ADB Asia Clean Energy Forum 2025

Resilient Energy Systems Against Extreme Weather events

Scaling up Investment for Energy Resilience – the Role of the World Bank

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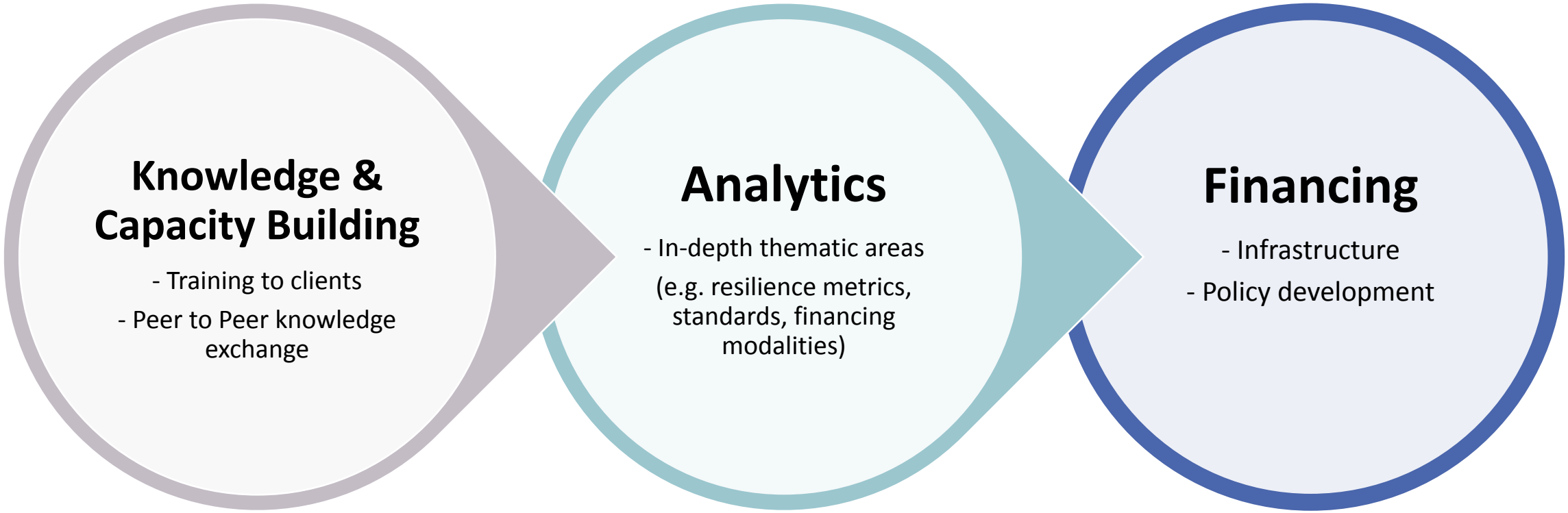
WB Energy and Extractive (EEX) Resilience Hub

Objective: mainstream climate and disaster resilience into WB-financed energy operations, analytics, and policy dialogues



In-depth support to investment and financing

1. Mainstreaming vulnerability assessment

- WBG corporate commitments – mandatory risk screening

2. Integration into financing operations

- Quantification of “delta” for climate resilience in power system planning and economic & financial analysis
- Tailored technical assistance: WBG M 300 mission – linking access with resilience; power interconnection projects - grids codes and standards etc.,

3. Investment at scale through private sector engagement

- IFC – private companies, utilities, insurance agencies to explore innovative financing models
- MIGA – risk mitigation modalities (e.g. investment guarantees)

1. Mainstreaming vulnerability assessment – Vietnam

Vietnam Typhoon Map

Devastating storms and typhoons

- 1997 – Typhoon Linda
- 1998 – Typhoon Bao Son
- 2000 – Tropical Storm Kaemi
- 2008 – Tropical Storm Kammuri
- 2009 – Typhoon Ketsana
- 2009 –Typhoon Minirae
- 2013 – Typhoon Haiyan
- 2016 – Typhoon Doksuri
- 2024 – Typhoon Yagi

Impact on EVN's transmission system

Downed Lines: High winds and flying debris can bring down power lines, disrupting service and creating hazards.

Structural Damage: Poles and towers may collapse or become damaged due to severe wind loads or falling trees.

Substation Vulnerability: Flooding and wind damage can affect substations, leading to equipment failures or structural integrity issues.

Restoration Challenges: Access to damaged areas might be restricted, delaying restoration efforts. Safety concerns for crews in severe weather conditions complicate repairs.

