Developing a roadmap to a low cost, low carbon India electricity system

Taking the next steps to decarbonised power

September 2019

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Key Messages

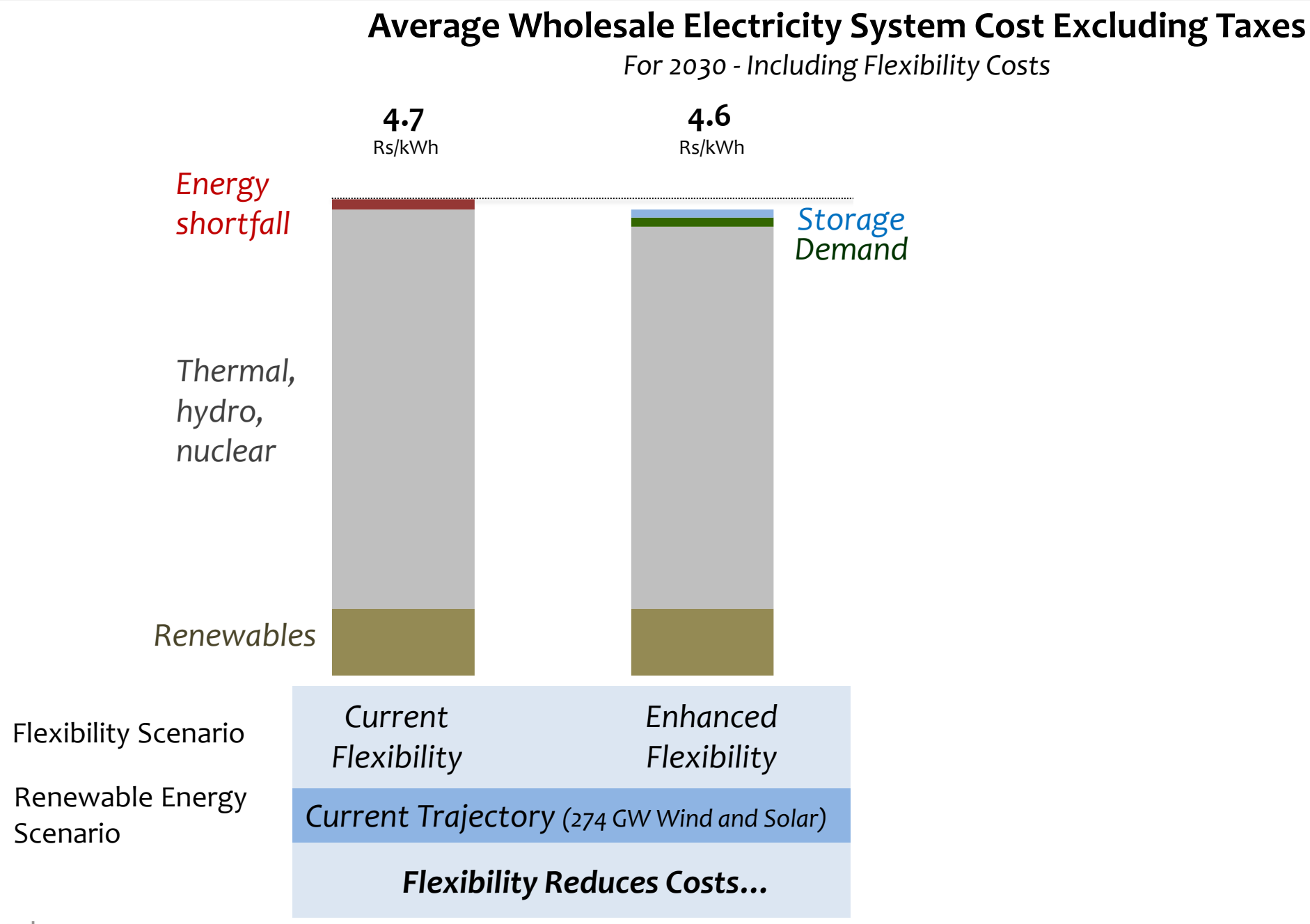
Increasing electricity system flexibility reduces costs

India's system flexibility needs are growing

Multiple sources of flexibility are available (and required) to meet India's needs

Integrating these diverse sources requires new types of incentives, infrastructure, markets, and investment

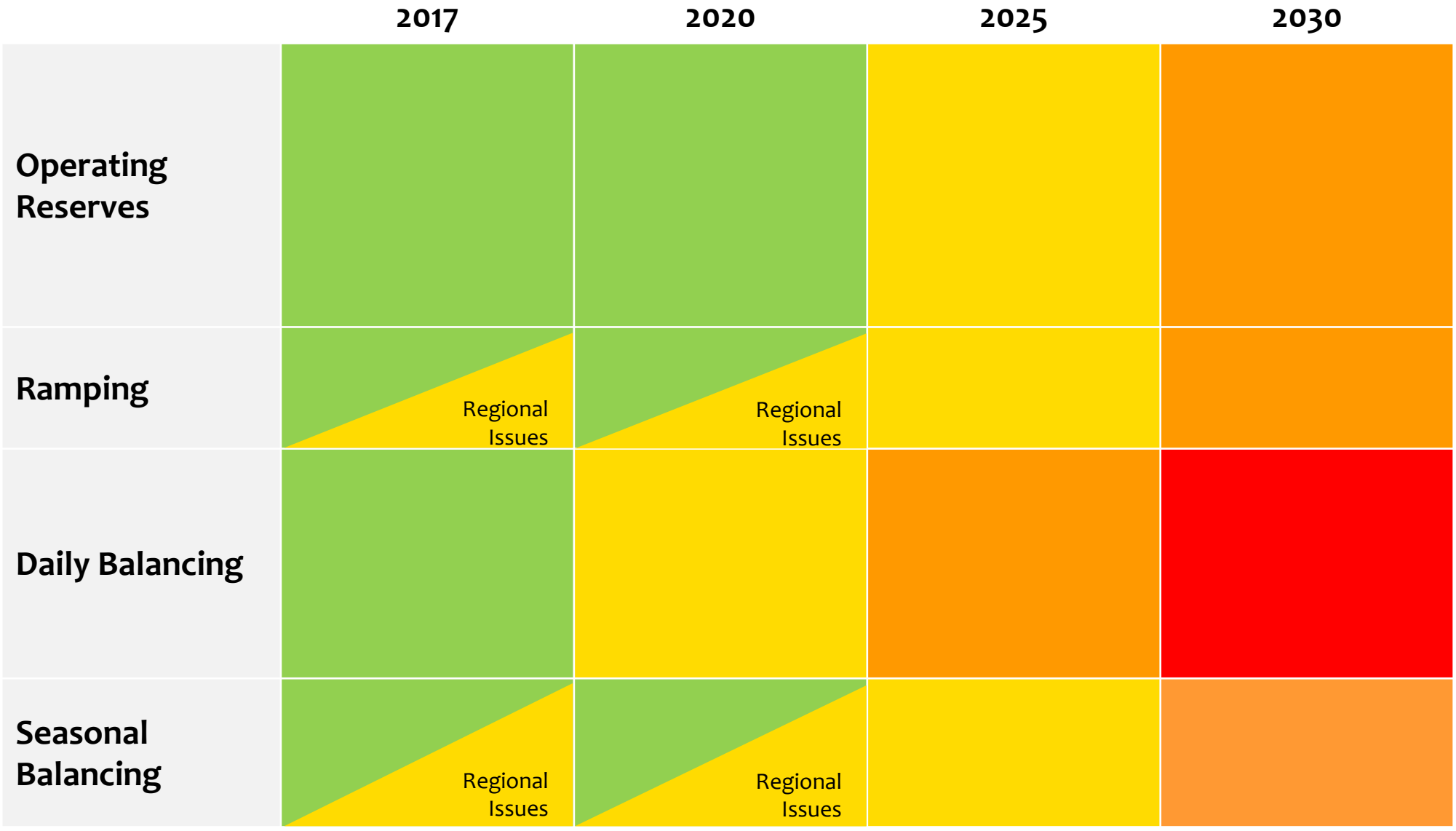
Enhancing flexibility will decrease India's cost of electricity and facilitate more electricity supply options



Without technology and/or policy changes, flexibility could become an issue in the next few years

