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Resilience Solutions

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Resilience Beyond Borders

Climate Risk and the ASEAN Power Grid

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Introduction



The ASEAN Power Grid (APG) will transform how energy moves across Southeast Asia. By creating a more integrated regional electricity market, the APG aims to drive renewable energy deployment, support cross-border electricity trade and strengthen regional energy security.

The APG also creates a new frontier for physical climate risk. Its development will add dozens of critical infrastructure sites as it drives electricity interconnections across the region. Each new piece of infrastructure must navigate risks from the climate hazards intensifying across Asia. Ensuring the resilience of this interconnected system will require attention to the assets and nodes that support it.

As the APG gathers unprecedented momentum with a growing pipeline of interconnection projects, new financing partnerships, and planned integration into the Pan-Asia Grid Initiative, this moment offers a unique opportunity to integrate climate resilience into the heart of this decades-old project. The ASEAN Centre for Energy's proposed Integrated Resource and Resilience Planning (IRRP) framework emphasizes the importance of integrating climate considerations into the process now. This report contributes to that agenda by providing a preliminary assessment of climate hazards across priority APG interconnection corridors and highlighting resilience considerations for future planning and investment decisions. The decisions made today – while governments, utilities, investors and development partners finance, plan and deliver these interconnections – will shape regional energy security, economic development and decarbonization.



Stakeholders must understand how climate risk is evolving, and how it is distributed across the network, to build resilience into the APG. In reports published in June 2026, Zurich Resilience Solutions found that planned renewable generation infrastructure across South and Southeast Asia already faces material and growing climate risks. This paper builds on that analysis by examining how climate risks extend beyond individual generation assets and across the interconnection infrastructure planned within the APG, highlighting opportunities to strengthen resilience at a system level. In doing so, it provides an initial evidence base that can support IRRP implementation.

In this paper, we did a preliminary screening to explore how climate hazard exposure could evolve across 18 priority APG interconnections. Failures at interconnection sites could have significant consequences across interconnected systems.

Across these sites, three consistent patterns emerge. Climate hazard exposure increases by a significant degree for nearly all examined locations. These increases are driven largely by the intensification of extreme heat and extreme precipitation. However, climate risk will not be distributed evenly across the future network. Each interconnection will navigate and manage substantially different risk profiles. Different parts of the network are exposed to different combinations of hazards, including wildfire, lightning, chronic heat stress and extreme precipitation.

For the ASEAN Power Grid, resilience will be a localized challenge with regional implications. These hazard patterns have practical implications for how the future grid is designed, financed and operated. They reinforce the importance of considering future climate conditions when making infrastructure decisions and identifying vulnerabilities before assets are built or upgraded.

With much of the APG still under development, hazard protections and resilience can be embedded into planning, engineering, investment and operational decision-making to create stronger, longer-lasting assets. As ASEAN advances the APG and explores wider regional connectivity through Pan-Asian Grid Initiative, stakeholders have an opportunity to develop resilience alongside connectivity rather than in response to it.



Scope and approach

The analysis presented in this paper examines climate hazard exposure across 49 sites named as endpoints for 18 priority ASEAN Power Grid (APG) interconnections. All sites are indicative locations where existing or planned cross-border transmission links connect to national electricity systems and where supporting infrastructure, such as substations and converter facilities, may be developed. Sites were drawn from published documentation on APG priority interconnectors identified by the ASEAN Centre for Energy in the ASEAN Interconnection Master Plan Study (AIMS) III, but they do not represent the final locations of APG infrastructure.

To account for uncertainty around the final location and footprint of future infrastructure, climate exposure was assessed by averaging hazards across locations in a radius around each site's projected location. Radius size was determined based on the planning stage for interconnection infrastructure in order to encompass the area where a project might be located, with larger radii as such drawn for projects that remain largely theoretical, such as the Philippines-Sabah interconnection. This approach provides an indicative view of future climate conditions without assuming the precise siting of assets.

Using Zurich Resilience Solutions' proprietary Climate Spotlight tool and climate data, we assessed exposure to multiple climate hazards that pose direct risks to electricity infrastructure. These hazards include hot days, heat waves, lightning, extreme precipitation, flooding, landslides, wind, sea level rise and wildfire. Since our models only cover current lightning and landslide hazard data, those hazards were not included in projections over time.

Hazard exposure was assessed under baseline climate conditions and future time horizons in 2030, 2060 and 2085 under a low-emissions scenario that assumes warming is limited to around 1.8 degrees Celsius by 2100. These time horizons and the scenario were selected to capture climate impacts across the potential lifespan of APG infrastructure. The APG has a target completion date of 2045. Given the typical lifespan of electricity infrastructure assets, the 2085 time horizon provides an indication of climate conditions that may be experienced toward the end of asset lifecycles.

