

Large Scale Interconnection to Assist Rapid Power System Growth



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Indian Power System : A Glimpse

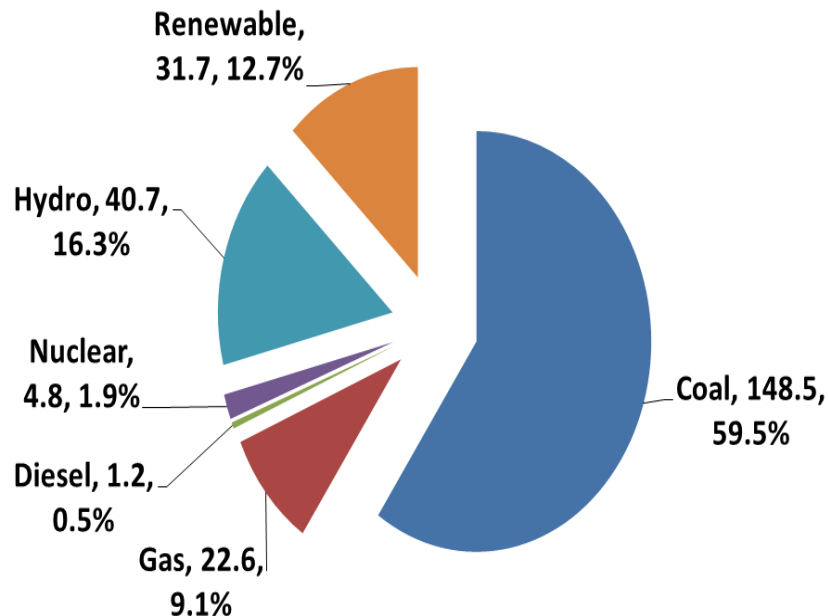
**Total Installed
Capacity - 249 GW**

**Peak Demand: 135
GW**

**Renewable:
31 GW**

**Growth Rate:
8–9 % p.a.**

Figures in GW (as on 30.06.2014)



Generation Mix

Transmission line	Existing (Jun'14)	By 2016-17*
	ckm	
1200 kV		363
765kV	12,367	32,250
400kV	127,261	144,819
220kV	145,561	170,980
HVDC Bipole (±500kV)	9,432	16,872
HVDC Bipole (±800kV)	-	1,728
Total	294,621	367,012
Transformation capacity	Existing (Jun'14)	By 2016-17*
	MVA	
765kV	88,500	174,000
400kV	180,872	196,027
220kV	258,444	299,774
HVDC	13,500 MW	225,000 MW
Total	541,316	692,301

Balancing Load Generation..

Growing Electricity Demand

Rapid Urbanization 31% in 2011;
40% by 2030

Higher Industrial growth

Residential consumption growing at 14%
over past 10 years

Realization of demand suppressed due to
load shedding

Future Generation Trend

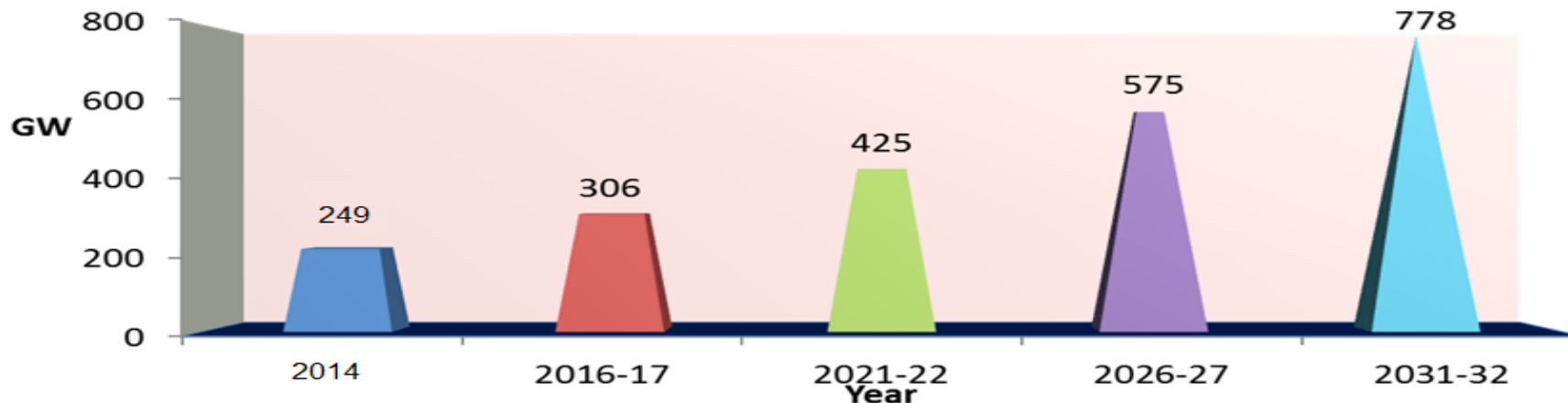
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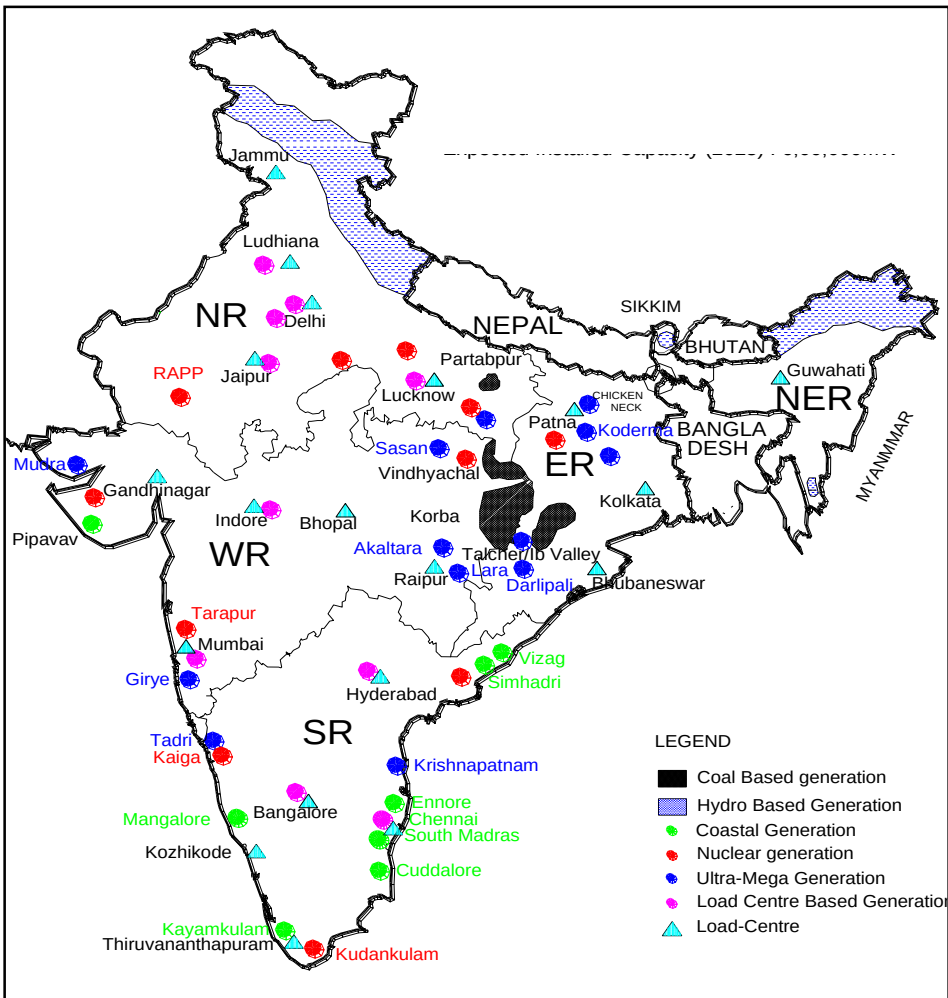
Realization of demand suppressed due to
load shedding

