Indian Power Horizon enriched by Wind

Plenary Session | April 26th, 2017

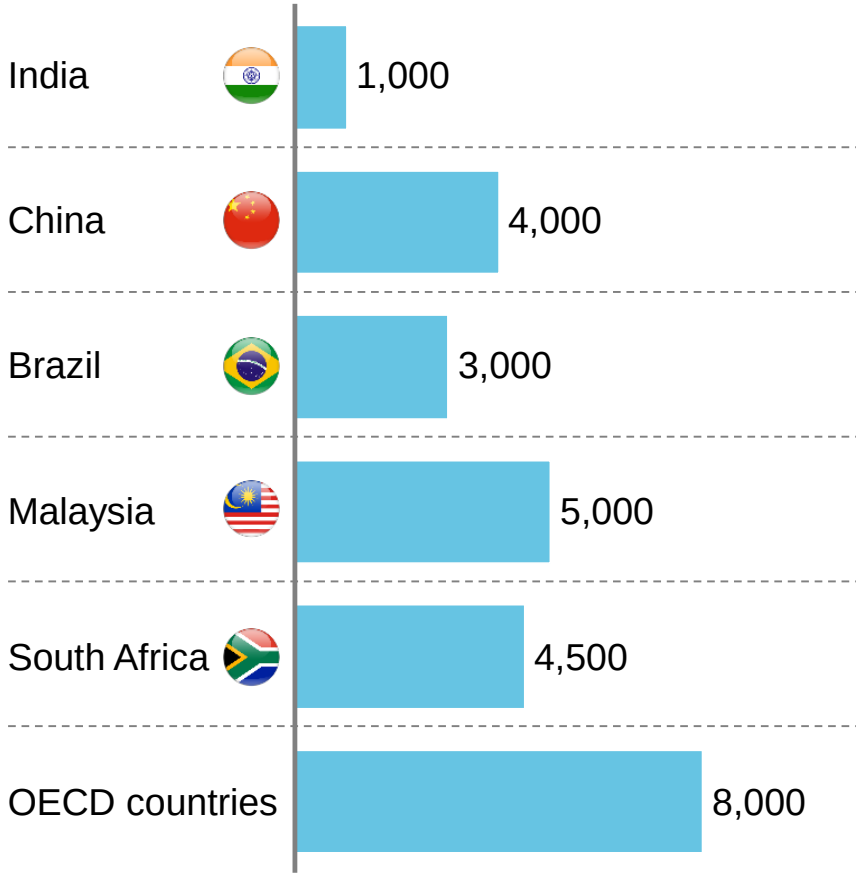
CONFIDENTIAL AND PROPRIETARY
Any use of this material without specific permission of McKinsey & Company is strictly prohibited

McKinsey&Company

The paradox of Indian Power Sector

Low Per capita annual consumption

(kWh, 2015)

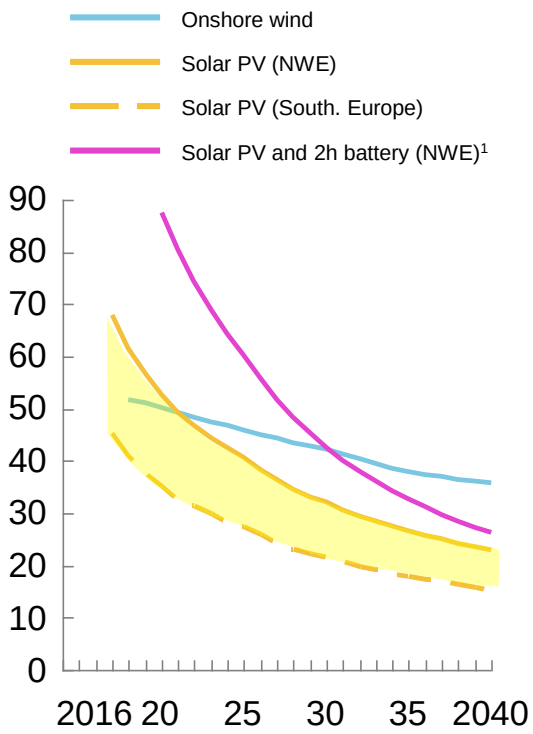


Yet thermal PLFs at all time low (<60%)

The global view : renewables expected to grow significantly, with politics unlikely to stop them