For each climate hazard, sites were assigned hazard scores on a scale of 0 to 1,000. These scores provide a relative measure of climate exposure based on current baselines. They enable comparison across locations, hazards and time periods. Throughout this report, hazard scores above 750 are classified as **high** and hazard scores of 1,000 are classified as **very high**, reflecting the strength of the hazard's potential impacts. This analysis is intended as a strategic climate risk screening exercise rather than an asset-specific engineering assessment. It does not assess asset vulnerability, model infrastructure performance or estimate electricity system impacts. Instead, it provides an indicative view of how climate hazards may be distributed across planned APG interconnections and where additional resilience measures may warrant consideration.

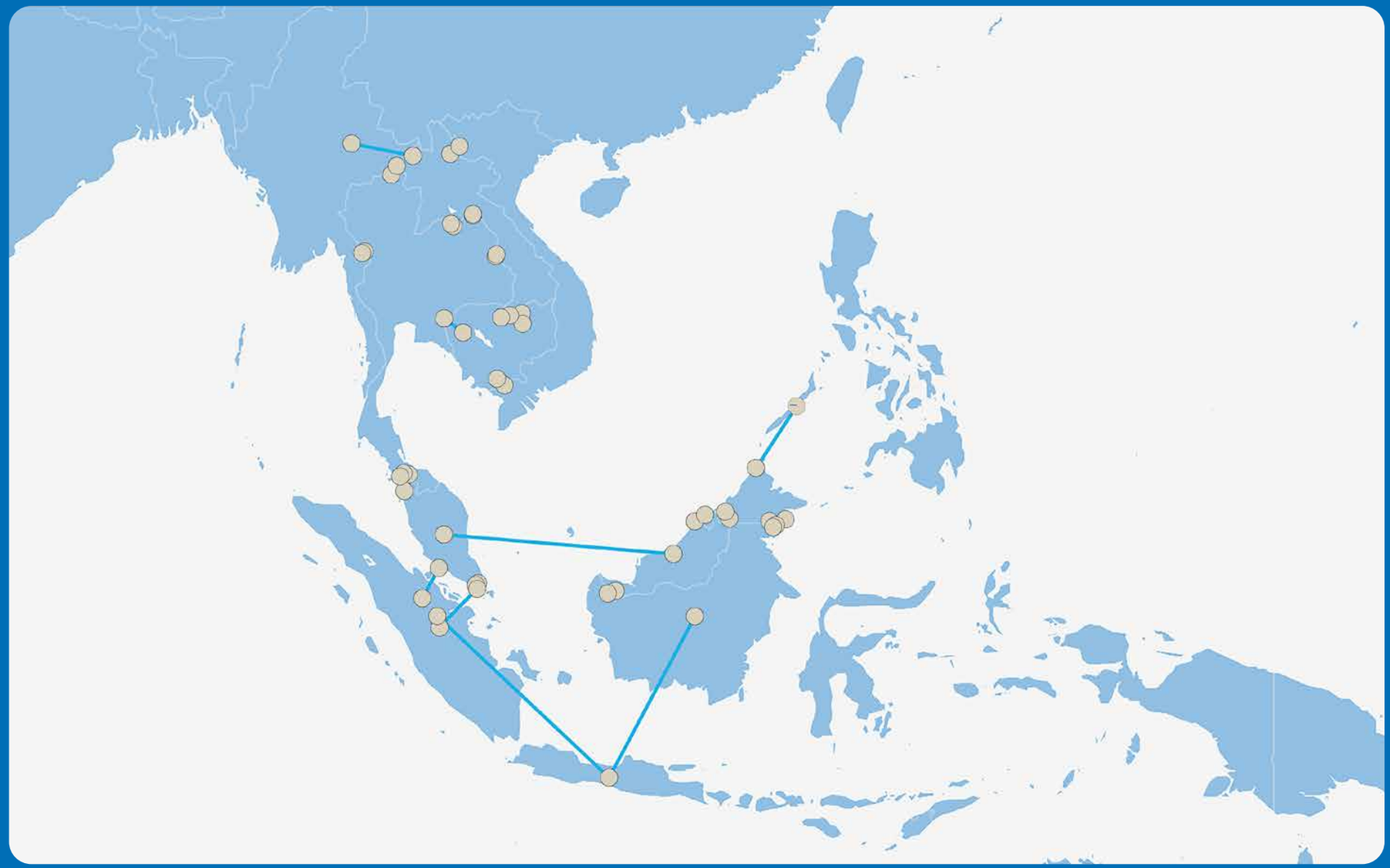
Priority interconnections for the ASEAN Power Grid:



