



Task Force 4
Refuelling Growth: Clean Energy
and Green Transitions



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EMBEDDING RESILIENCE IN POWER SECTOR PLANNING

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Abstract





Electricity is crucial in ensuring optimum healthcare, education, quality of life, and sustained economic development. As countries embed clean energy and move to a standard all-round electrification practice, the health of the power system assumes greater significance. However, power system reliability is threatened by two factors: the variability of generation sources to facilitate the clean energy transition; and climate-induced extreme weather events that can lead to cascading impacts through the electricity value chain.

Not accounting for climate risks can burden or delay the pursuit of the clean energy transition. Further, there is a need for diversified supply chains to hedge


against material availability risk, and ensure circular economic frameworks to maximise resource value.

The G20 should consider the following actions to build power sector resilience within the ambit of its wider international cooperation and knowledge-sharing work:

1. Include resilience in long-term power-sector planning
2. Invest in grid-hardening measures
3. Leverage distributed clean energy technologies and grid digitalisation
4. Invest in energy storage ecosystems that provide balancing services and flexibility



The Challenge



1



Climate change is a ‘threat multiplier’ due to its compounding effect on risks and a system’s exposure to high-impact, low-probability events. The power sector is vulnerable to climate change, thus adding a new dimension to the risks the sector faces. Power sector resilience is the ability of modern power systems to withstand extraordinary events, rapidly recover from such events, and learn to adapt to their operations such that the functionality of the whole system improves.

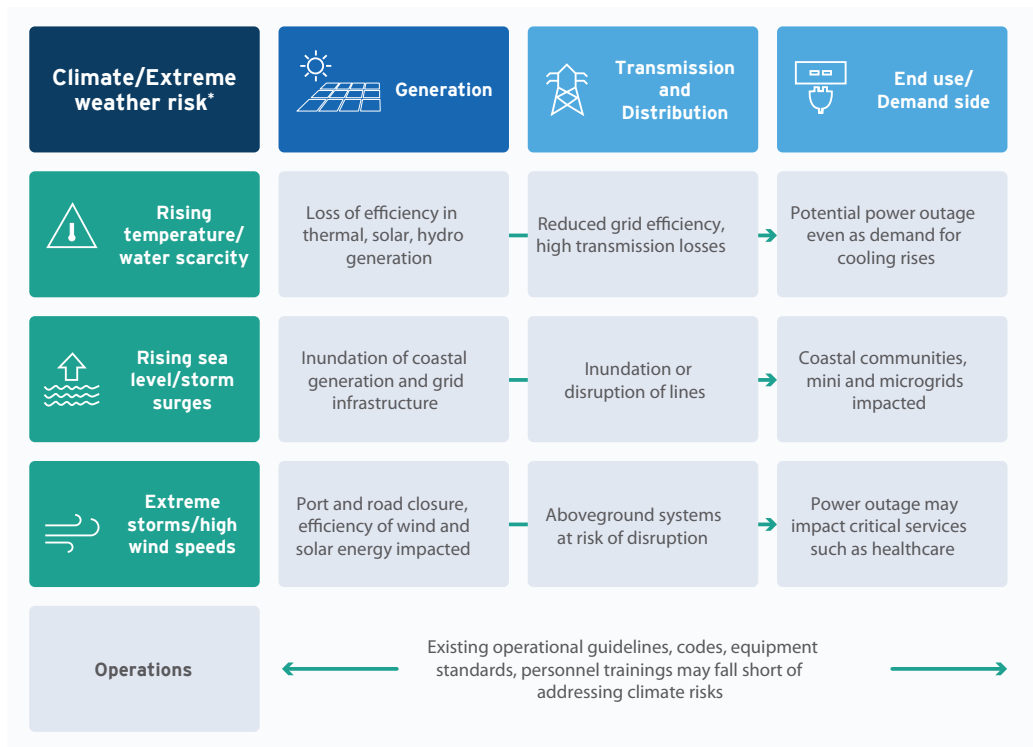
Increasing climate-induced extreme-weather events and the expanding extent of the electricity sector—both in terms of growing customers and the sectors to be electrified—stand to concentrate the risk of a system-wide disruption on electricity as a resource and the grid that transmits it (see Figure 1). Renewable energy (RE) assets and infrastructure, while contributing to climate change

mitigation, are not immune to physical damage from climate-induced extreme-weather events either.

Thus, without planning for a ‘resilient’ power sector, sustainable development remains at risk. By negatively impacting economic productivity, increasing power outages are linked to a reduction in the per capita income of households.¹ At the same time, inadequacy of data and uncertainty associated with climate impacts enhance the complexity of planning within the power sector.