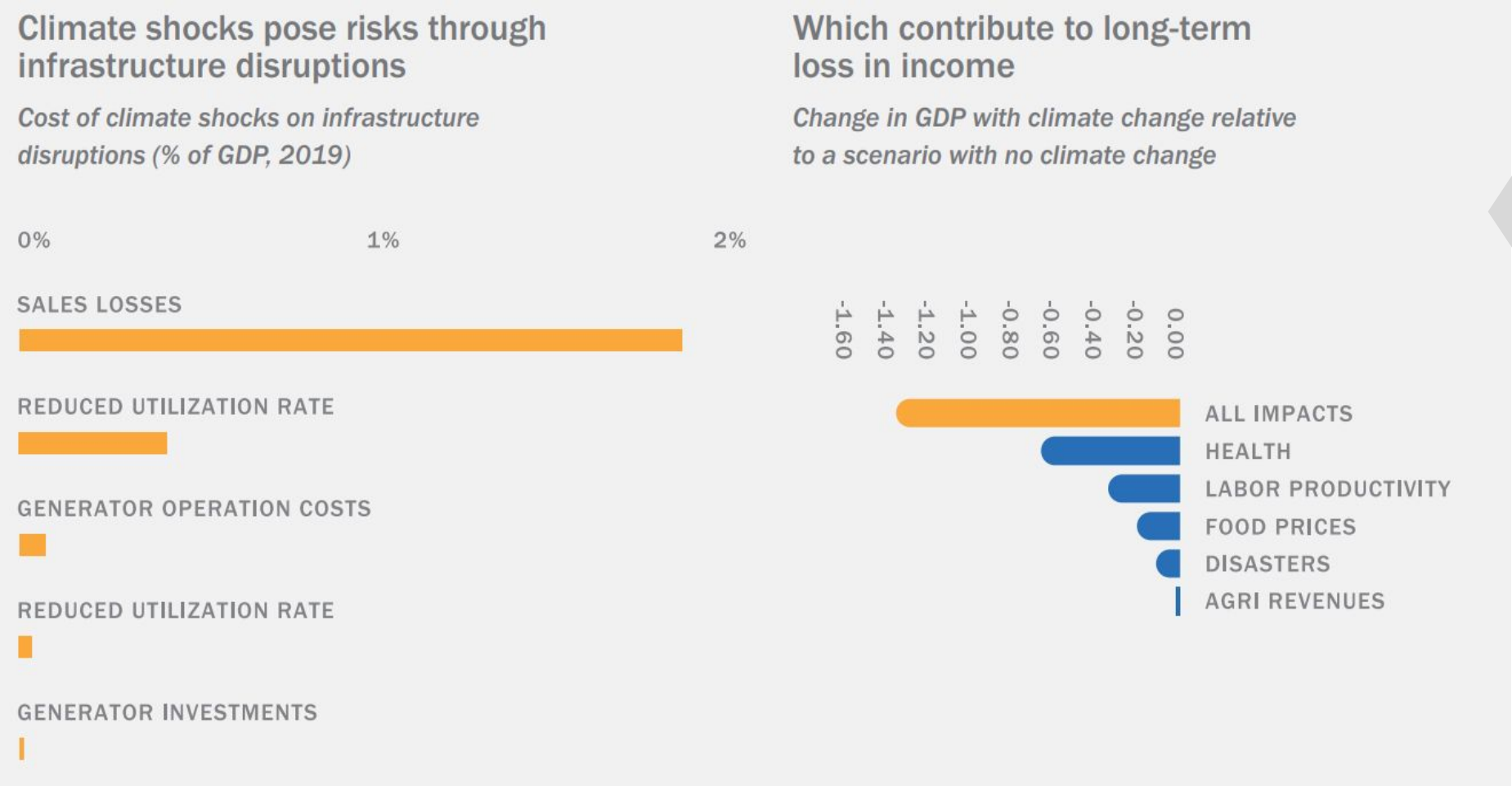
Frequent Inspections: After storms, utilities often need to conduct extensive inspections and maintenance to assess damage and ensure safety.

