SCALE UP for net zero

Benchmarking solar and wind growth in South, Southeast and East Asia

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Key Findings

1 **Economies in South, Southeast and East Asia need to scale up their solar and wind capacities more than fivefold by 2030 to align with domestic net-zero targets, as proposed by local independent institutions.** This would increase the share of solar and wind to approximately 30 percent of total electricity generation on average across the region by 2030, up from less than six percent today, and help drive sustainable economic growth, improve energy security and affordability, and enhance public health.

2 **Deploying wind and solar at such a speed and scale will require a regulatory reform boost and reorientating derisking mechanisms to incentivise renewables over fossil fuels.** Streamlining permitting processes, implementing transparent tendering schemes and enabling third-party grid access and corporate power purchase agreements can reduce delays and mobilise private sector investments. Measures to stimulate demand for wind and solar power, such as tax credits and rooftop solar subsidy programmes, also have an important role to play.

3 **Integration plans should be tailored to progressively address power system modernisation needs, as the share of solar and wind power increases.** Considering the low shares of solar and wind (less than five percent) in many systems in the region, most integration impacts in the next few years can be addressed via minor modifications to current processes and contractual arrangements. Higher shares will require transforming operational rules and introducing new technologies such as battery storage and smart meters.

4 **Expanding and upgrading grid infrastructure is critical to support growing solar and wind power.** Improved grid planning, operation and financing are needed to resolve grid bottlenecks and maximise the benefits of renewable energy. The importance of grid infrastructure is also reflected in the UN Climate Change Conference (COP) 29 pledge to add or refurbish 25 million kilometres of grids globally by 2030, with an additional 65 million kilometres by 2040. To realise this commitment, new financing models to attract private sector investment along with international climate finance are essential.

Introduction

Limiting global warming to 1.5 °C requires immediate action to avoid overshooting temperature limits that would lead to irreversible changes to the natural environment and an increased burden on countries to adapt to climate impacts. For Asia, the stakes are particularly high, as countries across the region are among the world's most exposed and vulnerable to climate-related hazards.

Recognising the global analytical work performed by the Inter-governmental Panel on Climate Change (IPCC), the International Energy Agency (IEA) and International Renewable Energy Agency (IRENA), more than 130 countries are committed to tripling the world's installed renewable energy generating capacity to at least 11,000 gigawatts (GW) by 2030, alongside doubling the rate of energy efficiency improvements.

The signatories of the Global Renewables and Energy Efficiency pledge also highlighted that any such action should consider different starting points and circumstances as well as the unique realities of each region. What does this global pledge mean in concrete terms for policymakers in South, Southeast and East Asia?

To answer this question, Agora Energiewende reviewed more than 35 long-term energy scenarios from Bangladesh, Indonesia, Japan, Pakistan, South Korea, Thailand, the Philippines, Vietnam, and Taiwan, China*. These scenarios are bottom-up analyses carried out by local institutions in close consultation with various stakeholders. They consider specific local constraints and political economy developments, including technology costs, resource potentials and social development targets. As such, they complement global analyses such as those done by the IEA and IRENA. This interactive publication offers an overview of the transition to a renewables-based, flexible power system, benchmarks wind and solar growth against the region's climate pledges and provides recommendations to accelerate the transition.

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Economies across Asia are grappling with energy security and affordability challenges

Economies across South, Southeast and East Asia experienced soaring gas and coal prices following the post-pandemic global fuel supply crunch and the subsequent Russian invasion of Ukraine. Liquefied natural gas (LNG) – previously regarded by Asian countries as a reliable and affordable transition fuel – saw unprecedented price surges and volatility as governments sought to secure alternatives to Russian piped gas.

While fuel prices have moderated, concerns about energy security and affordability have remained elevated in South, Southeast and East Asia due to a combination of various factors: rapid growth in energy demand, high reliance on fossil fuel imports, pressing economic development priorities, constrained government resources, rising geopolitical tensions and ongoing repercussions from fuel supply shocks. Moreover, intensifying climate change impacts are set to further strain fiscal budgets and exacerbate existing issues, particularly in low-income countries.

Global price of LNG, Asia

The monthly average price for LNG in Asia climbed to 37.42 USD/MMBtu and 54.16 USD/MMBtu in 2021 and 2022, respectively.

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Despite moderated fuel prices, energy security concerns prevail

South Asia

Between 2022 and 2023, Bangladesh and Pakistan faced multiple rolling blackouts and unplanned power outages amid record-breaking heatwaves, resulting in significant industrial decline, job losses and social unrest.

Increasing dependence on imported fossil fuels and a rapid currency devaluation against the dollar left the two countries heavily exposed to the recent global fuel crisis.

Compounding the issue were their aging, inefficient power grids, which have suffered from years of underinvestment and inadequate planning.

Southeast Asia

With domestic fossil fuel reserves declining against rapidly rising demand, Southeast Asia is becoming increasingly vulnerable to future external fuel supply disruptions.

Indonesia, the region's titan in oil and gas production, is set to become a net importer of gas by 2034; Vietnam and the Philippines have recently begun importing LNG following the inauguration of their first receiving terminals in 2023.

These developments are unfolding as the region continues to grapple with post-pandemic economic setbacks and increasingly frequent and severe climate disasters.

East Asia

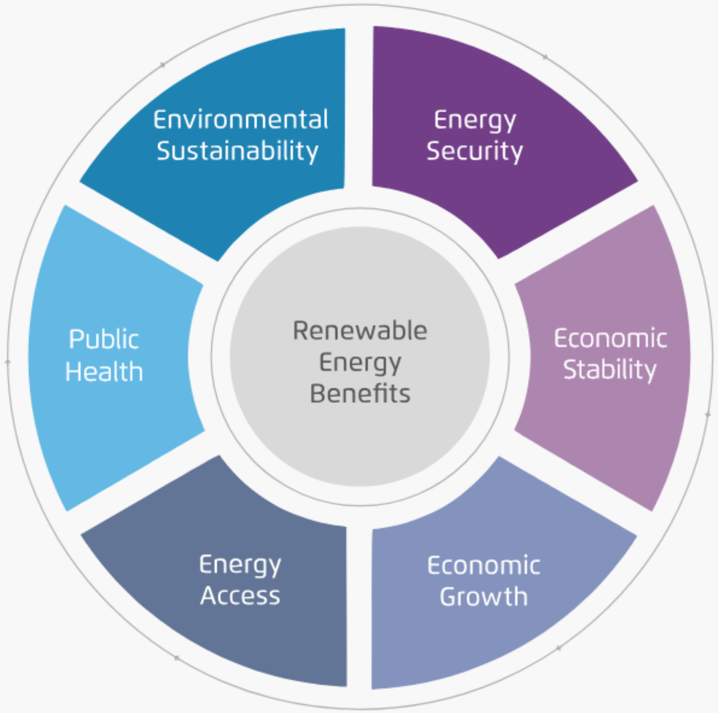
Taiwan, Japan and South Korea rely heavily on imported fossil fuels due to limited domestic resources. They respectively rank second, third and fourth lowest in Asia for energy self-sufficiency. As a result, they are particularly susceptible to the adverse impacts of global fuel supply shocks.

KEPCO, South Korea's state-owned electric utility, saw its debt skyrocket to 154 billion US dollars (USD) at the end of June 2023, following sustained exposure to the soaring fuel prices that emerged after war broke out in Ukraine.

Additionally, given their isolated power grids, Taiwan, Japan and South Korea do not currently have the option of leveraging electricity imports to enhance energy security and support renewables integration.

Renewable energy can deliver benefits that address ongoing challenges

Transitioning from fossil fuels to renewable energy will generate significant environmental benefits alongside extensive societal and economic gains. These include better public health outcomes, improved energy access, new job opportunities, lower costs for consumers, enhanced energy security and greater economic stability.



Energy security and affordability: Higher penetration of renewable energy in power systems can help to enhance energy security and affordability by reducing reliance on foreign sources of energy and lowering costs for consumers.

Economic stability: Given rising geopolitical tensions, decreased dependence on imported fossil fuels would also help to mitigate exposure to future fuel price volatilities and enhance fiscal stability by reducing the need for government subsidies to cushion the impact of sudden price spikes.

Economic growth: The renewable energy sector can boost local economies by creating jobs in various areas, including the construction, maintenance and operation of renewable energy facilities. A shift towards renewables can also help to foster growth in related industries such as steel, aluminium, and solar panel manufacturing.

Environmental sustainability: Replacing fossil fuels with renewable energy helps to mitigate climate change by lowering greenhouse gas emissions. Renewables also help to reduce other adverse environmental impacts associated with fossil fuel combustion, such as acid rain and eutrophication.

Public health: As the shift towards renewable energy helps to improve air and water quality, there are also significant gains to be realised in the public health sector through reductions in future healthcare costs associated with treating pollution-related illnesses.

Energy access: Renewable energy enables greater electricity access, particularly in remote communities in developing countries, thereby helping to reduce inequality and raise living standards.

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As a result, many jurisdictions announced ambitious net-zero targets

Recognising the global analyses by the IPCC, IEA and IRENA, more than 130 countries committed during COP28 in 2023 to tripling the world's installed renewable energy generating capacity to at least 11,000 GW by 2030, alongside doubling the rate of energy efficiency improvements.

Yet, the target to triple renewables capacity is a global one – and does not mean that each renewable energy needs to triple, or that individual geographies need only to increase by this amount. The signatories of the Global Renewables and Energy Efficiency pledge highlighted that any such action should consider different starting points and circumstances and the unique realities of each region.

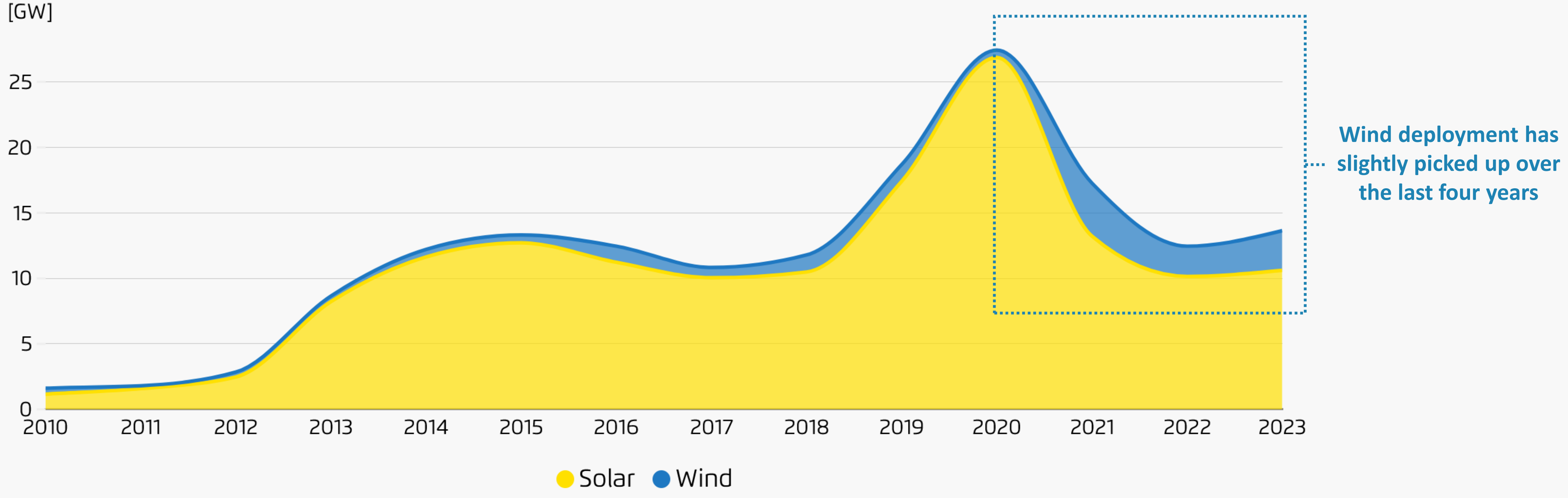
Renewable energies such as hydropower, bioenergy and geothermal will play an important role in future decarbonised energy systems. However, the bulk of renewable capacity additions will need to come from wind and solar power, given their potential in reducing emissions at least cost as well as their vast resource potential.