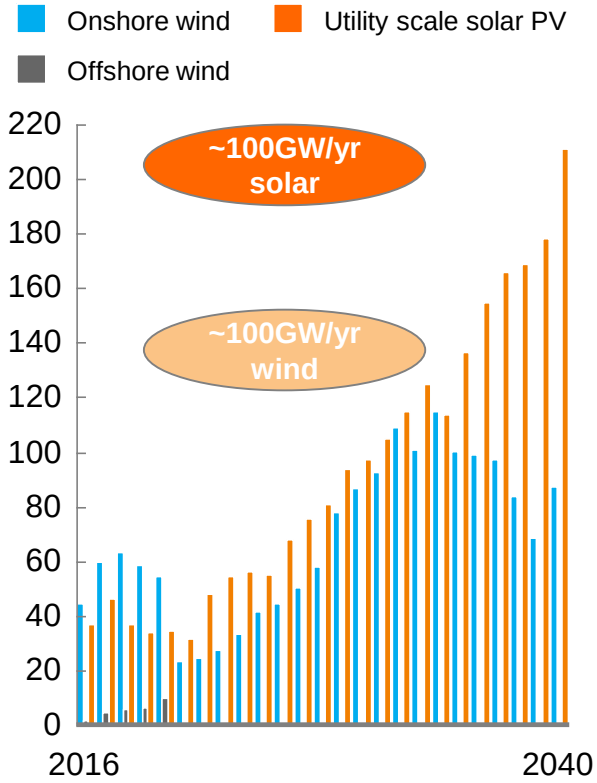
Decreasing LCOEs across sources

EUR/MWh



Strong growth in capacity installations

GW, worldwide



Growth in new geographies

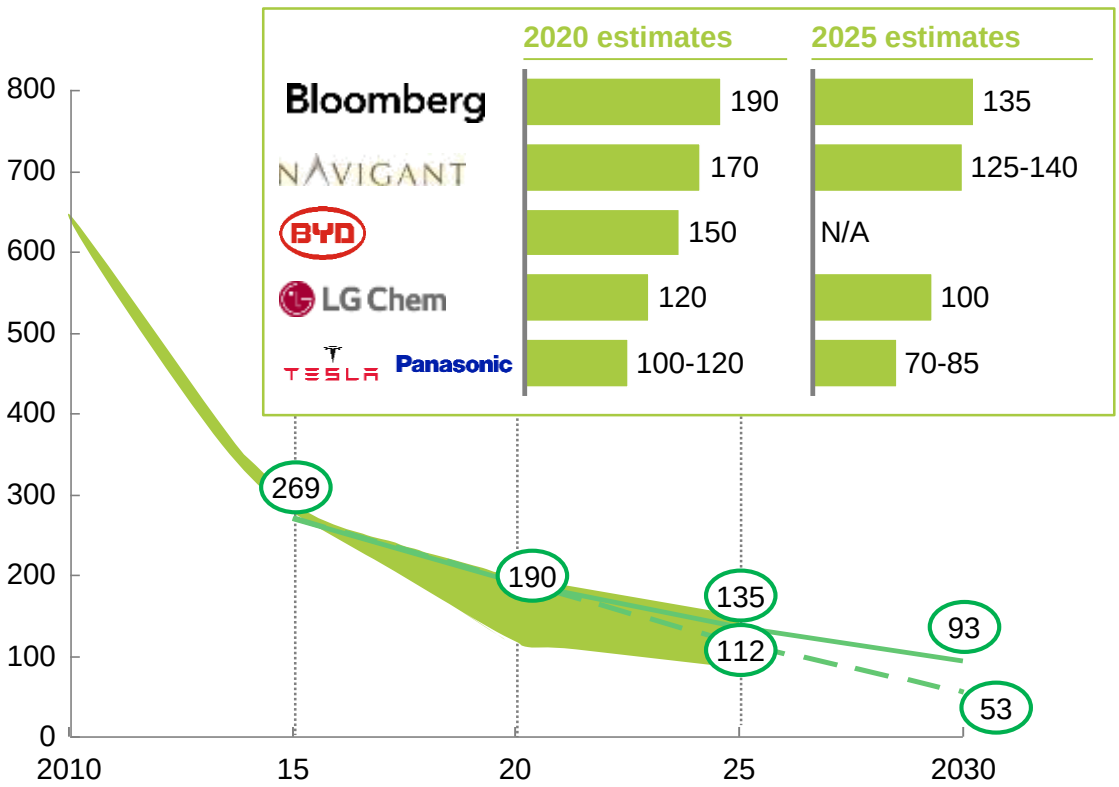
1 Tenders included: ACWA (70MW) in January, 2015; Enel (144MW) in February 2015; Enel (427MW) in March, 2016; Masdar/FRV (800MW) in May, 2016; Solarpack (120MW) in August, 2016; JinkoSolar/Maruben (350MW) in September, 2016

SOURCE: McKinsey; Bloomberg New Energy Finance 2016; publically available tender information

Storage costs are also declining rapidly, unleashing new sources of value

Industry outlook — McKinsey Base case — McKinsey Breakthrough

Battery costs will continue to fall, opening up new applications and increased opportunity for RES, Unit: $/kWh



- Rapidly falling pack prices driven by OEM scale-ups and increasing EV demand
- We expect prices to fall by 50% in the next decade, in line with other industry estimates

Storage profitable today in some regions / use cases

- Solar+storage to increase self-consumption (New Zealand)
- Demand-charge reduction (US)
- Provision of ancillary services (e.g., frequency regulation in US/PJM)
- Time-shifting of supply/demand in island systems (competing w/ diesel gen)
- Selective T&D investment deferral (e.g., Brooklyn/Queens substation project)

With additional opportunity on the horizon – applications can combine multiple revenue streams

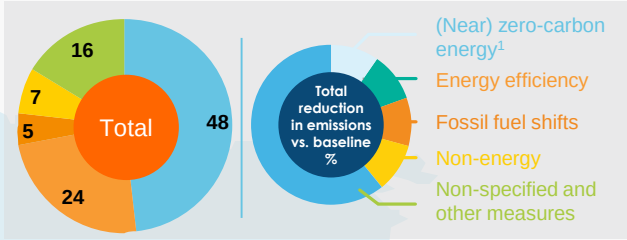
- RET integration / smoothing
- Renewables capacity firming
- Widespread T&D deferral / congestion relief
- Broad power quality ancillary services
- Capacity markets
- Wholesale market arbitrage

Pack price at which opportunities are material is dependent upon local, granular markets

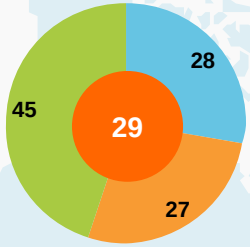
SOURCE: Expert interview, SNE research, Navigant, Avicenne Energy, Bernstein

Move to Renewables a key factor in India's INDC commitments

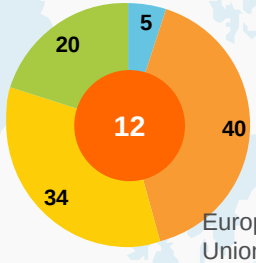
Share in emission reduction by INDC lever category, 2030; Percent



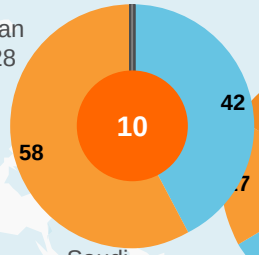
Note: Center numbers not comparable due to different baseline definitions



