Integrating Solar and Wind

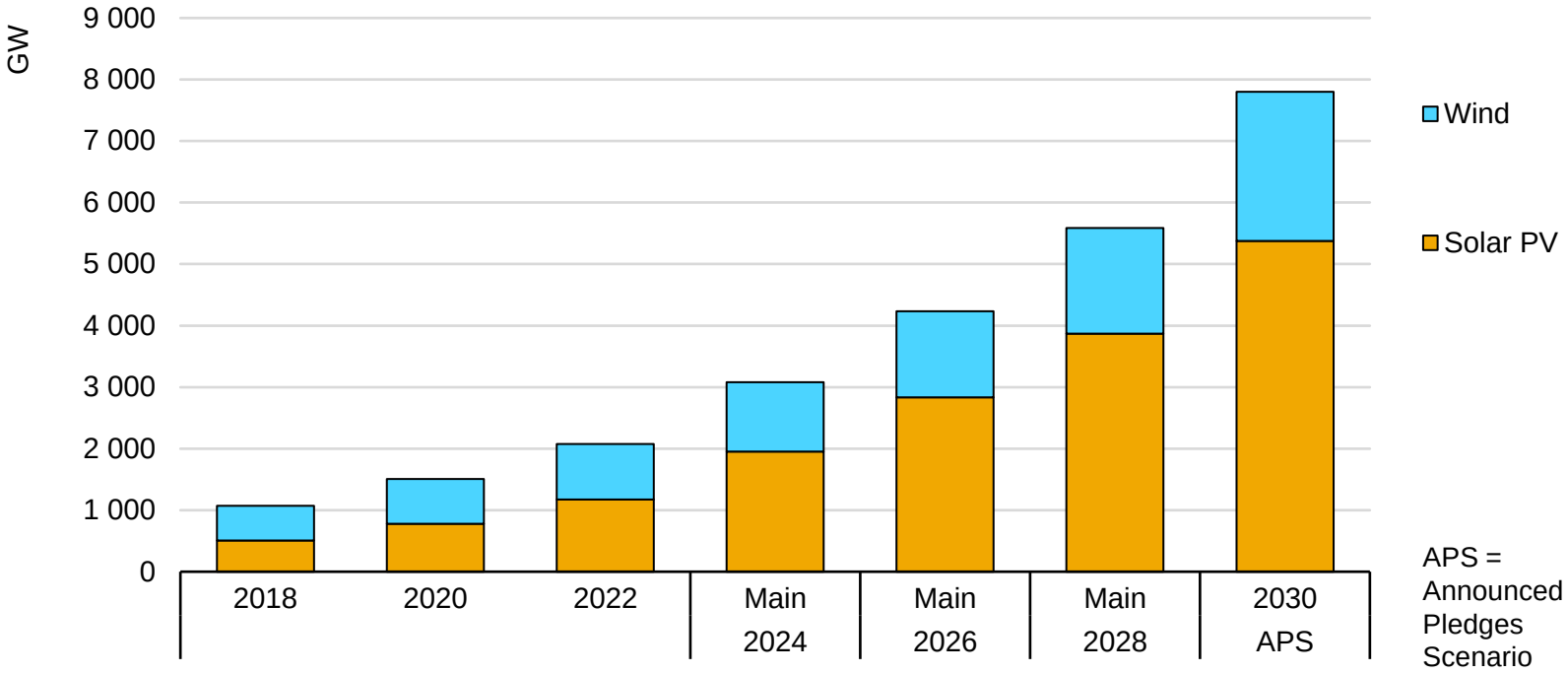
Global experience and emerging challenges

Global webinar

Paris, 2 October 2024

Deploying new VRE capacity is a necessary, but not the final step

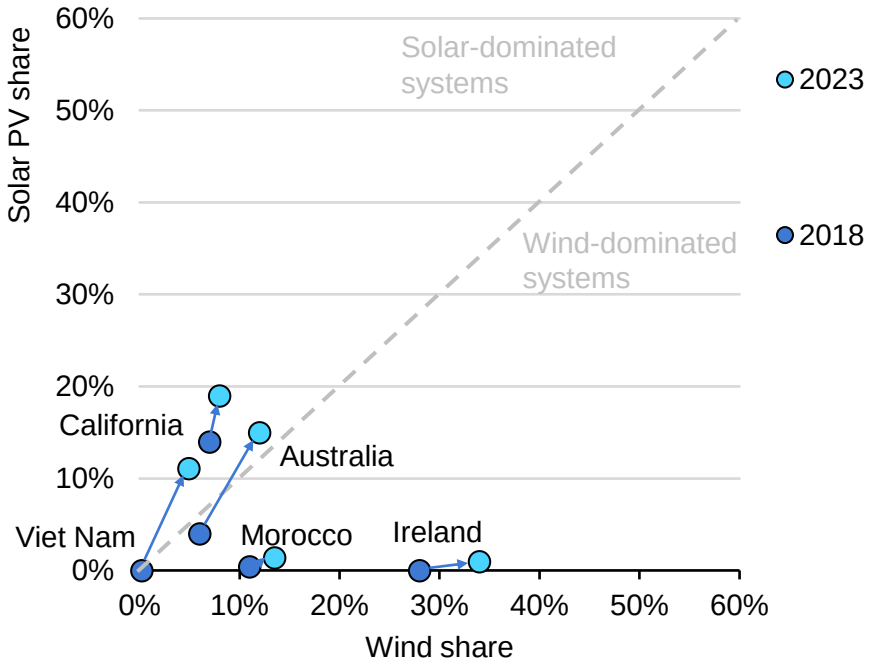
Historical and future cumulative solar PV and wind capacity in the Renewables 2023 main case (2024-2028) and APS (2030)