Wind and solar deployment in the region has increased since 2012

Solar PV has provided the vast majority of new capacity additions

Annual capacity addition of wind and solar power in all investigated countries

Japan, South Korea, Vietnam, Indonesia, Philippines, Thailand, Pakistan, Bangladesh, and Taiwan, China



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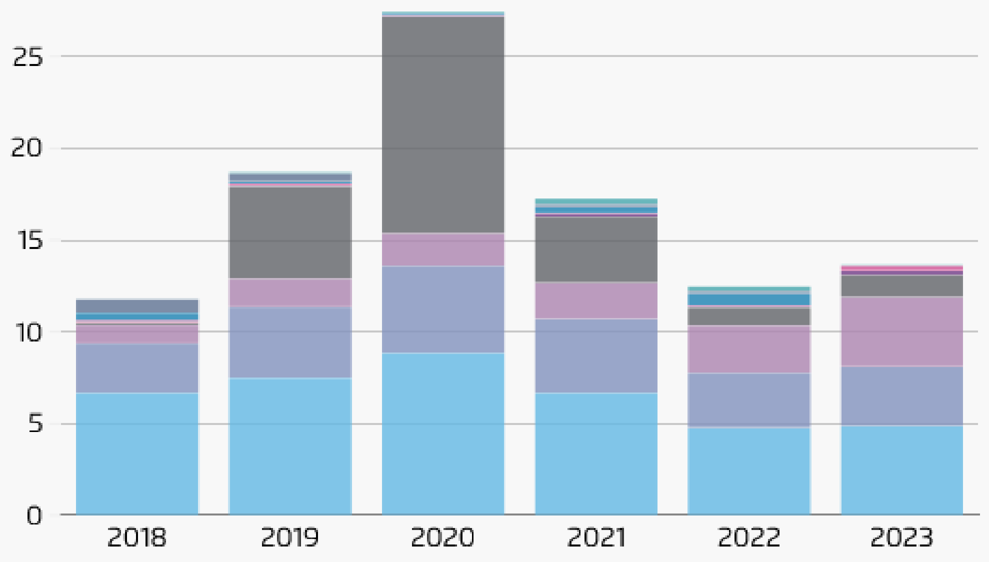
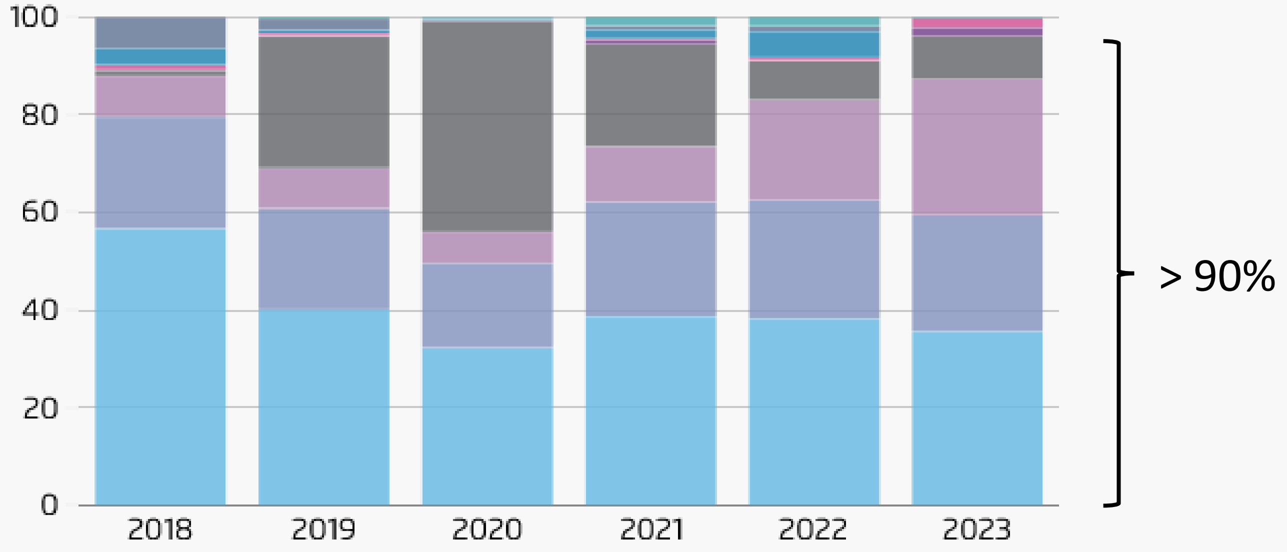
However, most wind and solar additions occurred in just four countries

Japan, South Korea, Vietnam and Taiwan, China account for more than 90% of wind and solar additions across the region

Annual additions of wind and solar [GW]



Annual additions of wind and solar [%]



Japan · South Korea · Taiwan, China · Vietnam · Bangladesh · Indonesia · Pakistan · Thailand · Philippines

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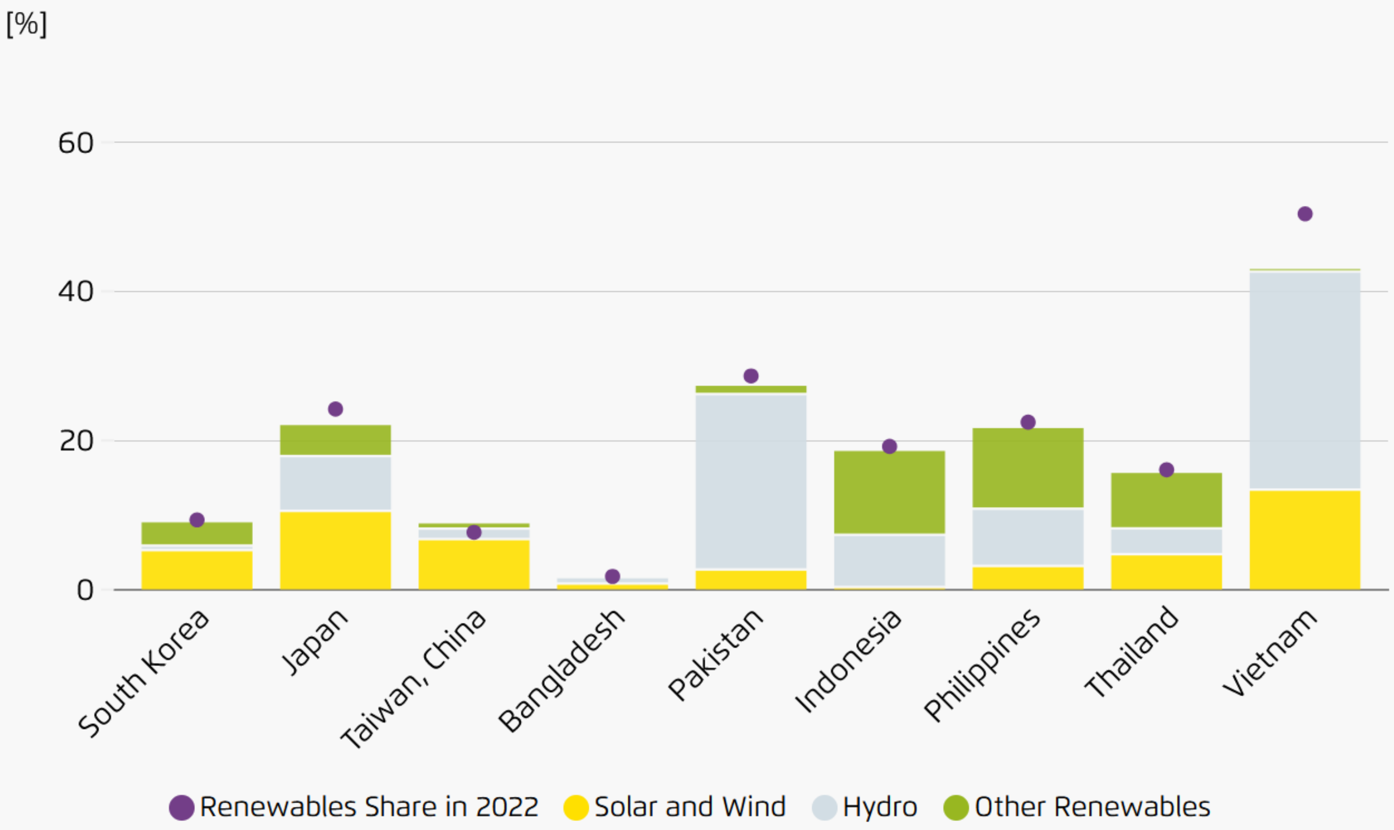
Still, renewable electricity shares have stagnated

Share of renewables in power generation, 2023 compared to 2022



In spite of the capacity expansion, renewables' generation shares have stagnated the same across the region as renewables deployment struggled to keep pace with rapidly rising power demand.

In fact, renewable shares decreased in some countries, as renewable generation was either outstripped by increasing fossil fuel generation or declined due to lower hydropower generation.

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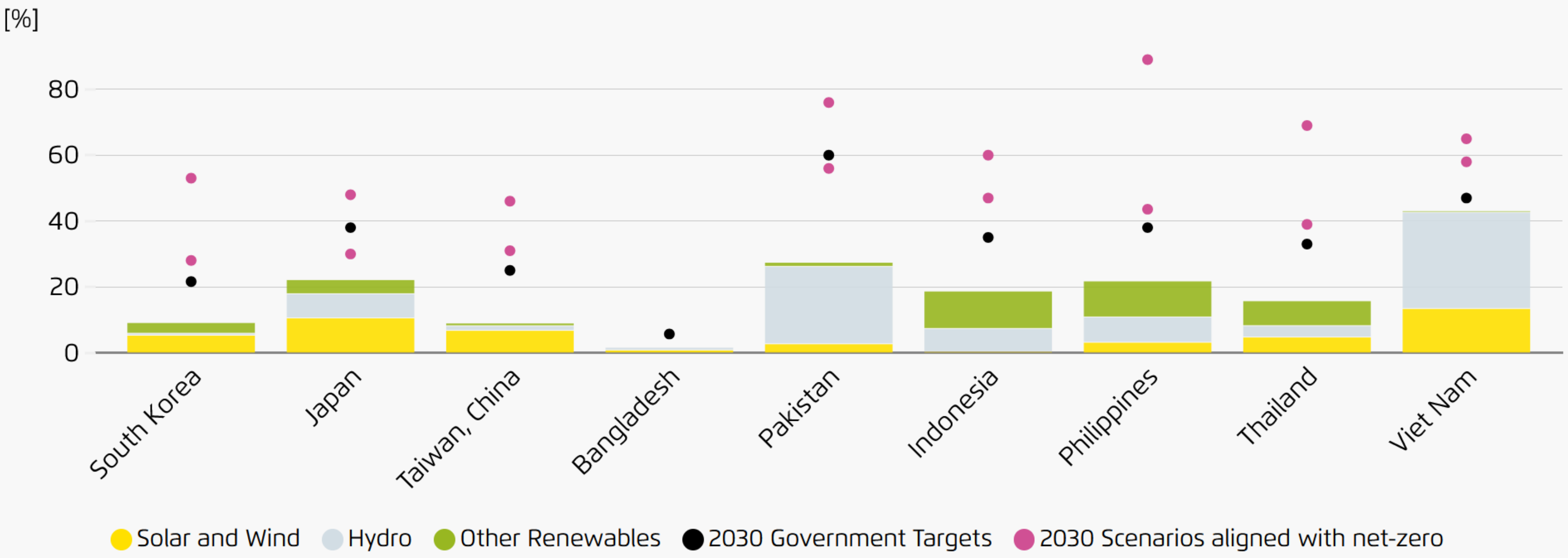
Many government plans for renewable energy remain insufficient and are not consistent with net-zero compatible trajectories