- Peninsular Malaysia – Singapore
- Thailand – Peninsular Malaysia
- Peninsular Malaysia – Sarawak
- Peninsular Malaysia – Sumatera
- Sarawak – Kalimantan (West Kalimantan)
- Philippines – Sabah
- Sarawak – Brunei Darussalam
- Sabah – Sarawak
- Thailand – Lao PDR
- Lao PDR – Vietnam
- Thailand – Myanmar
- Vietnam – Cambodia
- Lao PDR – Cambodia
- Thailand – Cambodia
- Sabah – Kalimantan (East Sabah – North Kalimantan)
- Sumatra – Singapore
- Lao PDR – Myanmar
- Internal Indonesia:
  - Java – Kalimantan
  - Sumatra – Java

Study sites

We analyzed climate risk across 49 interconnection infrastructure sites identified in 18 priority interconnections for the APG.



Source: ASEAN Centre for Energy. (2023). *ASEAN Power Grid interconnections project profiles*. ASEAN Centre for Energy

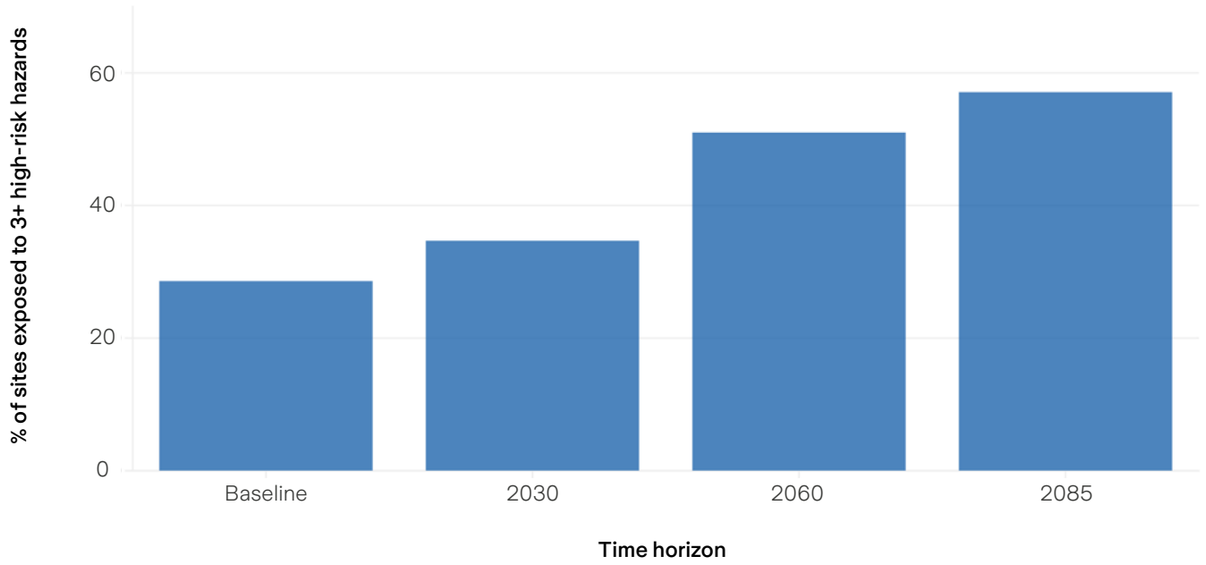
Findings

APG infrastructure sites already face climate risk. Hazards will intensify over time

Climate risk is already a reality for locations where APG infrastructure is planned. Under baseline conditions, approximately **29% of prospective interconnection infrastructure sites face at least three high-risk climate hazards.** Both the number and severity of these hazards are projected to increase over time under a low-emissions scenario. By 2030, **35% of sites** are expected to face at least three high-risk climate hazards. By mid-century, this share rises to just over half of all sites (**51%**), and by 2085, **57% of sites** are projected to face at least three high-risk climate hazards. These findings indicate that multi-hazard climate exposure is likely to become increasingly widespread across the future APG network.

The growth in exposure over time emphasizes that climate resilience cannot be deferred. Climate hazards already pose a material challenge at many planned interconnection infrastructure sites and are projected to become more frequent and more damaging over time. Interconnection infrastructure should be designed and operated with sufficient flexibility to respond to evolving climate risks throughout its lifetime.

