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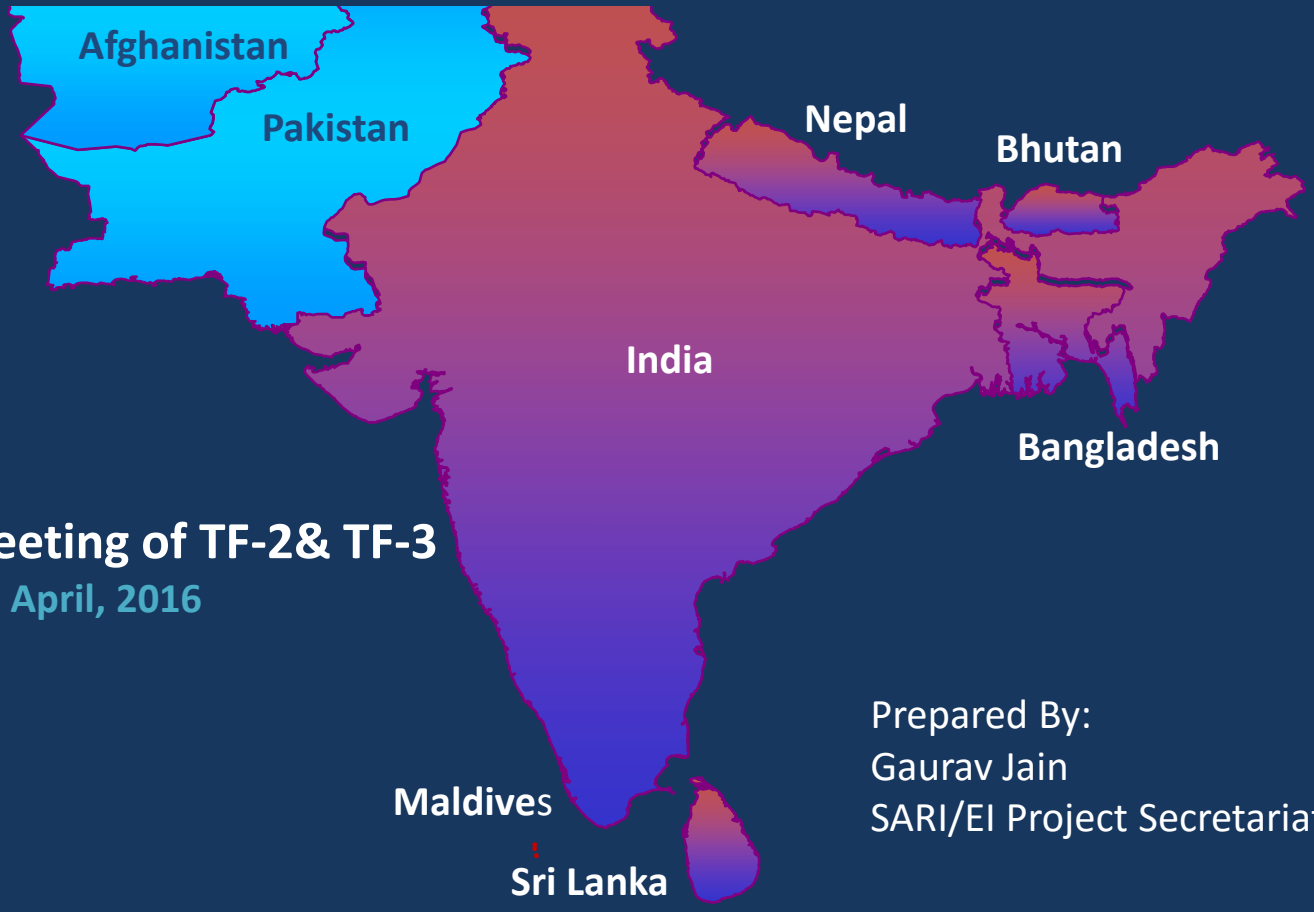
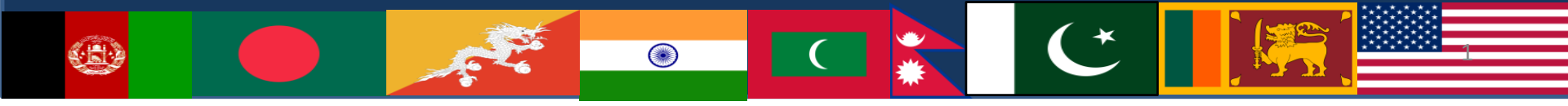
Findings of the Task Force 2 study on "Assessment of the Electricity Trading Potential in the South Asia region"