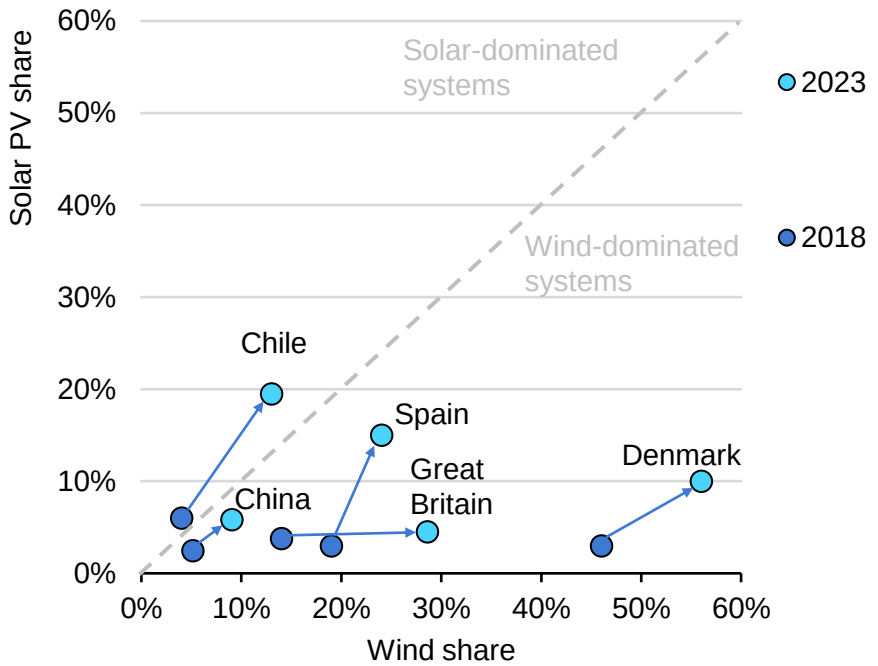


Solar PV and wind are set to grow further, with more efforts needed for the tripling renewable capacity goal by 2030. Reaping deployment benefits needs a range of measures to ensure that solar PV and wind capacity is securely integrated.

High VRE penetration is possible with varying mixes of solar and wind

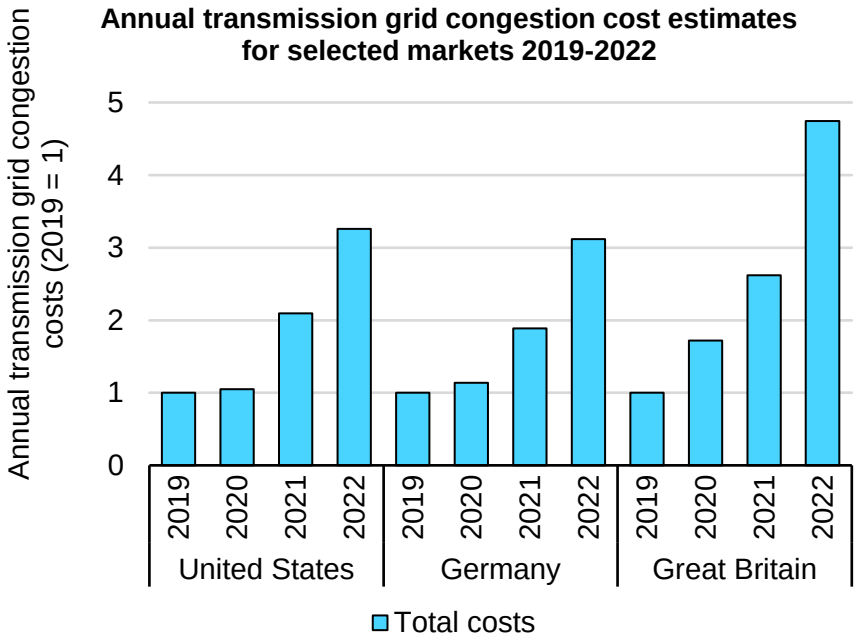
Annual solar and wind generation shares, selected countries and systems, 2018-2023

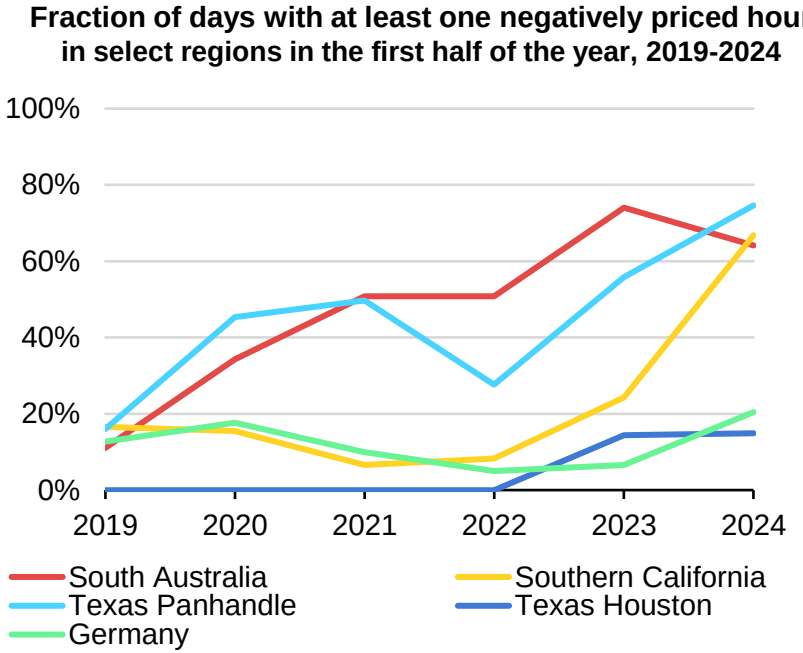




A wide range of experience exists with different mixes of solar and wind, region and VRE penetration level. Despite this extensive progress, prioritising measures adequate for local conditions remains challenging.

Symptoms of tardy integration signal urgency for targeted measures





Symptoms of integration challenges, such as grid congestion and negative electricity prices, are sending cautionary signals to investors in solar PV and wind.