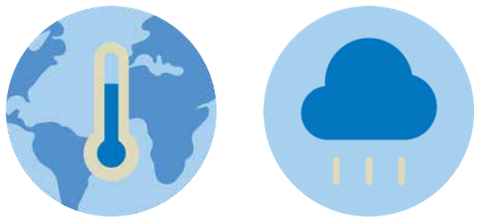
More sites are exposed to high-risk hazards over time



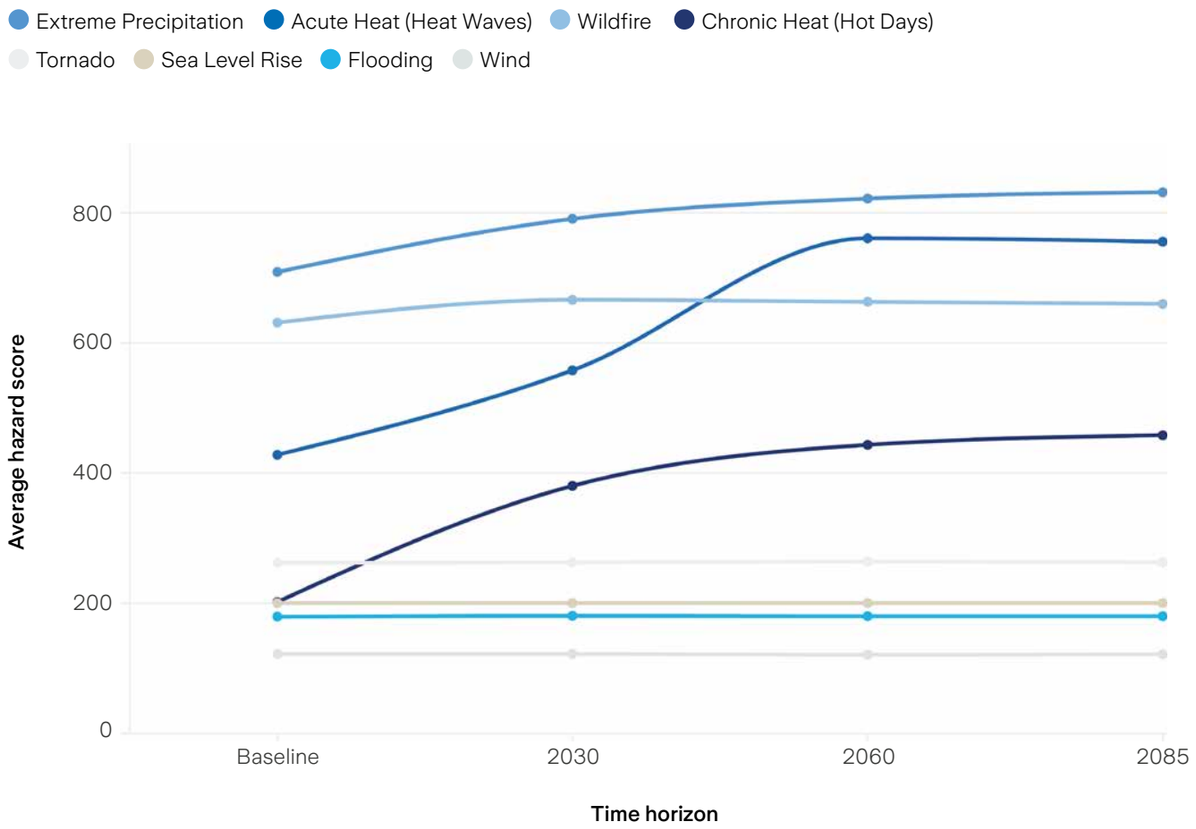
Extreme heat and extreme precipitation could become much more dangerous for grid infrastructure over time

Two climate hazards drive much of the increase in climate exposure across the APG. Over time, extreme heat and extreme precipitation emerge as network-wide challenges, posing risks to a growing share of future infrastructure sites as their severity increases and their distribution broadens.