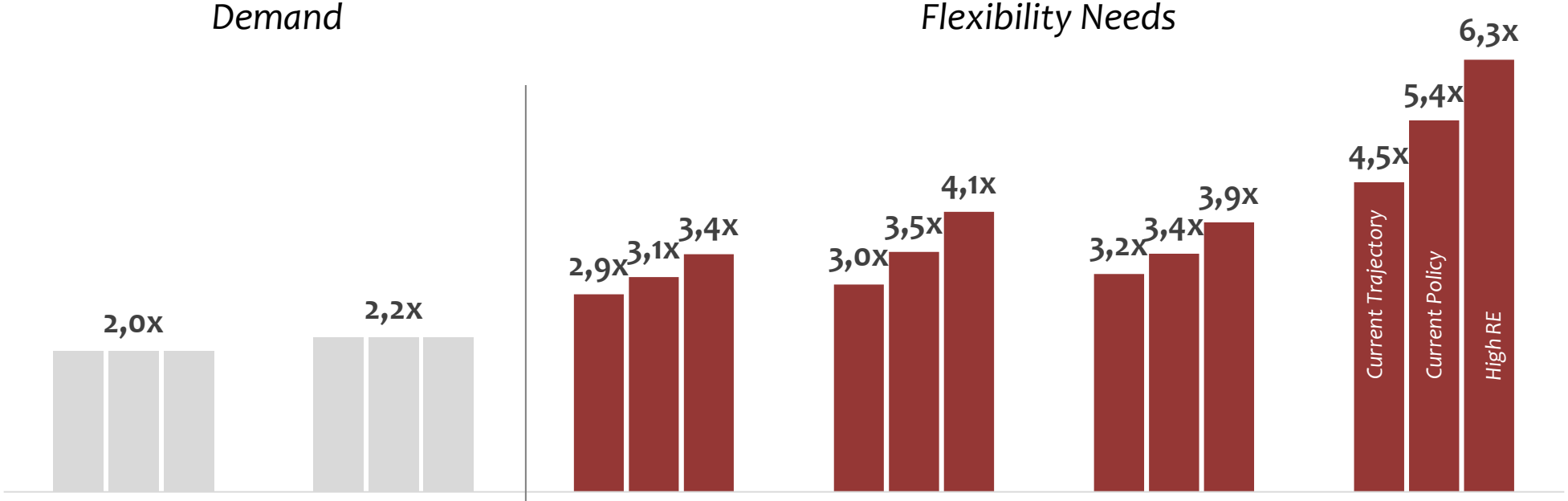
Preliminary evaluation of current Indian electricity system's ability to deliver key types of flexibility

Under TERI high renewable energy scenario



Flexibility needs will increase faster than electricity demand, driven by increased variable generation and changing consumption patterns

Growth in Key Flexibility Needs 2017-2030



Energy Requirement (TWh)

Peak Demand (GW)

Reserve Requirement (GW)

Estimated as 3% of peak demand plus 5% of peak renewable production, as a proxy for forecast errors

Maximum Ramp (MW/min)

Rate of maximum 1-hour ramp in a year

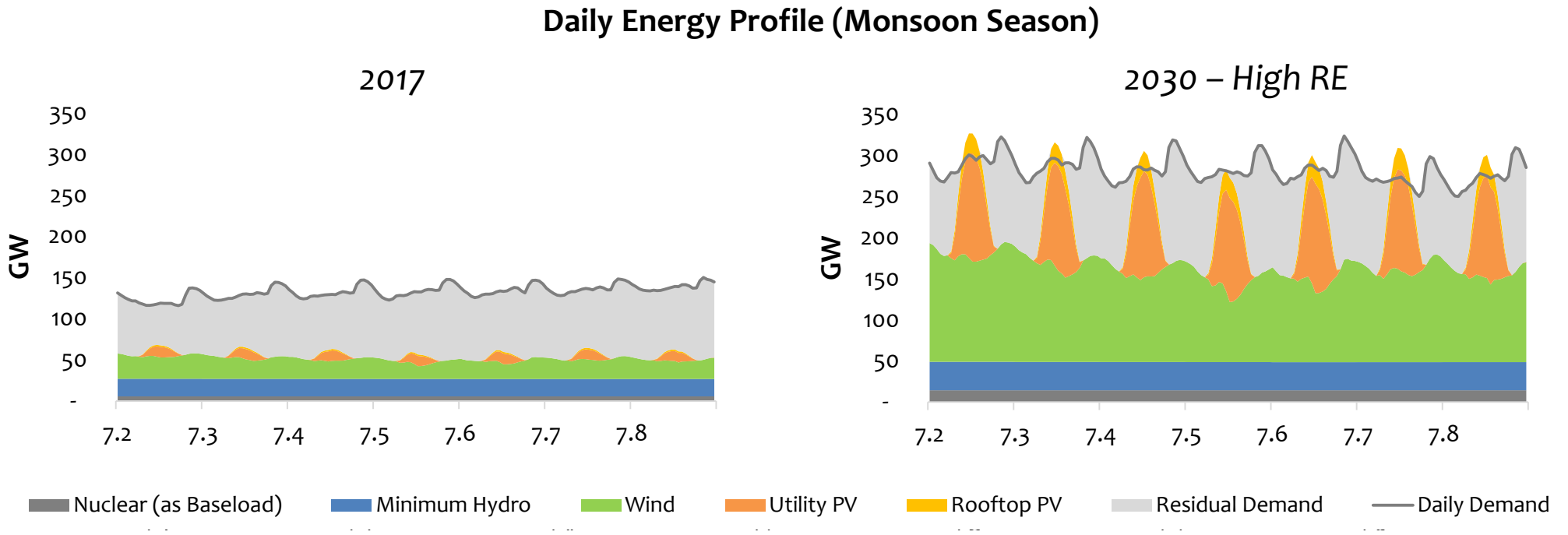
Seasonal Balancing (TWh/month)

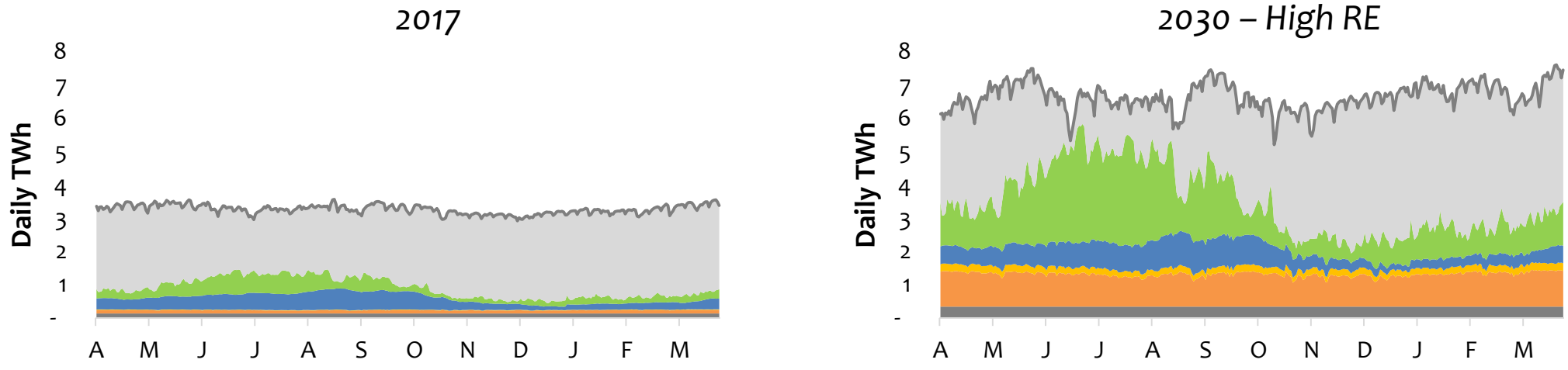
Residual energy requirement (after VRE) in highest vs. lowest month

Daily Balancing (GW)

Average spread between maximum and minimum residual demand (after VRE)

Flexibility needs will increase faster than electricity demand, driven by increased variable generation and changing consumption patterns