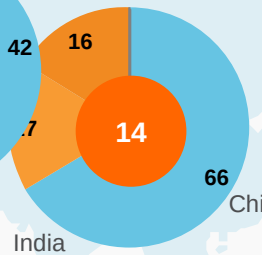
United States



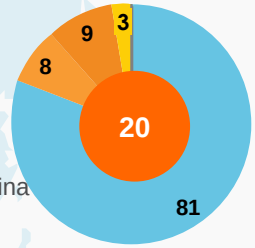
European Union 28



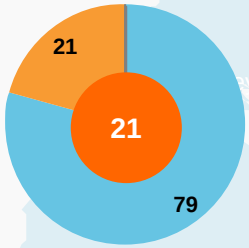
Saudi Arabia



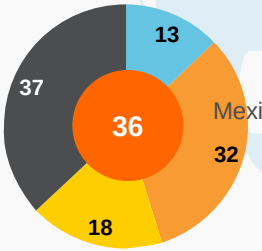
India



China



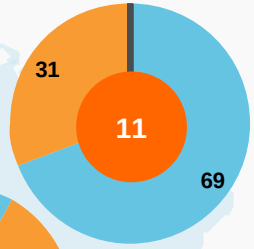
Nigeria

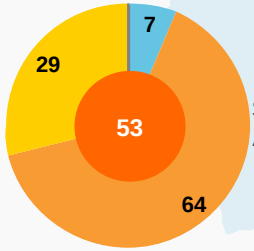


Mexico

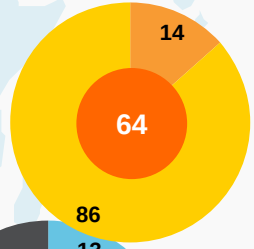
Vietnam

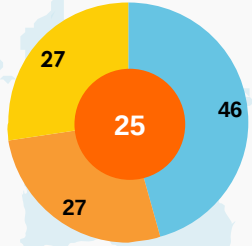
Ethiopia

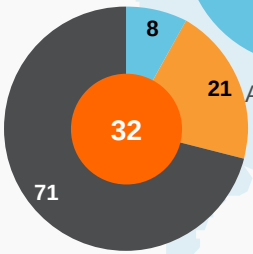




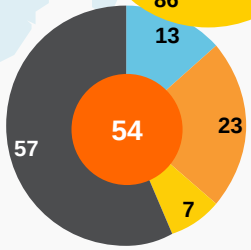
South Africa







Argentina



1 Renewables, nuclear, fossil fuels with CCS/CCU

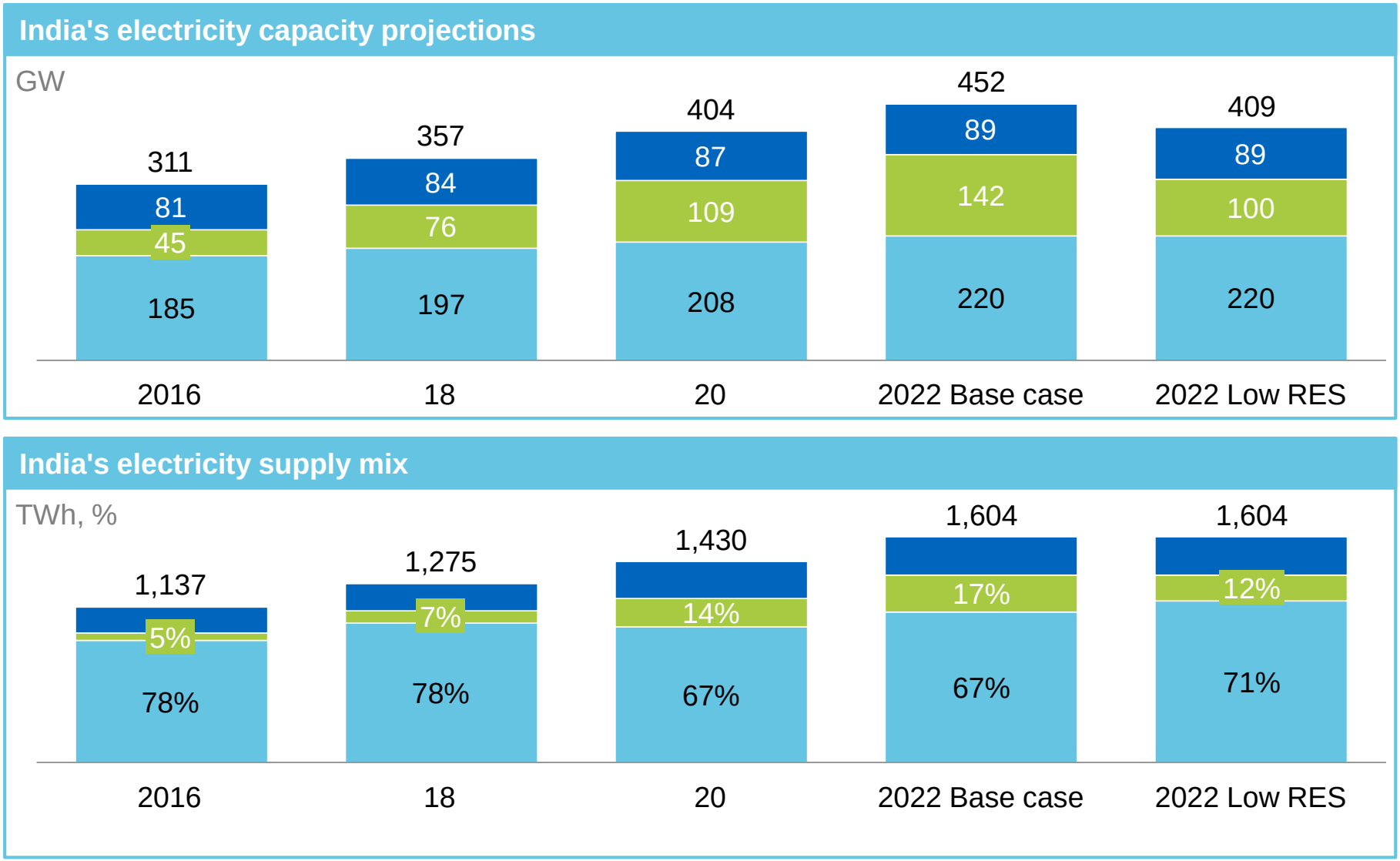
Note: Current Policies Baseline applied for US, EU and South Africa. Counterfactual emissions applied for China and India. Japan not shown as reductions are in line with current policy trends and a 'counterfactual baseline' could not be construct