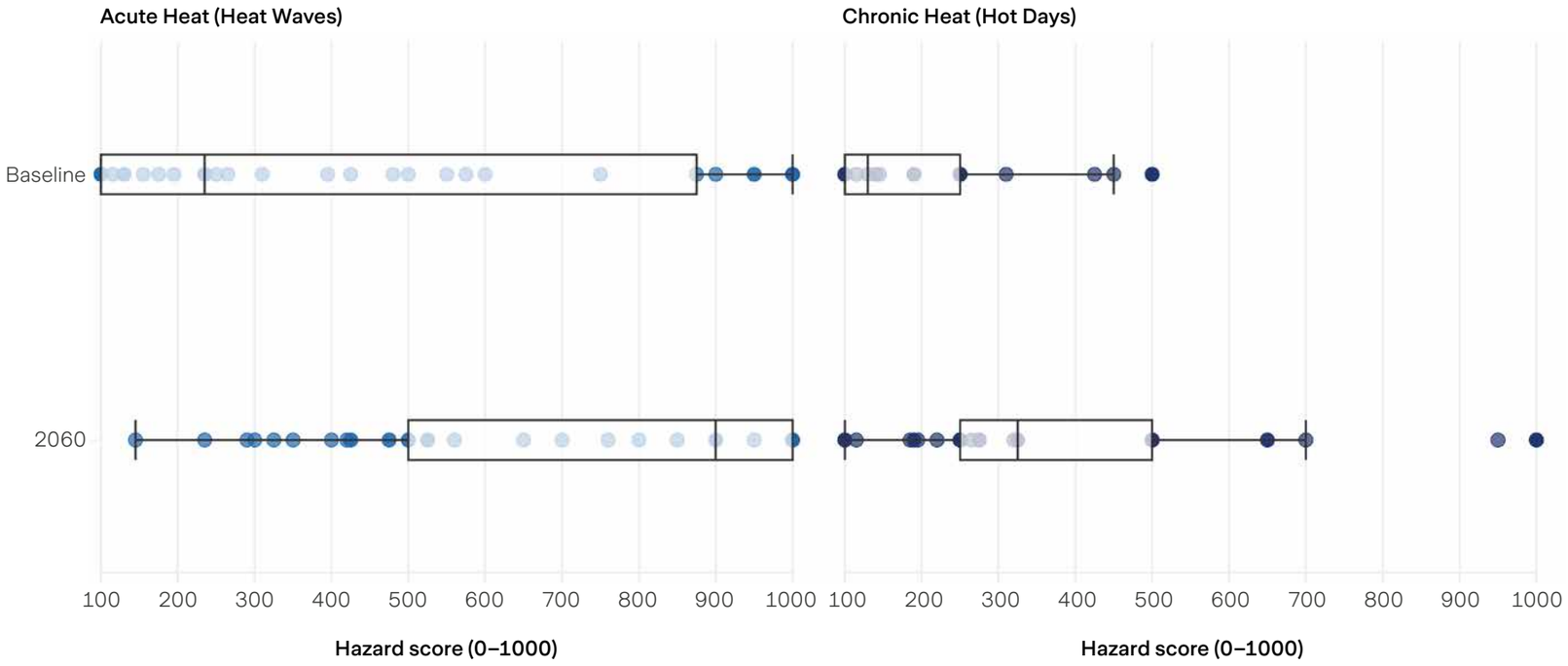
Flood risk increases slightly over time, but other hazards, including tornadoes and wind relatively stable. However, each can present severe local threats. While extreme precipitation and flooding are related, they do not represent the same hazard, as flood exposure depends on site-specific conditions including elevation, topography, drainage, and proximity to nearby water bodies.



Acute heat, chronic heat, extreme precipitation, and wildfire all increase in risk over time