Framework guides phased, timely implementation of VRE integration measures

Phases of VRE integration framework

Low phases

Phase 1: VRE has no significant impact at the system level

Phase 2: VRE has a minor to moderate impact on the system

Phase 3: VRE determines the operation pattern of the power system

High phases

Phase 4: VRE meets almost all demand at times

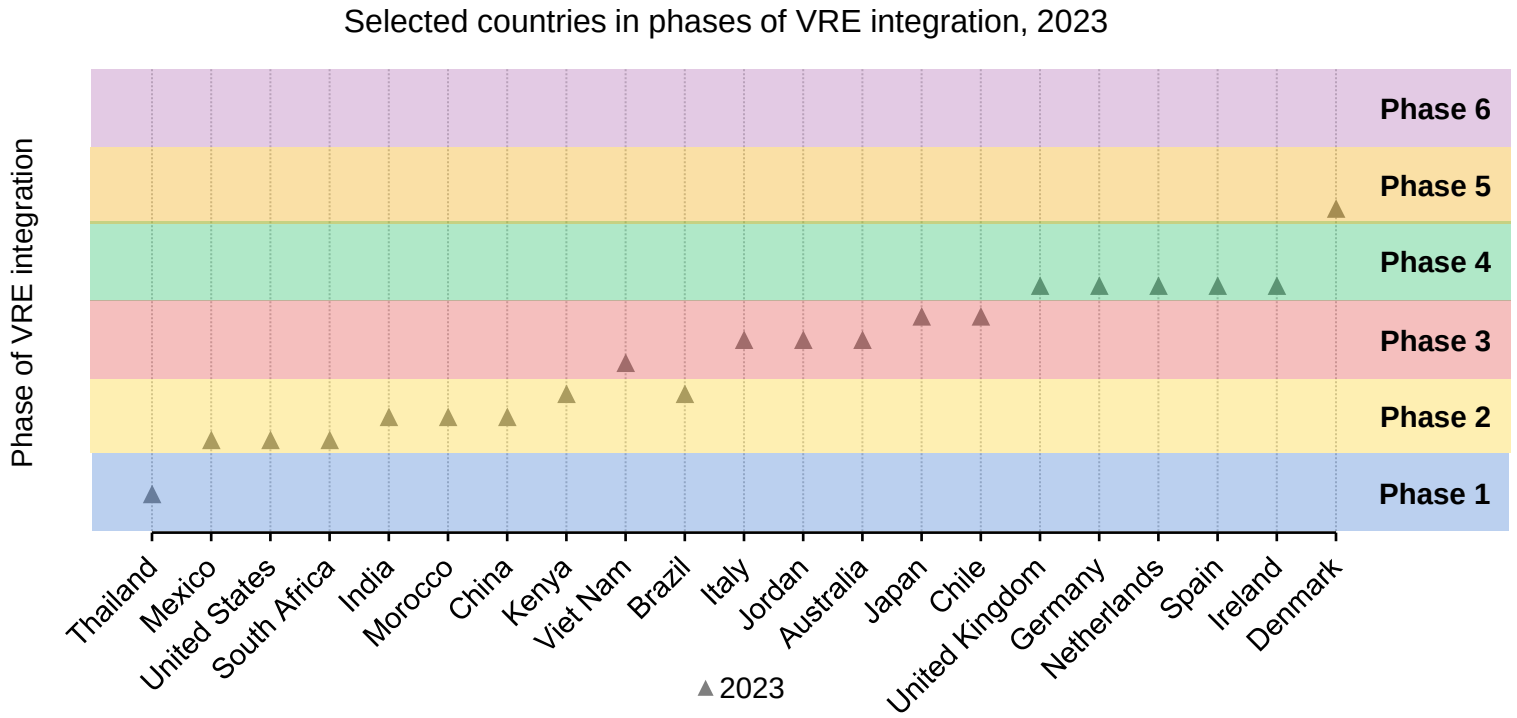
Phase 5: Significant volumes of surplus VRE across the year

Phase 6: Secure electricity supply almost exclusively from VRE

VRE = variable renewable energy

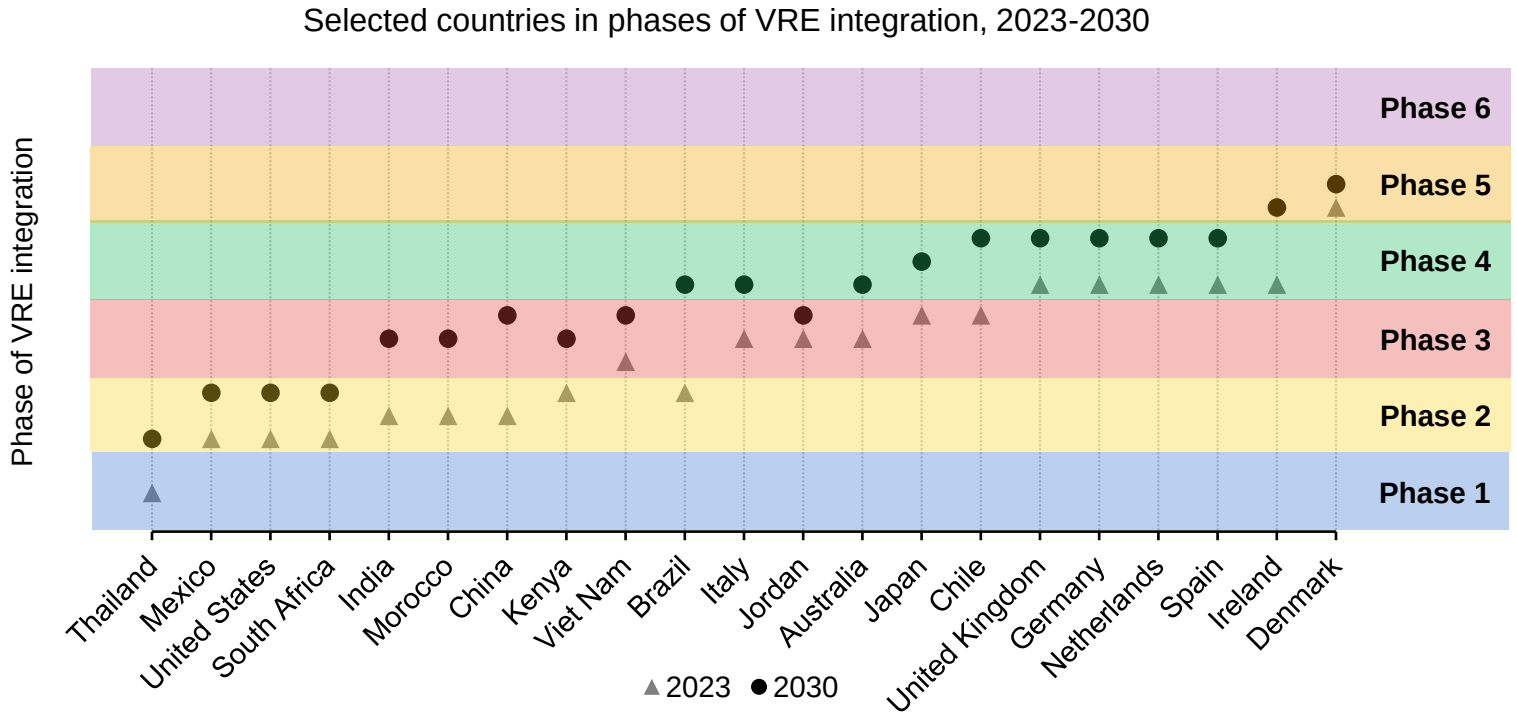
The framework allows policy makers to identify VRE integration measures that need to be prioritised at each phase to ensure its timely implementation.

Most power systems in the world are currently in low phases…



Several countries with different geographies and levels of economic development reached Phase 3 by 2023, indicating that there is a wealth of global experience to manage the challenges in low phases.

