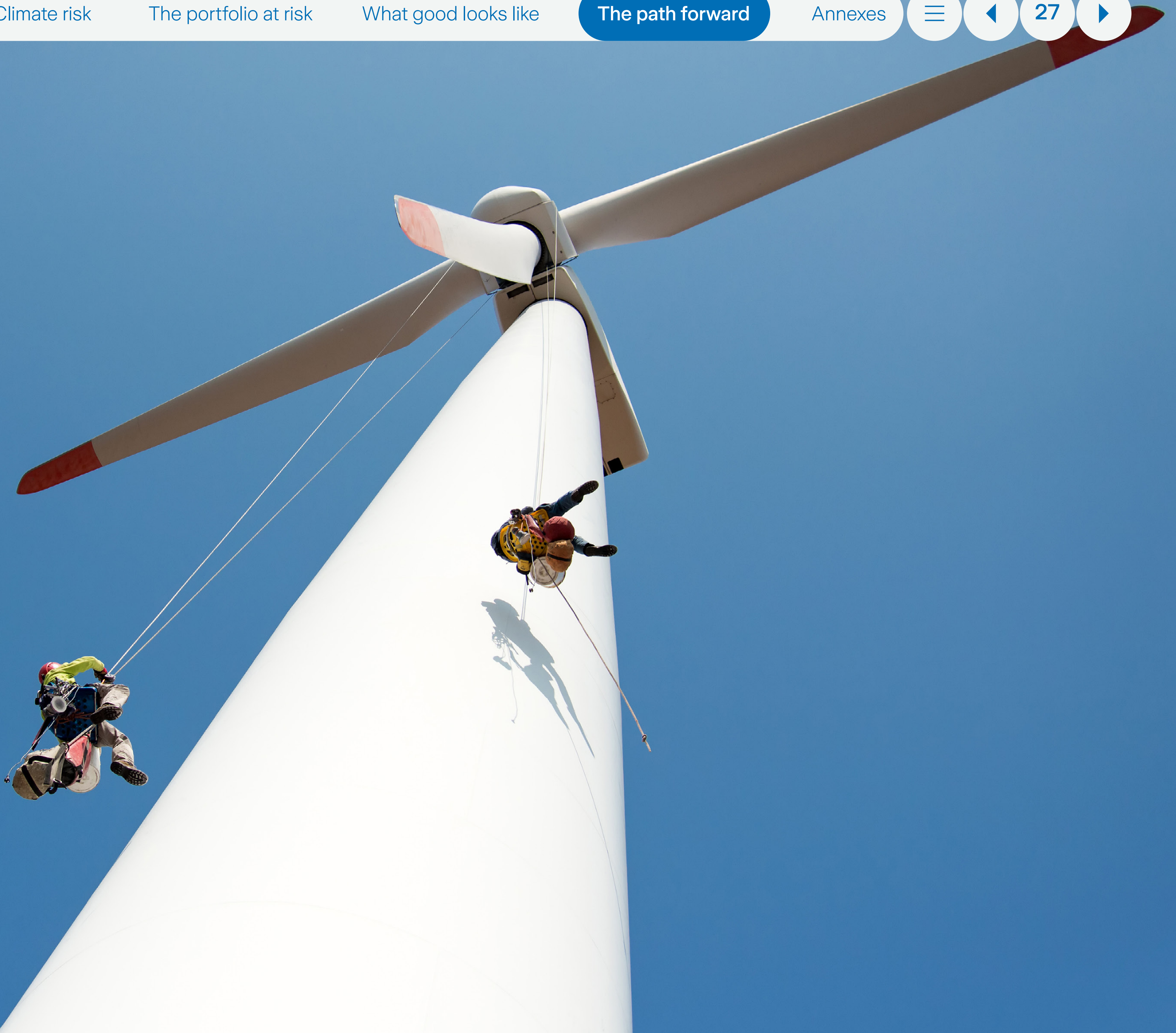
~USD 136 million
in avoided losses from a single resilience intervention

Recovery timeline reduced from
~21 months
to
~12 months

12. Outcome includes avoided severe-loss exposure and indicative operational performance improvements under scenario-specific assumptions.

The path forward

Seizing the opportunity presented by this analysis will take a coordinated effort between asset owners, operators and investors, as well as policy makers, governments and supra-national bodies. For renewable energy portfolios in Southeast Asia, five practical actions that could help move from risk to resilience in the short term stand out.



If an upfront design investment can materially reduce value at risk, improve insurability and strengthen bankability, then resilience becomes a financing issue as much as a risk issue. That creates a stronger basis for dialogue with lenders, insurers and investors.