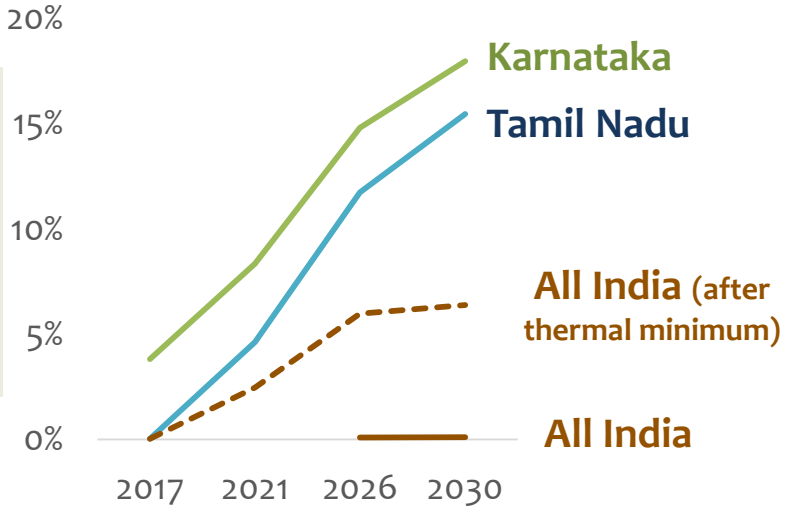




Flexibility needs will arrive sooner and be more significant in some states

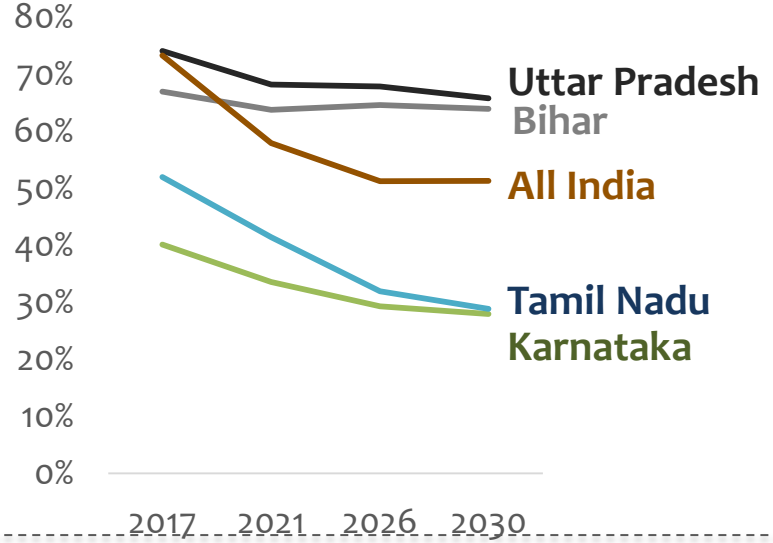
States with more renewables need transmission or flexible demand/storage to use excess production

Share of wind and solar production in excess of demand



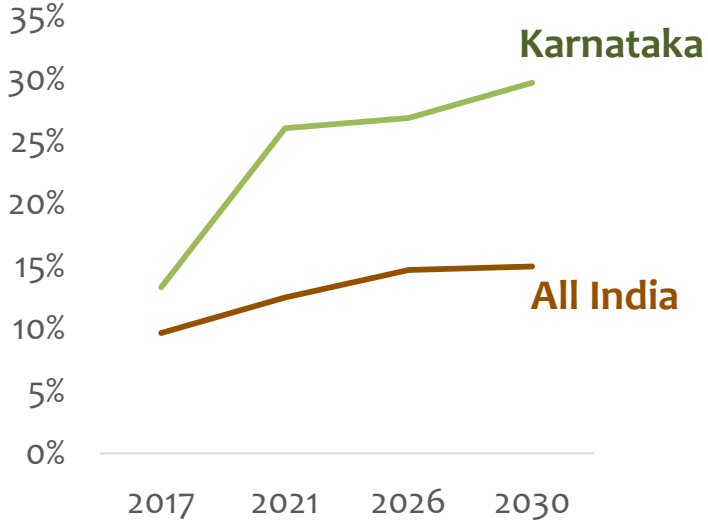
States with more renewables have lower load factors for their thermal plants

Annual load factor of residual demand after RE production



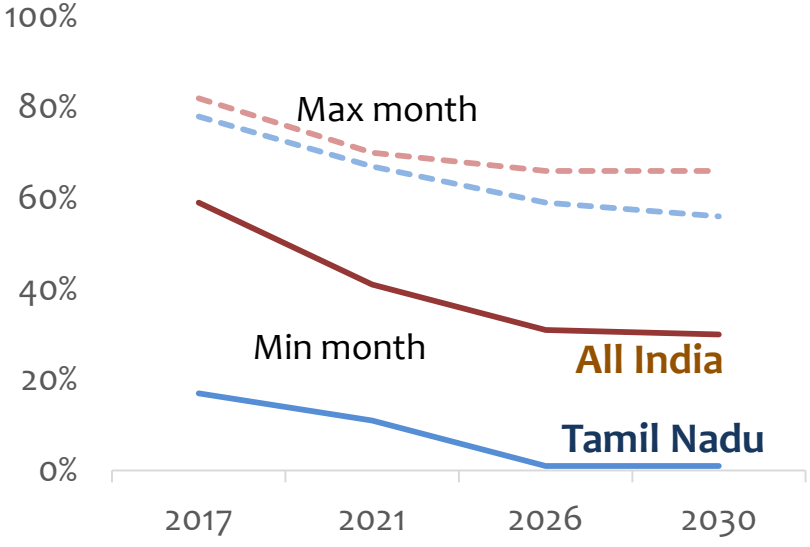
More solar PV will leads to higher ramping needs