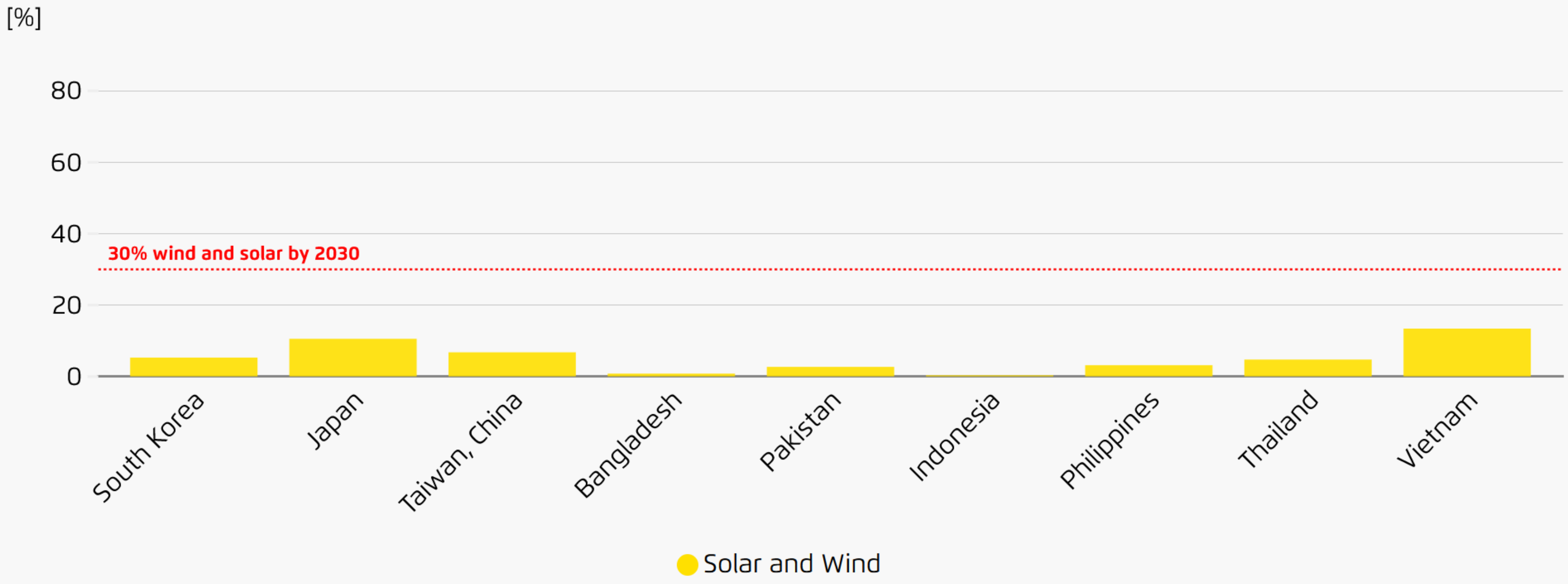
Share of renewables in power generation
Status quo (2023), government's 2030 targets, and scenario ranges to be aligned with net-zero



Wind and solar should reach, on average, 30% of electricity supply by 2030

This equates to a more than five-fold increase in solar and wind capacity by 2030

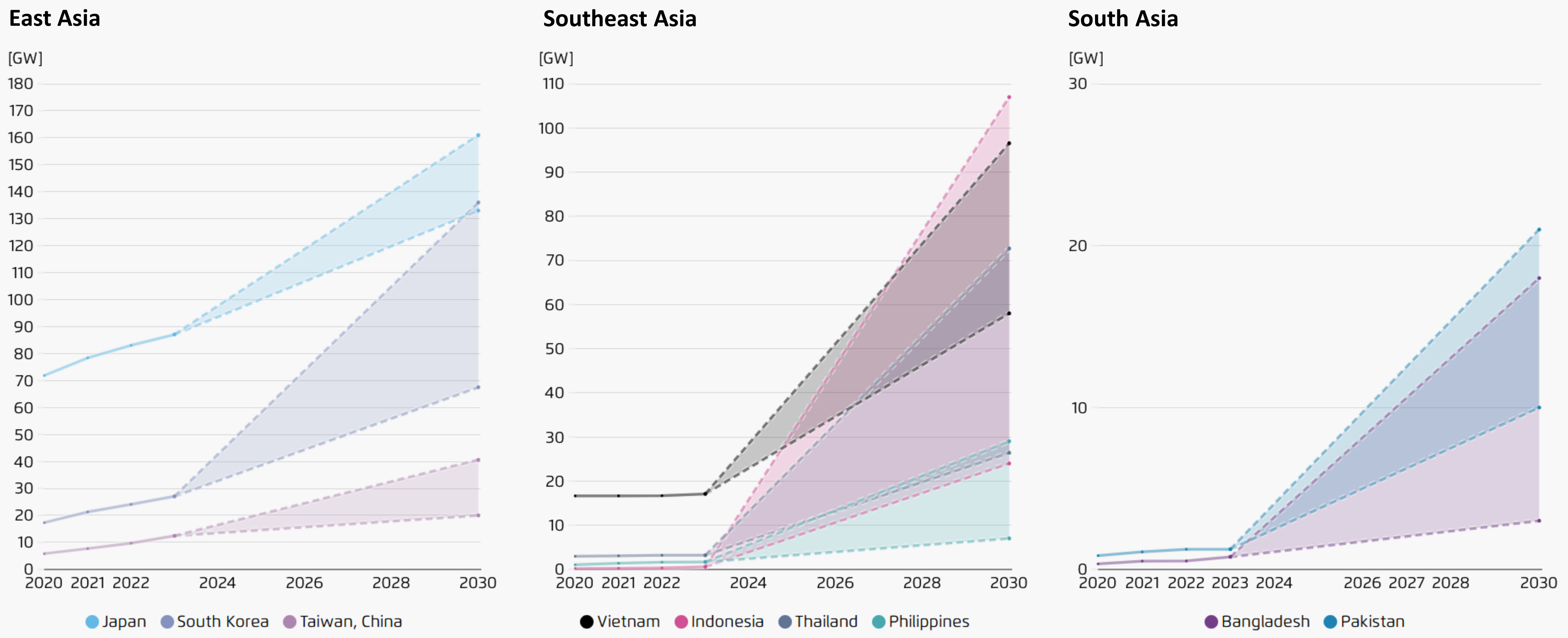
Share of renewables in power generation, 2023



Local net-zero scenarios indicate that solar capacity across the region needs to grow by at least four-fold by 2030

This means adding between 30 GW to 75 GW of solar per year

Total installed solar capacity needed to be in line with net-zero pathways



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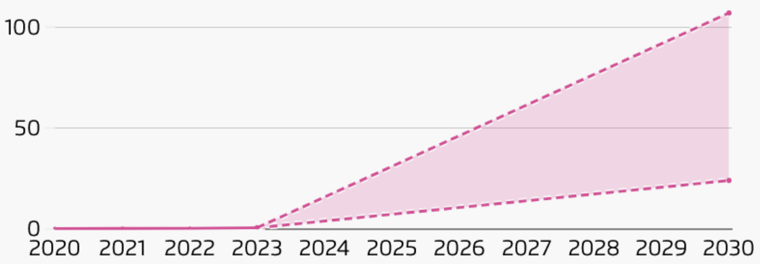
Southeast Asia needs to add at least 23 GW of solar annually to 2030

Total installed solar capacity needed to be in line with net-zero pathways

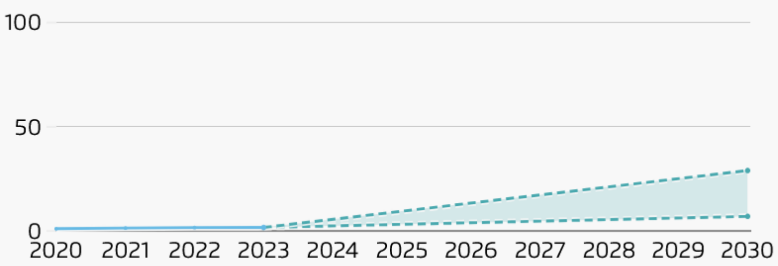
Indonesia: Solar

[GW/year]



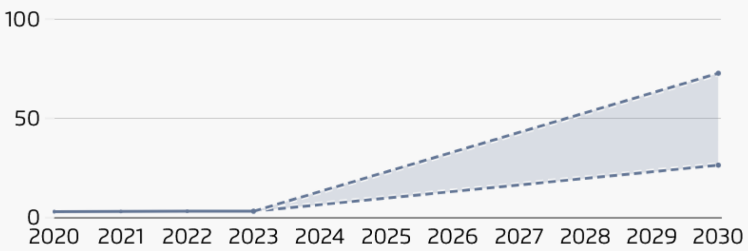
Philippines: Solar

[GW/year]



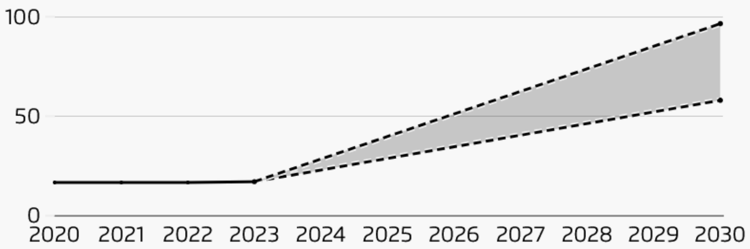
Thailand: Solar

[GW/year]



Vietnam: Solar

[GW/year]



→ In Southeast Asia, Indonesia needs to add at least 9 GW per year.

→ For the Philippines, 1 GW of Solar should be installed

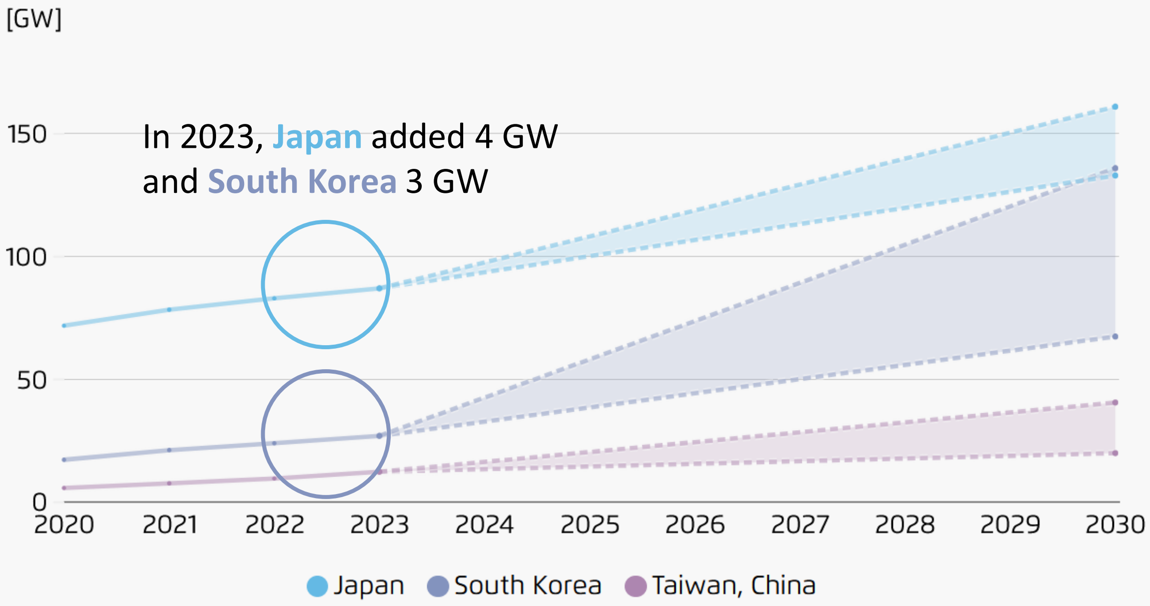
→ **Vietnam** and Thailand each need to install 6–7 GW per year.