The current power sector infrastructure is inadequately equipped to onboard RE and manage the associated variability without flexibility of resources. These conditions are together leading to an overhaul of the incumbent system of transmitting power from a central point of generation to distributed end consumers.

Figure 1: Cascading impact on the electricity value chain due to climate-induced extreme-weather events



*Not exhaustive


Source: Powering Through: A Climate Resilient Future (RMI and RMI India, 2021)²



The G20's Role



2

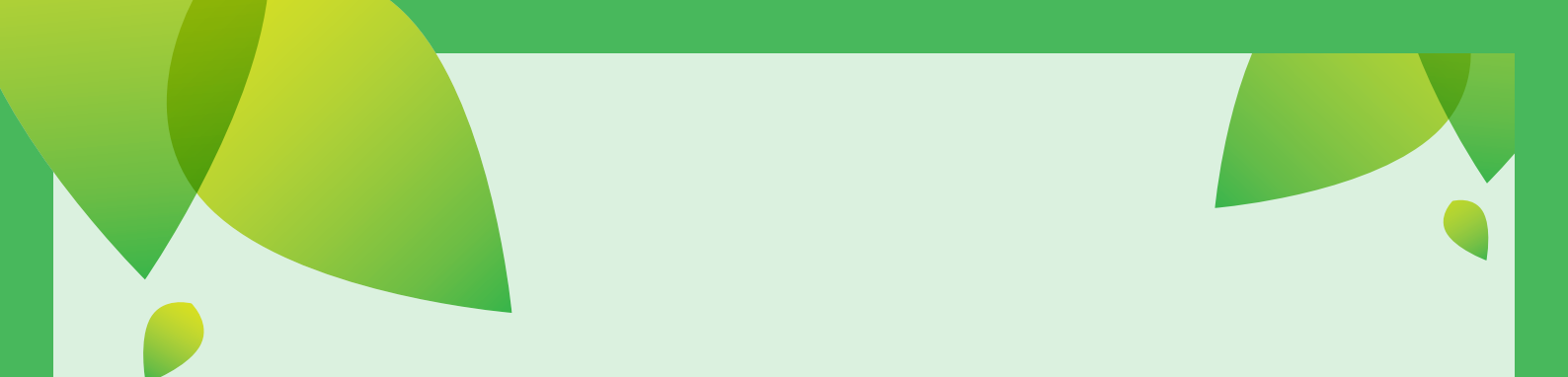


Ensuring electricity security and reliability is a growing concern for G20 member states, especially as per capita electricity demand in the group has risen 53.38 percent since 2000.³ Failure to plan for resilience can impose costs of repair and reconstruction on local administrations, affect critical services and, by extension, communities. In this context, the G20 should recognise the role of building power sector resilience in advancing energy security, net zero goals, and societal benefits.

Power sector resilience assumes an international essence as multilateral collaborations pursuing round-the-clock clean-energy sharing via transnational supergrids, such as the One Sun One World One Grid initiative, are beginning to take shape.⁴ Just like

extreme weather events do not adhere to national boundaries, the implied risk will notably impact regionally integrated grids.


As an international consortium, the G20 is committed to improving energy security to support energy transitions through collaboration, as captured in the G20 Naples Principles.⁵ Alignment within the group on employing power sector resilience as a crucial energy transition strategy will help build a collective understanding and more visibility around incorporating novel technologies and business models in power systems. With some of the world's strongest economies as its members, the G20 can effectively model and mainstream action on power sector resilience regionally and globally.



Recommendations to the G20



3



Include resilience in long-term power-sector planning

Actions


- Share granular climate risk data and expertise so they may be processed for the benefit of power sector planners, including utilities and policymakers
- Explore non-wires alternative (NWA) projects that can replace traditional physical infrastructure needs
- Convene in bilateral or multilateral groupings within the G20 to conduct joint planning exercises, training and capacity building, and test pilots as required

Rationale

Long-term power planning entails outlining the right power mix, infrastructure, and associated costs and benefits while accounting for changing future electricity requirements and other stressors emanating from economic, geopolitical or weather-related risks.⁶ Climate change, which operates on longer time scales and larger geographical scales than ‘weather’, is a new source of risks that the power sector faces.⁷

Climate impact manifests in different types of extreme weather events and slow changes overtime. Not only are 100-year events becoming more frequent and unpredictable but the current infrastructure does not account for risks that previously occurred only once in a century. For example, in 2022, South Asia recorded higher than standard summer temperatures when heatwaves swept across north and central India and its neighbouring countries. According to climate scientists, the frequency of these heatwaves has increased from once every 50 years in a world without climate change impact to roughly once every four years in the current climate scenario.⁸ The unexpected rise in peak demand to beat the heat has left power utilities underprepared, resulting in power outages that affected needs as diverse as cooling and irrigation.⁹