SOURCE: Source

India energy outlook 2022: Key premises

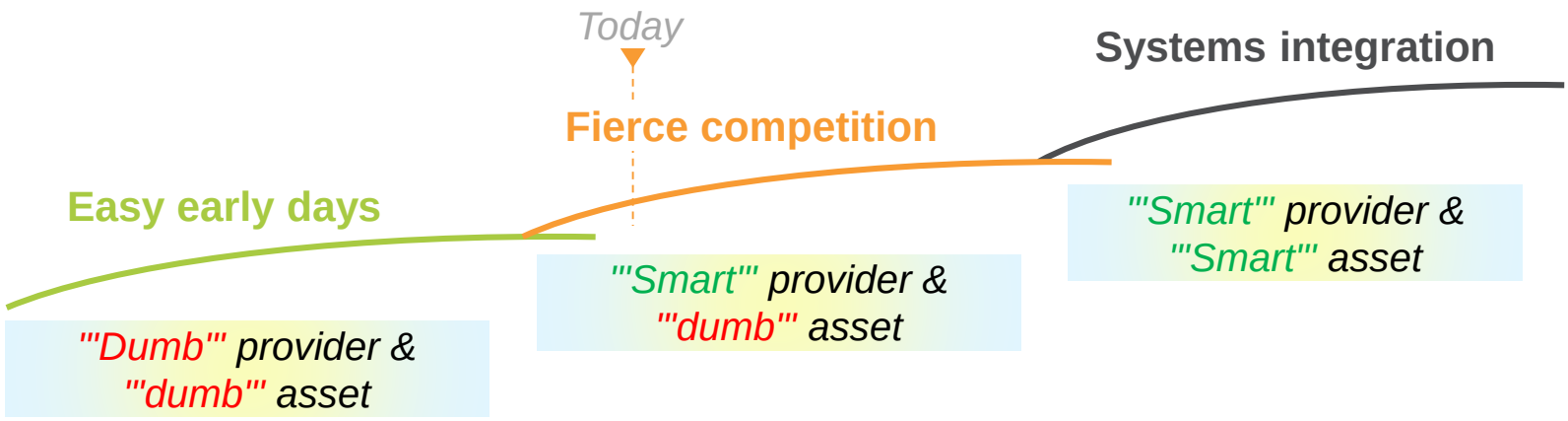
1	Demand	▪ **Primary energy demand** to grow by 5.2-5.8% CAGR, and reach 615-640 MTOE by 2022 ▪ **Electricity demand** to grow from 1137 TWh in 2015-16 to 1604-1668 TWh in 2021-22 (CAGR of 5.9-6.6%) – Strong growth is expected in residential demand (CAGR 8.2%) – Growth in industrial electricity demand is expected to be 4-5.6% – Electric Vehicle demand to remain low by 2022, but will increase significantly beyond 2022 ▪ **UDAY** is expected to reduce T&D losses from 24% to 17% by 2022; make in India to kick-in after 2019
2	Capacity addition	▪ **Expected net capacity addition** of ~35GW in coal, ~95GW in RES and ~10 GW in others, leading to 2022 capacity of 220GW of coal, 142 GW of RES – RES capacity expected to be ~142GW by 2022, as against govt. target of 175GW and will depend on land acquisition, grid absorption, and ability of discoms to buy power
3	Thermal sector implications	▪ **Plant Load Factor for coal** power plants is expected to be ~55% by 2022 ▪ Significant coal fired capacity is under stress due to lack of PPA and/or coal linkage; many states are over contracted in PPAs against peak demand putting pressure on merit order ▪ Key uncertainties due to: demand growth, revival of industrial growth, effect of demonetization, RES absorption
4	RES sector implications	▪ **RES** share of energy (TWh) can reach ~17% by 2022 (assuming 142GW) ▪ Cost of solar will continue to fall and is expected to reach parity with coal by 2019 ▪ Wind to continue growth - required at 5-6 GW per annum to reach target

RES expected to contribute up to 17% of India's supply by 2022



SOURCE: McKinsey analysis

RES paradigm shift also in process in India – but business models lagging



	Easy early days	Fierce competition	Systems integration
Value creation	▪ Prescribed feed-in-Tariffs – Technology-specific – Intermittent resource ▪ Limited risk/high margins	▪ LCOE-based auctions – Technology-neutral – Intermittent resource ▪ Margins under pressure	▪ Value to the grid – Technology neutral – Dispatchable resource ▪ Margin pool expansion
Business model	▪ One size fits all – "Build-own-operate"; value chain integration – Focused on 2 - 3 geos	▪ Granular business model, by tech/segment/region ▪ Hybrid ownership ▪ Financing innovation (YieldCo 2.0, PoolCo, etc)	▪ Developer+RSO[1]+ TSO – Focus from development to operations – Institutional investors become asset owner
Capabi-lities	▪ Opportunistic operations	▪ Standardized operations ▪ Lean and agile org ▪ Localization ▪ Scale ▪ Financing	▪ Systems integration ▪ Knowledge of the grid ▪ Advanced analytics ▪ Regulatory depth ▪ Technology partnerships

1 @Renewables System Operator"