Combined Meeting of TF-2& TF-3

20th April, 2016

Prepared By:
Gaurav Jain
SARI/EI Project Secretariat



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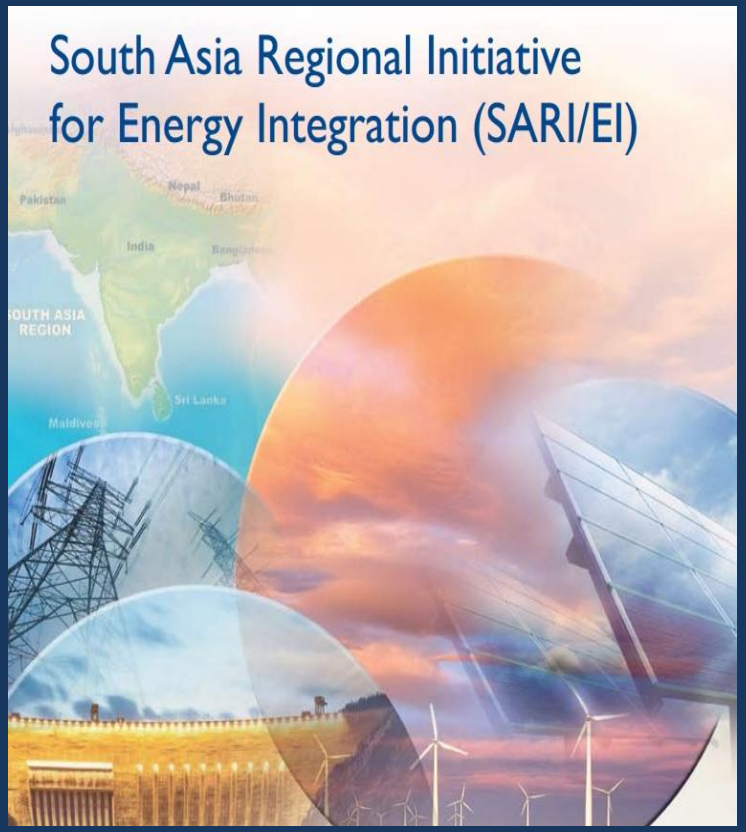
PRESENTATION OUTLINE



- Objective
- Scope of Work
- Approach and Methodology
- Key Assumptions
- Complementarities in the region.
- Modeling : Base Case
- Findings/Analysis
- Scenarios for Sensitivity Analysis
- Trading Potential of the South Asian Nations
- Way Forward and deliberation

OBJECTIVE

To identify the electricity trading potential of the South Asian nations (Bangladesh, Bhutan, Nepal, India, Sri Lanka, Pakistan)over a period of next 20 years.

SCOPE OF WORK

1.Collect, compile, review and analyse the existing long term D-S projections/data available including different scenarios.

2.Account all types of Generating plants viz Hydro, Thermal, Nuclear & Renewable.

3. Assess whether Demand-Supply(D-S) projections have explored the CBET potential and in the time horizon of 20 years.

4. If the data including the generation capacity addition projections are not available, a proper methodology needs to be adopted.

5. D-S projections shall include the year wise trading opportunities that arise out of seasonal variations, time zone difference, difference in load curves, different weekends and holidays.

APPROACH

The overall approach has been divided into following three parts:

- Data collection, Demand-Supply review and Transmission Capacity analysis
- Projecting the trade potential between countries using ICF's SA-IPM® (South Asia IPM®)(2015 to 2034)
- Scenario Analysis: Assessment of the impact of important variables on the trading potential through various scenarios.