To mitigate the effects of storms on the power transmission system, the Vietnamese government and utility companies have been investing in **grid modernization** and **resilience-building measures:**

- Upgrading infrastructure
- Implementing smart grid technologies
- Improving emergency response and recovery plans

2. Integration into financing operations - modeling

Example of WBG Indonesia Country Climate and Development Report (CCDR)



In 2019, costs to firms from infrastructure disruptions ~ 2.4 % of GDP

Projects loss of ~ 1.4% of GDP by 2030 under midrange climate assumptions relative to no climate change

2. Integration into financing operations – economic analysis

Example: Federated States of Micronesia - Energy access & reliability improvement financing project

BENEFIT			
Reduced diesel based generation cost through the use of renewable energy		***2025***	***2026***
Total electricity supplied without project (with demand forecast)	TJ	2,162	2,194
Electricity supplied without project	MWh	600,560	609,569
Total generation cost with 4 state utiltities *(*based on 2021 financial statement)*	USD	12,734,954	12,925,978
Solar PV + BESS addition	MWh	-	3,504
Total thermal generation with project (asuume 100% diesel generation mix. Need to adjust with RE generation)	MWh	600,560	606,065
Generation cost without project	USD	12,734,954	12,925,978
Generation cost thermal with project *(assume no generation cost solar PV/BESS with project)*	USD	12,734,954	12,851,676
Total reduction in generation cost	mUSD	-	0.07
Reduced energy losses in distribution networks through rehabilitation and upgrade of power grids		***2025***	***2026***
Electricity supplied without project	MWh	600,560	609,569
Technical loss without project	%	25%	25%
Technical loss with project	%	25.0%	24.5%
System loss reduction with project	%	0.0%	0.5%
Electricity loss without project	MWh	150,140	152,392
Electricity loss with project	MWh	150,140	149,344
Avoided loss in electricity supplied in project area	MWh	-	3,048
Total benefit of avoided loss with T&D rehabilitation	mUSD	-	1.05
Improved access to electricity		***2025***	***2026***
Residential			
WTP of households without access	USD/hh/yr	318	318
Demand (per customer)	kWh/hh/year	120	122
Customers in household *(*based on 2010 Census)*	#	607	616

Economic benefits:

- ***$43.6 m USD avoided damages***
- ***$15.4 m USD reduced outages,***

>> significantly outperforming the counterfactual of the project baseline

2. Integration into financing operations – measures and costs

Risk mitigation options for solar with cost range

Climate Hazard	Adaptation Measure	Impacts Addressed	General Range or Example Cost
Temperature increases	Leverage pole-top designs that improve passive airflow beneath photovoltaic mounting structures, reducing panel temperature and increasing power output	Power efficiency and output reductions	Module racking costs estimated to be 3 – 4 times more expensive than ground mount racking
Temperature increases	Install more heat-resistant photovoltaic models such as crystalline silicon cells, and module materials designed to better withstand operating conditions in extreme heat	Power efficiency	$0.8 - $1.3/W-DC
Cloud cover increases	Site solar photovoltaic systems where expected changes in cloud cover are relatively low	Power efficiency	
Coastal storms, Winds and Extreme Precipitation	Invest in improved weather prediction systems to improve reliability of expected panel output by removing critical equipment reinstalling after adverse weather conditions pass	Generation infrastructure damage	Estimated labor installation costs range from $0.14/W-DC to $0.48/W-DC
Drought and Winds	Invest in washing procedures to remove dust and clean panels to increase output and avoid related damages including hotspots	Generation infrastructure damage	$0.80-$1.30/kW-yr for an annual cleaning. For more frequent and optimized washing schedules, cost can be closer to $20/kW-year
Disaster	Leverage distributed energy resources (DER) to increase grid resilience and flexibility through on-site power generation (e.g., rooftop solar), battery storage (e.g., EV demand response, residential lithium-ion packs, utility scale batteries), resource efficiency programs, or microgrids that can go into island-mode at any time		

Source. World Bank. https://documents1.worldbank.org/curated/en/099051723120069604/pdf/P17463309adfa80100807c09e9505aa070d.pdf

2. Integration into financing operations – investment strategy

Indonesia
Estimation of investment costs

Region	Province with risk score 5 & 6	Cost of whole transmission lines in US dollars ($)	Cost of all the substations in US dollars ($)	System level investments (50% of total cost)	
				Transmission lines	Substations
Red River Delta	Bac Ninh	116,750,000	21,426,140	58,375,000	10,713,070
	Ha Nam	43,800,000	17,873,410	21,900,000	8,936,705
	Ha Noi	355,900,000	849,787,465	177,950,000	424,893,733
	Hai Duong	130,650,000	62,611,815	65,325,000	31,305,908
	Hai Phong	32,700,000	25,088,630	16,350,000	12,544,315
	Ninh Bình	102,100,000	28,641,360	51,050,000	14,320,680
	Thai Binh	39,000,000	14,320,680	19,500,000	7,160,340
Northern Midlands and Mountains	Bac Giang	136,650,000	14,320,680	68,325,000	7,160,340
North Central and Central Coast	Ha Tinh	265,550,000	545,420,680	132,775,000	272,710,340
	Quang Tri	155,850,000	21,426,140	77,925,000	10,713,070
	Da Nang	120,150,000	145,238,630	60,075,000	72,619,315