…but more systems will be at higher phases by 2030

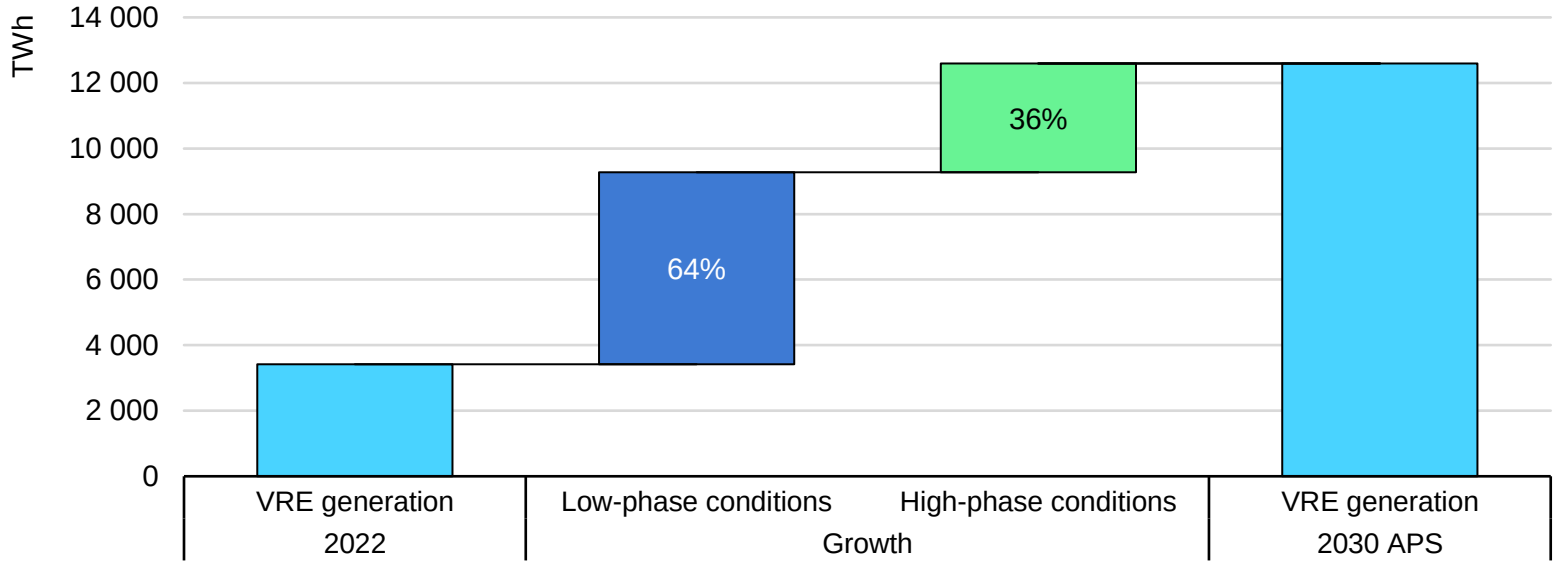


Some countries are currently classified at high phases with high wind penetration, but more systems will be at high phases by 2030 driven by solar PV penetration.

Solar PV and wind generation outlook and integration risks

Most new VRE generation out to 2030 occurs in low-phase conditions

Global solar PV and wind generation growth in conditions of low and high phases of VRE integration in the Announced Pledges Scenario, 2022-2030

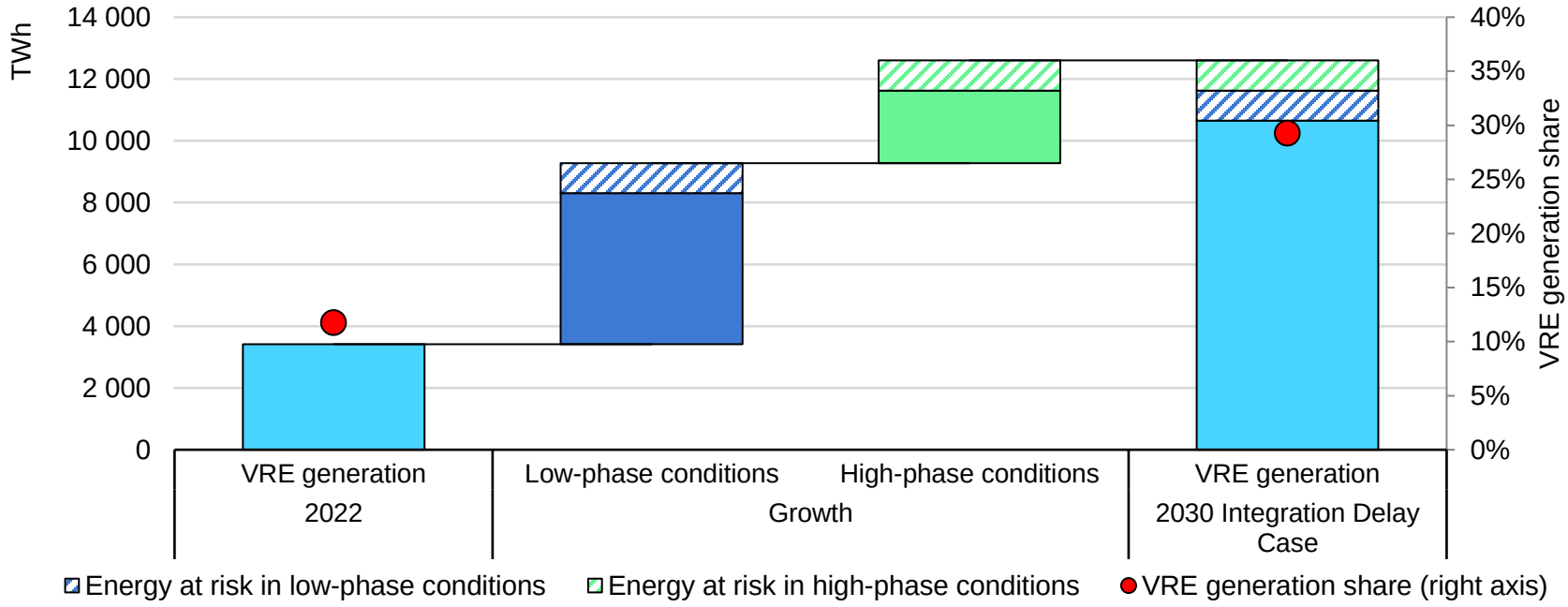


APS = Announced Pledges Scenario

64% of new VRE generation out to 2030 happens in systems in low-phase conditions – mostly found currently in emerging markets and developing economies.