Quality data on climate change impact and access to appropriate tools to interpret such data can go a long way in helping power sector planners and utilities. The right datasets can help ascertain interventions to meet peak demand such as demand flexibility, energy efficiency and RE capacity that itself is affected by the forces of climate change. Further, suitable data can also help in better asset management and



identification of locations where power infrastructure warrants retrofitting and where new, more resilient infrastructure can be built.¹⁰ However, such decision-making is difficult as the data around climate risks comes with uncertainties. Long-term climate forecasts have lower reliability than short-term weather forecasts. Developing capabilities such as advanced RE and electricity-demand forecasting can help address such variability and uncertainty. For improved forecasts, it is essential to build quality granular and long-term climate datasets and as well as capability to interpret the same. Actions to this end include integrating resilience thinking within institutional and governance frameworks and defining standards for “high-quality data”.¹¹

Investment in non-traditional NWA projects, such as leveraging energy efficiency, demand response, and distributed energy resources (DERs) such as rooftop photovoltaic solar and energy storage, can be also explored as substitutes to traditional costly infrastructure to meet system needs as they may be at lower physical risk.¹² A framework comparing the cost and performance of traditional and non-traditional NWA projects can alleviate reliability and system performance

concerns of distribution entities regarding the NWA due to its limited track record as an emergent solution.¹³

Thus, there is immense scope for collaboration and sharing of best practices across geographies to develop a shared understanding of how climate change affects power sector planning and infrastructure and the ways to act on it.

Invest in grid-hardening measures

Actions

- Develop frameworks to identify the risks to physical infrastructure and provide critical grid-hardening policies that can be adopted at the local and national levels to reduce vulnerability
- Catalogue steps taken by utilities in response to climate risks to aid rapid development of grid-hardening plans
- Share updated strategies for improving power sector resilience by upgrading regulations and adequacy mechanisms and processes for the approval of new infrastructure across countries

- Identify sources of low-cost financing to enable a reliable and resilient electricity system

wind generation infrastructure are susceptible to physical damage and power disruption.¹⁵

Rationale

Few infrastructure assets are not affected by the risk from climate-associated extreme-weather events. In fact, US utilities may see costs of damage to physical infrastructure increase by 23 percent by 2050.¹⁴ Electricity transmission and distribution lines and substations are especially vulnerable to certain extreme weather conditions. Even renewable generation resources such as solar PV and

Government regulators should implement strategies to enhance grid resilience, including developing response plans to climate change risks to grid infrastructure. An overarching resilience strategy should include identifying targeted goals to achieve grid-adaptation needs. Utilities must perform need assessments of critical transmission and distribution infrastructure, such as substations. Further, utilities should also develop

Figure 2: Energy infrastructure risk

Energy Infrastructure	Sea-Level Rise and Tidal Floods	Riverine and Pluvial Floods	Hurricanes, Storms, and Typhoons	Tornadoes and Other Wind	Drought	Heat (Air and Water)	Wildfire
Thermal and Nuclear Power Plants	☐	☐	☐	○	☐	☐	○
Wind Power Plants	☐	☐	☐	○	○	☐	○
Solar Power Plants	○	☐	☐	○	☐	☐	○
Hydroelectric Plants	○	☐	○	○	☐	○	○
Transmission and Distribution Lines	☐	☐	●	☐	○	☐	●
Substations	☐	☐	☐	○	○	○	●

○ Little or No Risk ● Increased Risk

Source: *Will Infrastructure Bend or Break Under Climate Stress?* (McKinsey Global Institute, 2020)¹⁶

pathways for long-term grid-hardening based on localised risks. Actions by utilities can be aided by access to open-source information on steps taken by peer organisations internationally.

Grid-hardening investments are an adaptive measure taken against inevitable catastrophes to mitigate the costly risk of failure for physical infrastructure. However, the higher upfront cost of grid hardening is a key hurdle for vulnerable regions. Infrastructure adaptation costs are estimated to be between 60 percent and 80 percent of the climate change adaptation globally.¹⁷ At the same time, the value of prevented damages can save up to US\$11 for every dollar invested in repair costs over time.¹⁸ A holistic approach around resilience strategies for physical infrastructure, investing in grid hardening and exploring NWA for grid upgrades can eliminate costly disruptions and repairs.