Capacity requirement to be doubled by next decade and quadrupled in next two(2) decades



Energy Resources Map

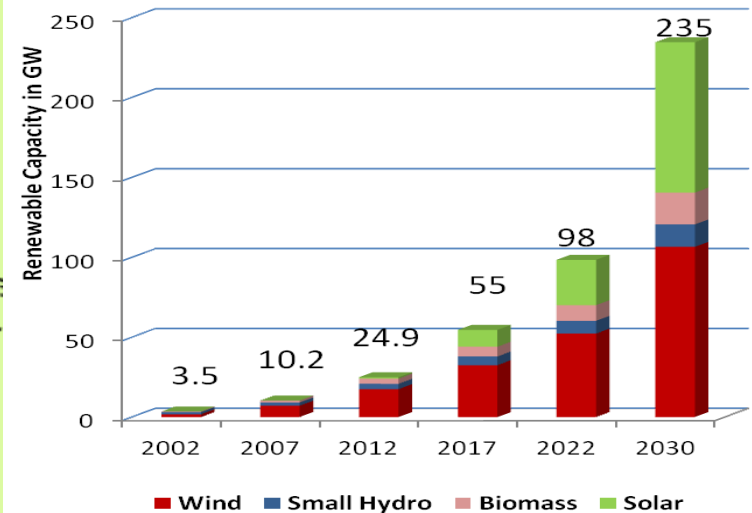
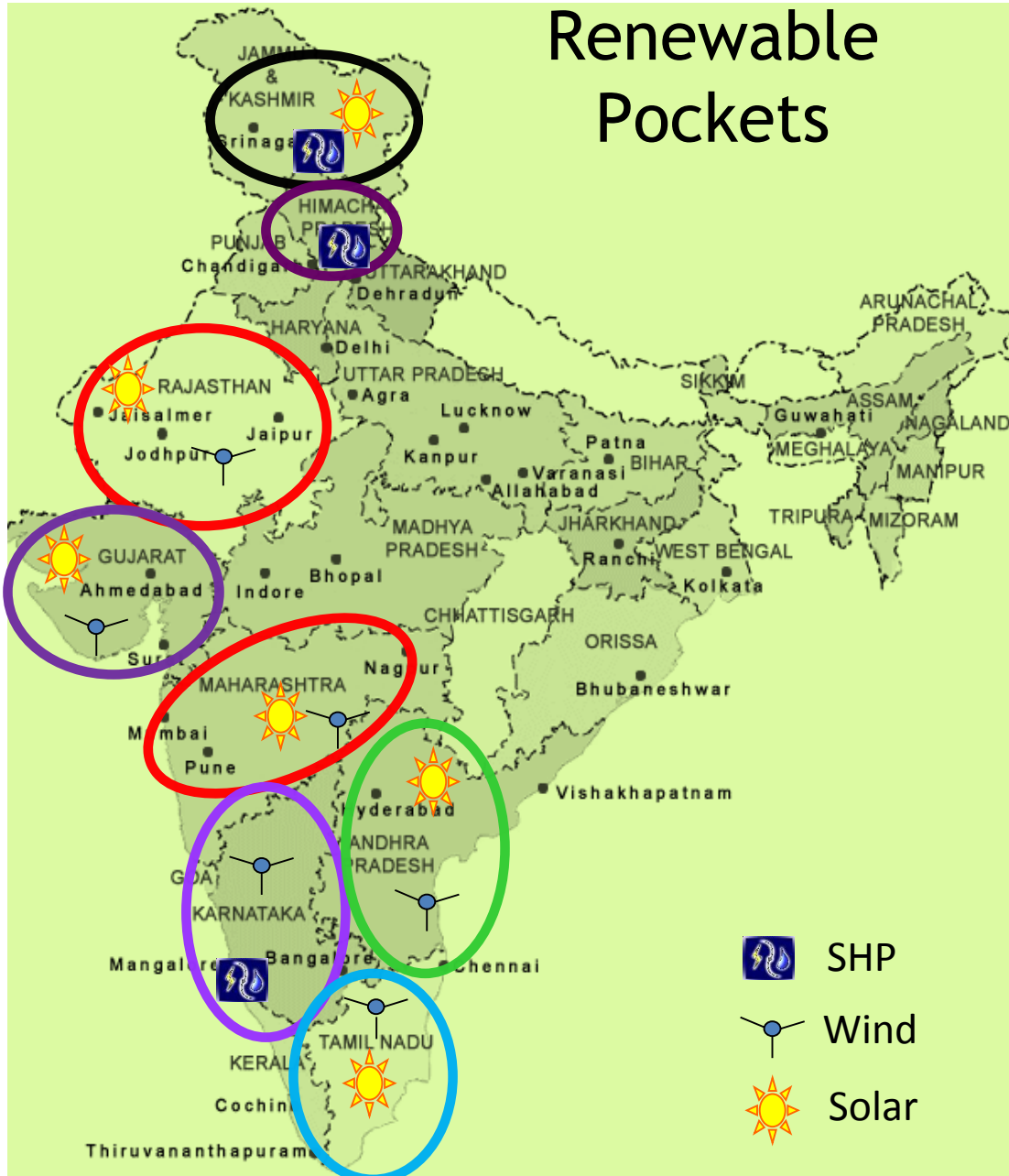
Energy resources (coal, water etc.) unevenly distributed



Potential being harnessed to meet demand in next 7-8 years

- Coal – In Central India
 - Chhattisgarh : 58,000 MW
 - Orissa : 30,000 MW
 - Jharkhand : 15,000 MW
 - Madhya Pradesh: 16,000 MW
- Hydro – In North Eastern & Northern Himalayan region
- Coastal based
 - Andhra Pradesh: 24,000 MW
 - Tamil Nadu : 10,000 MW
 - Gujarat : 11,000 MW