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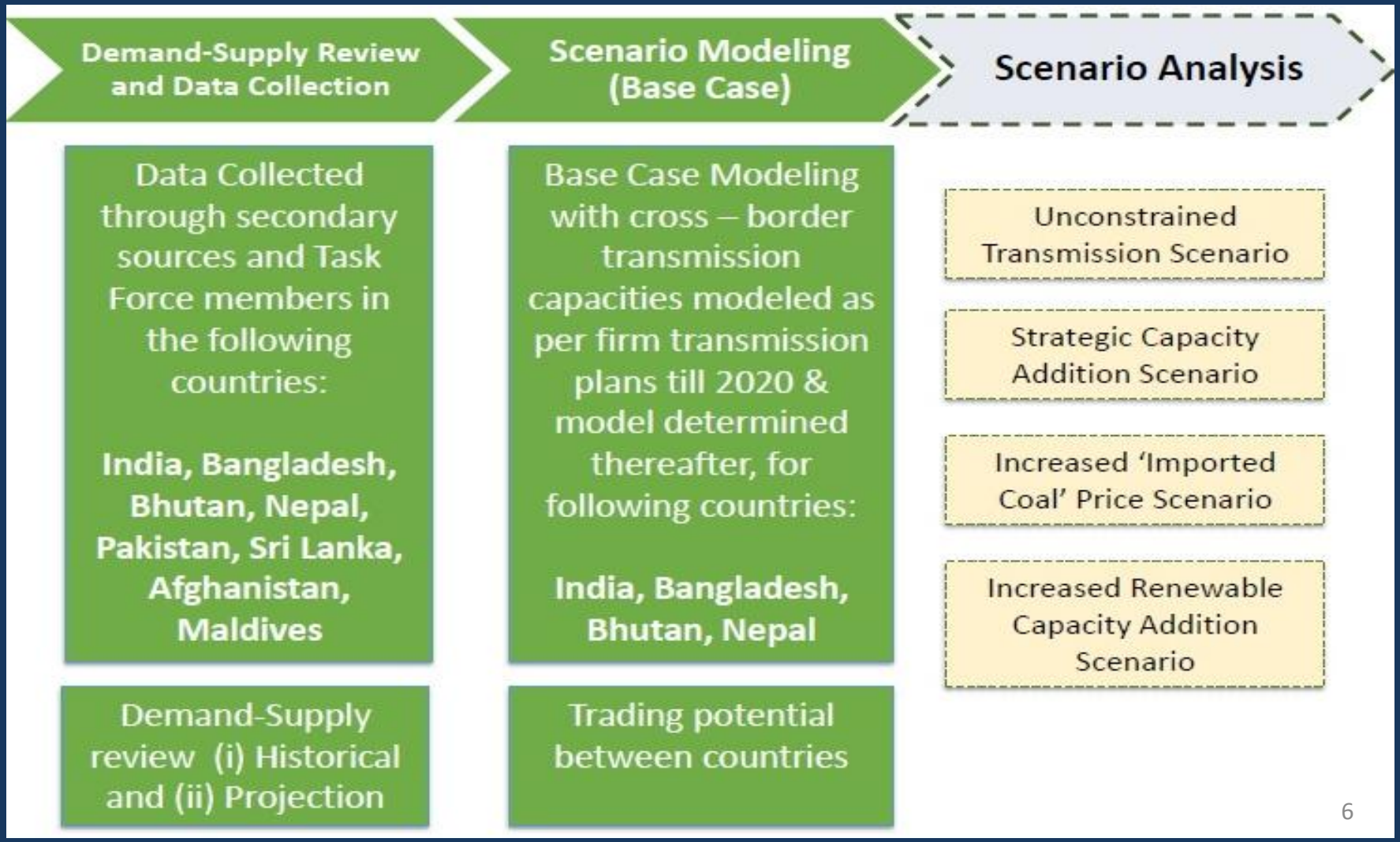
STUDY WORK FLOW



METHODOLOGY

Unrestricted electricity demand (GWh) forecast have been estimated using the following methodology:

- Actual electricity demand for 2013 (or 2014) as the base Energy Demand.
- For the period 2014-34 (or 2015-2034), electricity demand growth computed as the product of GDP growth and electricity elasticity for each year.
- Electricity supply (GWh) forecast (up to 2034), if unavailable, has been developed by either estimating generation from upcoming power plants or by assuming the generation of the last year up to which forecast is available to remain constant for future years.
- Peak demand (MW) forecast, if unavailable, has been estimated by using five-year Compound Annual Growth Rate.

INTEGRATED PLANNING MODEL® (IPM®):

- Multi-regional, deterministic and dynamic model.
- Linear-programming based optimization approach.
- Simulates least-cost plant dispatching and least-cost investments in generation capacity and interconnections to meet projected load.
- Long-term capacity expansion and production costing model for electric power systems including generation & transmission.

BASE CASE MODELING:

- Joint simulation of the power markets of the South Asian countries to estimate the trade potential using ICF's South Asia-IPM® .
- Cross – border transmission capacities are modeled as per respective national firm transmission plans till 2020 & model (SA-IPM®) determines thereafter.

SCENARIOS FOR SENSITIVITY ANALYSIS

- **Unconstrained inter-country transmission capacity scenario:**
  Provides an overall potential estimate of the trade that might actually happen in case 100% of the requisite transmission capacity is developed.

- **Strategic capacity addition scenario:**
  The impact of strategic capacity addition(50% of planned capacity addition) in South Asian countries is assessed on CBET.

- **Imported Coal Price Scenario:**
  Evaluates impact of 25% increase in the price of imported coal as compared to the prices in the base case (increase will be over a 4 year period from 2015).

- **Increased Renewable Capacity Scenario:**
  The impact of increased RE capacity additions plans (based on RPO) in respective countries on the trading potential is evaluated.

KEY ASSUMPTIONS

Demand Side

- Electricity demand is considered at wholesale level i.e. the demand that a plant has to meet at its plant bus bar.
- Energy Efficiency (EE) and Demand Side Management (DSM) measures have been accounted for in total electricity forecast.
- Hourly load profile (8760 hours) of each zone is modelled separately.
- No Captive or off-grid demand considered since it is expected to merge with mainstream demand over time.
- Unrestricted demand is modelled which does not include latent demand.
- Price elasticity of demand is not considered.

Supply Side

- Supply is modelled at generation unit level i.e. for each plant operating in the system.
- No Captive or off-grid demand considered.
- Long term PPA's of plants are modelled.
- Power supply is modelled from each existing and new plant.
- Supply capacity has been divided into three categories as follows:
- Existing – Plants currently in operation
- Firm – Plants under construction and likely to be operational in a span of next 5-6 years
- Potential – SA-IPM® forecasts capacity addition based on cost economics. Cost and efficiency assumptions for such plants are provided by the model. However, capacity forecast across zones is constrained as per the likely potential envisaged for that zone.