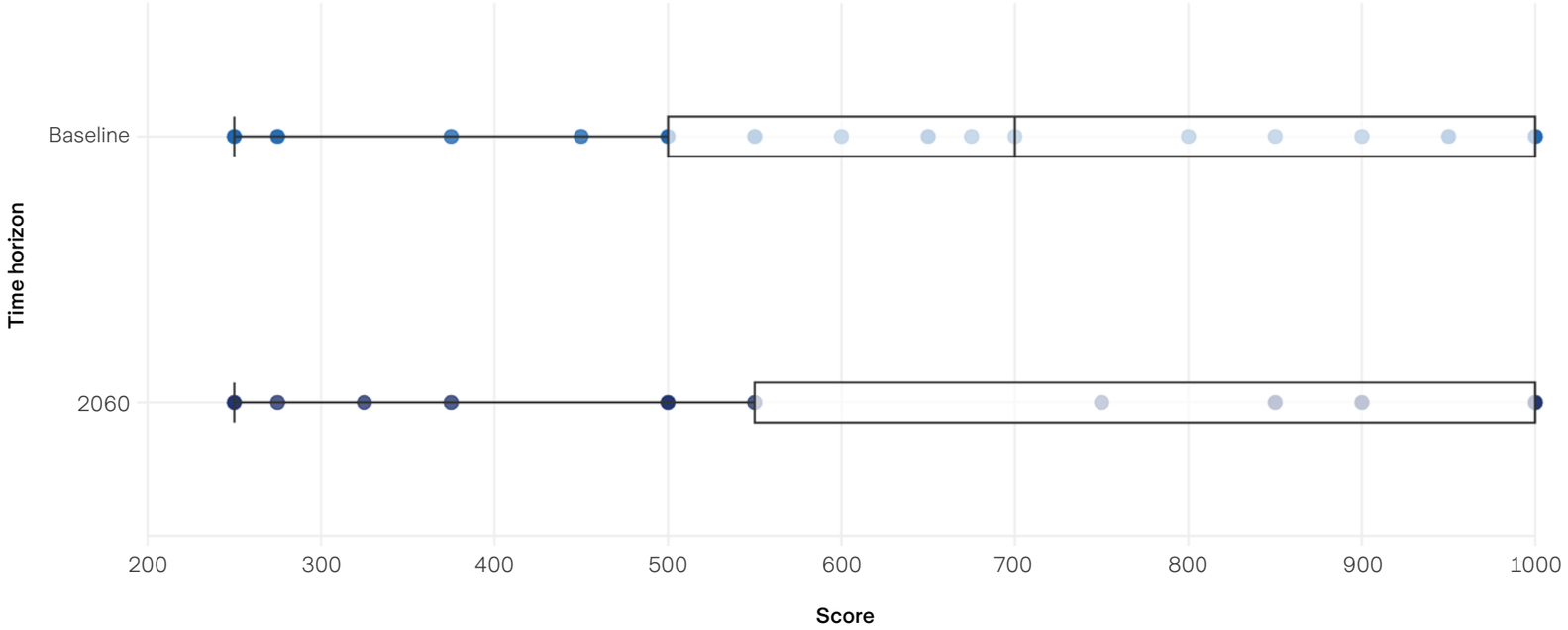


Both acute and chronic risk pose higher risks over time



Heat hazards take acute and chronic forms, but both kinds of hazard are projected to intensify across future interconnection infrastructure sites. Chronic heat, measured as the annual frequency of days above 35 degrees Celsius, is currently below the high-risk hazard threshold at all APG sites analyzed. By mid-century, **chronic heat will increase in severity by 127%** and is projected to exceed the high-risk threshold at approximately one-quarter of sites, with around one in seven sites reaching the maximum hazard score. Meanwhile, acute heat, measured through the length of heat waves, **increases by 77.7% by mid-century.**

Extreme precipitation is a bigger risk to infrastructure over time



Extreme precipitation already represents a high-risk hazard across the APG network, exceeding the high-risk threshold at **nearly two-thirds of the sites analyzed** under baseline conditions. By mid-century, this exposure is projected to become even more widespread, with more than three-quarters of sites exceeding the high-risk threshold. The share of sites reaching the maximum category rises from **approximately two-fifths of sites today to nearly two-thirds by 2060**.

Understanding the hazards driving increases in climate exposure can help governments, utilities and grid operators prioritize adaptation efforts. Because extreme heat and extreme precipitation affect sites across multiple APG corridors, they present opportunities for coordinated resilience planning and investment. Measures that address these shared challenges may deliver benefits across the wider network.

What extreme heat and precipitation mean for the ASEAN Power Grid

Heat and precipitation are critical hazards to consider for grid infrastructure because they affect more than individual assets. They influence how effectively electricity can be transmitted across an interconnected network. Because heat-related hazards reduce the amount of electricity transmission lines can safely carry, they increase stress on transformers and substation equipment, accelerate asset degradation and increase the rate of failures, and raise wildfire risk around critical infrastructure. Higher conductor temperatures cause thermal expansion, increasing line sag, and reducing ground and vegetation clearance. These challenges can be amplified during periods of extreme heat, when electricity demand is often highest.

Meanwhile, extreme precipitation can damage infrastructure directly through flooding, erosion, and slope instability. Extreme precipitation can also disrupt supporting infrastructure such as roads and maintenance access, delaying repairs and extending outages. As these hazards evolve across the network, early resilience actions will only become more critical. These strategies are not complicated, but must be tailored to site conditions and developed through proactive conversations with experienced risk engineers. Resilience actions could include updating maintenance frequencies, considering nature-based solutions, and ensuring the stability of supporting infrastructure. Zurich Resilience Solutions can develop guidance around managing these emerging chronic risks for long-term infrastructure reliability.

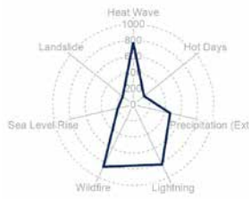
Climate risks will not be distributed evenly across the APG

For each of the 18 priority interconnections, we calculated an average hazard score across their interconnection infrastructure sites and identified the key climate hazards that may affect each project by 2060. While extreme precipitation and heat remain consistent risks, climate risk takes a different shape across the network. As a result, resilience measures will need to reflect local conditions, such as localized vulnerabilities to wildfire, lightning, landslides, and sea level rise. Even within a single interconnection project, the dominant hazards can vary between sites. This makes resilience a specialized challenge, but a collective problem.