Renewable Pockets

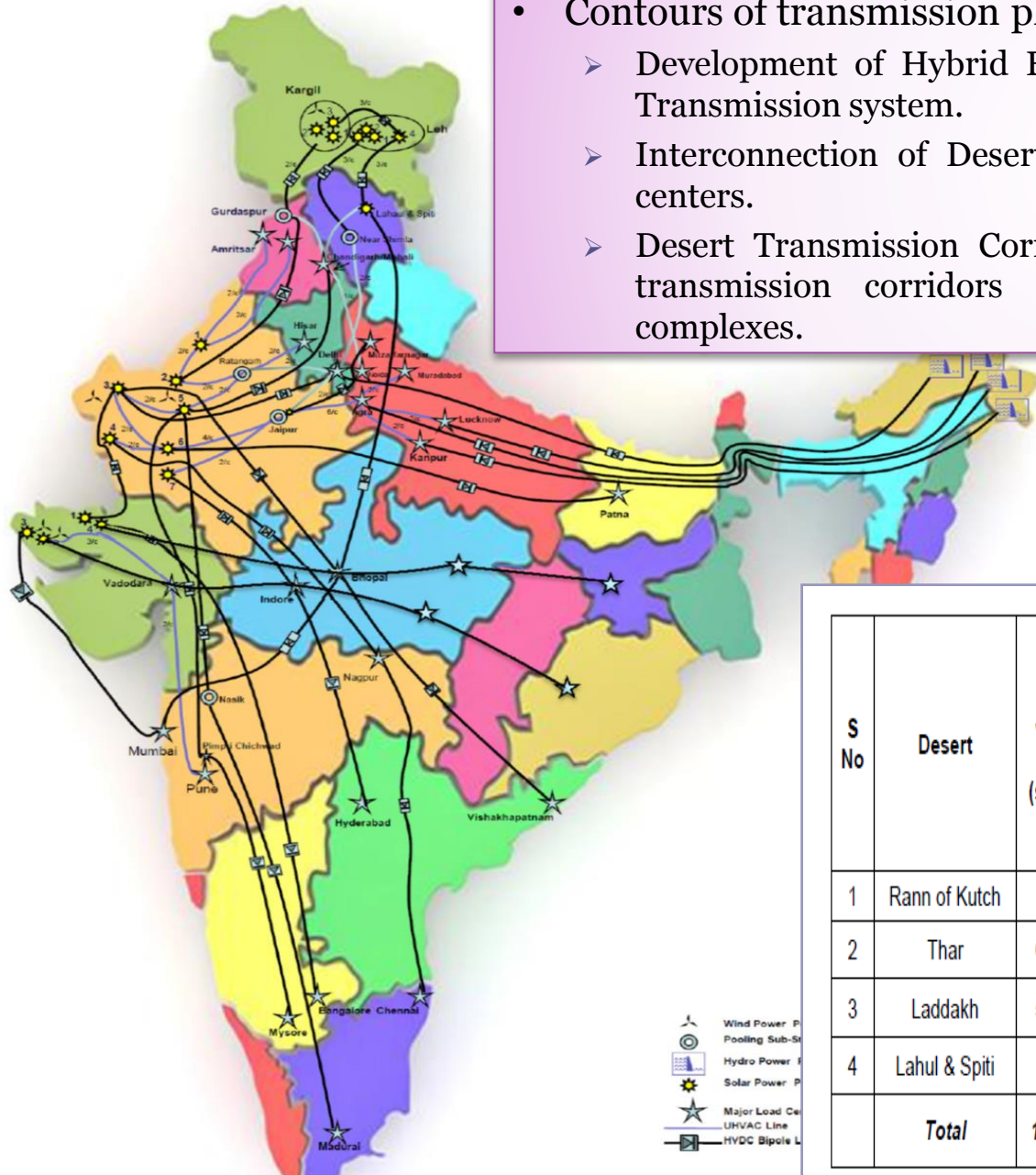


Scenario	Energy Penetration (%)	Capacity Penetration (%)
Present	6	13
2017	>13	>21
2030	>21	>35
2050	>33	>50

Desert Power : Utilization of Wasteland

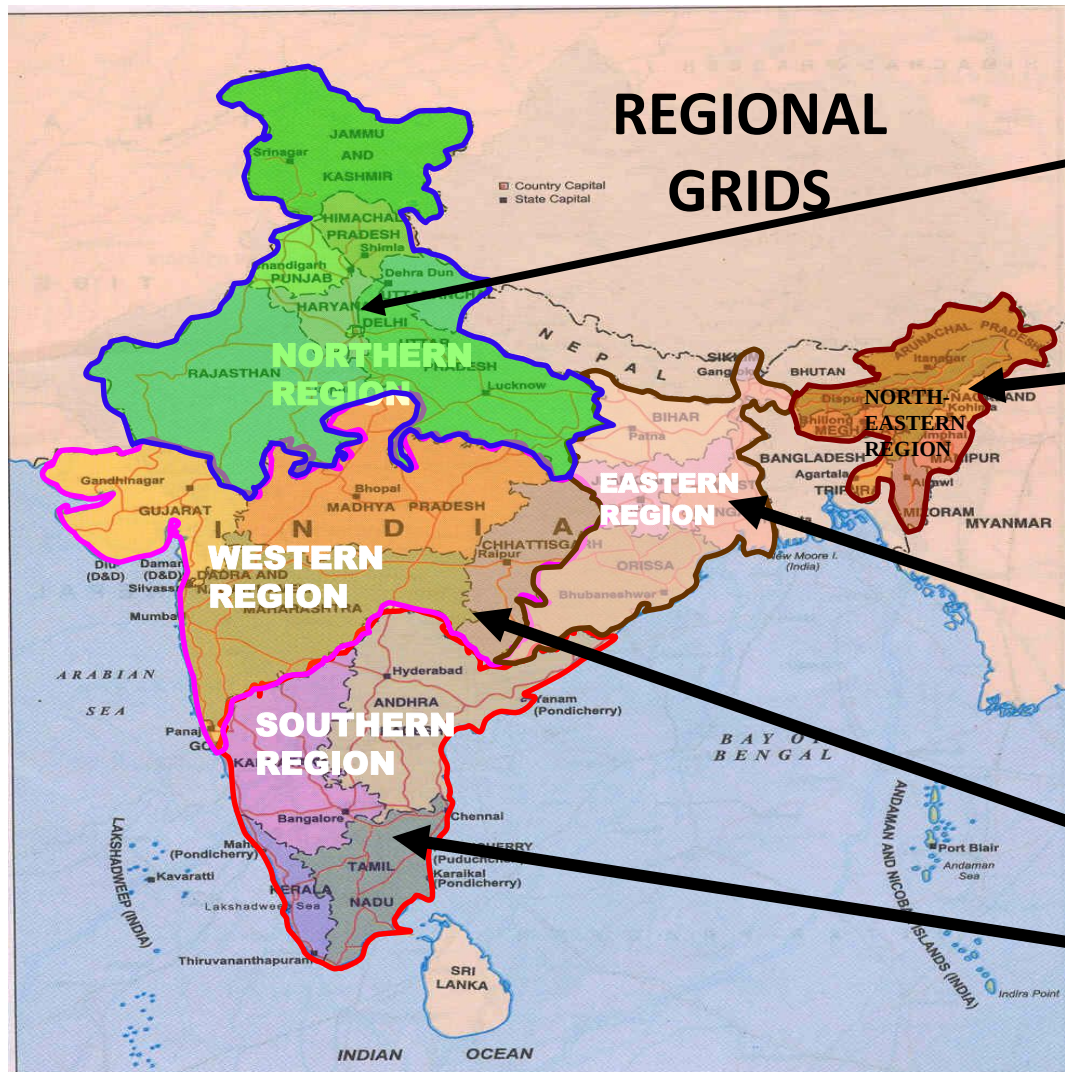
- Contours of transmission plan-

- Development of Hybrid EHV AC/ HVDC (VSC) / Super Conductor Transmission system.
- Interconnection of Desert Transmission Corridors with major load centers.
- Desert Transmission Corridors integrated with other high capacity transmission corridors associated with conventional generation complexes.