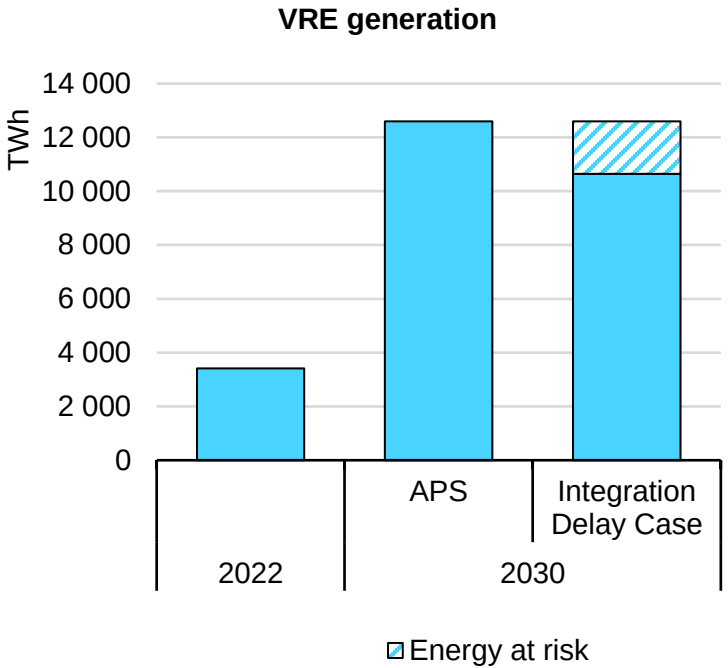
Delaying integration measures puts solar and wind uptake at risk

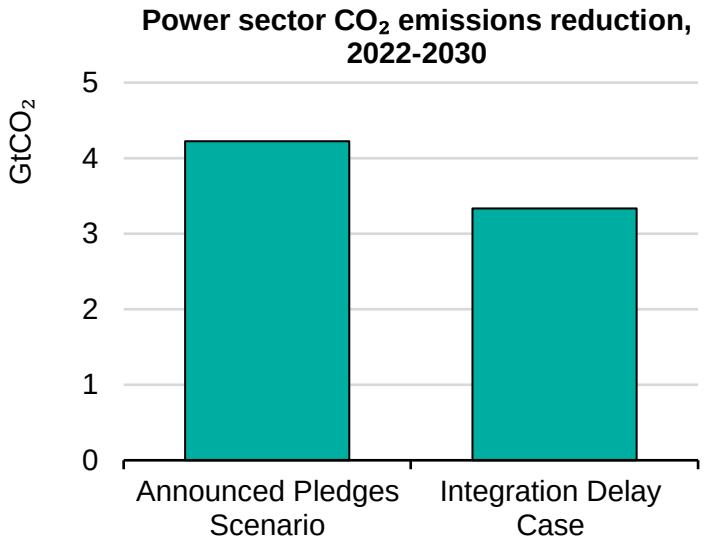
Global solar PV and wind generation at risk in the Integration Delay Case and the Announced Pledges Scenario, 2022-2030



Delaying the implementation of measures to support integration could jeopardise up to 15% of global solar PV and wind generation by 2030.

Delaying VRE integration can have significant consequences





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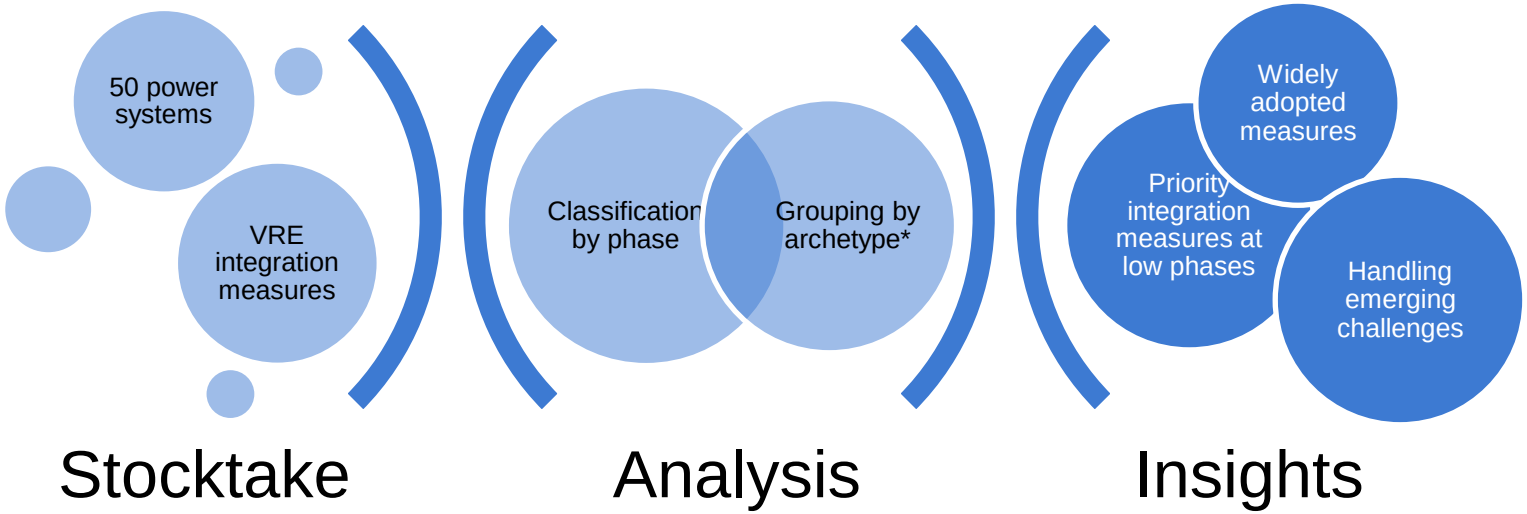
If this decrease is compensated by increased reliance on fossil fuels, it could lead to up to a 20% smaller reduction of CO_2 emissions in the power sector out to 2030, putting electricity affordability and climate targets at risk.