1-hour ramping needs as % of peak demand

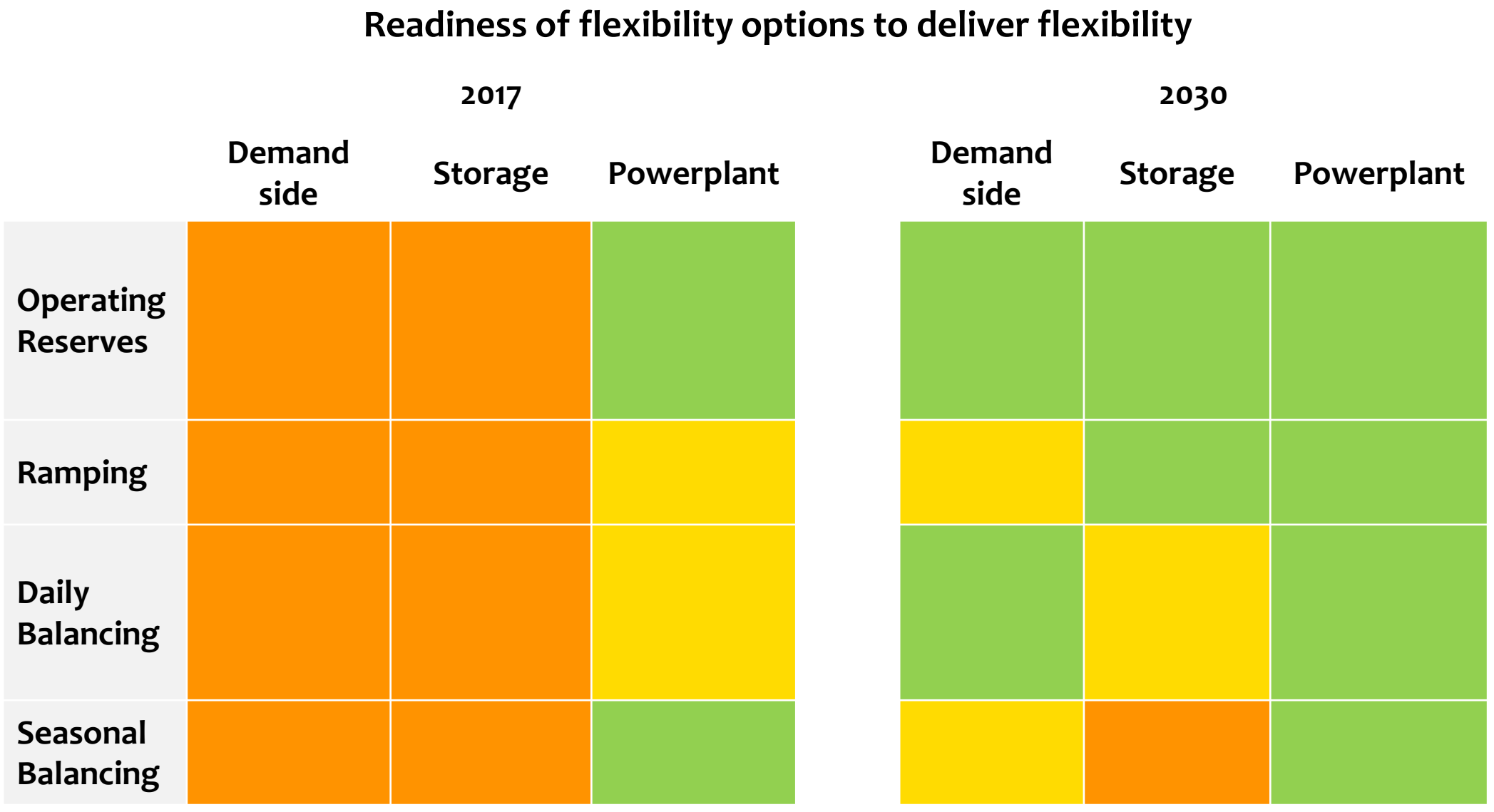


More wind leads to higher seasonal shifting needs

Minimum and maximum monthly load factor of residual demand after RE production



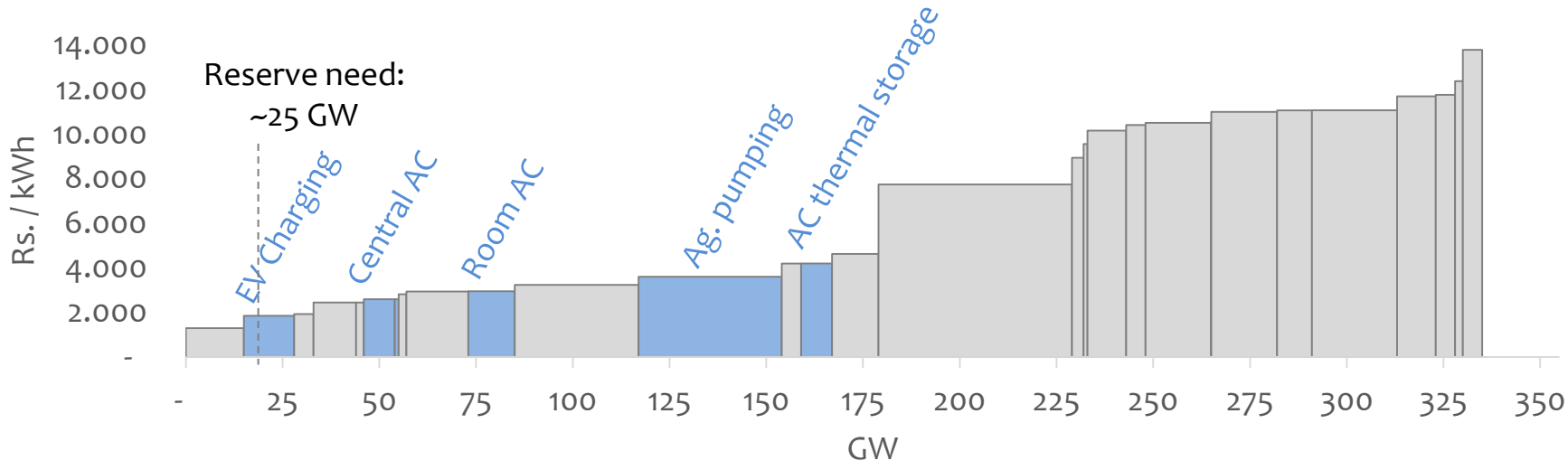
India may have new options beyond existing power plants - flexible demand and storage - to help meet flexibility needs by 2030



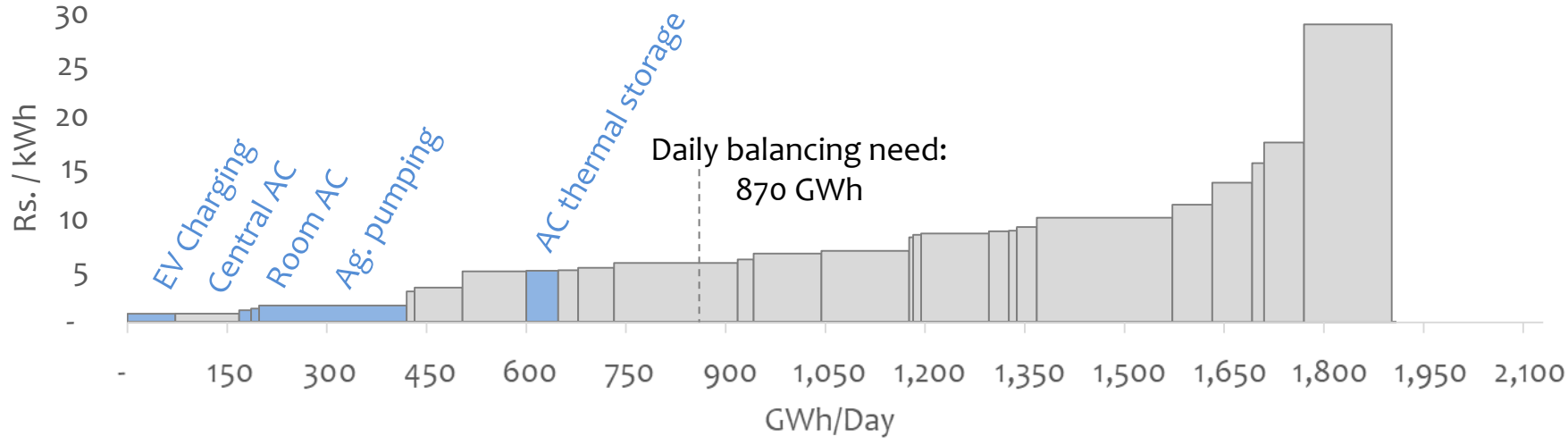
Demand side measures have high potential and low cost