SOURCE: McKinsey

Recent policy initiatives to encourage wind uptake in India

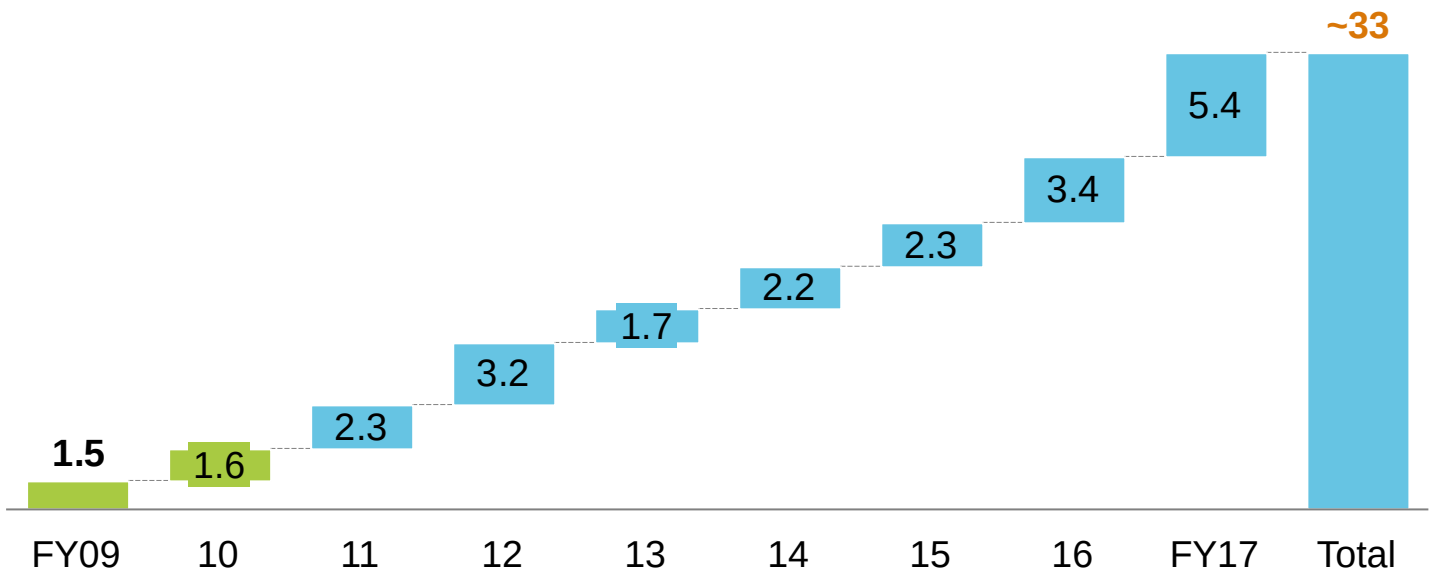
	Policy initiatives	Potential implications
1	**Shift from FITs to competitive bidding**	▪ First wind auction resulted in a record low tariff – Winning bid tariff for 250 MW auction at INR 3.46/kWh was ~31% lower than average Feed-in-tariff of INR 5/kWh	▪ Guaranteed offtake for developers will reduce payment delay risk ▪ Connection to high voltage grid likely to incur less network losses
2	**Waiver of interstate-transmission charges**	▪ Amended National Tariff policy waiver of ISTS charges and losses for interstate sale of wind power – Applicable for 25 years for projects commissioned till March 31, 2019	▪ Greater offtake options in short term power market given uneven regional power demand-supply and concentration of renewable in few pockets
3	**Recent policy interventions**	▪ Repowering policy announced in Aug' 2016 – est potential of 3 GW ▪ Draft Wind Solar Hybrid Policy issued in Jun' 2016 ▪ National Offshore Wind Energy Policy approved in Sep'2015 ▪ Tax incentives ended	▪ Optimal utilization of available wind resources