S No	Desert	Total waste land (sq km)	Selected Wasteland (sq km)	Selected Wasteland (sq km)	Generation (GW)		
					Solar	Wind	Total (Wind+Solar) GW
					35 MW/sq km	9 MW/sq Km	
1	Rann of Kutch	19120	12607.4	1260.7 (10%)	30.9	3.4	34.3
2	Thar	67285	57538.5	8630.8 (15%)	211.5	23.3	234.8
3	Laddakh	50362	31211.8	1560.6 (5%)	38.2	4.2	42.4
4	Lahul & Spiti	11177	2393.8	119.7 (5%)	4.2		4.2
Total		147944	103751.5	11571.8	284.8	30.9	315.7

Peculiarities of Regional Grids



Deficit Region

Snow fed - run-of-the-river hydro

Highly weather sensitive load

Adverse weather conditions: Fog & Dust Storm

Very low load

High hydro potential

Evacuation Concerns

Low load

High coal reserves

Pit head base load plants

Industrial load and agricultural load

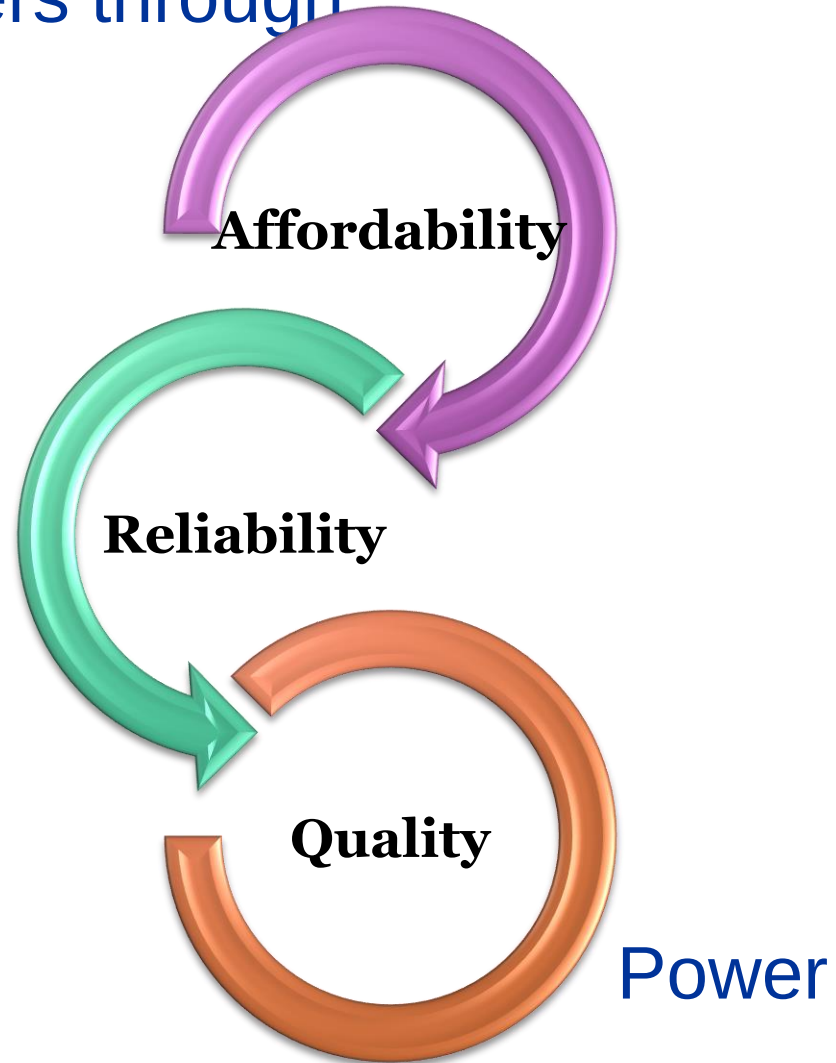
High load (40% agricultural load)