Demand Flexibility

2030 Reserve Supply Curve



2030 Daily Balancing Supply Curve

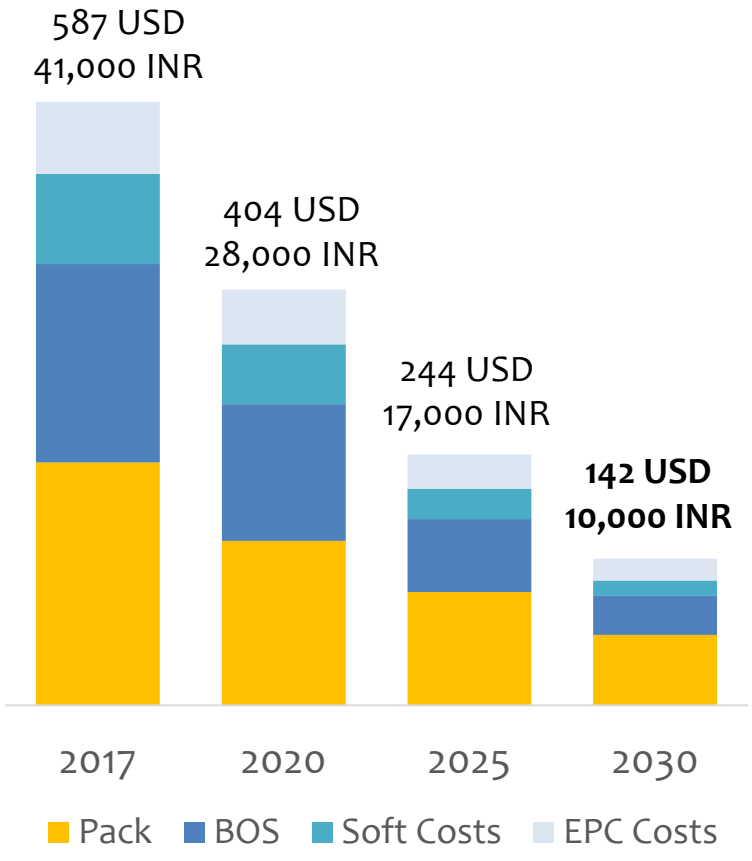


Battery costs are declining rapidly driven by the electric vehicle market

Storage

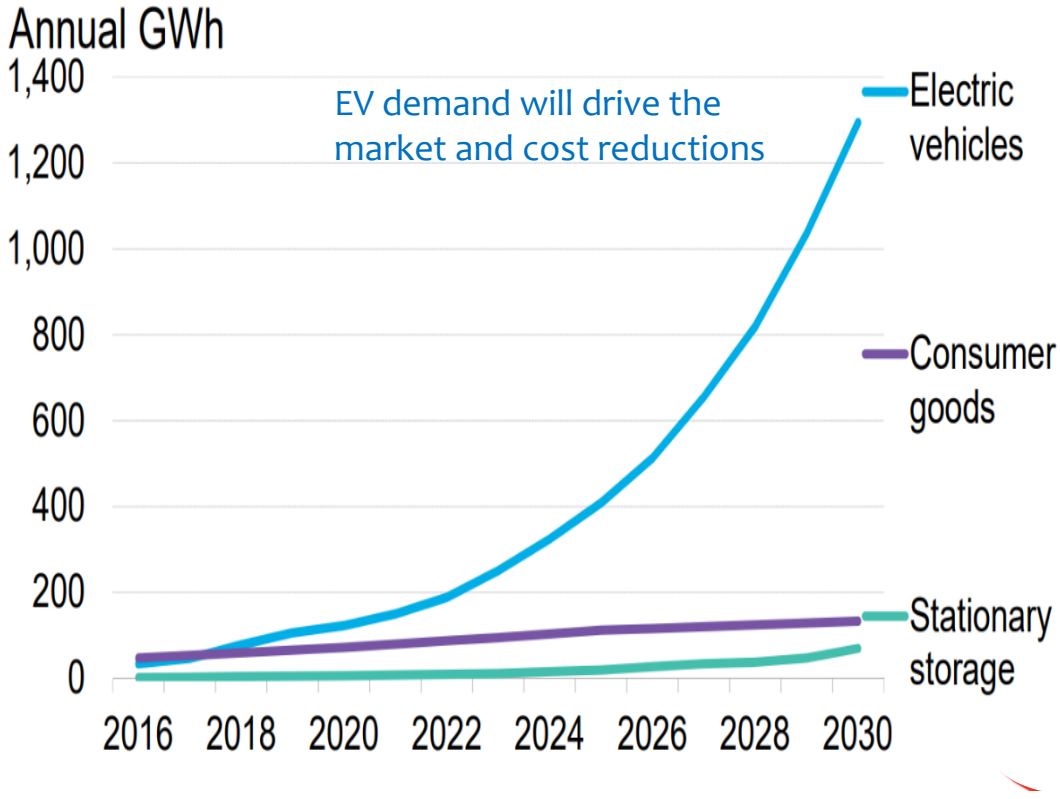
Lithium Ion Battery Storage System Capex Cost

(per kWh of energy storage capacity)



Based on McKinsey figures, assuming India BOS discount of 25% by 2030, increasing from no discount in 2017. 2030 extended based on 2017-2025 CAGR. Exchange rate - 70 INR/USD.

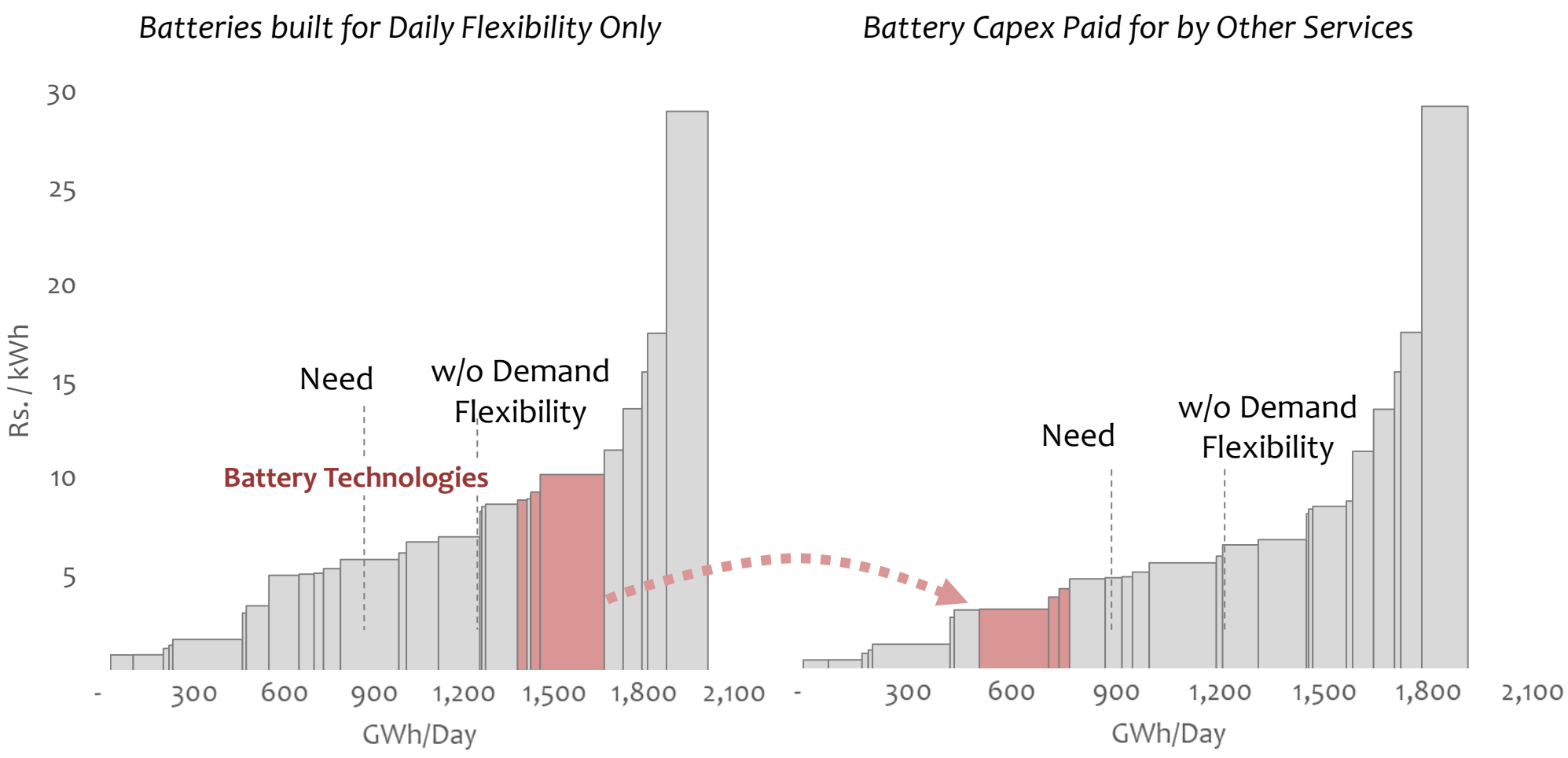
Global Lithium Ion Battery Demand (GWh/yr)



Source: BNEF 2018, assumes 100% of stationary storage demand met by lithium ion.

Batteries can serve multiple flexibility needs, and stacking values makes storage competitive