SOURCE: India infrastructure, Ministry of Power, MNRE, Team analysis

Wind : need to maintain 5-6 GW per annum capacity additions

Wind capacity additions, GW

Installed capacity, FY08: ~8-9 GW

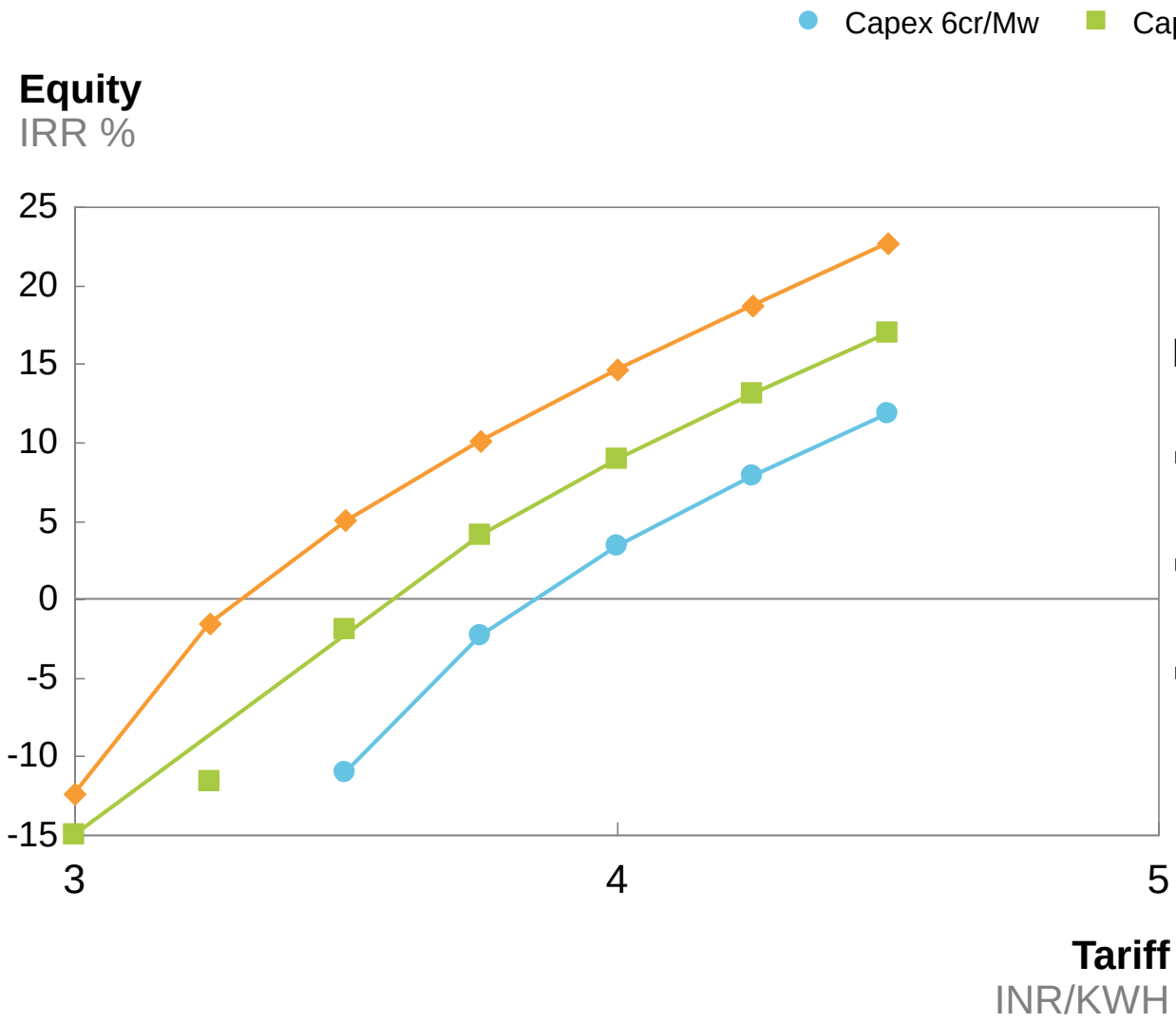


Average capacity addition (FY09-15) **~3.0 GW**

Planned annual addition (Next 5 years) **~5.4 GW**

SOURCE: MNRE, Team analysis

Falling tariffs : irrational exuberance or catalyst for innovation?



Returns compressed due to

- Falling tariffs
- Curtailment
- Payment delays

SOURCE: Mckinsey analysis

What factors can impede the growth?

	Challenges
Financial viability of DISCOMs	▪ DISCOMs have annual losses of INR 70k crs; lose Rs 0.8/unit ▪ Leading to payment delays to RE IPPs ▪ UDAY has seen initial success (INR 2+ lakh crores bonds issued); but operations improvement/governance changes will take time
Grid integration of renewables	▪ Impact being seen in regional grids; curtailment risk borne by developer: ▪ Fast ramp-up sources, dynamic voltage/frequency compensation equipment; removal of transmission bottlenecks needed
Low domestic capital availability	▪ High bank NPAs limiting domestic debt capital to renewable projects ▪ DISCOMs finding it difficult to get loans for working capital post RBI guideline
Market development	▪ Forecasting and scheduling ▪ Anciliary services and availability ▪ Greater facilitation of open access
Reduced returns	▪ Sub-INR 4/unit tariffs compressing project returns ▪ Threat to returns from curtailment and delayed payments

SOURCE: McKinsey; expert interviews

How can RES players continue to create value?

Technology and design innovation	▪ Larger machines, higher hub heights ▪ Next gen turbine, blade and drive train ▪ Design-to-value especially in BOS
EPC execution	▪ Applying lean manufacturing principles ▪ End-to-end quality management ▪ Project supply chain / monitoring and management
Analytics & digital in O&M	▪ Power curve analytics ▪ Condition based monitoring ▪ Power optimisation ▪ Remote monitoring, drone based surveillance
Commercial optimisation	▪ Proactive regulatory management ▪ Wind/solar hybrid models ▪ Integrated dispatch / O&M planning
Cost of financing	▪ Wider range of sources of financing ▪ Risk mitigation

SOURCE: Source

Incremental improvement opportunities still seen in Wind

= Trend outlook

		Description	Current state & trajectory	Cap. factor
Solar	Conversion efficiency	How much incident solar energy converted into electricity	***15-20%*** typical today, **incremental growth** of ~0.3% p.a., but ceiling is mid/high-20s	**Capacity factors 10-20%, *~flat***
	Resource availability	How often and how strongly the sun shines; function of latitude and cloud cover	Strong dependence on location; expected to be **relatively constant going forward**	
	Equipment availability	Uptime of solar system; i.e., reliability	Typically ***~99%,*** no change foreseen	
	Project life, tech. & fin.	Expected lifetime used for financial calculations, and expected technical lifetime	**Contractual: *20 year PPAs*** most common **Technical: *>20 years***, developers claiming up to 30-35 years	
	On-budget development	Are solar projects completed on time, and on-budget	Although many projects (38%) over-budget, **mean overrun only ~1%. Challenge to maintain** going forward as developers bid forward cost curve	
Wind	Conversion efficiency	How much available wind energy converted into electricity	***50-52%*** efficient today, theoretical limit is Betz's limit (59%), further improvements unlikely to be material	**Capacity factors 25-45%, onshore, *rising***
	Resource availability	How often the wind blows at the location & elevation of the wind turbine	Increasing as tower heights rise on-shore, greater availability off-shore where winds more persistent	
	Equipment availability	Uptime of wind system; i.e., reliability	Now at **~96-98% vs ~92% a decade ago,** diminishing returns to further improvements	
	Project life	Expected lifetime used for financial calculations, and expected technical lifetime	**Contractual: *20 year PPAs*** most common **Technical: *20-25 years*** – no impetus to improve financing term lengths not changing	
	On-budget development	Are wind projects completed on time, and on-budget	Like solar, **low mean overspend (8%).** Off-shore largely "TBD" but will experience will likely make development more predictable	

Wind, solar perform much better than coal/nat gas plants – 67% over-budget, 13% mean overrun