Monsoon dependent hydro

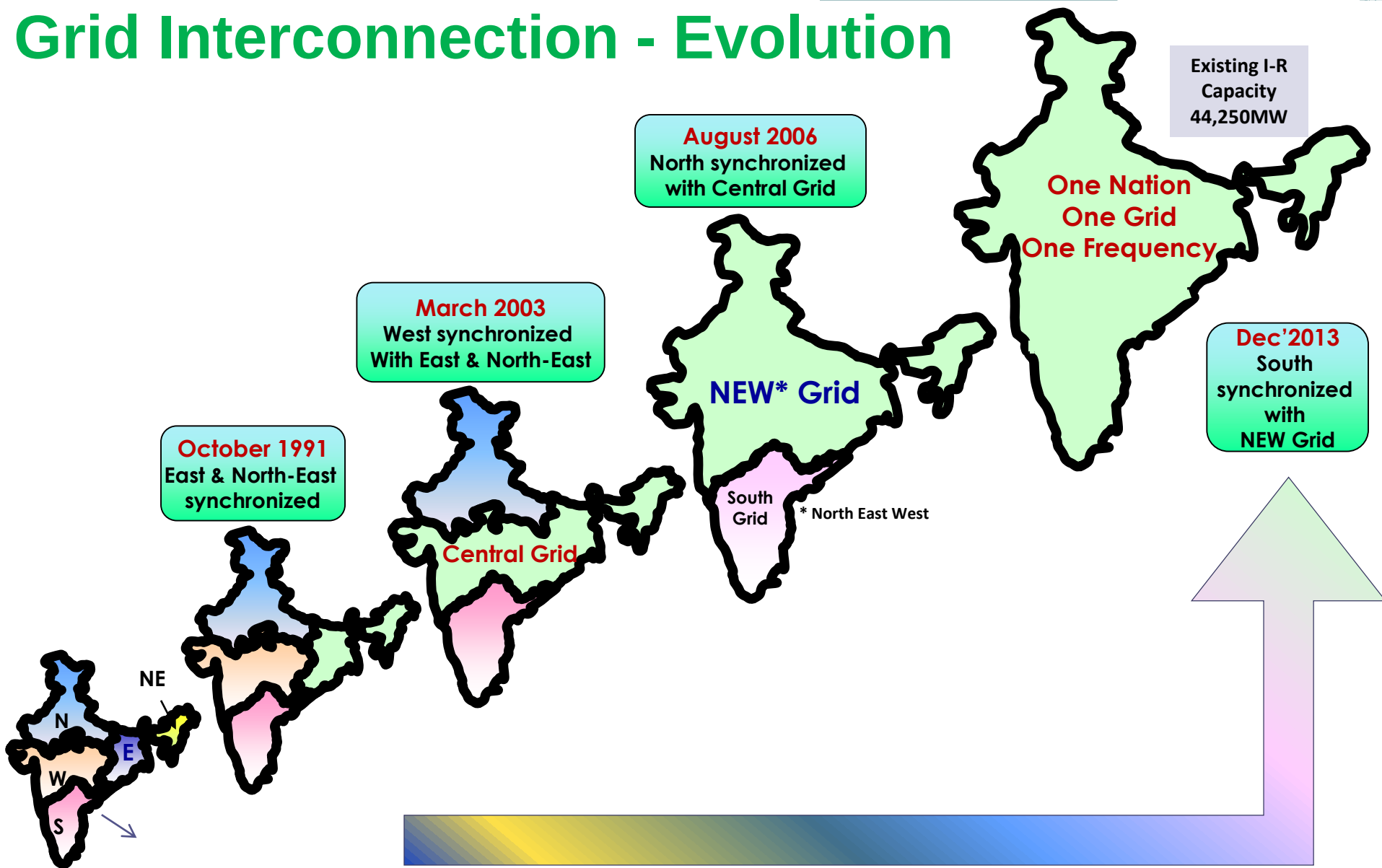
Renewable Rich

Objective of large scale interconnections

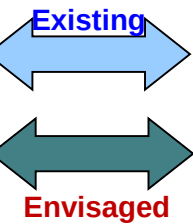
- Service to the consumers through



Grid Interconnection - Evolution

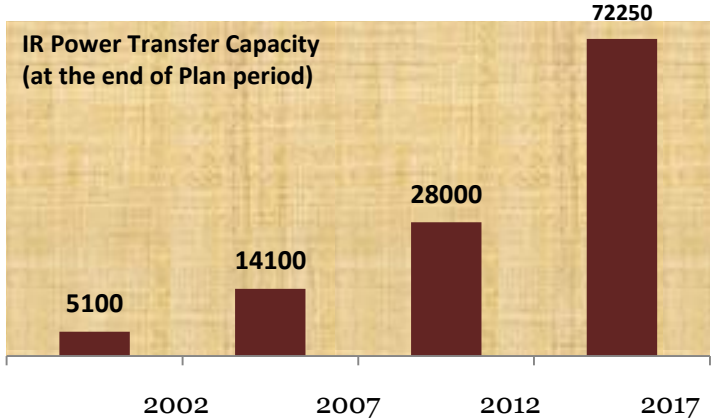
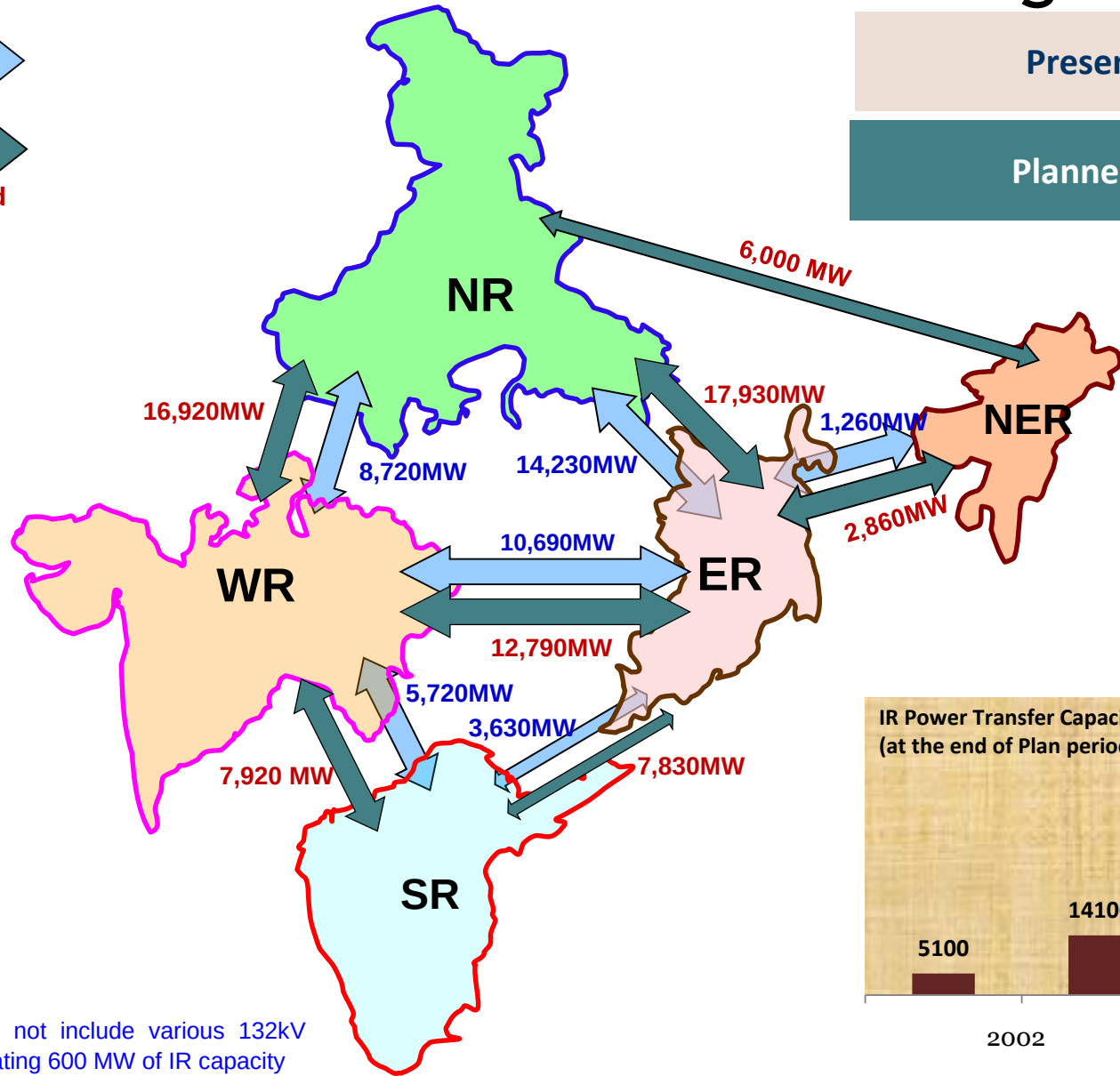


National Grid - Present and Envisaged



Present IR Capacity: 44,250 MW

Planned IR Capacity: 72,250 MW



Picture does not include various 132kV lines aggregating 600 MW of IR capacity

High Capacity Transmission Corridors



NEW TECHNOLOGY INITIATIVES

1200kV UHVAC;
 ± 800 kV HVDC

High Temperature Super
Conductor Line, Fault
Current Limiter

Dynamic Compensation –
Large and Medium size
STATCOMs

Smart Transmission- Wide
Area Measurement System
(WAMs)

VSC based HVDC and DC
Grid

Smart Grid (AMI, OMS,
DSM/DR), Energy Storage

Renewable Integration Issues

Maintaining Real Time Load Generation Balance, Stability & Security of the network: A Challenge