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 75% 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 gap between severe loss exposure and less severe loss scenarios with mitigation, identify the dominant loss drivers 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

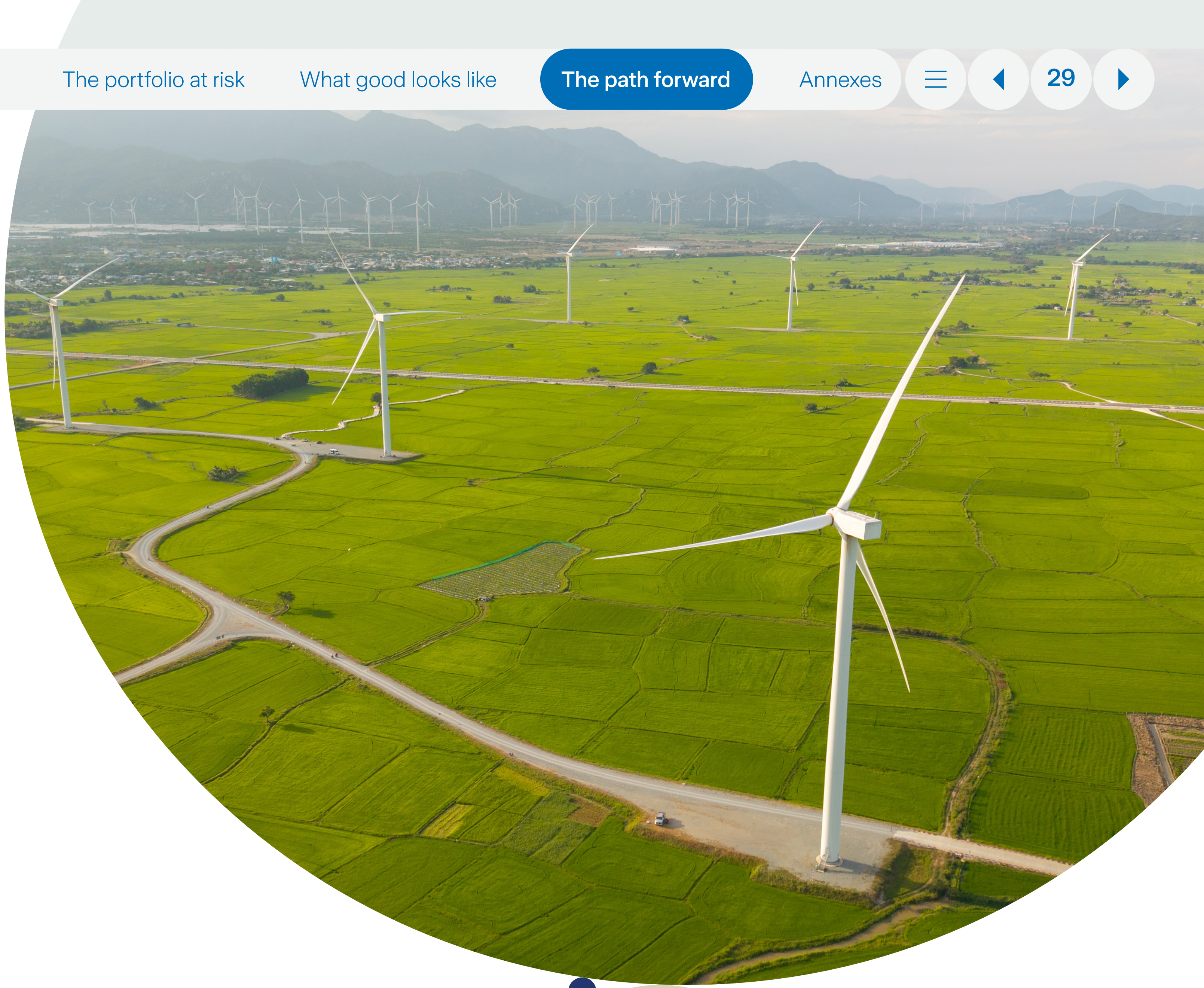
One of the strongest arguments for resilience is that it can be translated directly into financial terms. An indicative resilience investment equivalent to around 2% of CAPEX could reduce severe-loss exposure by ~40–50% under the assessed assumptions, corresponding to an indicative avoided-loss multiple of approximately ~6.5x, while supporting stronger insurability and bankability outcomes.

The external context supports these action points. The ADB's 2024 climate work highlights both the scale of future economic loss as well as the large adaptation finance gap across the region.

Simultaneously, Southeast Asia's investment needs show the scale of capital that now needs to flow into higher-quality energy infrastructure. As the region increases ambition, the quality of project development will matter as much as the quantity of capacity installed.

That is why asset resilience should be on the agenda of energy leaders. CFOs need to see resilience as part of a capital protection and finance strategy. Heads of Sustainability need to see it as part of delivering a credible energy transition rather than simply reporting one. Heads of Risk need to use it to move from exposure awareness to actionable mitigation. When those functions align, resilience becomes a source of value creation rather than simply a bottom-line cost.

The broader strategic implication is straightforward: buyers of risk management services should not treat climate resilience as an afterthought. In Southeast Asia, it is increasingly part of what determines whether the transition delivers reliable power, protected asset values, stronger insurability and durable long-term returns.



Annexes

Scope

The analysis in this report covers announced, planned, pre-construction and under construction-renewable energy assets across countries in Southeast Asia. It assesses solar PV, onshore wind, hydropower and geothermal generation sites.

We have used open-source data (Global Energy Monitor) to create a dataset for this analysis covering 1,380 energy generation assets across Southeast Asia. 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 create 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 1,380 energy generation assets across Southeast Asia.
- 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 Assesment

- 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

Acknowledgements and disclaimer

This report is intended as a thought-leadership and decision-support document for enterprise audiences. It combines our Southeast Asia portfolio analysis and risk engineering work with external contextual sources including the World Meteorological Organization, the Asian Development Bank and public reporting on the energy transition and climate risk environment.

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