To mitigate the risk of both financial and physical damage to power infrastructure, power sector planners should identify their vulnerabilities and incorporate relevant actions across all levels of planning and decision making.¹⁹ This includes updating regulations (codes, equipment standards and other

guidelines), procurement and contractual processes as well as conducting iterative reviews.²⁰ Where utilities lack the financial wherewithal to undertake resilience interventions including routine operations and maintenance or large capital investments, the right financing routes must be identified.

The Global Shield Initiative announced at COP27 and coordinated by the G7 can serve as an important template for means to rapidly deploy protection funding.²¹ Replicating a similar programme across G20 member states can improve access to low-cost financing needed for grid hardening.

Leverage distributed clean energy technologies and grid digitalisation

Actions

- Engage in collaborative efforts and strategic investments to optimise the deployment of DERs, supported by the implementation of favourable regulatory upgrades
- Share upgrades to policy frameworks that enable DERs and DER aggregators such as virtual power plants (VPPs) to participate in electricity markets

- Share best practices of balancing incentives for DER owners while meeting the needs of grid/power utilities

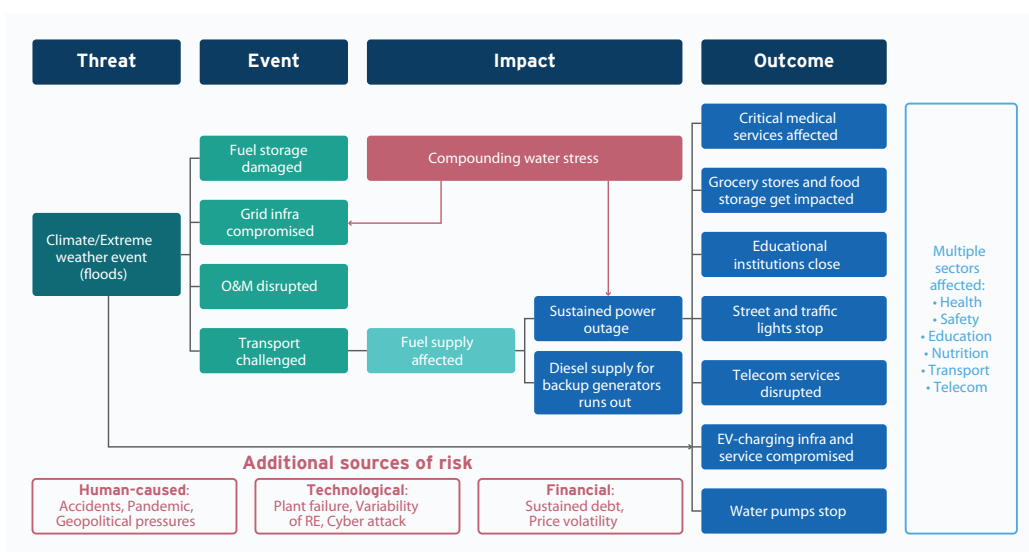
Rationale

Electricity demand is set to rise across the world, particularly due to increasing per capita electricity demand and electrification of multiple sectors in China and other Asian countries.²² The buildings and transportation sectors too are taking steps to boost electrification while sourcing electricity from renewable sources where available. Industry, the largest consumer of energy, is gradually increasing the share of electricity used in its processes.


While increasing electrification reduces localised emissions, it also concentrates the risks of widespread disruption on the grid by stressing the existing grid network and generation capacity. Earlier, where a power outage may have affected only access to lighting and powering appliances, it will soon have a bearing on cooking, commuting and industrial productivity, as these sectors transition to an electricity-based energy source to achieve necessary decarbonisation goals (see Figure 3).

In 2021, severe winter storms put over half of Texas's generating capacity offline and left millions without power for days.²⁴ The state's natural gas

Figure 3: Direct and indirect impacts of a climate-induced extreme-weather event



Source: *Powering Through: A Climate Resilient Future (RMI and RMI India, 2021)*²³




infrastructure, which is the dominant source of electricity, was ill-prepared to withstand extremely low temperatures due to a lack of necessary infrastructural upgrades and higher-than-expected peak demand.²⁵

Decentralisation—diversifying in terms of scale and location while adopting more RE—and digitalisation—moving to ‘smart’ infrastructure for power transmission and distribution—represent lucrative interventions in the power sector due to the value they offer, including, but not limited to, resilience services.

DERs include distributed solar and wind, electric vehicles (EVs), microgrids, energy storage, demand response and energy efficiency.²⁶ They can integrate RE locally in both grid-connected and off-grid formats, and alleviate the centralisation of risks on the main grid infrastructure. Digitalisation of the electricity sector can support interventions for improved distribution network management. Advanced communication and remote management capabilities through interventions such as smart meters, smart grids and creation of digital twins can help respond to disruptions

in real time. For example, microgrids can introduce redundancy into power systems with the process of islanding, wherein microgrids can be disconnected from the main grid during a disruption using intelligent control systems and run independently while generating electricity locally.²⁷ These functionalities are especially useful for communities vulnerable to extreme weather events.