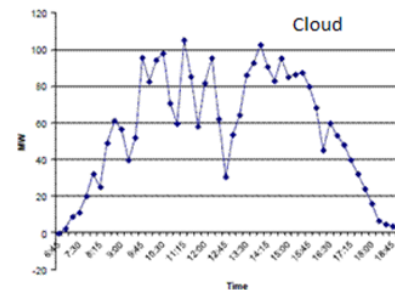
Intermittency & Variability

Issues

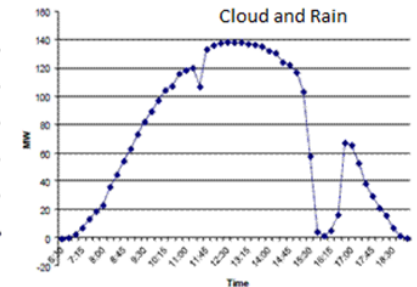
Non Predictability

Location Specificity

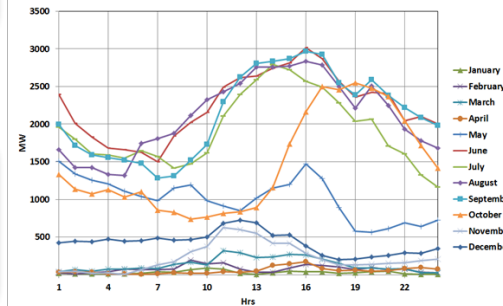
Charanka Solar Generation on 11.04.12



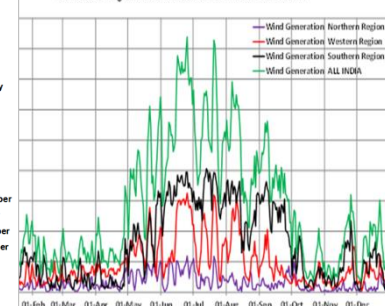
Charanka Generation on 13.04.12



Tamil Nadu Typical Daily Wind Generation Pattern Month wise



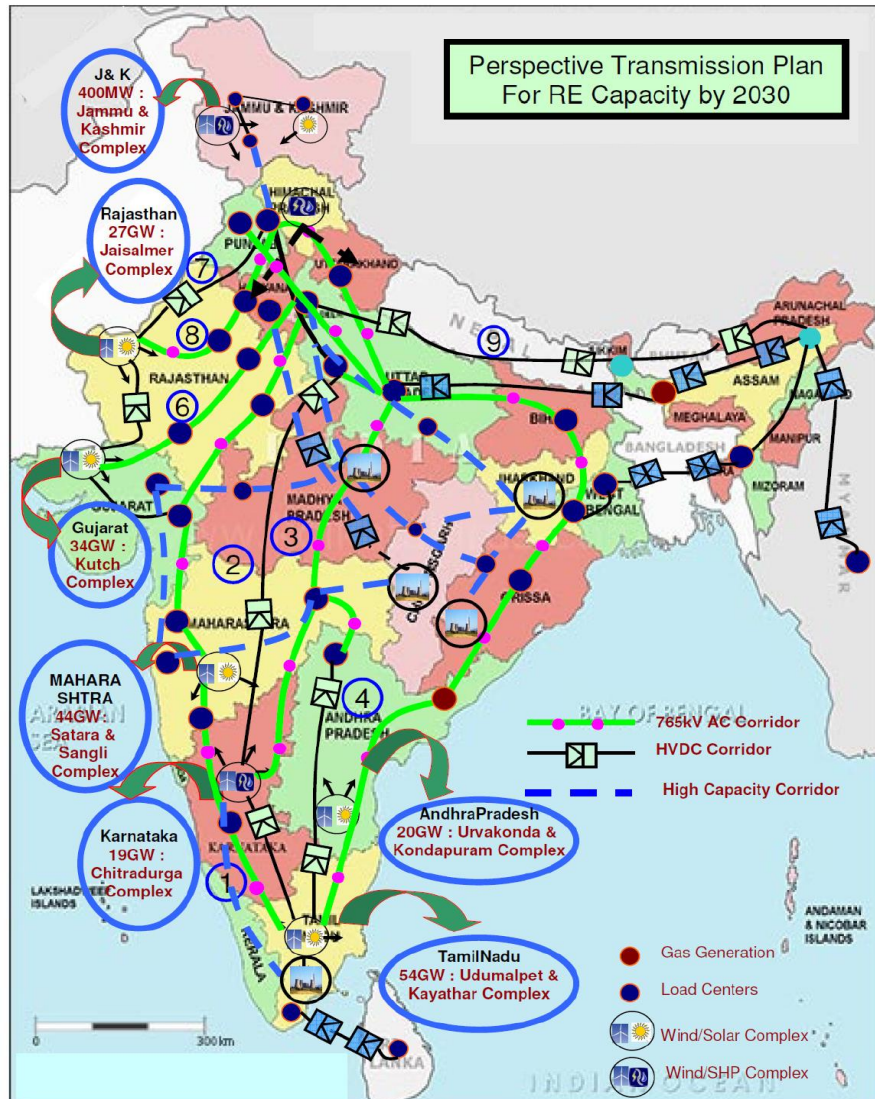
All India & Region Wise Annual Wind Generation Pattern



Renewable volatility can be managed through: Flexible Generation, Energy Storage, Demand Response/Demand Side Management, Smart Grid

Strong Grid Interconnection facilitate enlargement of balancing area

Green Energy Corridor : Integration of Renewables

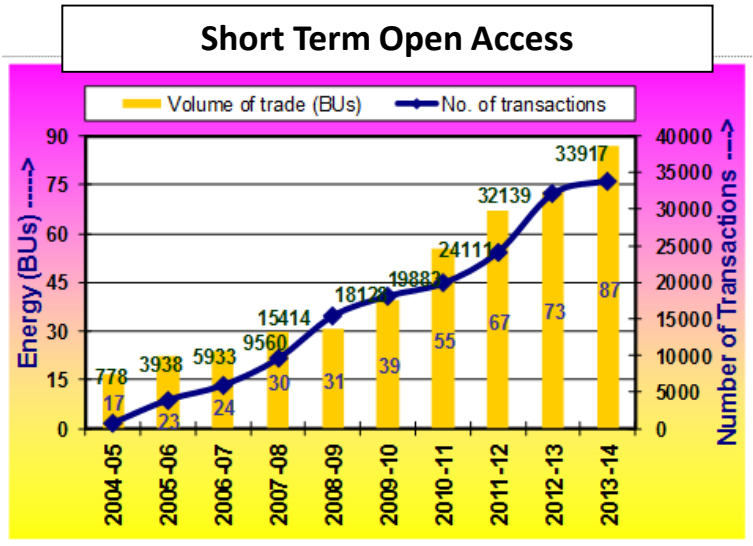
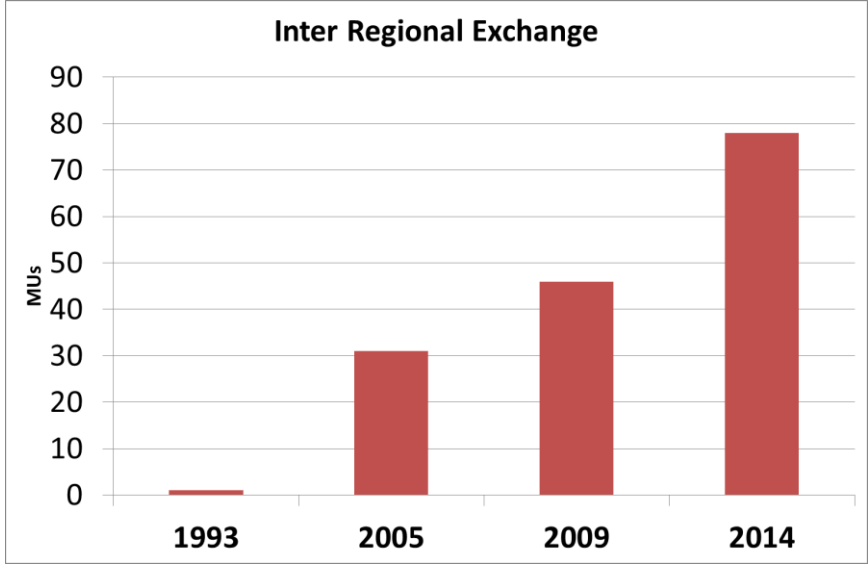


- Green energy corridor to facilitate Grid integration of large scale renewables
- About 33GW capacity addition envisaged through wind & solar in next 4-5 years
- The Plan includes
 - Transmission strengthening(s)
 - Dynamic reactive compensation,
 - Energy Storage,
 - Smart grid applications,
 - Establishment of Renewable Energy Management Centre enabling forecasting of renewable generation, real time monitoring, etc.