Ongoing cost declines forecasted to be larger in solar, but wind not perceived as being 'tapped out,' with incremental improvements ongoing

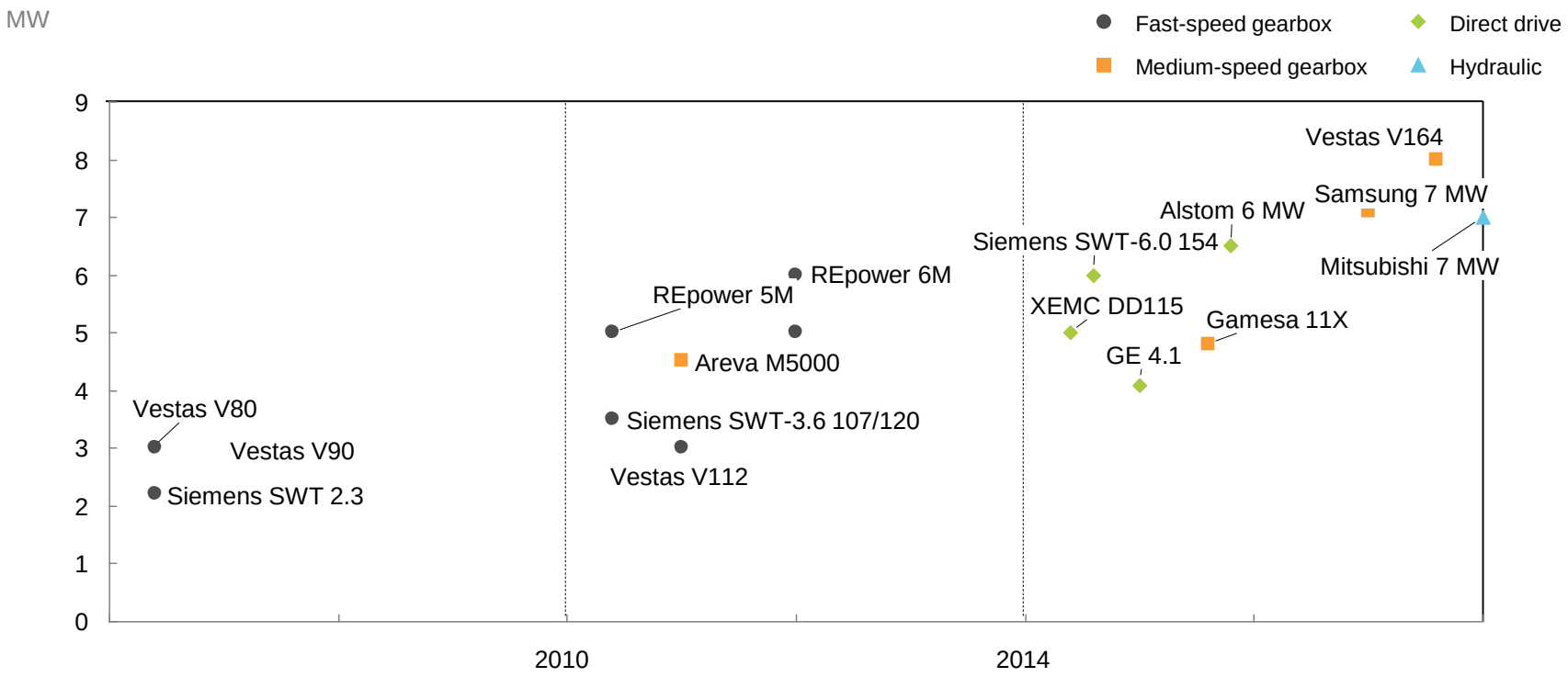
SOURCE: Expert interviews; Literature; Press clippings; *The Electricity Journal* (2014)

Last Modified 1/3/2017 3:22 PM Pacific Standard Time

Printed

Technology transformation: Wind turbines continue to grow in capacity; major OEMs are developing 3rd generation product offerings

Selected commercially available WTG in the market over time



First generation

- Turbine rating ≤3 MW
- Only fast-speed geared drive
- Onshore turbines put offshore with few modifications
- Rotors <100m

Second generation

- Scaling up to 3-6 MW
- Fast speed geared; Areva hybrid configuration only exception
- Rotors >100m but <130m

Third generation

- Scaling up to 6-8 MW
- Mix of direct drive (in search of better reliability / min. O&M costs) and medium speed as mid-step solution between proven geared technology and direct drive
- Rotors >150m

SOURCE: Press; company Web sites; IHS Emerging Energy Research

New technologies are being adopted through wind power value chain, but maturity differs

Early · Early - medium · Medium

Categories	New technology	Description	Players	Maturity[1]
Component and sub-system 	Hybrid drive train	▪ **Integrate generator with gearbox** – compact design	winergy	Early
	New GB design	▪ Modular gearbox **repairable in nacelle** ▪ **Multi-output gearbox**	winergy	Early
	Anti-erosion coating	▪ New **coating materials** to protect blades from erosion	BASF We create chemistry	Early - medium
	Lighter blade	▪ **Carbon fiber** material ▪ Carbon fiber + glass fiber hybrid	LM WIND POWER	Early - medium
Turbine design 	Direct drive	▪ **Rotor blades** drives **generator** without gearbox	ENERCON SIEMENS GE	Medium
	Two-blade design	▪ **Two blades** comprise a rotor, instead of three blades	MINGYANG WIND POWER PERFORMANCE BY NATURE	Early
	New concept design	▪ **Floating wind** turbine ▪ **Airborne** wind turbine ▪ Vertical-axis turbine	ALTAEROS energies	Early
Wind farm operation 	Drone inspection	▪ Use **drones** to inspect wind turbines and come up with analysis	windspect	Early
	Digital wind farm	▪ Use **digital model** to optimize wind farm operation	GE	Early

1 Early means prototype, piloting projects or early adoption; Medium means it is accepted by the industry but not adopted at large scale