KEY ASSUMPTIONS

FUEL

❖ **Domestic Coal & Gas:**

✓ Domestic supply considered from each fuel supply region.

✓ Fuel cost is considered separately for each fuel supply region along with related transportation cost.

✓ Option of using imported coal is provided to all the power plants in the system.

❖ **Imported coal :**

✓ Supply is considered unconstrained.

✓ Prices are indexed to international coal index of New Castle (Australia), and Richard Bay (South Africa).

❖ **Imported gas (primarily R-LNG):**

✓ Supply is considered unconstrained

✓ Prices are indexed to international R-LNG spot market.

TRANSMISSION

❖ The model treats each zone as a separate power market and connects these zones through the inter-zone transmission network for any possible power flow between them.

❖ Transmission capacity is defined by Total Transfer Capacity (TTC) and Available Transfer Capacity (ATC).

❖ Each transmission line is assigned an ATC (in MW) which defines maximum capacity that can be transferred over the link for each hour.

Table 1. Key economic data: Capital costs power generation technology by type

Generation Technology	India	Bhutan	Bangladesh	Nepal	Pakistan	Sri Lanka
Super Critical Coal	1066		1066		1829	1913
Combined Cycle	574		574		813	1108
Combustion Turbine (CT)	525	525	525	525		
Nuclear - PHWR/LWR	1967		1967		3048	4605
Hydro (RoR)	1656	1656	1656	1656	1829	2109
Hydro (Storage based)	1803	1803	1803	1803	2540	2109
Wind	958	958	958	958	958	958
Small Hydro	1166	1166	1166	1166	1166	1166
Solar PV	776	776	776	776	776	776
Solar Thermal	1967		1967		1967	1967
Biomass	1107		1107		1107	1107

KEY ASSUMPTIONS

Demand Side

- Electricity demand is considered at wholesale level i.e. the demand that a plant has to meet at its plant bus bar.
- Hourly load profile (8760 hours) of each zone is modelled separately.
- No Captive or off-grid demand considered since it is expected to merge with mainstream demand over time.
- Unrestricted demand is modelled which does not include latent demand.
- No load shedding considered.

Supply Side

- Supply is modelled at generation unit level i.e. for each plant operating in the system.
- No Captive or off-grid demand considered.
- Long term PPA's of plants are modelled.
- Supply capacity has been divided into three categories as follows:
- Existing – Plants currently in operation
- Firm – Plants under construction and likely to be operational in a span of next 5-6 years
- Potential – SA-IPM® forecasts capacity addition based on cost economics. Cost and efficiency assumptions for such plants are provided by the model. However, capacity forecast across zones is constrained as per the likely potential envisaged for that zone.

Regional Complementarities in South Asia

Why Regional Power Trade??????

- Untapped energy reserves
- Power crunch
- Achieving economies of scale
- Economic efficiency
- Exploitation of complementarities
  - ✓ Resource availability
  - ✓ Existing Fuel Mix
  - ✓ Seasonal Variation
  - ✓ Hourly variation

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Comparative attributes for South Asian countries Power Sector

Parameters	Bangladesh	Bhutan	India	Nepal	Pakistan	Sri Lanka
Installed Capacity (MW)	10,304	1,488	2,50,257	770	23,663	3,322
Per Capita Electricity Consumption (Kwh)	274	2420	879	103	458	449
Electricity Access	62%	57%	75%	63%	69%	94%
Peak deficit	9%	6%	4%	34%	24%	V.L.
Hydro Electric Potential (GW)	0.3	30	150	83	59	2
Population (in Million)	160.4	.7	1251.6	28	193.2	20.7

Key Points:

- The per capita electricity consumption of South Asian countries is much below the world average (>3000 Kwh).
- The region is endowed with ample hydro resources. However due to financial/investment related issues countries are not able to reap the benefits of these resources.

Regional Complementarities

- **Resource Complementarities:** The degree to which two countries symmetrically contribute dissimilar resources, in terms of both type and amount, to an alliance.