Departing from the traditional one-way flow of electricity, grid-connected DERs and smart appliances will enable consumers to interact with the grid through two-way power flow and participate in demand flexibility and demand response programmes. These features can help manage load on the grid during both regular operations and disruption. DERs, including rooftop solar, EVs and batteries, can provide emergency backup services. Bundled DERs can offer compounded benefits still. For instance, VPPs can leverage multiple DERs by aggregating latent potential of these assets into a unified portfolio to provide benefits to DER owners and other electricity users on the grid. Through digital networks, VPPs can charge and discharge DERs in response to market signals and grid needs.²⁸



However, existing business models and regulations can present challenges in realising the full potential of DERs. Therefore, upgrades to regulatory frameworks, which provide more certainty to DER owners such as on asset ownership and income-generation potential by opening up electricity markets to participation by DERs and aggregated DERs, can help unlock benefits.

Invest in energy storage ecosystems that provide balancing services and flexibility

Actions

- Collaborate on policies that foster enabling environments for rapid deployment of energy storage technologies
- Provide a framework for system assessments to determine storage needs with a key focus on flexibility and explore mechanisms for incentivising resilience through flexibility

- Cooperate to create incentive structures to continue developing innovative storage technologies that cater to various end uses.

Rationale

Energy storage technology is key for successful transitions to low-cost variable RE sources and DERs. Global cumulative installed storage capacity projections are expected to exceed 411 gigawatts by 2030, 15 times of that in 2021.²⁹ This is understandable given the wide range of services that storage provides, such as shifting load, providing ancillary services for balancing, and restoring operations during blackouts. For utilities, storage can defer or avoid costly infrastructure investments that may be at risk during extreme weather events. For consumers, storage can provide backup power and enable islanding to avoid service disruptions.³⁰ Many of the services reinforce grid resilience, improve the performance of DERs, and prevent harm or disruption of critical services during times of system failure.



Figure 4: Resiliency cases of battery storage

Battery Use Case	Uninterruptible Power Source	Off-Grid	Grid-Connected Islandable	On-Site Hosting
Use Description	Battery backup ready to be discharged	Provide continuous power for off-grid services in lieu of utility grid	Lowering cost of utility purchases and providing backup power through islanding during grid outages	Hosting large-scale generation on-site for off-site sale
Location	Sites with critical loads that have zero tolerance for disruption	Remote sites with high fuel costs and/or low grid reliability	Sites with demand, time-of-use charges, or ancillary service markets	Sites in deregulated markets with interested off-takers
Primary Power Supply	Utility grid	DERs, typically including generators	Utility grid + DERs	Utility grid
Backup Power Supply	Uninterruptible power source	Not impacted by grid disruptions	DERs	DERs


Source: *Planning a Resilient Power Sector (Resilient Energy Platform, 2019)*³¹

Policies that foster enabling environments for rapid deployment of energy storage technologies will be required to meet power system needs. This includes addressing key hurdles by creating market pathways to improve storage project economics, improving access to finance, and continuing cooperation on research and development of innovative technologies.³²

In geographies with liberalised electricity markets, storage deployment can be economically incentivised through market mechanisms that boost

resiliency and flexibility services.³³ In addition, G20 member states must consider how to improve finances for more attractive returns and provide clear policies to address and alleviate uncertainty around project timelines.³⁴

Incentive structures should be utilised for continued development of innovative storage technologies that cater to various end uses. Technologies that perform in a range of environments with fast response and appropriate discharge durations are critical to improving power system resilience. Targeting development, commercialisation and



deployment of new technologies suited for resilience needs ensures that suitable products are in place during disruption.


The production-linked incentive (PLI) scheme for advanced chemistry cell batteries initiated in India provides one framework for incentivising the development of best-fit application technologies. The PLI scheme bolstered the domestic manufacturing of innovative battery technologies by


awarding incentives based on key performance criteria. The subsidies were linked to technologies that adhered to these criteria beyond incumbent chemistries being manufactured at scale. The greater an innovative technology performed as per the identified criteria, the higher was the subsidy rewarded.³⁵ Scoping policies with incentives based on key performance criteria suitable for resiliency ensure that system needs are met.

Attribution: Nuvodita Singh, Benny Bertagnini, and Jagabanta Ningthoujam, "Embedding Resilience in Power Sector Planning," *T20 Policy Brief*, June 2023.

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