→ Government procurement schemes, such as the Green Energy Auction Programme in the Philippines, can help boost renewables.

East Asia needs to add around 18 GW of solar per year, while South Asia shows strong prospects for rapid growth

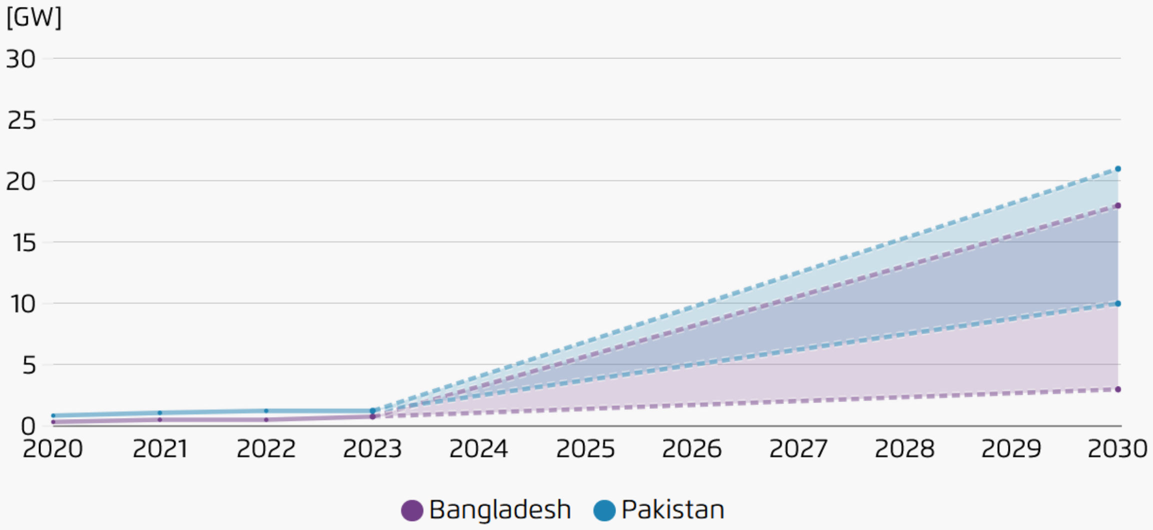
Japan and South Korea should each deploy on average 9 GW of solar power per year.

Total installed solar capacity needed to be in line with net-zero pathways
East Asia



Pakistan and Bangladesh each need to add at minimum 2 GW per year. This may well be within reach for Pakistan, as the recent boom in off-grid solar applications means 2.9 GW has already been deployed in 2024, and some projections suggesting 17 GW could be added by 2030!

Total installed solar capacity needed to be in line with net-zero pathways
South Asia



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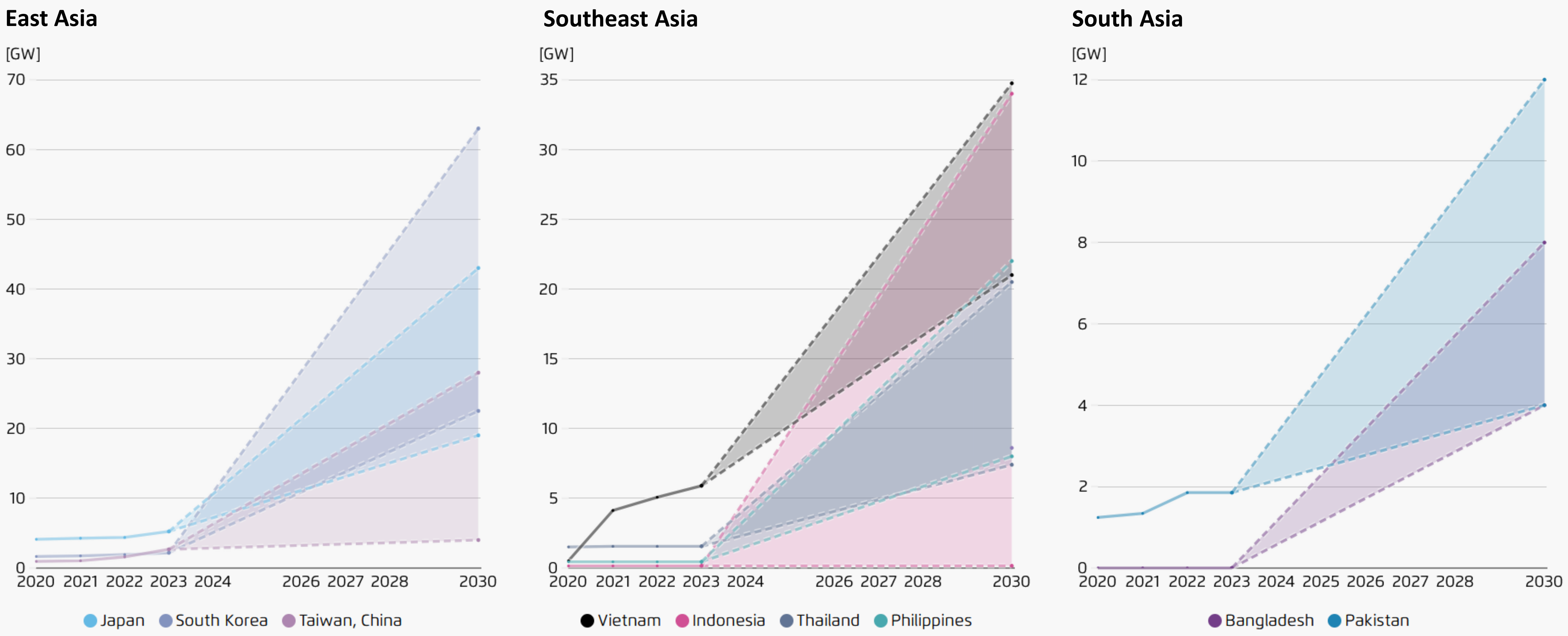
Wind will need to grow by nine-fold to be in line with net-zero pathways

In 2023, 20 GW were operational. This means East, Southeast, and South Asia should add around **23 GW per year.**

Total installed wind capacity needed to be in line with net-zero pathways



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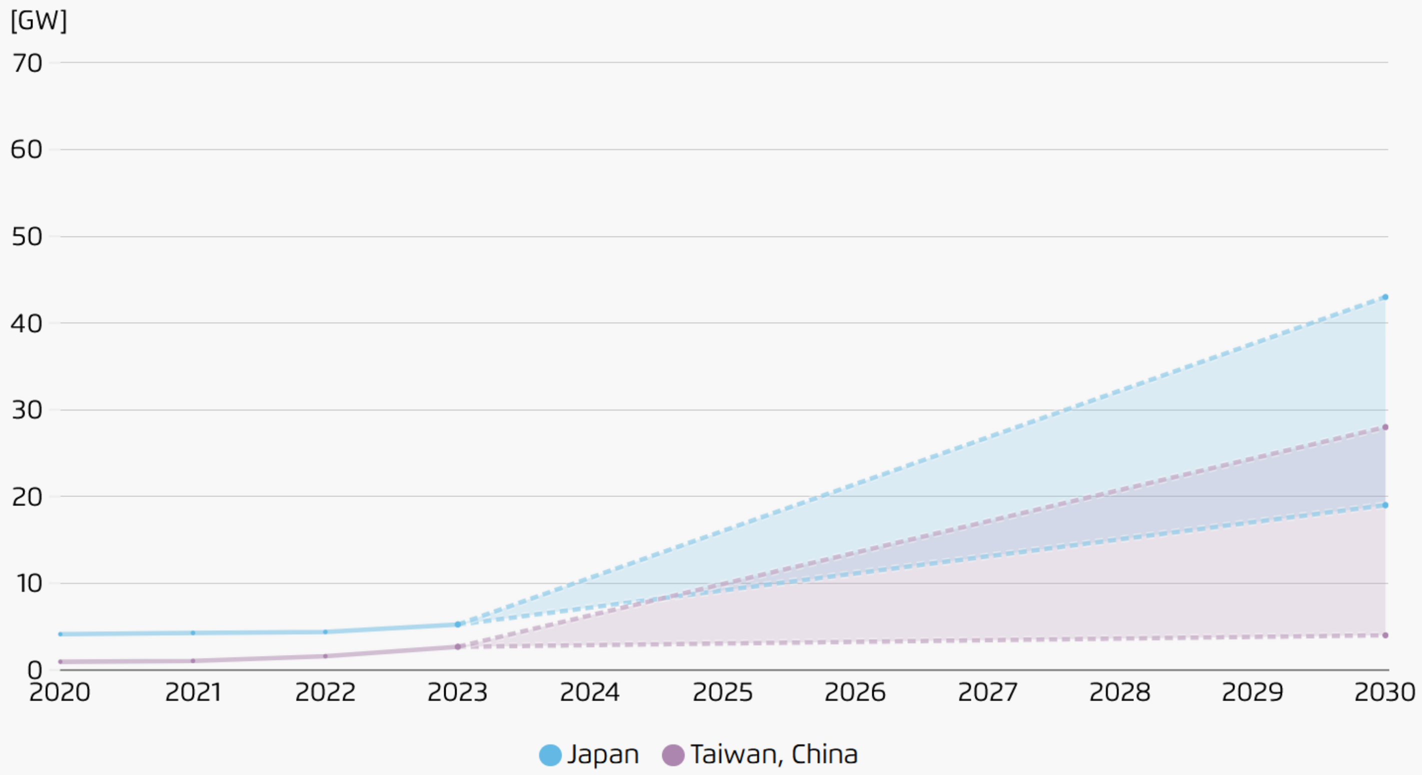
East Asia, home to some of the highest wind potential in the region, must lead the charge in advancing wind deployment

Total installed wind capacity needed to be in line with net-zero pathways
East Asia: Japan and Taiwan, China