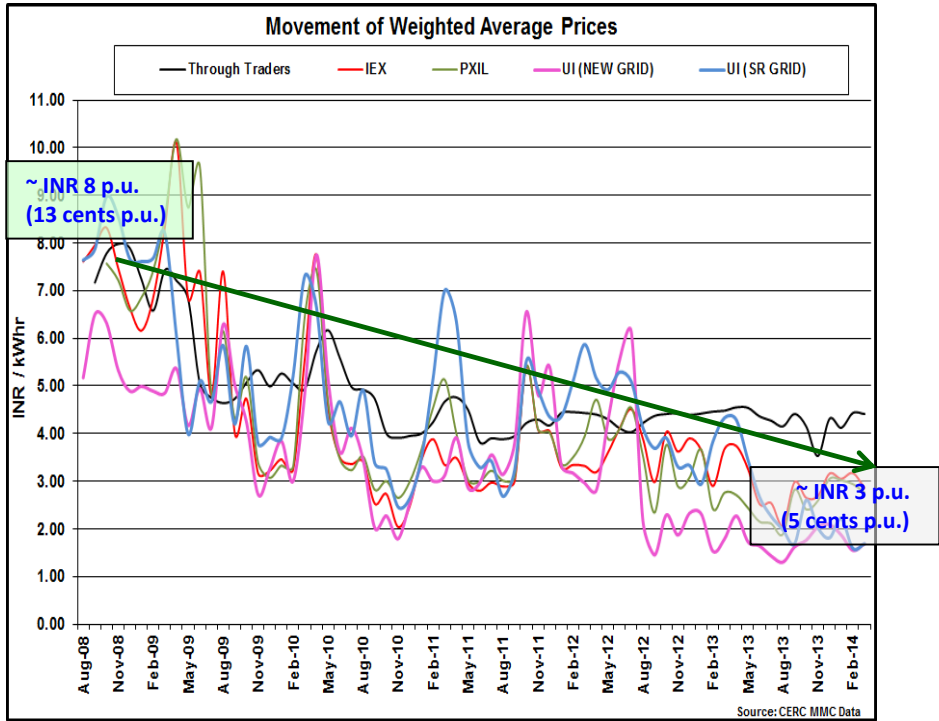


Large scale Interconnection : Indian Experience

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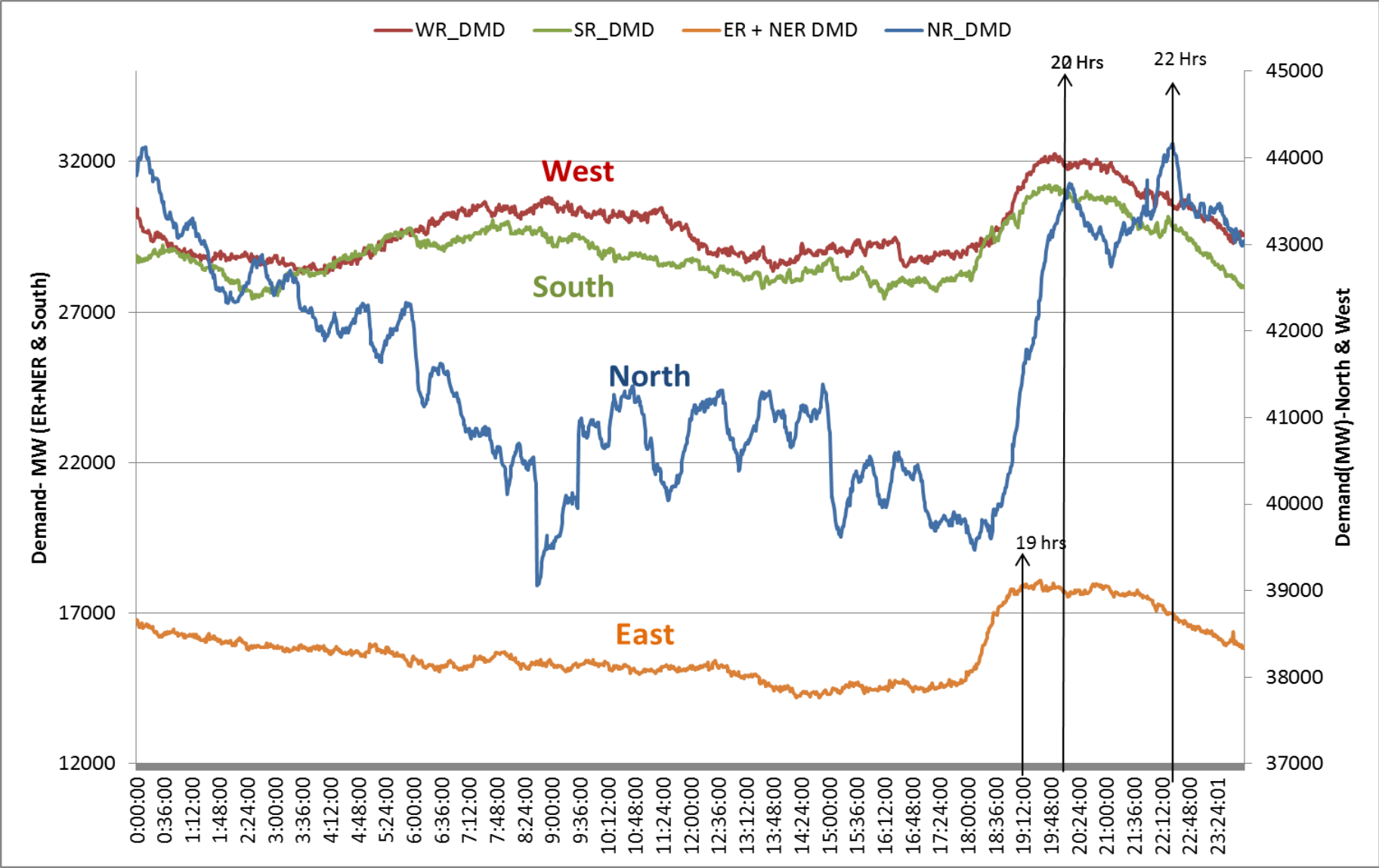


*Includes Bilateral + Collective transactions

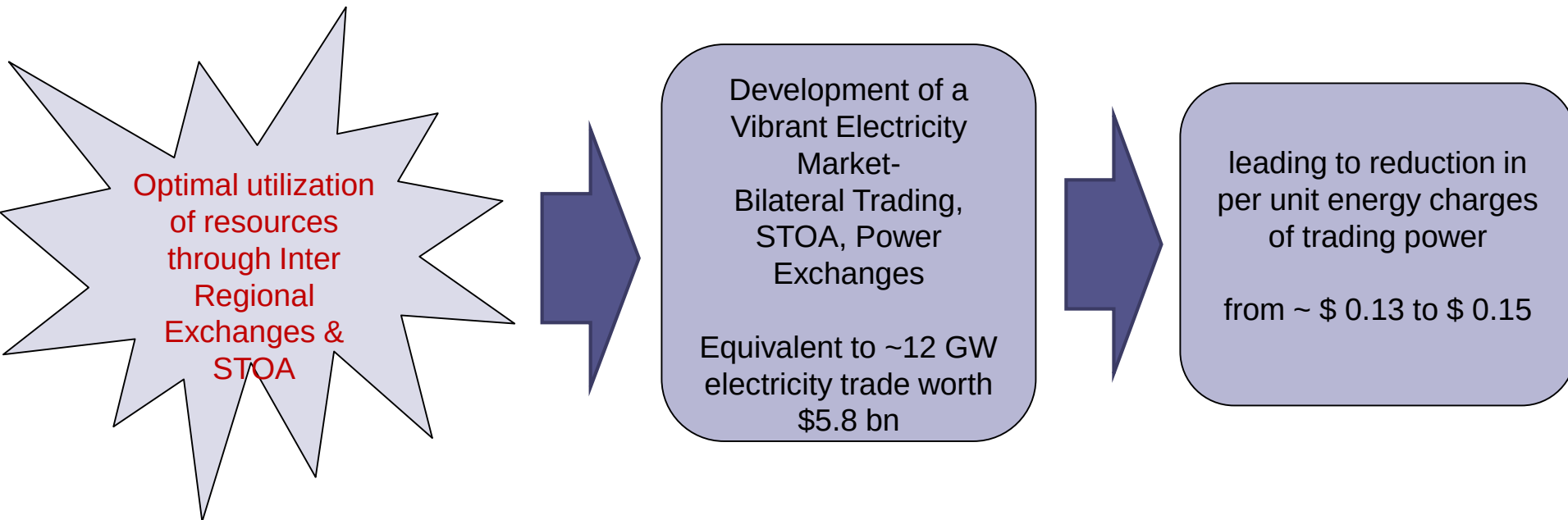


Peak Time Diversity in different Regions

A Typical Day



Large scale Interconnection : Indian Experience



- Increased efficiency through Merit Order operation - Saving \$300 million / annum
- Economy in Generation – Reduction in Capacity addition by about 12GW (\$ 9 bn)
 - Advantage from Time Diversity
 - Sharing of operational reserves through Improved Resource Management

Large scale Interconnection : Indian Experience

- Enable Setting up of large Pit Head stations having Lower Cost of Energy – Saving of about \$600 million / annum
- Reduced length of transmission line
 - Reduction in capital cost
 - Reduction in losses
- Facilitate clean development - reduced GHG emission
- Nations Investment towards Fuel Transportation avoided
- Improved reliability, stability and efficiency
- Sharing of balancing resources enabling large scale renewable integration – Hydro and flexible demand
- Facilitate utilization of Pumped Storage Hydro capacities