Investment measures and CBA

Infrastructure and Assets	Investment scope	Benefits
Emergency Transmission Infrastructure • **25% of Total Costs for high risk** • **15% for medium risk**	These alternative transmission lines and substations act as backup systems.	continuous power availability, minimizes downtime during outages, and enhances the overall reliability of the electrical grid
Replacement and Upgrading of Existing Assets • **5% of Total Costs for high risk** • **3% for medium risk**	This includes updating old transmission equipment, replacing worn-out components, and upgrading facilities to incorporate the latest technology and standards	improve the efficiency and safety of the electrical grid, reduce the likelihood of unexpected failures, and extend the lifespan of our infrastructure.

3. Investment at scale through private sector engagement

Upstream policy development to create enabling environment

- Mainstreaming resilience policy actions and reforms through WB Development Policy Financing to foster enabling environment for private investment

Consolidating business cases - IFC & MIGA

- Deep dive on business case for private investment on climate and disaster resilience
- Emerging financing modalities (e.g. wildfire funds, insurance schemes)

Knowledge generation and exchange

- WB livewire series: investment cost estimates, resilience metrics to guide investment, governance etc.,
- WB BBL series: bringing utilities and regulators to capture emerging best practices

3. Investment at scale through private sector mobilization
- Knowledge generation and sharing

Knowledge sharing series on

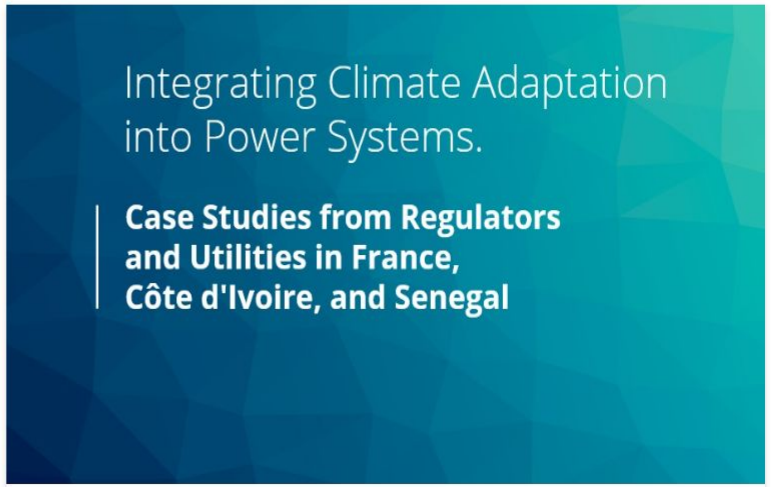
Integrating Climate Adaptation into Power Systems: Why – How – And Who should do and pay for it

Case Studies from Regulators and Utilities in Kenya, the UK, and Brazil

Session 1: Wednesday, May 21, 2025 | 09:00 AM - 10:00 AM ET I Room: MC 6-795 & on Teams

Session 2: Details forthcoming

June 2025



Session 3: Details forthcoming

June 2025

Link to recording and presentations:
https://www.worldbank.org/en/topic/energy/brief/the-utility-knowledge-exchange-ukep-platform

3. Investment at scale through private sector mobilization
- Leveraging concessional funds to scale up resilience efforts

ESMAP Energy Sector Management Assistance Program

PPIAF Enabling Infrastructure Investment

GFDRR Global Facility for Disaster Reduction and Recovery

ADAPTATION FUND

CSF CLIMATE SUPPORT FACILITY

QUALITY INFRASTRUCTURE INVESTMENT PARTNERSHIP

CIF CLIMATE INVESTMENT FUNDS

Strategic use of concessional funds to facilitate private capital mobilization

- Public-Private Infrastructure Advisory Facility (PPIAF) – *PPP framework climate resilience investment for hydropower projects*
- Energy Sector Management Assistance Program (ESMAP) – *Knowledge and capacity building with public and private players*

Thank you!

EEX Resilience Hub Resources

Past WB energy resilience studies and relevant publications can

- **Climate Impacts on Energy Systems**
- **Good Practice Note Energy Sector Adaptation**
- Integrating resilience into the **Economic Analysis of Power Projects**
- **Stronger Power:** Improving Power Sector Resilience to Natural Hazards

World Bank Climate and Disaster Risk Screening Tool is a useful qualitative tool here. For more systematic approach, see the **Resilience Rating System**.

- **Climate Change Knowledge Portal (CCKP)**, including temperature and projections based on CMIP5 and CMIP6
- **WB Development Data Hub** for country-level risk assessment and global databases

And more to come…!