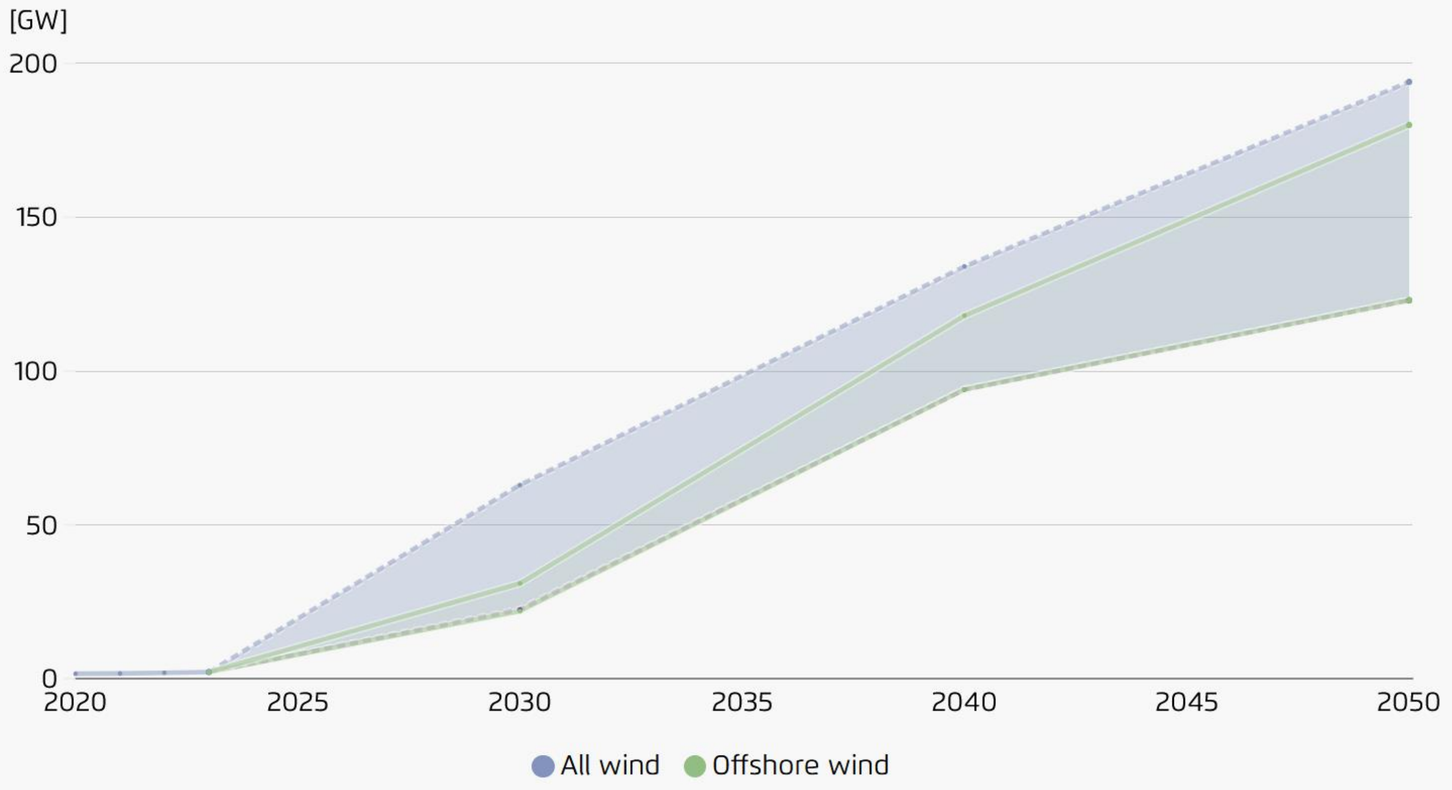
Japan needs to add on average about 5 GW each year until 2030, with 1 GW coming from offshore, while Taiwan, China should deploy around 2 GW annually.

South Korea needs to add around 6 GW of wind capacity per year to 2030

Offshore wind deployment is expected to significantly increase after 2030

Total installed wind capacity needed to be in line with net-zero pathways

South Korea: onshore and offshore wind for net-zero



While the majority of wind capacity added until 2030 is expected to come from onshore wind, offshore wind is set to swiftly gain momentum.

This is reflected in the South Korean government's near-term plans to build an 8.2 GW fixed-bottom and a 6 GW floating wind power complex.

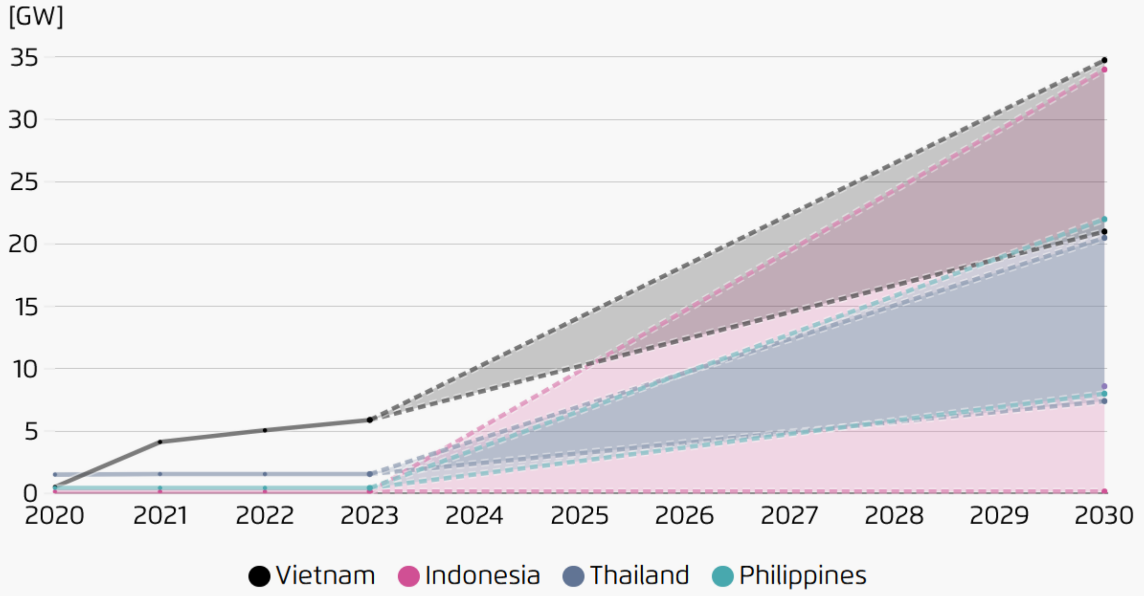
By 2050, offshore wind would represent around 80% of total wind capacity.

Having a clear deployment framework and readiness of grid infrastructure are key to make this ambition a reality.

Between 1 and 6 GW of annual wind capacity additions are needed across each Southeast and South Asian country

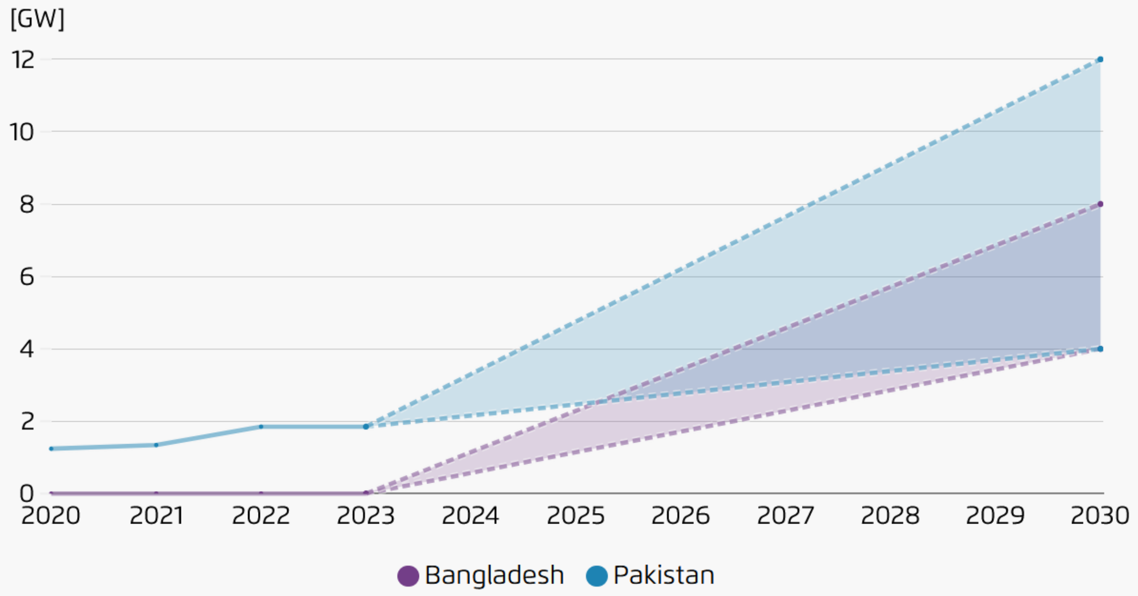
Vietnam, **Thailand**, and **the Philippines** will each need to add on average 2 GW until 2030. Indonesia needs to install 6 GW per year.

Total installed wind capacity needed to be in line with net-zero pathways
Southeast Asia



Pakistan and **Bangladesh** each should add around 1 GW per year.

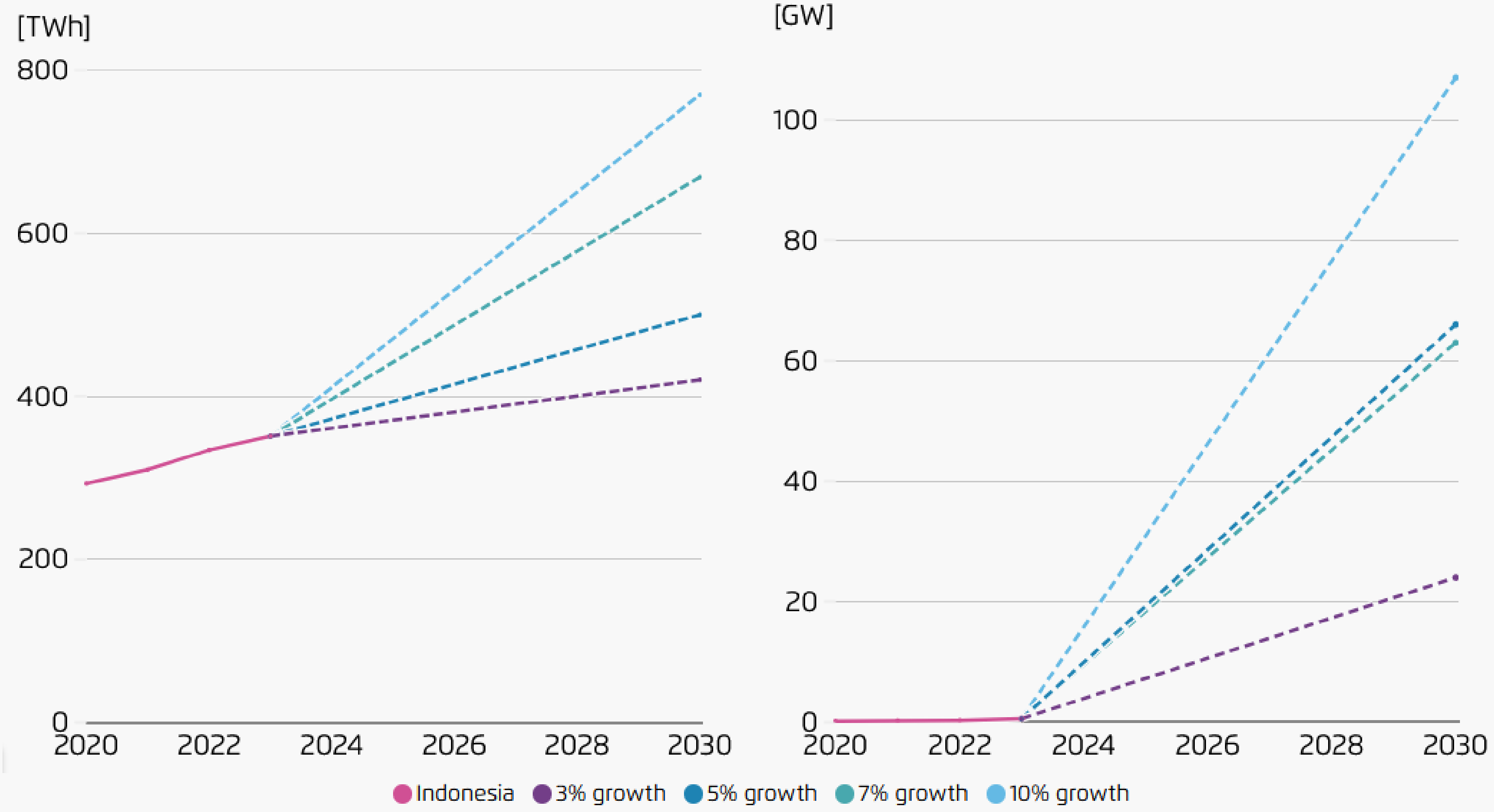
Total installed wind capacity needed to be in line with net-zero pathways
South Asia



The required solar and wind growth ranges are the product of a review of over 35 net-zero compatible scenarios with varying assumptions

Electricity Demand growth until 2030 in Indonesia in various scenarios

Solar capacity expansion in Indonesia in various scenarios



These scenarios come from different energy system models which build upon a wide range of assumptions and results of feasible pathways to net zero.