Stocktake of VRE integration measures

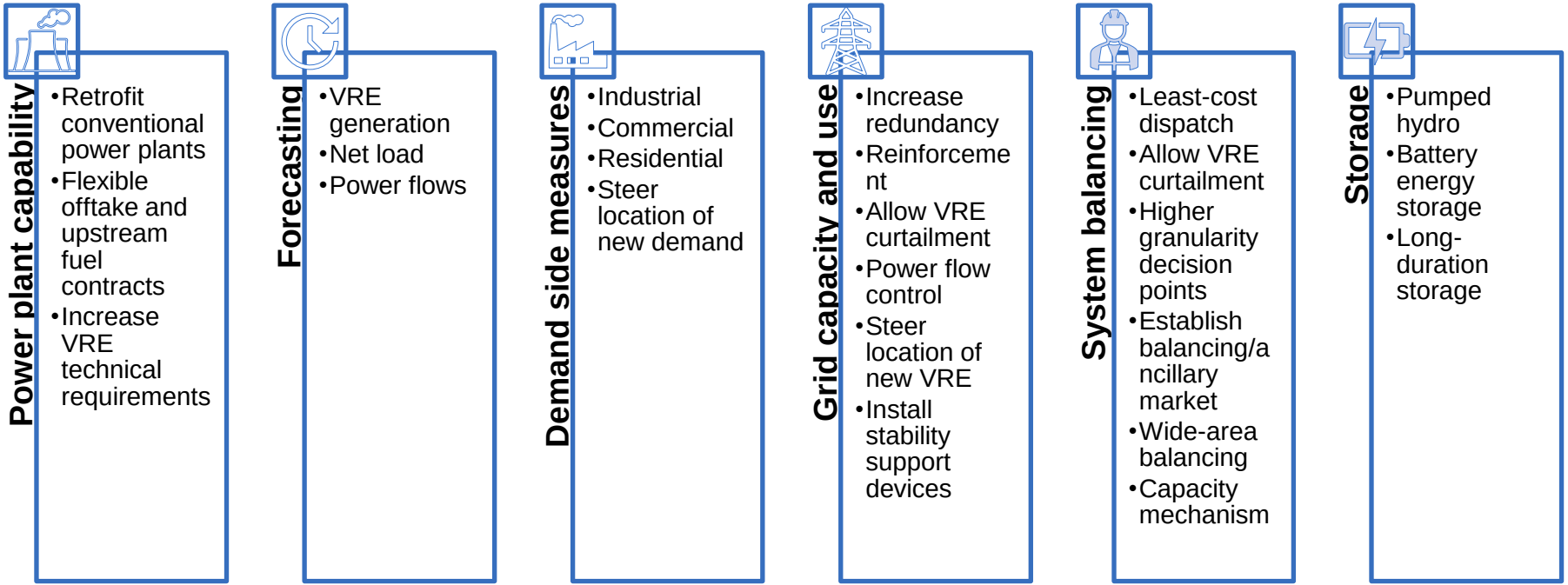
Global stocktake informs how to prioritise VRE integration measures



First-of-its-kind stocktake capturing worldwide experience on how to integrate solar PV and wind, classified by phase helps policymakers to prioritise phased VRE integration measures, to ensure timely implementation.

*Grouping together of systems sharing similar characteristics that affect their ability to deal with the challenges at each phase of VRE integration

Widely adopted VRE integration measures are often straightforward



Commonly practices involve modifications to existing assets or operational arrangements that increase flexibility.

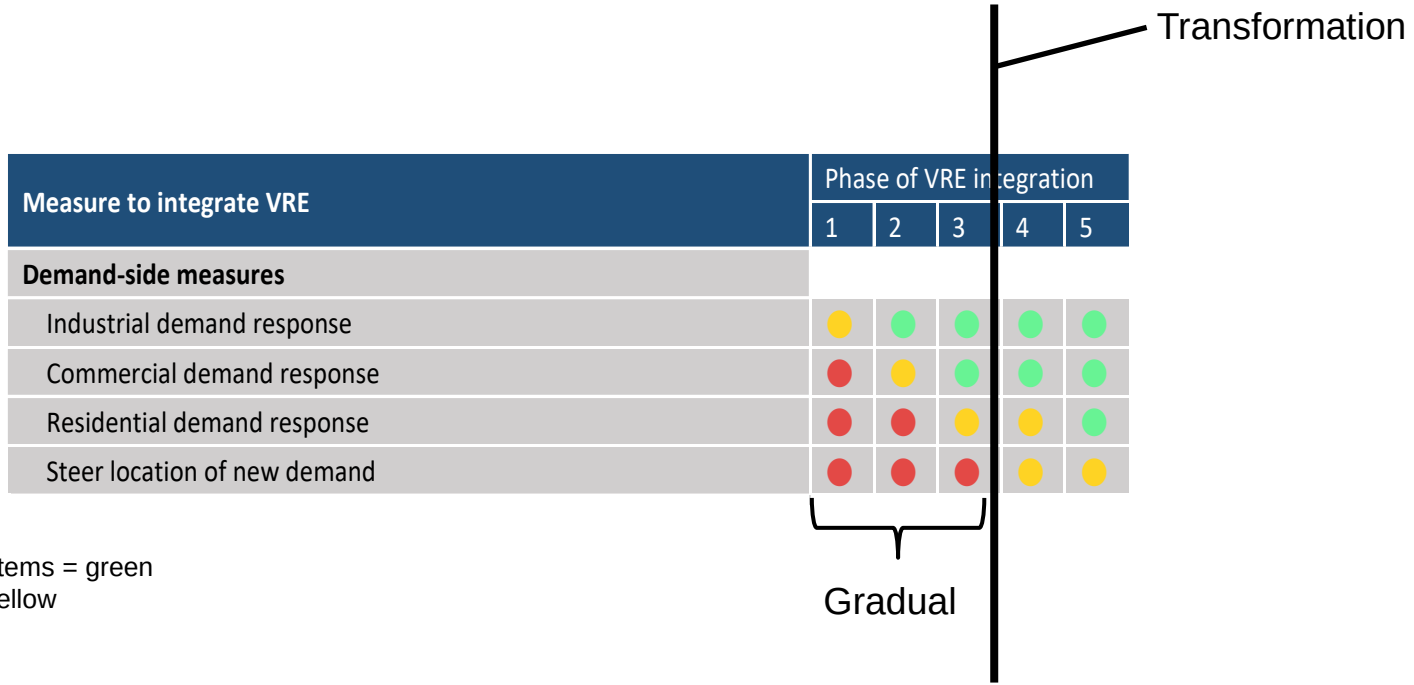
Measures based on progressive and targeted adjustments can integrate most new capacity in low-phase systems

Measure to integrate VRE	Phase of VRE integration				
	1	2	3	4	5
Enhance power plant capability					
Retrofit conventional power plants	🔴	🟡	🟡	🟢	🟢
Flexible offtake and upstream fuel contracts	🔴	🔴	🟡	🟢	🟢
Increase VRE technical requirements	🟡	🟢	🟢	🟢	🟢
Forecasting					
VRE generation	🟡	🟢	🟢	🟢	🟢
Net load	🔴	🟡	🟡	🟢	🟢
Power flows	🔴	🟡	🟡	🟡	🟡
Demand-side measures					
Industrial demand response	🟡	🟢	🟢	🟢	🟢
Commercial demand response	🔴	🟡	🟢	🟢	🟢
Residential demand response	🔴	🔴	🟡	🟡	🟢
Steer location of new demand	🔴	🔴	🔴	🟡	🟡
Modify system operation rules					
Allow VRE curtailment	🔴	🟡	🟡	🟡	🟢
High granularity/closer to real time	🔴	🟡	🟡	🟢	🟢
Least-cost dispatch	🟡	🟢	🟢	🟢	🟢
Capacity mechanism	🔴	🟡	🟡	🟡	🟡
Establish balancing market	🔴	🟡	🟡	🟢	🟢
Establish ancillary service market	🔴	🟡	🟡	🟡	🟢
Enhance use of interconnection	🔴	🟡	🟡	🟢	🟢
Enhance grid capacity and use					
Install stability support devices (STATCOMs, SYNCONs)	🟡	🟡	🟡	🟡	🟢
Interconnection/redundancy/mesh	🟢	🟢	🟢	🟢	🟢
Reinforcement	🟡	🟢	🟢	🟢	🟢
Allow VRE curtailment	🟡	🟢	🟢	🟢	🟢
Power flow control	🔴	🟡	🟢	🟢	🟢
Steer location of new VRE	🔴	🟡	🟡	🟢	🟢
Storage					
Pumped hydro	🟡	🟢	🟡	🟡	🟢
Battery energy storage	🔴	🟡	🟡	🟢	🟢
Long-duration storage	🔴	🔴	🔴	🔴	🟡