SOURCE: McKinsey analysis; Industry interviews

D **Analytics/ Predictive maintenance:** Many utilities are already taking action to capture Big Data and predictive maintenance benefits

Predictive maintenance, case examples

IBERDROLA

- Detects **abnormalities in operational data** to identify the type of trouble
- Detects **signs of trouble in the early stages**, as well as **reduced availability and power plant failures**, and at the same time also supplies problem-solving methods to supervisors

Edipower

- A **predictive monitoring solution** that **prevents** equipment **failures and service interruptions**
  - **Reduces forced outage time and greatly increases plant availability**
  - **Sends out notices in real time to minimize outage time and emergency maintenance**

EDF

- Introduced a **predictive maintenance** system for around **10 nuclear power units**, and realized **on-site on-demand data collection** by EDF engineers and operators
- A **system that monitors** all of the **equipment** that plays an **important part in nuclear reactor availability** (unit availability elements)

DONG energy **egemsa**

- **Automatically identifies failures**, **sends out a highly reliable notifications** and estimates lead time until inspection
- Prevents failures to reduce outage time and costs while increasing availability, reliability and income

Enercia 中国電力

- For Shimane Nuclear Power Plant #2, an **"invariant analysis technology"** developed by NEC **is used to analyze vibration, pressure**, temperature, rate of acceleration, etc. to **predict failures**

MITSUBISHI HEAVY INDUSTRIES, LTD.

- Collects around 200 types of data from gas turbines and generators and analyzes them using the Mahalanobis-Taguchi Method
- **Grasps the signs of failure** and uses advanced predictions **to perform regular inspections and part replacement**

LONGVIEW POWER **PGE** **Statoil**

- A predictive management system that notifies about equipment failure in advance
- Provides an integrated control strategy using a platform that unifies boilers and turbines
  - **This leads to unit stabilization and major increases in reliability**
- Improves availability and performance of electronic equipment and facilities

SOUTH MISSISSIPPI ELECTRIC POWER ASSOCIATION

- A patch system that quantifies and analyzes cause/effect relationships and uses predictive control based on the analysis results to optimize equipment performance

Analytics/ Predictive maintenance : Detailed Power curve tracking and analysis can be useful for creating value and reducing production losses

Requisites for best in class

- Data collection – 10 minute data
- Create own power curve independent of OEM
- System to draw data, create curve store and raise deviation alarm
- Performance dialog and routine check through supervisory tools

Software provider

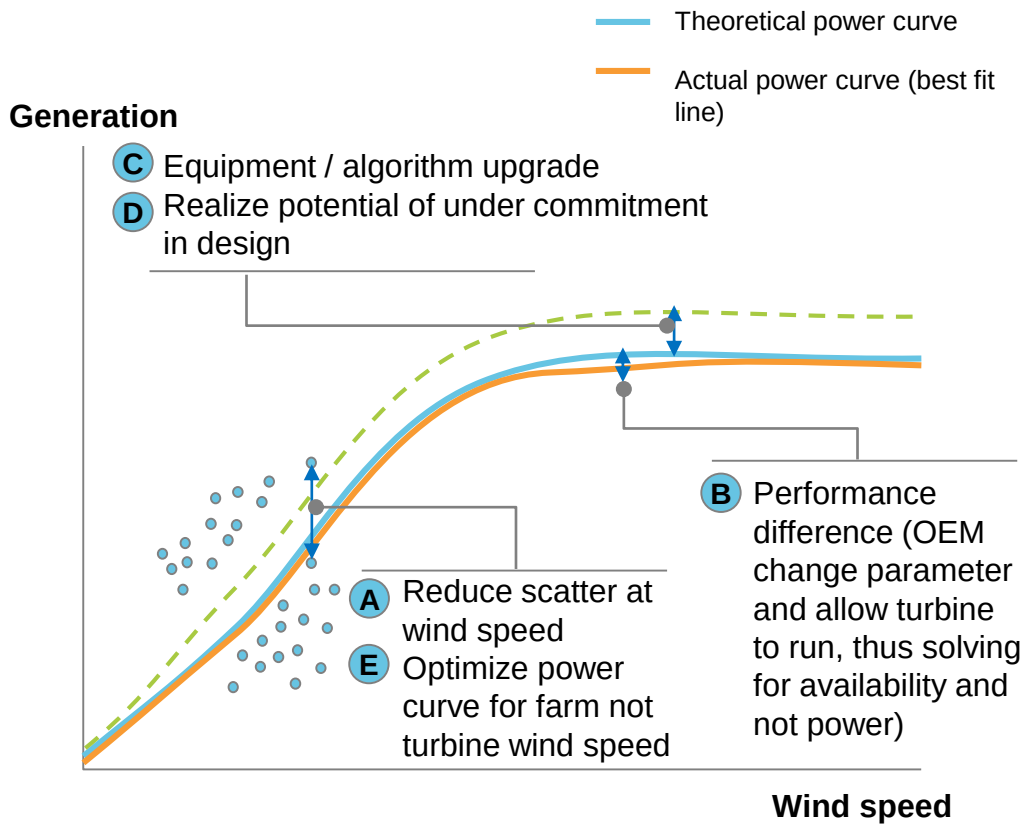
UPTIME ENGINEERING

VISTA DATA VISION

EMD International A/S
www.emd.dk

GE Energy

5 opportunity area from power curve



SOURCE: Source

In summary

1. India power sector in transition – RES can reach 17% of output by 2022. Wind has recorded stellar growth recently while attracting investors

2. Wind industry well placed with headroom for further growth – however, returns being compressed:
   - Intensified competition and falling tariffs
   - Continued concern on discom health and payment delays
   - Curtailment and grid integration

3. Opportunities for players
   - Continue to pursue newer technologies
   - O&M excellence esp using advanced analytics
   - Commercial optimization and financing

4. Priorities for policy and regulation:
   - Strengthen forecasting and scheduling
   - Accelerate market development : Anciliary Services, availability
   - Ensuring transmission availability for intra and inter state flows