Assumptions related to economic growth, energy efficiency improvements, or the rate of electrification, can lead to different projections of total electricity demand. For example, all the scenarios for Indonesia assume similar economic growth.

Without electrification of transport sector, the electricity demand grows modestly at **3% per year**.

Electrifying transport and industry at different rates results in higher electricity demand.

Less electricity demand will likely mean less wind and solar deployment needed, provided all else remains the same.

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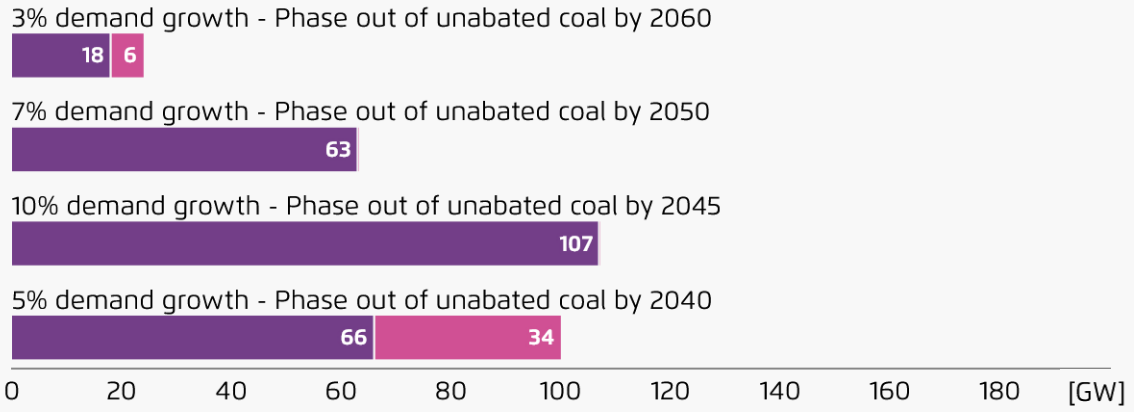
The scale and rate of wind and solar deployment is impacted by factors such as the rate of coal phase-downs

The speed of coal phase out timeline affects the total wind and solar power capacity needed to decarbonise the power system. Recent statement from Indonesia's president on phasing-out coal by 2040 corresponds to the need of having 100 GWs of installed solar and wind by 2030 (against less than 1 GW today)

Indonesia solar and wind capacity 2030

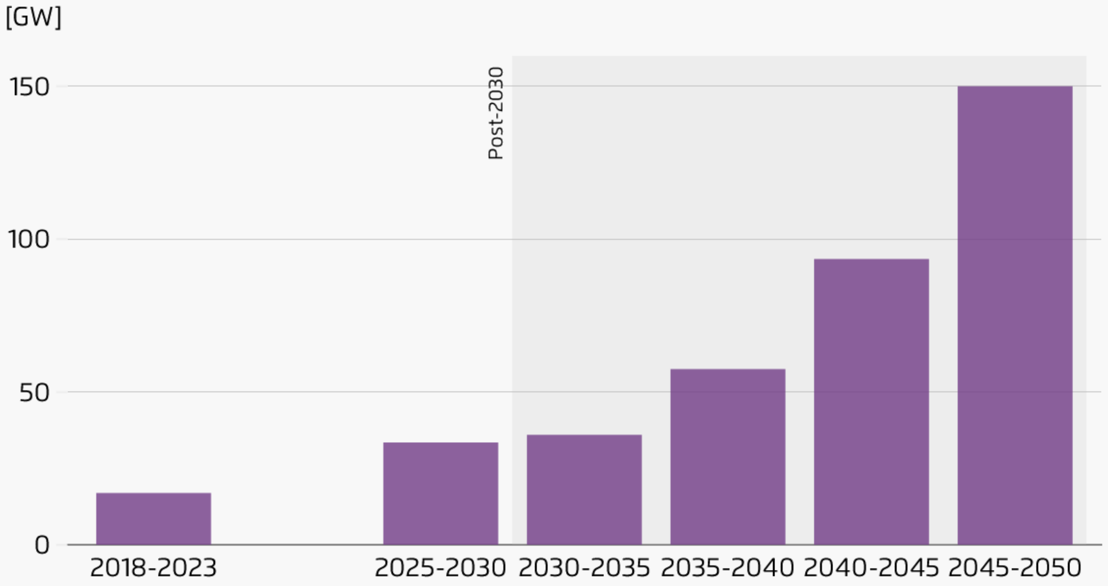
Each bar shows a scenario from different studies with different model assumptions



It is important to keep in mind that capacity additions will need to continue to increase beyond 2030, especially as almost all scenarios require higher rates of deployment after 2030.

Vietnam solar capacity additions (5 year intervals)

Historical and scenarios consistent with net-zero



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Accelerating solar and wind deployment at the scale and pace required calls for a multi-faceted strategy

Integrated approach for scaling up solar and wind deployment

S	Strengthen targets to align with ambition	Build a strong foundation
C	Coordinate across institutions for effective implementation	
A	Activate enabling policy and regulatory frameworks	Deploy targeted measures
L	Lower costs, risks, and barriers to attract investments	
E	Expand the consumer base for renewable electricity	
U	Upskill and reskill talent to support the transition	Set up for the transition
P	Promote system flexibility and grid development to integrate VRE	

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Raising targets and aligning efforts across institutions are key building blocks

Build a strong foundation

Strengthen targets to align with ambition

Governments should strengthen commitments and align targets with a net-zero trajectory. As highlighted in the previous section, for the region to realise such a pathway, it would need to scale up solar and wind capacity by more than five-fold by 2030. This would translate to a four-fold and nine-fold increase in solar and wind capacity, respectively, from 2023 levels. In addition, governments should clearly announce strategies and timelines to enhance target credibility and foster stakeholder confidence.

Coordinate across institutions for effective implementation

Institutional capacity and coordination efforts between government agencies, utilities and other stakeholders must also be strengthened across all levels to enable consistent planning and efficient implementation. Coordination should also be cross-sectoral to ensure that solar and wind deployment helps to advance social and economic development priorities and boost public support for the transition. For instance, policymakers across relevant government agencies can collaborate to incorporate socioeconomic considerations into land use planning for solar and wind.

Unlocking growth necessitates enabling frameworks and targeted measures

Deploy targeted measures

Activate enabling policy and regulatory frameworks

Policies and regulatory frameworks create an enabling environment for solar and wind deployment. They should be designed to address the challenges encountered as well as potential social and environmental impacts to ensure a smooth transition. Regulators should streamline zoning, siting and permitting processes to reduce project development delays. Together, these arrangements must incorporate mechanisms to safeguard ecosystems and community interests. Trade and industrial policies can be tailored to strengthen the supply chains for solar and wind technologies and enhance their resilience against future supply disruptions.

Lower costs, risks and barriers to attract investments

Costs, risks and barrier reduction is crucial to drive solar and wind growth. New capacity should be procured through transparent and predictable schemes (e.g., auctions) to effectively decrease costs. Risk reduction and re-allocation measures such as government-backed guarantees and insurance schemes should be introduced to enhance project bankability and lower interest rates for developers. To complement these measures, efforts must be undertaken to phase out fossil fuel subsidies and other market barriers.

Expand the consumer base for renewable electricity

Demand-side interventions are also essential. Governments can incentivise renewable energy consumption through tax credits, rebates and rooftop solar programmes. Mechanisms and initiatives that support demand for green electricity among large consumers, such as direct power purchase agreement (PPA) schemes and RE100, should be promoted as they hold significant potential to help accelerate solar and wind growth. Where feasible, regulations that mandate higher shares of renewables consumption may also be an effective tool.

Ensuring people and system readiness are crucial to facilitate a successful transition

Set up for transition

Upskill and reskill talent to support the transition

Countries must also set themselves up from a human capital perspective to adapt to the changing energy landscape. The transition away from a conventional fossil fuel-based system towards one based on green technologies necessitates the acquisition of new skills among the energy sector workforce and other stakeholders. This is especially vital given the increasing role of digital and automated solutions in power systems. Governments and industries must therefore collaborate to identify future skills gaps and ensure appropriate training opportunities are in place.

Promote system flexibility and grid development to integrate VRE

The power system must also evolve to successfully accommodate the variable nature of solar and wind and enable the realisation of their full potential. This requires a shift away from the baseload paradigm towards one based on flexibility, underpinned by a modernised grid and a wide range of resources to balance supply and demand. However, as the subsequent section demonstrates, this transformation need not – and should not – be tackled in one go but rather in a progressive manner.

Near-term priority measures to boost solar and wind deployment

Bangladesh
Solar and wind generation **0.8%**

Translate announced ambition into concrete implementation plans with interim goals and targets

Develop a transparent renewable procurement scheme with clear rules

Announce clear guidelines and timelines for renewables project development (e.g., especially related to land acquisition)

Simplify loan application and disbursement processes for project developers

Increase developers' access to alternative financing options (e.g., green bonds) and ramp up cooperation with multilateral development banks

Identify and phase out the most costly and inefficient fossil fuel power plants

Pakistan
Solar and wind generation **2.7%**

Restore investor confidence through policy consistency

Adjust benchmark tariffs for auctions to account for the country's high investment risks

De-risk utility scale projects, such as through financial guarantees

Accelerate implementation of the Competitive Trading Bilateral Contracts Market (CTBCM)

Streamline permitting and land acquisition processes

Facilitate early retirement of unutilised capacity

Indonesia
Solar and wind generation **0.3%**

Increase target capacity, transparency and the number of rounds for solar and wind procurement

Streamline the contract negotiation process between PLN and private renewable energy developers to reduce transaction costs

Amend minimum off-take obligations in fossil fuel plants' PPAs to mitigate future curtailment risks for solar and wind

Establish a nationwide framework for DPPAs

Expand the Renewable Energy Certi-ficates (REC) scheme to solar and wind

Establish spatial planning regulations to facilitate solar and wind installations

The Philippines
Solar and wind generation **3.2%**

Revise ceiling prices for RE auctions to reflect market prices and to account for regional and project size variations

Provide market-based guarantees to support small developers in securing project financing

Expedite the enactment of the National Land Use Act to facilitate the approval process for new RE projects

Introduce a coal phase-out plan and extend carbon pricing beyond fuel excise taxes

Bridge the investment gap for early offshore wind projects through partnerships with multilateral development banks

Upgrade port infrastructures to support offshore wind development

Near-term priority measures to boost solar and wind deployment

Thailand
Solar and wind generation **4.8%**

Set higher targets for replacing the planned expansion of gas capacity with solar and wind in the PDP

Set specific targets for distributed PV and introduce distributed PV/net billing programme for commercial and industrial consumers

Replace the feed-in-tariff scheme with an auction mechanism for procuring utility-scale projects

Accelerate the implementation of third-party grid access and scale the DPPA scheme further

Assign renewable energy zones and priority areas for solar and wind development

Reduce lead times and transaction costs for project development through a simplified permitting process

Japan
Solar and wind generation **10.6%**

Introduce a comprehensive strategy and roadmap for offshore wind deployment

Set specific targets for floating and fixed-bottom offshore wind to effectively steer investments

Build out a domestic supply chain and upgrade ports to accommodate growth in offshore wind

Ensure all relevant data, including survey data, is available to project developers significantly in advance of public tenders

Bridge the investment gap for early off-shore wind projects through partnerships with multilateral development banks

Actively engage stakeholders and mitigate environmental impacts to increase public support for utility-scale projects

Vietnam
Solar and wind generation **13.4%**

Establish a clear framework and timeline for renewables procurement, including the auction mechanism

Expedite the launch of the DPPA scheme

Introduce curtailment limits and compensation for curtailed electricity

Redesign PPAs to lower risks

Improve spatial planning and assign renewable energy zones and priority areas for solar and wind development

Set up a one-stop coordination agency for zoning, siting and permitting support

South Korea
Solar and wind generation **5.3%**

Raise auctioned volumes under government-led auction programmes

Build public support for renewable energy projects through strengthened community engagement

Launch regulations to streamline the permitting process at the local government level

Pilot a curtailment compensation framework on Jeju Island and gradually expand it to other regions

Expedite the roll-out of the offshore wind siting scheme

Phase out free allocation of emissions allowances in the K-ETS to facilitate the shift away from coal and gas

Wind and solar integration measures can and should be tackled in stages

A diverse array of measures exist to support the integration of VRE in power systems. However, it is generally neither necessary nor economical for power systems that are in early stages of VRE deployment to roll out all these integration measures simultaneously. At these stages, the impacts of solar and wind's variability on the system are minimal and can generally be addressed without complex solutions (e.g., aggregated demand response). At low levels of VRE penetration, managing the net load (i.e., total load minus VRE input) does not fundamentally differ from the conventional way of managing the load without renewables infeed. Interventions that require significant system transformation generally become critical only after VRE penetration surpasses a certain threshold.