Hazard exposure takes a different shape across each interconnection corridor

Note: This analysis excludes wind and flooding, as those hazards pose consistently low risk across the analyzed corridors

East Sabah
North Kalimantan



Internal Indonesia



Lao PDR – Cambodia



Lao PDR – Myanmar



Lao PDR – Vietnam



Peninsular Malaysia
Sarawak



Peninsular Malaysia
Singapore



Peninsular Malaysia
Sumatra



Philippines – Sabah



Sabah – Sarawak



Sarawak
Brunei Darussalam



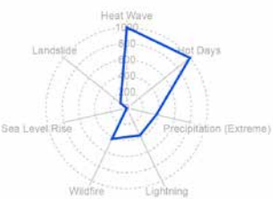
Sarawak
West Kalimantan



Sumatra – Singapore



Thailand – Cambodia



Thailand – Lao PDR



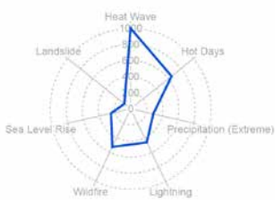
Thailand – Myanmar



Thailand
Peninsular Malaysia



Vietnam – Cambodia



Interconnected networks are only as strong as their weakest links. As power systems become more integrated, climate-related disruptions at a single highly exposed site may affect electricity flows far beyond the location where the event occurs by reducing transmission capacity across the network. The resilience of the future grid may therefore depend less on average conditions and more on the performance of its most climate-exposed assets, including understanding which hazards affect each location and how those impacts extend across the interconnected region.

The APG will make the energy security of ASEAN member states increasingly interdependent. Vulnerabilities at individual locations may become shared challenges as the effects of climate hazards propagate across the network. As such, **resilience becomes a collective benefit**.