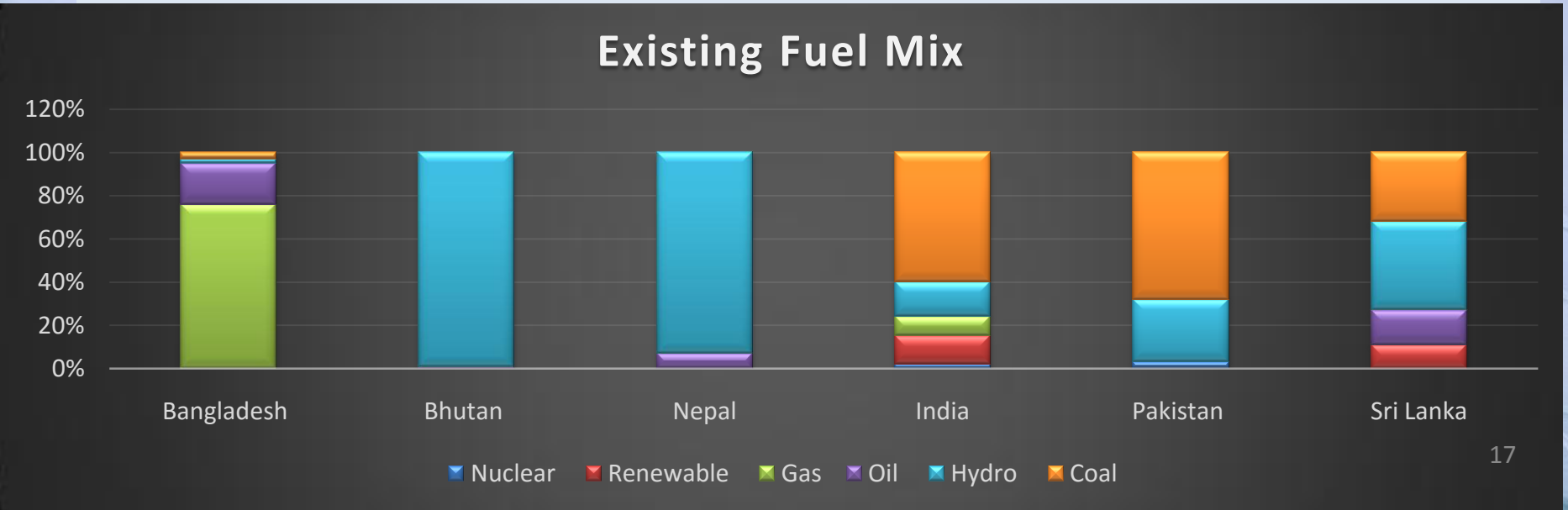
- The region is blessed with diverse natural resources ranging from the most conventional forms (i.e. coal) to hydro and non-conventional forms (i.e. solar and wind).

Country	Coal (Million tons)	Oil (Million barrels)	Natural Gas (Trillion cubic feet)	Biomass (Million tons)	Hydropower (GW)	Wind (MW)	Solar Power (Kwh/Sq m per day)
Bangladesh	884	12	8	0.08	0.33	Limited	3.8-6.5
Bhutan	2	-	-	26.6	30	4,825	2.5-5
Nepal	-	-	-	27.04	83	3,000	4.0-7.0
India	90,085	5700	39	139	150	151,918	3.6-6.2
Pakistan	17,550	324	33	-	59	24,000	5
Sri Lanka	-	150	-	12	2	25,000	NA

Regional Complementarities

- **Existing Fuel Mix:** Countries are having an skewed fuel mix in the region. By regional power trade, the countries will able to increase the energy security and reduce the dependency in a particular form of energy.

- Key Point:
  - ✓ Bangladesh's generation is mainly gas based and hence provides a contrast with Bhutan and Nepal which are majorly hydro based electricity generation.
  - ✓ Provide an opportunity to harness the renewable energy by extending an market and provide an balancing opportunity by other fuel resources.

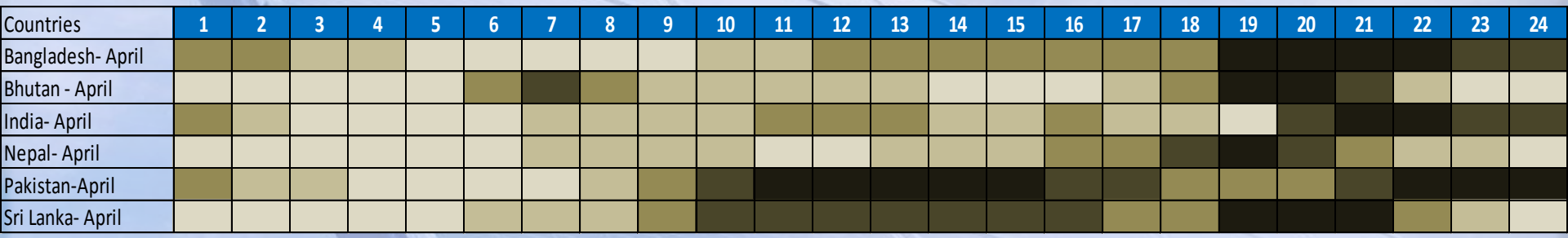


Regional Complementarities

- **Hourly complementarities:** The countries of the SAR have non-coincident demand peak across the year; here hourly complementarities between countries electricity demand represented.

Key Point:

- Peak and off peak hour difference between countries.