2030 Daily Balancing Supply Curve

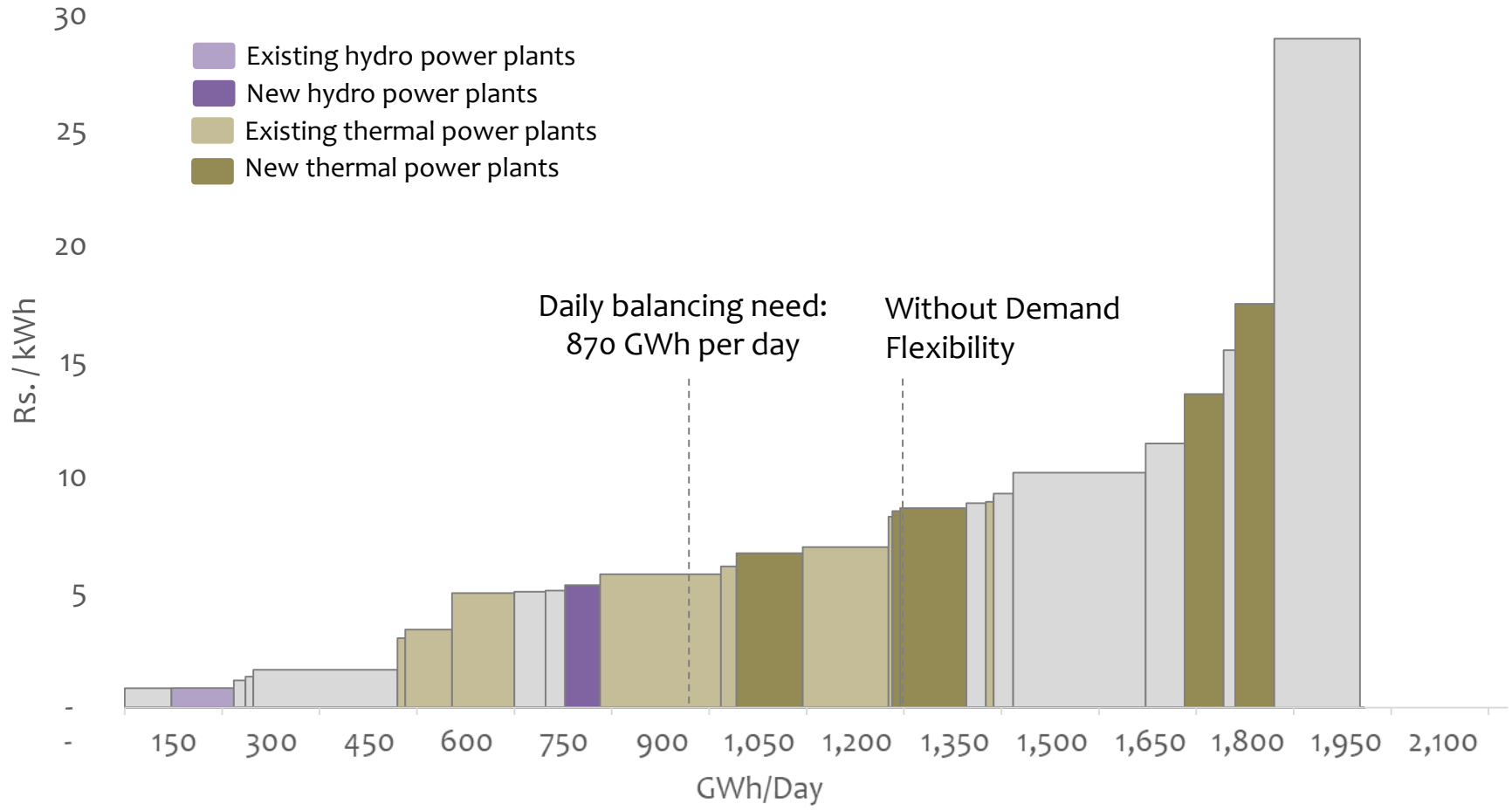


Batteries become highly cost-competitive when capex costs are amortized across multiple services

Existing power plants are a cost-effective source of flexibility for many needs

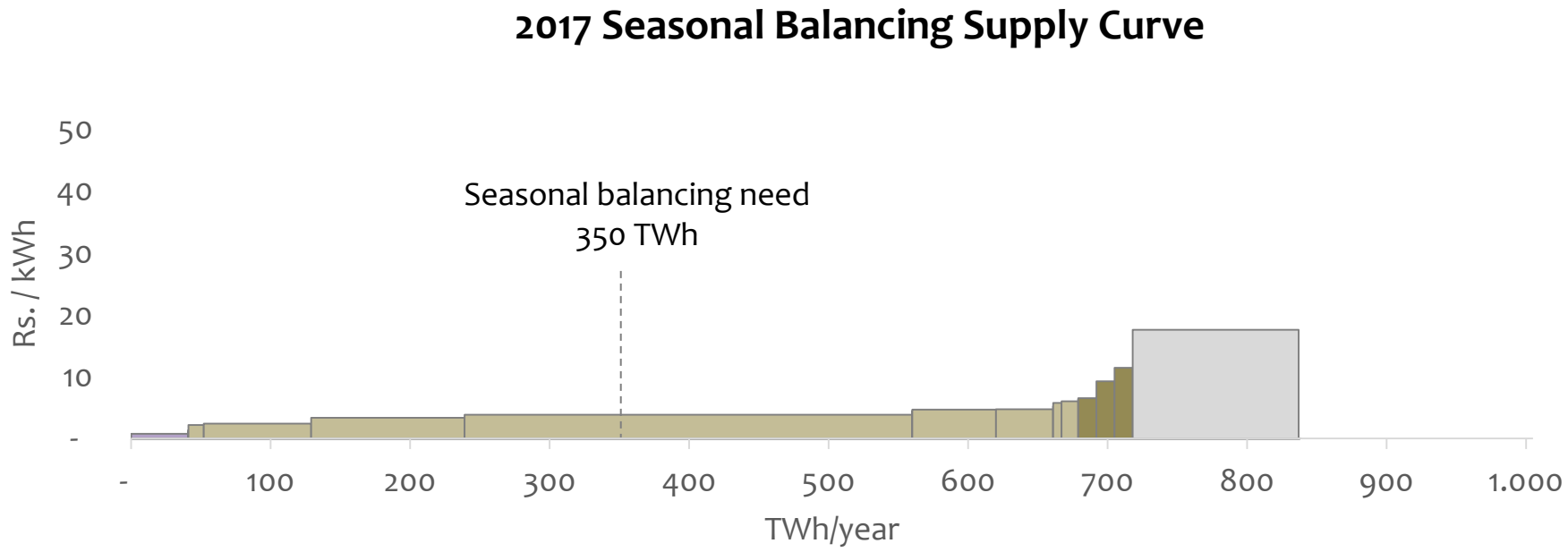
Power plant Flexibility

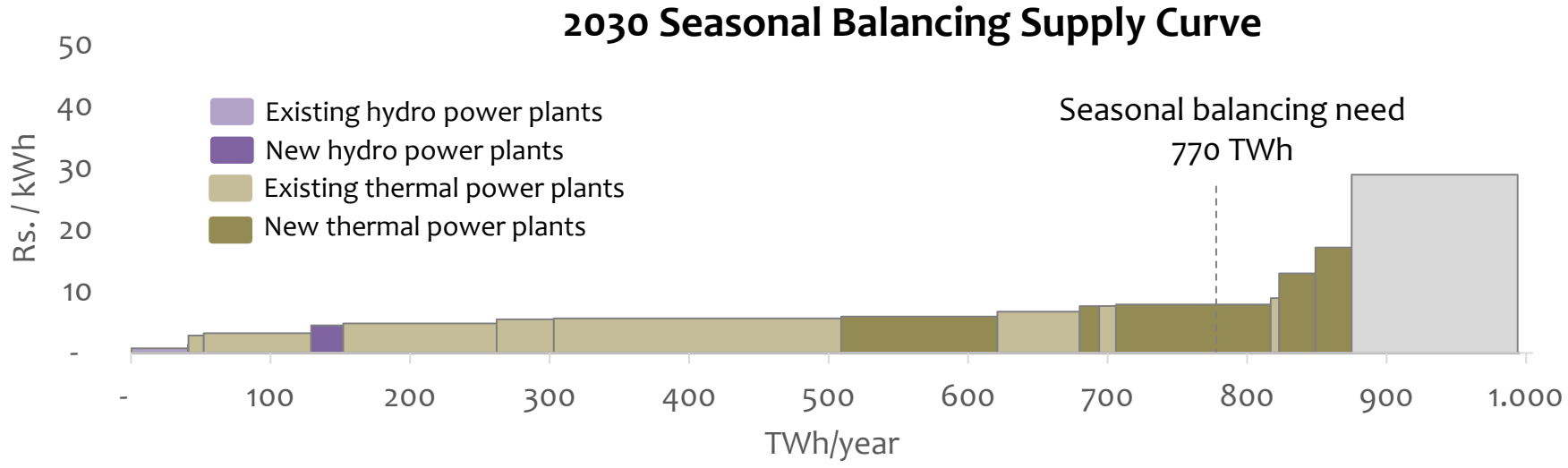
2030 Daily Balancing Supply Curve



Expected coal development under high renewable scenarios would be sufficient to meet seasonal needs through at least 2030