more than 80% of systems = green
50-80% of system = yellow
less than 50% = red

Countries that currently have low shares of VRE can typically boost deployment without enacting sweeping, system-wide changes. Well-known and tested measures – implemented gradually as the need arises – tend to be sufficient.

Measures based on progressive and targeted adjustments can integrate most new capacity in low-phase systems



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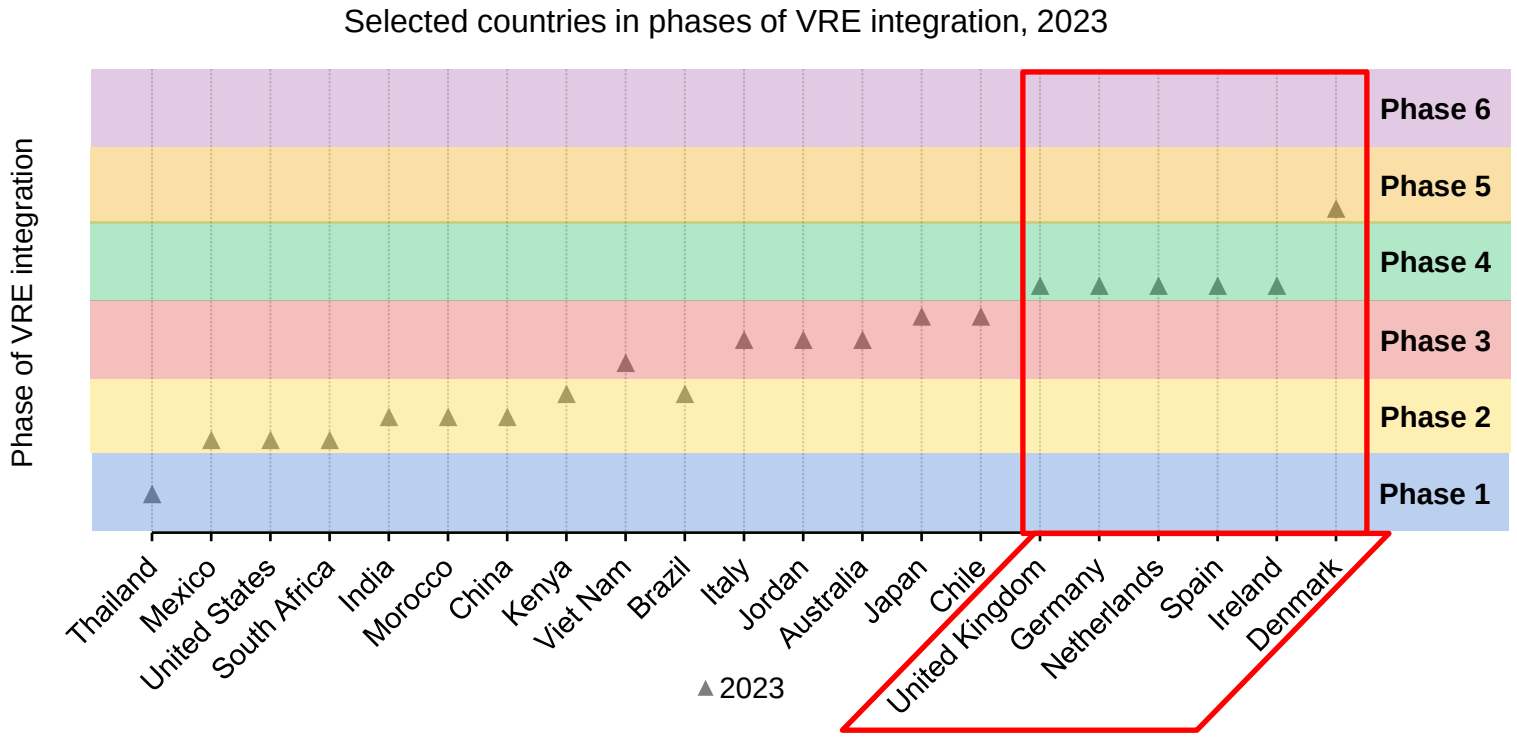
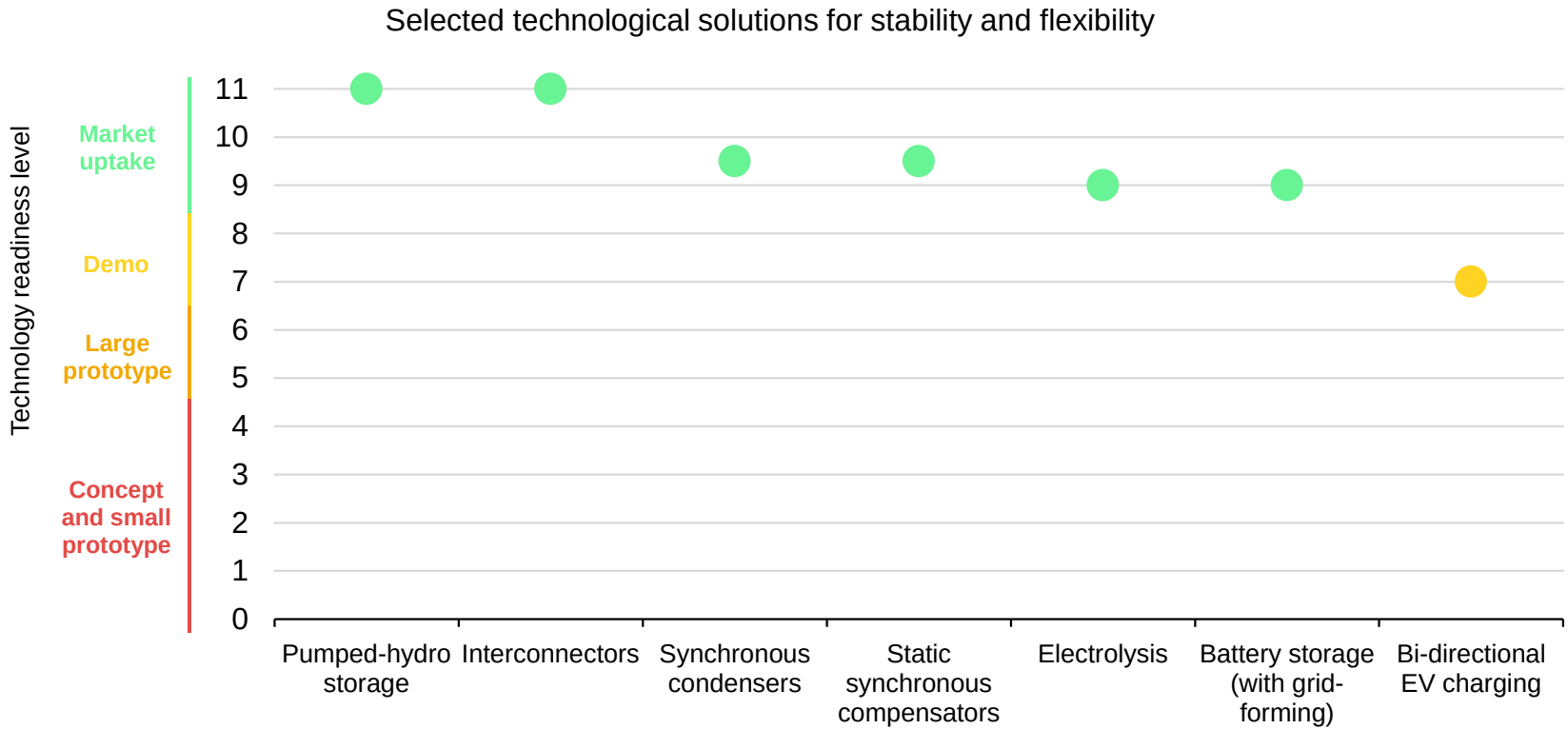
Emerging challenges and solutions at high VRE shares