Phase 1
VRE's system impact: negligible
(local impacts may be higher)
e. g., Indonesia, Thailand

- → Set minimum standards and technical requirements for VRE
- → Develop a register for VRE plants to increase data transparency
- → Incentivise VRE forecast accuracy
- → Build forecasting capabilities
- → Enable demand response from industrial consumers
- → Dispatch based on principles of economic merit

Phase 2
VRE's system impact:
minor to moderate
e. g., Taiwan, China

- → Reinforce the grid to accommodate new and increased power flows
- → Improve asset visibility and controllability
- → Update grid codes to enhance system stability
- → Reduce dispatch intervals to allow for adjustments closer to real-time
- → Enable demand response from commercial consumers
- → Leverage existing storage assets for system balancing

Phase 3
VRE's system impact:
pronounced
e. g., Japan, Vietnam

- → Transition towards centralised solar and wind forecasting
- → Deploy battery storage to complement VRE assets
- → Implement power flow control solutions
- → Enable demand response from residential consumers
- → Widen adoption of smart grid technologies
- → Let system needs dictate locations of new wind and solar

Phase 4
High phases of VRE integration

- → Revise system adequacy framework to include a diverse range of resources
- → Strengthen forecasting capabilities for power flows
- → Scale flexible AC transmission systems
- → Maximise cross-sectoral synergies (i. e., sector coupling)
- → Enhance demand response to widen coverage and utilise advanced technologies
- → Extensively leverage cross-border interconnections for system flexibility

VRE integration plans should be customised to account for the local power system's unique characteristics and constraints

Countries in the region are currently at what the IEA regards as "low" phases of VRE integration (Phases 1-3). Specifically, based on the IEA's analysis, the following power systems are at Phase 1: Bangladesh, Indonesia, Pakistan, the Philippines, South Korea, and Thailand. At this phase, system-level impacts are generally negligible, with challenges mostly confined to specific geographical areas (e.g., Jeju in South Korea). Therefore, efforts to integrate VRE in these systems should focus on easing local grid congestion and laying the groundwork for the next stages (e.g., establishing technical standards for VRE and building forecasting capabilities). In countries that are at Phase 3, such as Japan and Vietnam, the priority should shift towards modifying rules and assets to facilitate the flexible operation of the power system. This stage often requires a significant boost in the adoption of technologies that support system flexibility, including battery storage and smart meters.

It is important to keep in mind that each power system may not fit neatly into the categories outlined. Different regions within a country may not necessarily be at a similar phase of VRE integration (e.g., Kyushu is at Phase 4 despite Japan as a whole being at Phase 3). Consequently, power sector regulators and system operators should customise their VRE integration plans as appropriate. The system's unique characteristics and constraints must be accounted for when referencing the VRE integration framework so that the most suitable set of interventions can be identified and deployed for each region based on their actual needs. For example, the need for system flexibility and ancillary services on Jeju Island is significantly more pronounced than in other regions in South Korea, due to the former's higher level of VRE penetration, relatively low grid redundancy and limited connection to the mainland.

Regardless of the type of power system a country has, this principle remains essential: VRE integration measures should be implemented progressively, with priority at each stage assigned to those that can best meet system requirements in a cost-effective manner.

Near-term priority measures to support solar and wind integration

Bangladesh
Solar and wind generation **0.8%**

Increase the accessibility and comprehensiveness of data related to grid capacity and availability of substations for connection

Conduct technical assessments on the grid's condition and identify priority areas for development

Run simulations with increasing VRE penetration to determine improvements required for grid stability and reliability

Set technical standards for solar and wind plants

Set up an ecosystem to efficiently collect data from VRE plants

Strengthen the system operator's solar and wind forecasting and scheduling capabilities

Pakistan
Solar and wind generation **2.7%**

Systematically track off-grid installations

Strengthen regulatory support for BESS to reinforce off-grid and distributed RE growth

Conduct studies to identify grid reinforcement needs

Finalise wheeling charges to support CTBCM implementation

Improve capabilities for high-quality VRE and demand forecasts

Enhance flexibility of thermal power plants

Indonesia
Solar and wind generation **0.3%**

Incorporate criteria for flexibility service provisions in PPAs for fossil fuel power plants

Eliminate the domestic market obligation for coal miners to address market distortions and facilitate economic dispatch

Proactively lay the regulatory groundwork for demand-side flexibility ahead of future solar and wind growth

Strategically plan for distribution system upgrades to support distributed resources

Accelerate planning and implementation for inter-island and cross-border trans-mission connection

Resolve legal ambiguities surrounding third party grid access

The Philippines
Solar and wind generation **3.2%**

Synchronise grid development with upcoming solar and wind projects under the GEAP

Simplify grid connection procedures (e.g., shorten the execution timeframe for the NGCP's system impact studies)

Ensure distribution system planning across different utilities would account for future integration of distributed energy resources

Eliminate distortions in the WESM and PSAs that disincentivise flexibility from fossil fuel plants

Integrate procurement of flexibility (e.g., batteries) into the GEAP

Expand coverage of time-differentiated electricity pricing to induce greater demand-side flexibility

Near-term priority measures to support solar and wind integration

Thailand
Solar and wind generation **4.8%**

Renegotiate existing PPA and gas supply contracts to reduce minimum off-take volume and include provisions for remunerating flexibility and ancillary services

Harmonise grid codes and interconnect-tion codes between the three utilities

Progressively update other technical regulations and requirements as VRE share increases

Pursue earlier adoption of BESS in the capacity mix

Enhance demand response programmes, especially in the commercial and industrial sectors, to support grid balancing

Ensure electric vehicle growth plans are aligned with grid development plans

Japan
Solar and wind generation **10.6%**

Improve locational price signals to alleviate local imbalances

Ease participation of BESS in the capacity and ancillary services markets

Introduce additional incentives (e.g., investment tax credits) for BESS installations where flexibility is most needed in the system

Reinforce interconnection between regions

Upgrade local electricity grids

Enhance the role of demand response aggregators to support system flexibility

Vietnam
Solar and wind generation **13.4%**

Create an enabling environment for mobilising private finance for grid development

Introduce a framework to procure BESS alongside VRE

Enhance the system operator's capabilities in integrating forecasts in decision-making

Set up arrangements for solar and wind aggregators to participate in the VWEM

Strengthen regulatory framework and incentives to leverage demand-side flexibility

Improve coal and gas plants' ability to provide system flexibility

South Korea
Solar and wind generation **5.3%**

Advance grid financing models that leverage private investments to help expand the transmission and distribution (T&D) network

Implement measures to mitigate impacts from grid development and ensure the redistribution of future benefits to build public support and reduce project delays

Accelerate the introduction of intra-day and ancillary services markets

Specify clear rules for renewable energy forecasting

Introduce incentives for flexibility from dispatchable renewables

Address safety concerns surrounding battery energy storage system (BESS) incidents to revitalise BESS deployment

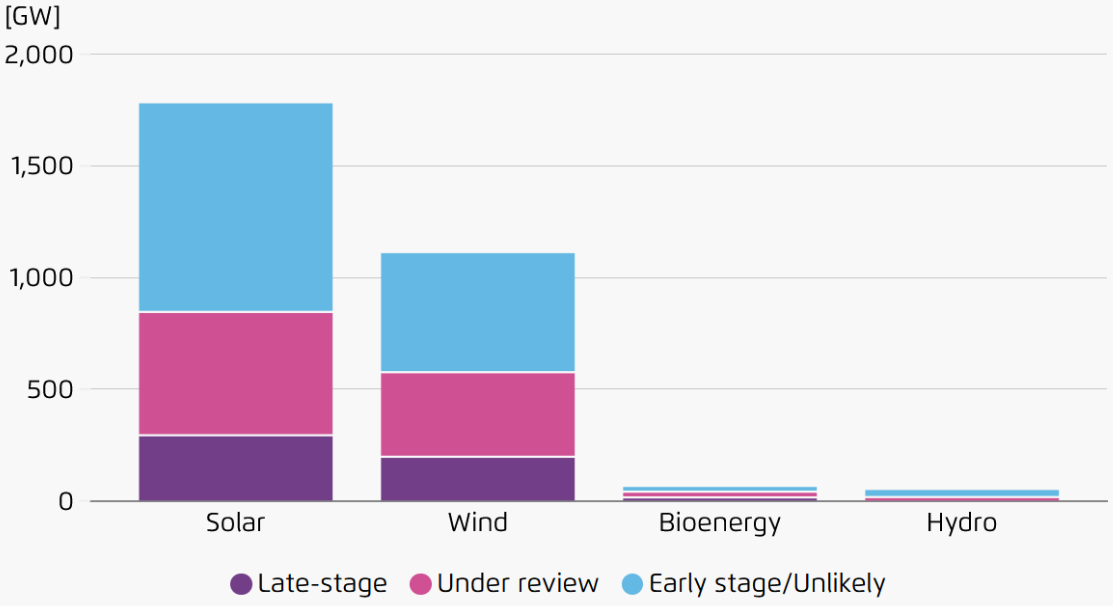
Grid development is critical across all phases of solar and wind integration

Among the different VRE integration measures, grid development perhaps warrants the greatest attention. Most notably, this is because grid constraints have emerged as a major bottleneck for solar and wind growth as transmission and distribution (T&D) build-out struggles to keep pace.

T&D planning has generally been inadequate in accounting for upcoming renewable projects, in part due to the large disparity in deployment lead times between VRE and grid projects. This has resulted in insufficient grid capacity, leading to long lines of renewable projects waiting to be plugged into the electricity network.

Earlier this year, South Korea rejected a USD 7.5 billion offshore wind proposal, citing, among other reasons, a lack of transmission grid capacity. Southeast Asia faces similar challenges, with new solar and wind projects encountering substantial delays in grid connection and existing ones facing increasing technical curtailment risks. These issues combined significantly erode solar and wind's financial viability and diminish investor confidence.

Worldwide renewables capacity in grid connection queues



Already, at least 1,500 GW of solar and wind projects at advanced stages are stuck in grid connection queues globally.