Power plant Flexibility

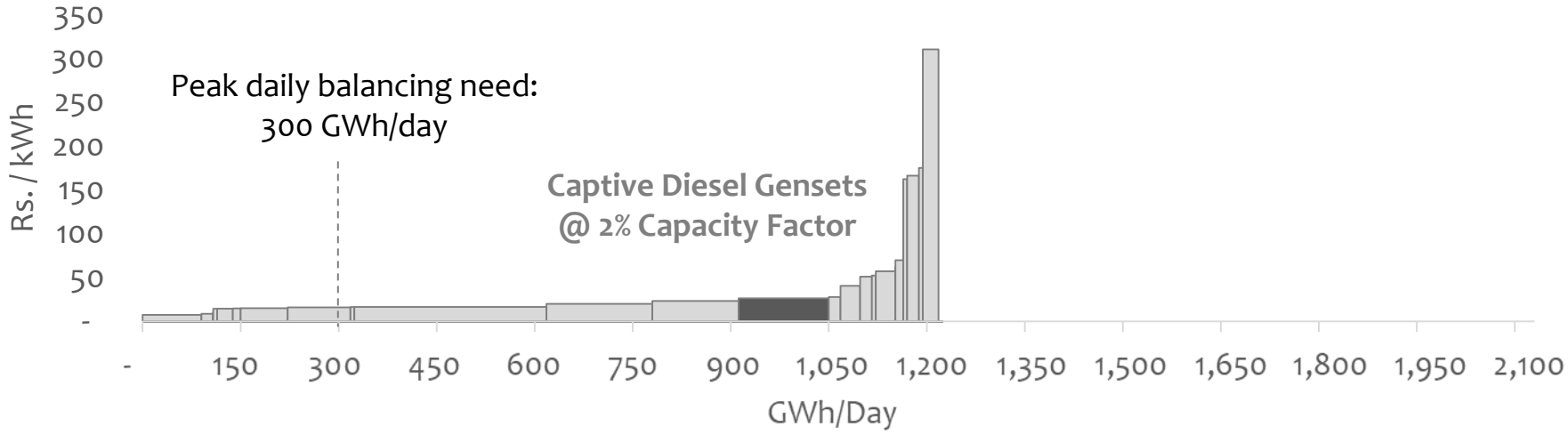




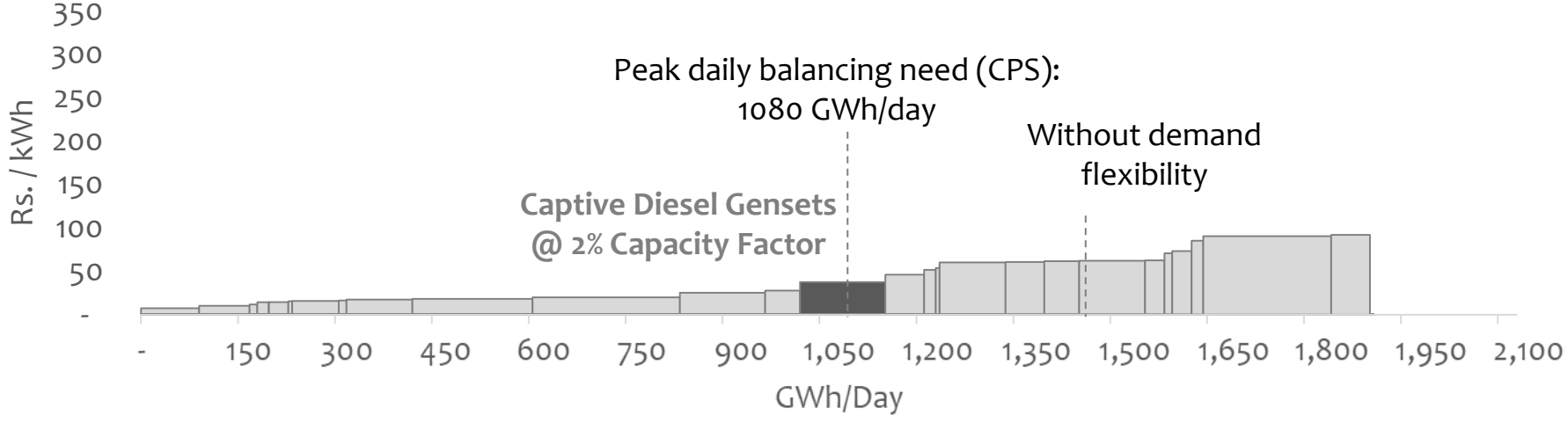
Integrating captive diesel generation into grid operations for flexibility may be an important option to meet peak daily balancing needs