Countries with high VRE shares unveil challenges and solutions



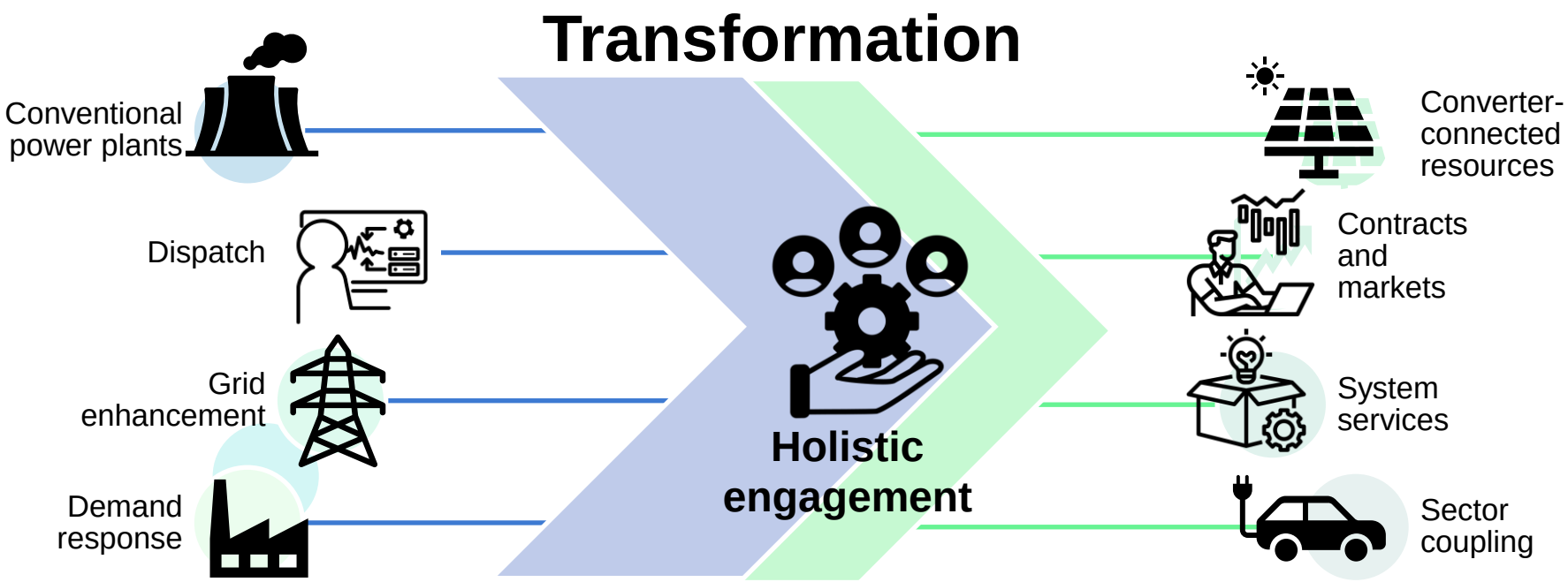
Frontrunner power systems are effectively managing high levels of VRE, integrating 35 to 75% of annual VRE share. Their experiences managing emerging challenges – with a higher focus on stability and flexibility - provide valuable insights.

A portfolio of technologies will need to be deployed in high phases



Most technological solutions needed to address stability and flexibility are mature or nearing maturity. Their successful rollout relies on appropriate policy and regulatory action.

A strategic transformation is required at high phases



New frameworks to extract further flexibility and system services from a wider range of sources, and new technologies to ensure stability and manage surplus energy, will need to be considered

Six key policy actions to accelerate effective VRE integration

Assess the system's preparedness for VRE integration by improving understanding of power system resources, identifying infrastructure needs, and gaps in funding, data and skills.

Ensure secure grid operation with clear requirements from VRE such as forecasting accuracy, asset visibility and controllability, and its reaction to disturbances.

Unlock flexibility from the existing power system to manage increasing variability by optimising dispatch, activating demand response, and making existing generation operate flexibly.

Design incentives to garner flexibility and system services from a wider range of sources by defining and quantifying the need and creating procurement frameworks.

Accelerate technology integration and innovation with regulatory, market, and strategic support to rapidly scale up and develop technologies that are key for long-term decarbonisation.

Adopt a holistic approach to power system planning, by integrating cross-sectoral dynamics, incorporating resilience in addition to security and efficiency and leveraging global expertise.

* System-friendly VRE refers to planning, operating or contracting solar and wind power plants in a way that supports the overall outcomes for the system.