Color Coding	Range	
	Min	Min+ (Max-Min)*20%
	Min+ (Max-Min)*20%	Min+ (Max-Min)*40%
	Min+ (Max-Min)*40%	Min+ (Max-Min)*60%
	Min+ (Max-Min)*60%	Min+ (Max-Min)*80%
	Min+ (Max-Min)*80%	Max

Country	Peak Hour
Bangladesh	19^{th} -22^{th}
Bhutan	19^{th} -20^{th}
India	21^{st} -22^{nd}
Nepal	19^{th}
Pakistan	11^{th} -15^{th} & 22^{nd} – 24^{th}
Sri Lanka	19^{th} -21^{th}

Seasonal Complementarities

- **Seasonal Variation:** The countries are showing substantial electricity demand seasonal variation.

- **Key Points:**

1. Bangladesh is having an high demand of electricity from month of April to September.
2. Nepal and India peak month of electricity demand are June and July.
3. Sri Lanka is having an peak demand of electricity in March and Bhutan is having peak demand in December.
4. Pakistan peak month of electricity demand is April and May.

Month	Bangladesh	Bhutan	India	Nepal	Pakistan	Sri Lanka
Janurary						
Feburary						
March						
April						
May						
June						
July						
August						
September						
October						
November						
December						

Few Important Facts together

India:

- Biggest power market of the region.
- Source and sink for the regional power market.
- Having peak power shortage mostly.
- Variation of 1-2% in the electricity demand will change the dynamics of regional electricity Market.

Bhutan

- Abundant untapped hydro resources.
- Already tasted fruitful outcome of regional power trade. Source for a power in the regional market.
- Only country in the region in the existing scenario is power surplus.

Bangladesh

- Facing severe power crunch in the region. It will continue act as power sink in the regional market.
- Regional power trade could be a blessing to mitigate high power shortage of the country.

Few Important Fact together

Nepal

- Upcoming few years country may act as power sink, however in the longer run having an capability to become an power source for the region.
- Highest peak deficit in the region and having an very good hydro potential to harness.