Power plant Flexibility

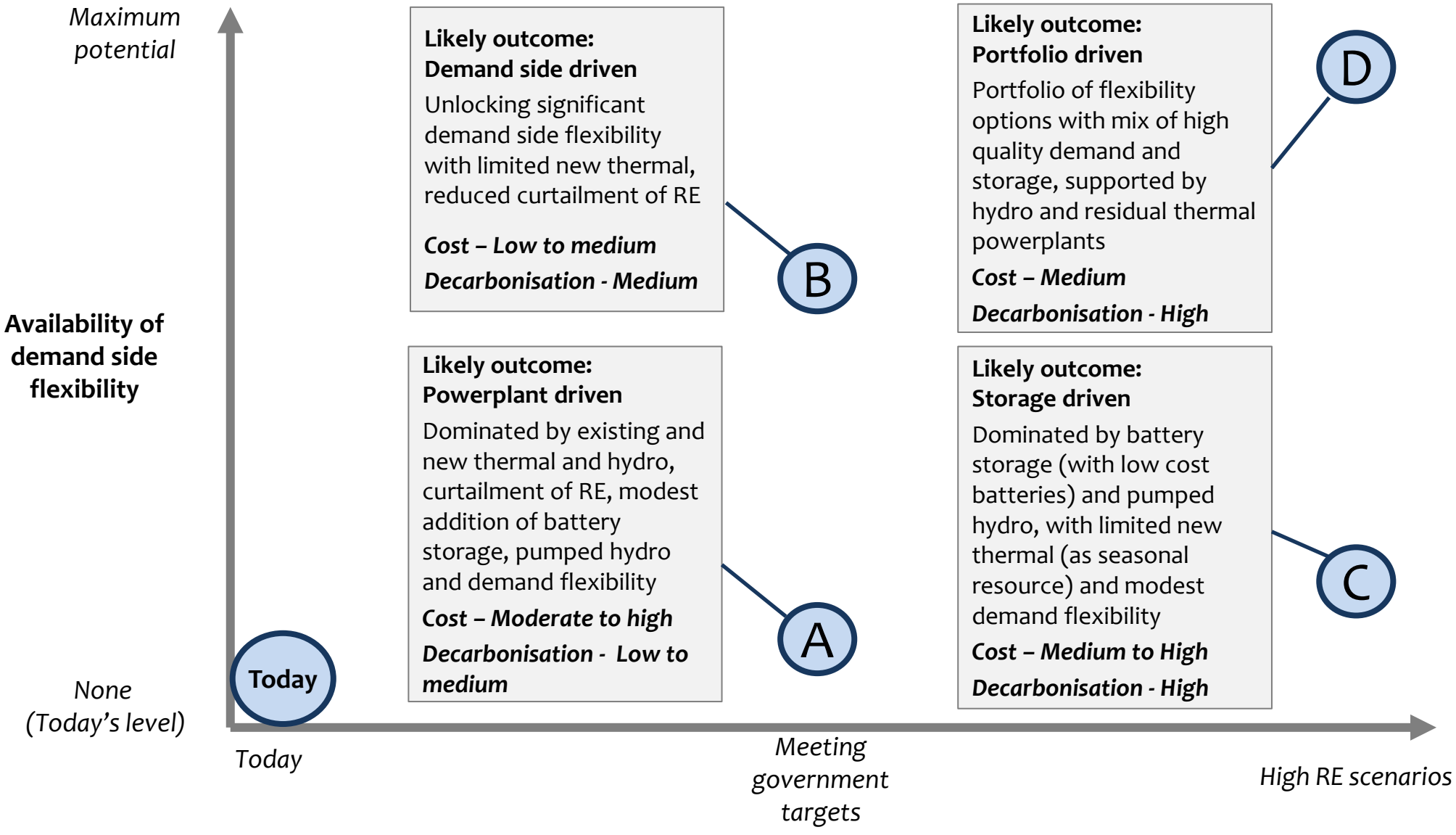
2017 Peak Daily Balancing Supply Curve



2030 Peak Daily Balancing Supply Curve



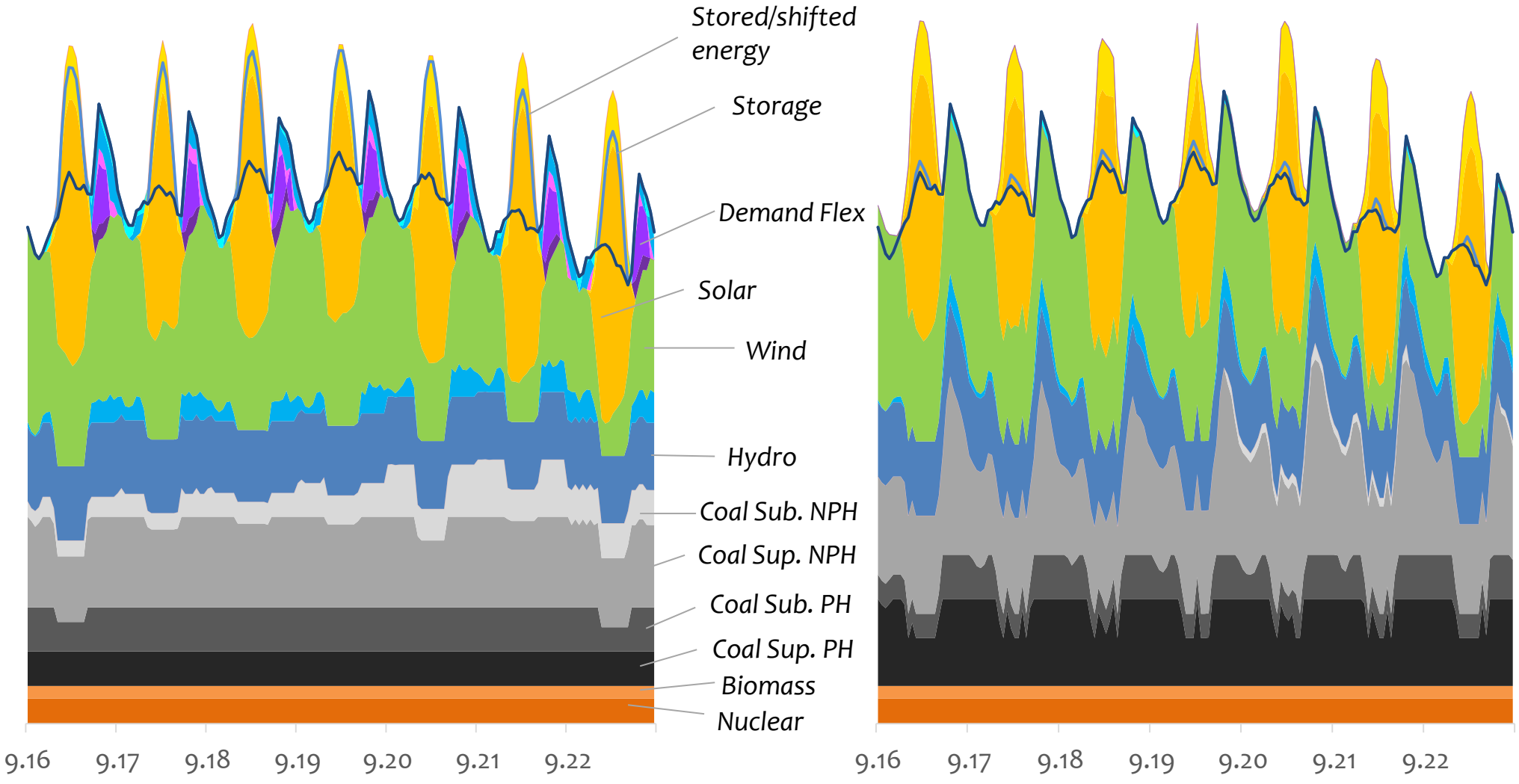
The cost and construction of optimal flexibility portfolios will depend on the level of variable renewable energy and the availability of demand side flexibility



A portfolio dependent entirely on powerplants, even with flexibility upgrades, will have a very volatile and costly dispatch pattern

Demand Side and Storage Driven Portfolio

Thermal Driven Portfolio



Portfolios of demand, storage, and powerplant flexibility perform best on most metrics, and are the least risky

Portfolio Performance (2030) – Current trajectory

Scenario	Target Met?	Excess Energy	Total Cost	Carbon emissions
Power-plant Driven	Yes	10%	4.8 (Rs/kWh)	0.6 (t/MWh)
Demand Flex Driven	Yes	-83%	-6%	-6%
Storage Driven	Yes	-95%	-4%	-6%
Balanced Portfolio	Yes	-97%	-5%	-8%

Portfolio Performance (2030) – High RE

Scenario	Target Met?	Excess Energy	Total Cost	Carbon emissions
Power-plant Driven	Yes	13.8%	5.0 (Rs/kWh)	0.5 (t/MWh)
Demand Flex Driven	Yes	-63%	-7%	-9%
Storage Driven	Yes	-80%	-5%	-10%
Balanced Portfolio	Yes	-82%	-8%	-12%

Regions and states may require a different flexibility profiles

Flexibility Drivers (Projected 2030)	**Karnataka**	**Tamil Nadu**	**Uttar Pradesh**	**Bihar**
RE Penetration				
Transmission bottlenecks				
Load shedding				

Flexibility Options	**Karnataka**	**Tamil Nadu**	**Uttar Pradesh**	**Bihar**
Space Cooling				
Agriculture Pumping				
Industrial load				
EV				
Storage				
In state thermal capacity				
Transmission Capacity to Export Flexibility				

Flexibility Profile	***Flexibility Importer***	***Flexibility Importer***	***Flexibility Exporter***	***Flexibility Self-Consumer***

Improving flexibility requires new market designs among a number of other requirements like data, infrastructure, technology, and new business models

	Data Develop, improve, disseminate	**Technology** Develop, deploy, cost reduction	**Infra-structure** Plan, finance, build	**Awareness** Build and drive behavior	**Business Models** Facilitate development	**Incentives** Provide and harmonize	**Market Design** Improve and integrate
Demand flexibility Develop, test, and roll out options	• Demand statistics • Potential • Cost	• IT and control systems	• IT and control systems	• Opportunities • Consumers	• Models for aggregators	• Investment • Dispatch	• Integrate all options cost effectively
Storage Develop and install	• Potential • Cost	•Cost reduction •Local application •Indian manufacture	• Deploy, integrate, finance	• Opportunities	• Aggregators • Producers • Suppliers	• Capital Investment • Dispatch	
Powerplants Encourage operation and regulatory changes and investment	• Integrated assessment of system plant • Value • Potential	•Test and deploy upgrades	• Test and deploy	• Overcoming entrenched practices • Operating and regulatory	• Plant owners • Upgrades	• Capital Investment • Dispatch	
Transmission Continue expanding with flexibility needs under consideration	• Regional data • Cost compare • Flexibility in planning	•Use state of art as deployed in India	• Finance • Integrate	•Tradeoffs with flexibility	• Local, regional and national	•Regulation, trading, markets	
Integrate Each of the options to minimize cost	• Central clearinghouse for planning	• IT for systems integration and markets	• Financial capacity and planning		•Build aggregators •Help players work together		

Darker blue = more urgent requirement

…and the electricity system needs to consider both medium term development and long term design

Market Design and Transition

Market transition questions

What should we do to develop technologies and flexibility options?

How can we accelerate decarbonisation of electricity supply?

How can we encourage investment in an evolving sector, and new technologies and businesses, while maintaining low financing costs?

How can we overcome entrenched practices to encourage new behaviours and models required for the new energy system?

How can we facilitate transition to a long term market design and new technologies and behaviours with a minimum of disruption and cost?

Long term market design questions

How should supply and flexibility resources be incentivised, dispatched, compensated, etc?

How should ancillary services procured and compensated?

How should we balance and compensate for locational differences?

How to plan, achieve, maintain, and grow a reliable energy system at a low cost?

… to make choices across different resources to meet system flexibility needs and ecosystems be built to support their development

Illustration – Battery Storage

DESIGN STAGE: SELECTION

Application:
Reserves and Balancing or
Ramping or
Daily shifting

Identification of appropriate Storage Technology**: Li-ion battery is recommended**

Sizing, considering charging/ discharging, efficiency, response time and cost

SUPPORTING MECHANISMS

Pricing mechanisms such as Time of Day or Real time

Day ahead, Real time and Ancillary Markets to trade capacity

Incentives for response from behind the meter capacity

Development of battery manufacturing in India, of new domestic value chains

Linking battery manufacturing with EV supply change

INVESTMENT CONSIDERATIONS

Utility / Discoms or

Institutional and Strategic Investors or

Customers

Financing costs

Cost of capital

Counterparty risk

Return on Investment and payback periods

Regulations and supporting policy framework