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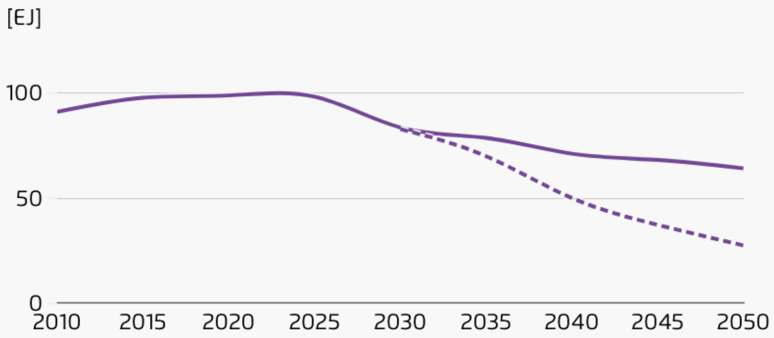
Grid delays would significantly disrupt global decarbonisation trajectories

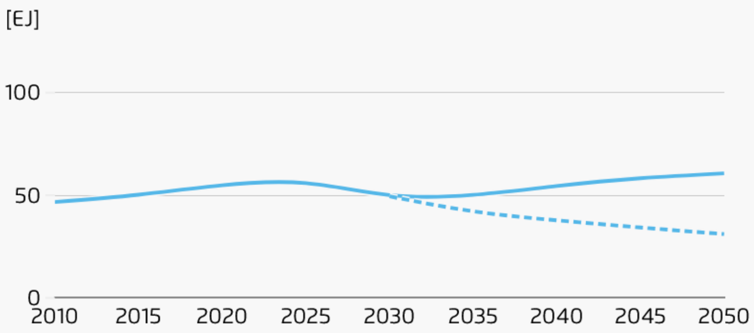
Global annual CO_2 emissions may remain above eight gigatonnes by 2050 given an insufficient grid buildout

Solid lines = Grid Delay Case; Dashed lines = Announced Pledges Scenario

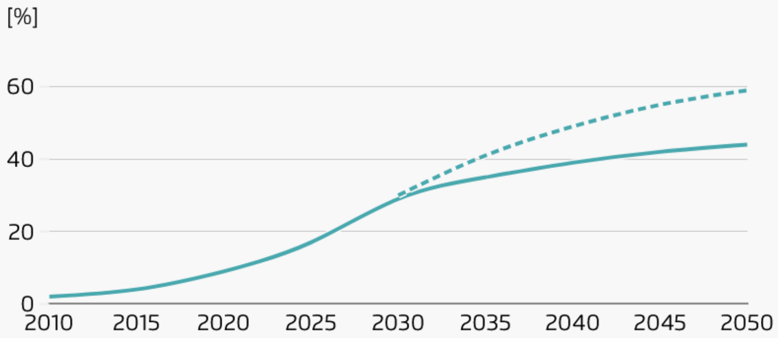
Global coal consumption in the power sector



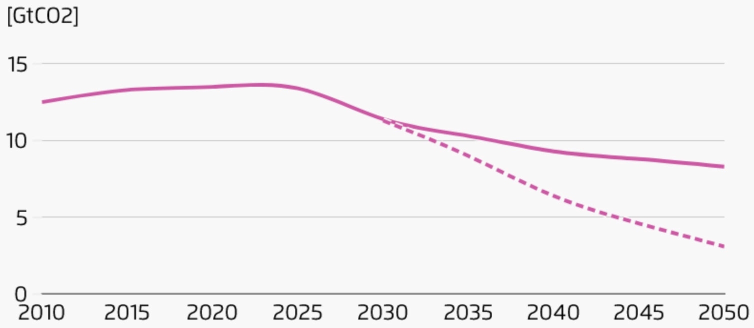
Global gas consumption in the power sector



Global share of wind and solar in power generation



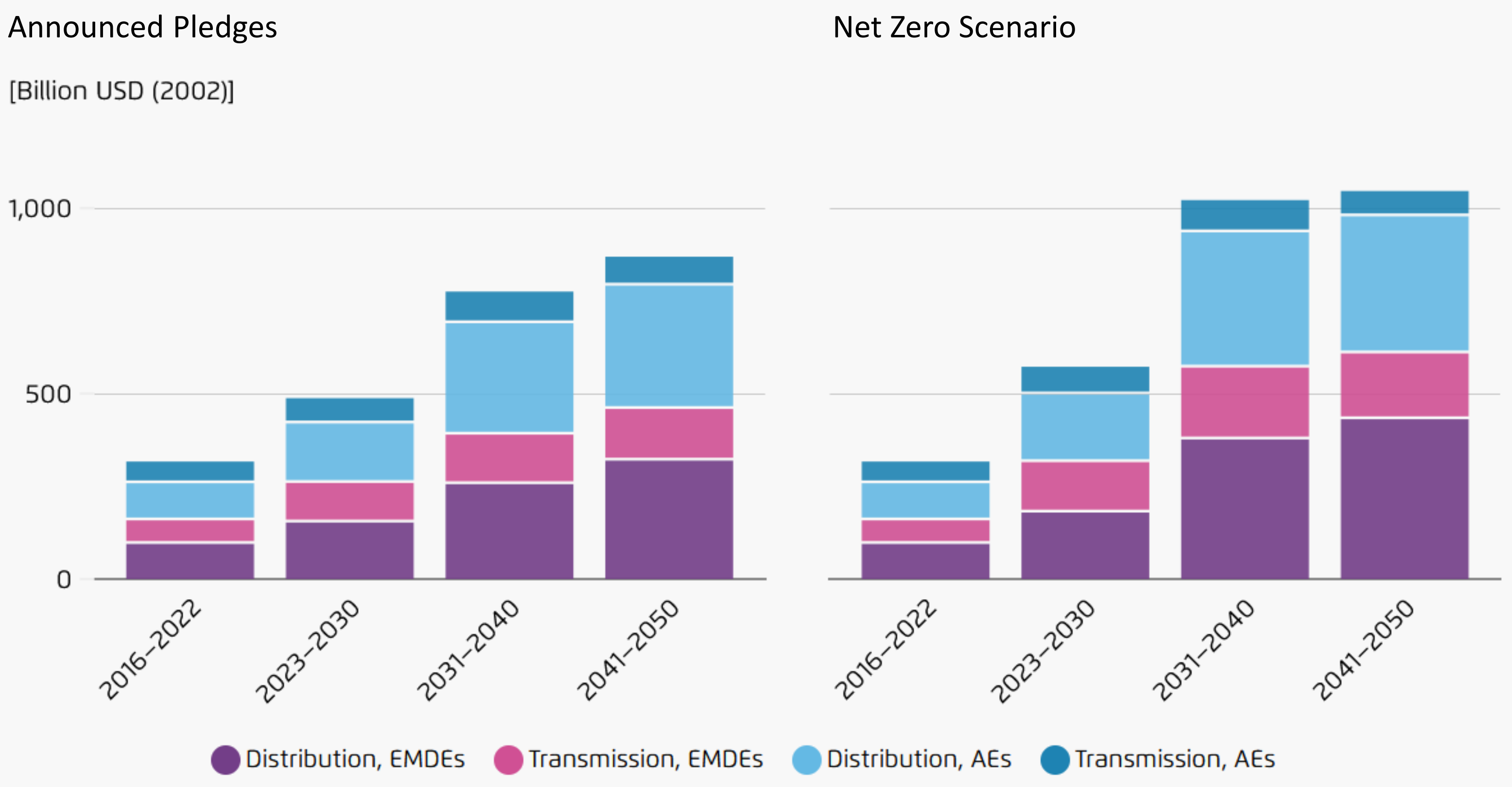
Global power sector carbon dioxide emissions



Beyond planning challenges, grid investments also require massive amounts of financial capital, which governments and utilities may struggle to secure. Developing countries in particular face several challenges with grid financing, including high cost of capital, tight fiscal budgets and limited access to private finance due to the structural constraints of their T&D business. In many countries, the transmission system operators (TSOs) and distribution system operators (DSOs) are state-owned and part of a vertically integrated utility. Their ability to raise capital for grid investments is significantly hampered by regulated rates of return that prioritise affordability for consumers at the expense of the utilities' financial health.

Global grid investments should grow from USD 400B to USD 750B annually by 2030 to meet Net Zero targets

Average annual transmission and distribution investment under the IEA's



On average, the world invested almost USD 320 billion in grid development annually between 2016 and 2022. Based on current investment plans, this number is expected to rise to around USD 400 billion by 2030.

This would put the world at around USD 200 billion short of what's required by 2030 to be aligned with announced government pledges. To be on track for net zero, countries will have to go even further and ramp up grid investments to USD 750 billion annually by 2030.

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Grid planning and financing shape climate goals achievement

The IEA projects that over 80 million kilometres of grid infra-structure – roughly the size of the global grid infrastructure today – will need to be added or upgraded worldwide by 2040 for countries to reach their domestic energy and climate targets. In recognition of this urgency, the COP29 Presidency has called on countries to pledge their commitment to add or refurbish 25 million kilometres of grids globally by 2030, with an additional 65 million kilometres by 2040.

To achieve this goal, governments must bring grid development to the forefront of their agendas. Regulations must be designed to facilitate an accelerated build-out. This would involve measures to streamline processes and tackle bureaucratic hurdles. Proactive long-term planning is crucial, especially considering the long lead times for grid infrastructure projects. In countries where public consultation is extensive, permitting and construction for high-voltage and extra-high voltage lines can take up to eight and thirteen years, nine respectively. Grid planning must anticipate potential high growth rates of solar and wind penetration to ensure sufficient capacity to accommodate deployment and effectively evacuate power to demand centres.

The planning process should also be integrated with that in other sectors to promote increased sector coupling.

For most jurisdictions in South, Southeast, and East Asia, overcoming financial barriers for grid investments requires restructuring utilities' remuneration framework and enabling private sector participation. Remuneration structures for T&D utilities must be revised to strike a balance between current consumer needs and the utilities' ability to fulfil grid investment requirements, keeping in mind the various benefits associated with a modern and robust grid that extend far beyond its ability to integrate VRE (e.g., network resilience against extreme weather events, reliable electricity supply that underpins economic growth). Alongside tariff reforms, efforts should be made to enable private investment in T&D projects. This would involve exploring alternative models for grid financing, such as corporate bond issuance by utilities, blended finance, public-private partnerships and independent power transmission projects. Opportunities to mobilise international climate finance should also be pursued as an additional source of funding for grid development.

References

1. World Bank. (2024). Pathways Out of the Polycrisis. Washington, DC: International Bank for Reconstruction and Development / The World Bank. Retrieved from documents1.worldbank.org/curated/en/099101424092027337/pdf/P500855154ddde0b31827a1e9377c43d15e.pdf

2. IMF. (2024, July 11). International Monetary Fund. Retrieved from IMF Data, Primary Commodity Price System: https://data.imf.org/?sk=471dddf8-d8a7-499a-81ba-5b332c01f8b9&sid=1393552803658

3. IESR. (2023). Indonesia Energy Transition Outlook 2024. Jakarta Selatan: Institute for Essential Services Reform (IESR). Retrieved from iesr.or.id/wp-content/uploads/2023/12/Indonesia-Energy-Transition-Outlook-IETO-2024.pdf

4. Lowy Institute. (2024). Lowy Institute Asia Power Index. Retrieved October 2024, from power.lowyinstitute.org: power.lowyinstitute.org/data/resilience/resource-security/energy-selfsufficiency/

5. Reuters. (2023, November 8). KEPCO to hike industrial electricity price, sell assets as debt hits $154 billion. Retrieved from www.reuters.com: www.reuters.com/business/energy/kepco-hike-industrial-electricity-price-sell-assets-debt-hits-154-bln-2023-11-08/

6. EMBER. (2024). 2030 Global Renewable Target Tracker. Retrieved from EMBER: https://ember-energy.org/data/2030-global-renewable-target-tracker/

7. Renewables First. (2024). The Great Solar Rush in Pakistan. Islamabad: Renewables First & Herald Analytics. Retrieved from uploads.renewablesfirst.org/The_Great_Solar_Rush_in_Pakistan_38157451a3.pdf

8. IEA. (2024). Integrating Solar and Wind: Global experience and emerging challenges. Paris: International Energy Agency. Retrieved from iea.blob.core.windows.net/assets/4e495603-7d8b-4f8b-8b60-896a5936a31d/IntegratingSolarandWind.pdf

9. IEA. (2023). Electricity Grids and Secure Energy Transitions. Paris: International Energy Agency. Retrieved from iea.blob.core.windows.net/assets/ea2ff609-8180-4312-8de9-494bcf21696d/ElectricityGridsandSecureEnergyTransitions.pdf

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