Large scale Interconnection : Indian Experience

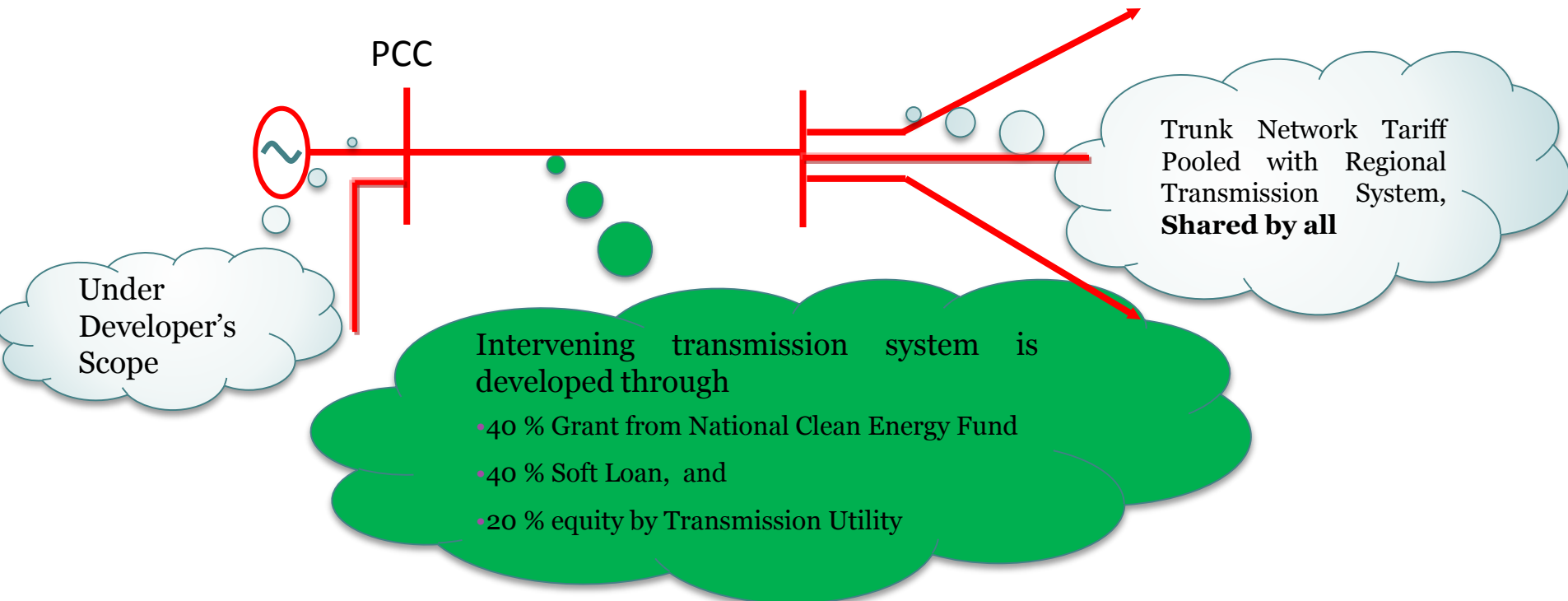
- Low Gestation period of Renewable projects (about 12-15 months), whereas Transmission development about 30-36 months requires:
 - Identification of Renewable generation pockets
 - Prioritization of generation pockets for development
 - Transmission development should be undertaken for the prioritized complex much ahead of Gen. Project

Transmission to lead the renewable generation

- Wide geographical dispersion of Renewable resources, Balancing resources/mechanism to take care of intermittency and variability necessitate comparatively more Transmission capacity development

Large scale interconnection : Indian Experience

- Low Capacity Utilization Factor (CUF) of Renewable (RE) generator coupled with less utilization of network from RE generator to Point of common coupling (PCC) as well as intervening system in comparison to trunk network necessitate rationalization of transmission tariff.



Emerging Requirements

- Balancing Infrastructure including Large Energy Storage to facilitate Renewable Integration
- Hybrid AC / HVDC system to provide operational flexibility
- Dynamic Compensation -STATCOMs
- Smart Grid enabling Renewable Integration and Real time monitoring / control



Large scale Interconnection : International Experience

India's neighbors



Features

- Huge Reserves of Natural Resources
 - Thermal resources – cheaper to transport in electricity form
 - Hydro resources – can only be transported in electricity form
- Benefit to Countries with limited resources
- Huge hydro Resources of certain countries can be effectively utilised
- Utilises peak diversity, time diversity and weather diversity
- Exporting countries benefit economically
- Importing countries benefited by deferring investment towards setting up power plants

International Experience

India-Bhutan

- Around 80% of Power generation from Bhutan exported to India. Power exports account for more than 40% of National Revenue and about 25% of Gross Domestic Product (GDP) in Bhutan.
- **Existing Transmission Capacity:** 2896MW
- **On-going:** 400kV inter-connection and Alipurduar HVDC station (3000MW) in progress for on-going Punatsangchu (1200 MW) project.
- **Future:** Masterplan made for evacuation of about 11,500 MW (from 14 HEP) by 2020 and 26,500 MW (from 75 HEPs) by 2030.

India-Bangladesh

- Bangladesh gets an economic boost from 500 MW power import from India.
- **Existing:** 500MW HVDC back-to-back link
- **Future:** Masterplan made for evacuation of about 11,500 MW (from 14 HEP) by 2020 and 26,500 MW (from 75 HEPs) by 2030.

India – Nepal

- **Existing:** About 120-150MW in radial mode.
- **On-going:** 400kV Muzaffarpur(India) and Dhalkebar (Nepal) inter-connection in progress.
- **Future:** High capacity transmission interconnection is being planned for evacuation from future about 20,000MW hydel projects in Nepal.

India – Sri Lanka

- Feasibility Study carried out for 1000MW HVDC bipole interconnection between India(Madurai) and Sri Lanka (Anuradhapura).



Issues for Large scale Interconnection

Issues for Large Scale Interconnection

Technical

- Planning of Interconnection Mode(synchronous/asynchronous), Voltage, Capacity, location, time frame, Quantum of power exchange in either direction, duration and Source
- Scheduling of power exchange
- Operation & maintenance of interconnection
- Reliability Criteria and Security aspects

Commercial

- Long term agreements
- Pricing of power and tariff mechanism
- Recovery of transmission charges
- Payment Security Mechanism
- Metering arrangement having common standard of accuracy
- Terms for disruption of Transmission service
- Funding arrangement like multilateral, private etc.

Regulatory / Legal

- Harmonization of Grid Code
- Firming up of procedures for dispute settlement and Arbitration
- Institutional Arrangement for settling legal disputes
- Applicability of Laws of Respective countries/ International Laws

Institutional Arrangement

- Establishment of Co-ordination committees Technical, Operational, Commercial etc. at working level & National Level
- Establishment of National Regulatory Commission to support development of interconnections between the two countries

large scale interconnections : A Force Multiplier to Assist Rapid Power System Growth

Grid Flexibility

- Help in harnessing the diversity available on account of weather, festivals, culture, lifestyle, growth disparities, etc

Green development

- Provide flexibility to the grid to incorporate large scale renewables
- Sharing of Balancing Resources

Quality power at affordable price

- Economic exchange of electricity leading to high benefit-cost ratio even without considering its impact on emissions
- Merit Order Operations
- Improve reliability of electricity grid

Market Development

- Acts as a power highway for smooth transportation and trading of energy



Thank You