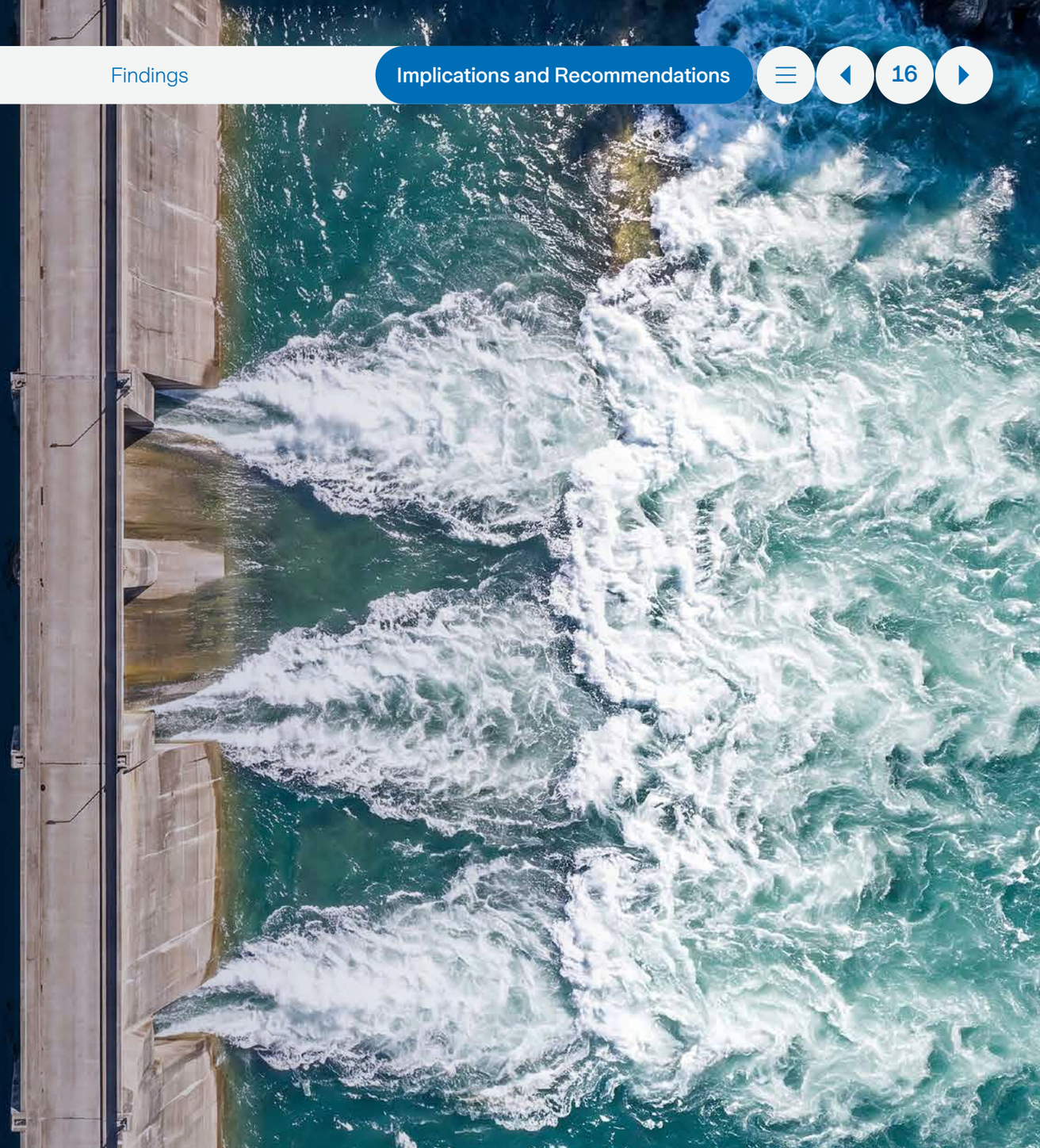


Implications and Recommendations

Putting grid resilience into action

The APG is an increasingly interconnected system where physical climate risk is a severe present challenge and an intensifying future threat. With much of the grid still under development, there is an opportunity to embed climate resilience into planning, investment and operations at the outset of the process. The value of these investments extends beyond individual assets. As regional electricity systems become more interconnected, building tailored resilience at critical sites can help support the performance and reliability of the wider network.

To support the resilience of the APG, the following actions are recommended.





Use site-level assessments to help build APG infrastructure for future climate realities

Our analysis shows that ASEAN will become hotter and wetter over the coming decades, while climate risks become increasingly complex as hazards intensify and new risk patterns emerge. While regional climate screenings like ours can identify where risks may be concentrated across the network, the localized nature of these risks requires site-specific assessments and resilience measures.

The Zurich Resilience Solutions approach combines climate hazard information with asset characteristics, operational dependencies and vulnerability considerations to evaluate risk drivers, assess potential impacts and identify targeted resilience measures. Site-level assessments will be essential to help APG stakeholders build grid stability. These assessments can recommend ways to adapt individual assets to withstand future climate conditions, from enhancing lightning protection and drainage systems to strengthening structures and revising technical specifications. By identifying vulnerabilities and the measures needed to address them, these assessments ensure infrastructure is built for the climate it will operate in, rather than the climate of the past.



Integrate climate resilience into infrastructure planning and design

Resilience begins, but cannot end, at a site-level assessment. ACE's proposed Integrated Resource and Resilience Planning (IRRP) approach provides a framework for integrating resilience into regional power system planning. Given the hazard trends identified in this report, climate considerations should become a core input to the next edition of the ASEAN Interconnection Masterplan Study, including climate-risk screening of proposed interconnections and the use of climate-risk information to inform project prioritization and resilience investments.

As ASEAN Member States develop and implement national adaptation plans, there is an opportunity to connect adaptation priorities with the planning, financing and development of cross-border power infrastructure. ASEAN policymakers should establish a coordinated regional approach to physical climate resilience within APG governance. This should include shared principles for assessing future climate risk, incorporating resilience into project requirements and financing frameworks, and addressing cross-border vulnerabilities and operational dependencies. Singapore's 2027 ASEAN Chairmanship provides a timely opportunity to advance this agenda through regional discussions on the APG and climate resilience.



Strengthen regional climate-risk intelligence

ASEAN has already taken major steps to strengthen regional energy data-sharing through initiatives such as the ASEAN Energy Database System (AEDS). We recommend building on this foundation by incorporating climate-risk and resilience information. While current efforts focus on power-system and market data, future APG planning will also benefit from a shared understanding of how climate risks are evolving across interconnection corridors, including standardized climate-hazard datasets across multiple planning horizons and common risk-screening methodologies. As climate conditions become increasingly variable and extreme events more frequent, this shared evidence base can help stakeholders anticipate emerging risks, support adaptive decision-making, and strengthen resilience across the network.

Developing a regional repository of resilience measures, adaptation practices and lessons learned from utilities, transmission operators and infrastructure developers could further accelerate learning and reduce duplicated effort. Combined with regular expert-led resilience assessments of key assets and governance structures, these mechanisms can help identify emerging vulnerabilities, inform planning and investment decisions, and ensure resilience is embedded as an ongoing conversation.

The ASEAN Power Grid is an opportunity not only to strengthen regional energy security and support the clean energy transition, but also to demonstrate how climate resilience can be embedded into the planning, governance and operation of complex cross-border infrastructure.

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