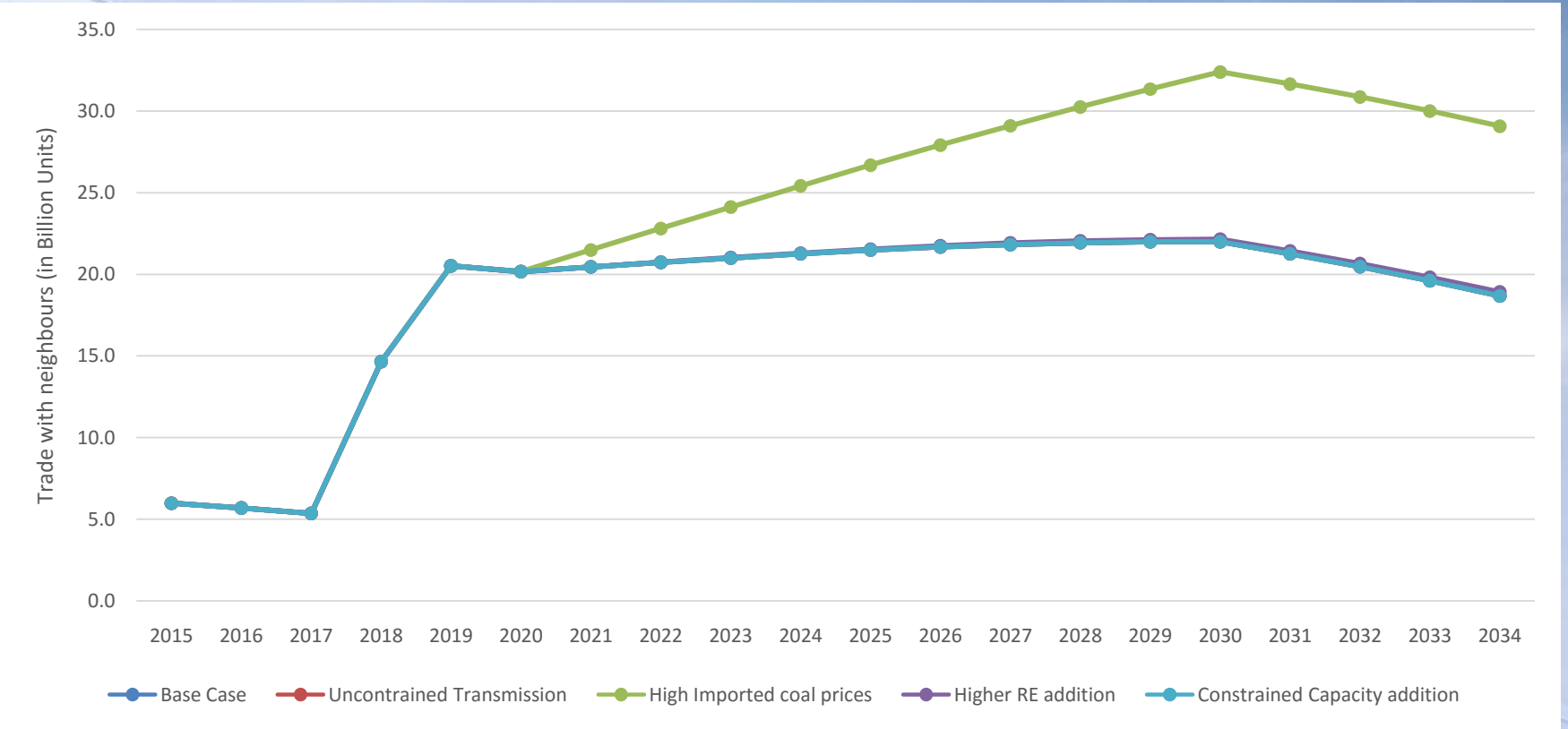
Pakistan

- Facing severe power crunch in the region.
- Regional power trade could be a blessing to mitigate high power shortage of the country.
- Most power starved country of the region and will continue act as power sink in the regional market.

Sri Lanka

- Having highest electricity access and very low power shortage.
- In the existing scenario, country seems self sufficient in terms of meeting its own demand , however as per the long term plan country will dependent on the imported coal.

BHUTAN : One of the regional starts

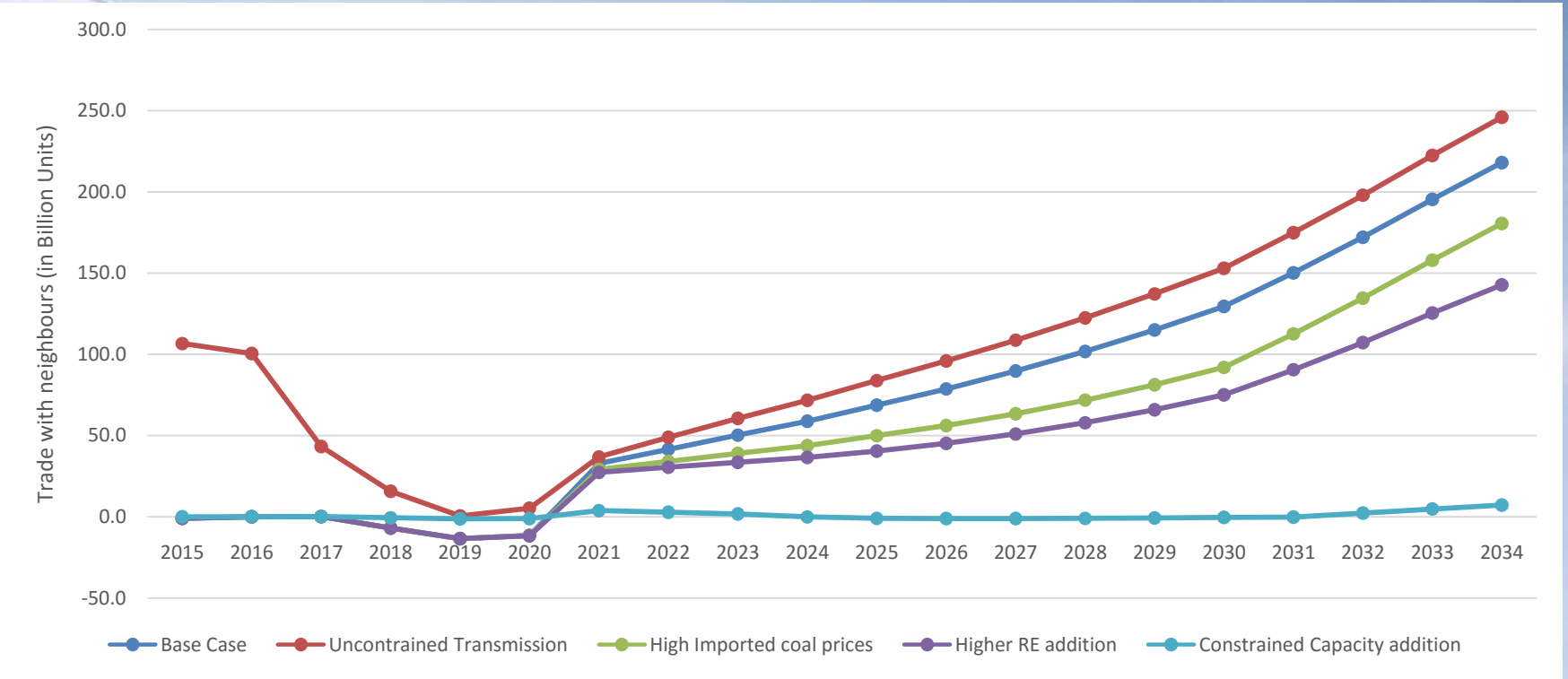


- **2015 to 2020: Trade is not impacted by any of the variables.**
- **2021 onwards: Higher imported coal prices result in higher trade volumes.**
- **Values on positive axis indicate Exports.**

NEPAL: Promise of Plenty

- ❖ **Factors that impact trade volumes for Nepal:**
- ✓ **Transmission constraint (for 2015 and 2016 till Dhalkebar-Muzzafarpur400 kV line is fully operational)**
- ✓ **Higher imported coal prices and higher RE penetration.**
- ❖ **Values on positive axis indicate Exports.**

INDIA: Biggest market in the Region



- ❖ **Factors impacting trade volume for India:**
- ✓ **2015 to 2020: Transmission constraints**
- ✓ **2021 onwards: Being the largest power system in the region, India plays a crucial role in CBET. A number of factors come into play with respect to Trade.**
- ❖ **Values on positive axis indicate Exports.**

BANGLADESH: Looming Shortages

- 2015 - 2020: Unconstrained case shows the highest trade potential
- 2021 onwards: Increased RE Capacity Addition Scenario and Strategic Capacity Addition Scenario obviates the need for imports from neighbouring countries, thus lower trade volumes.
- Values on negative axis indicate Power Imports.

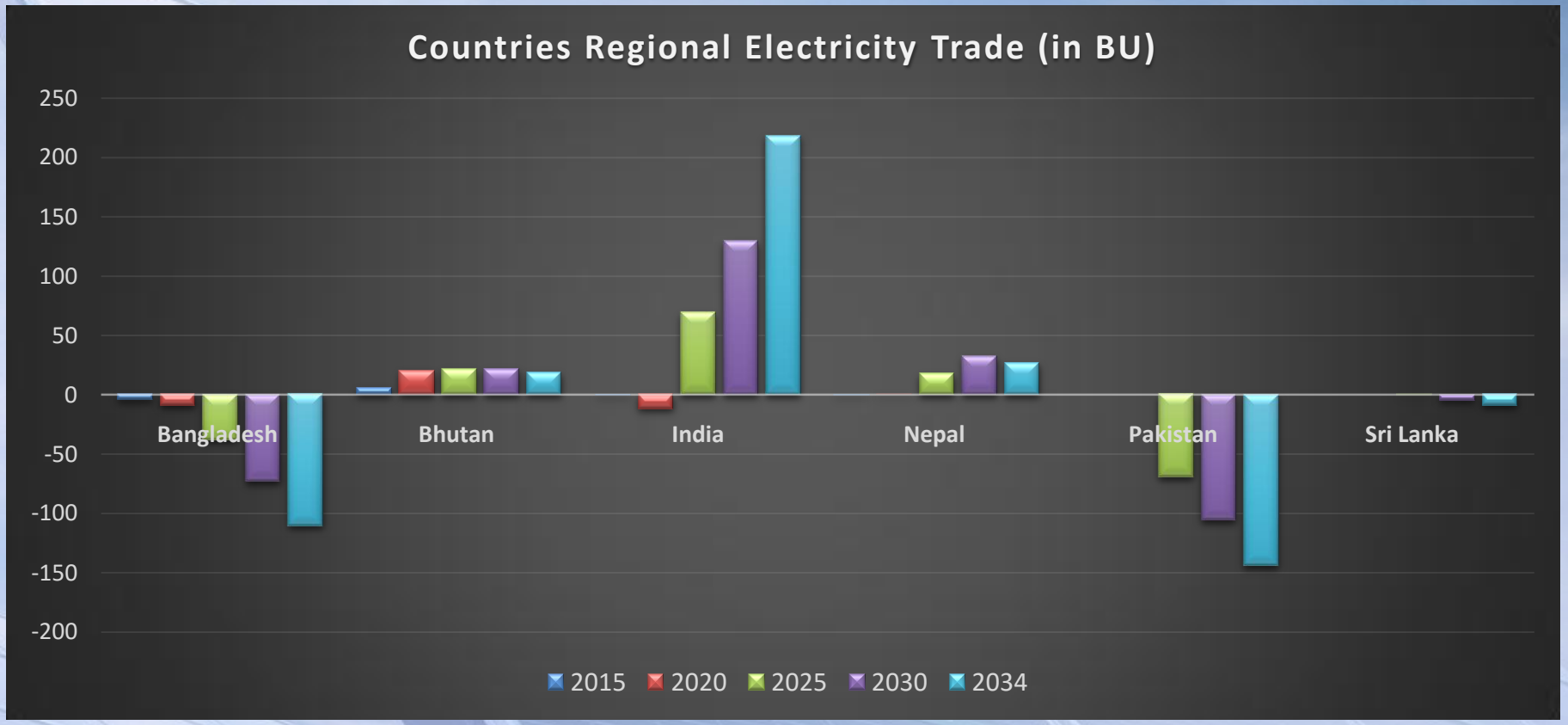
PAKISTAN: Other opportunity

- **2015 - 2020: Unconstrained case shows very high trade (import) potential due to using the high cost fuel such as Diesel/FO/HSD etc.**
- **In the constrained capacity/strategic capacity addition scenario, cue to country long term plan model pushed imported coal based generation.**
- **Higher RE scenario, country own RE resources may use on priority for meeting internal demand.**
- **Unconstrained scenario shows the highest trading potential.**

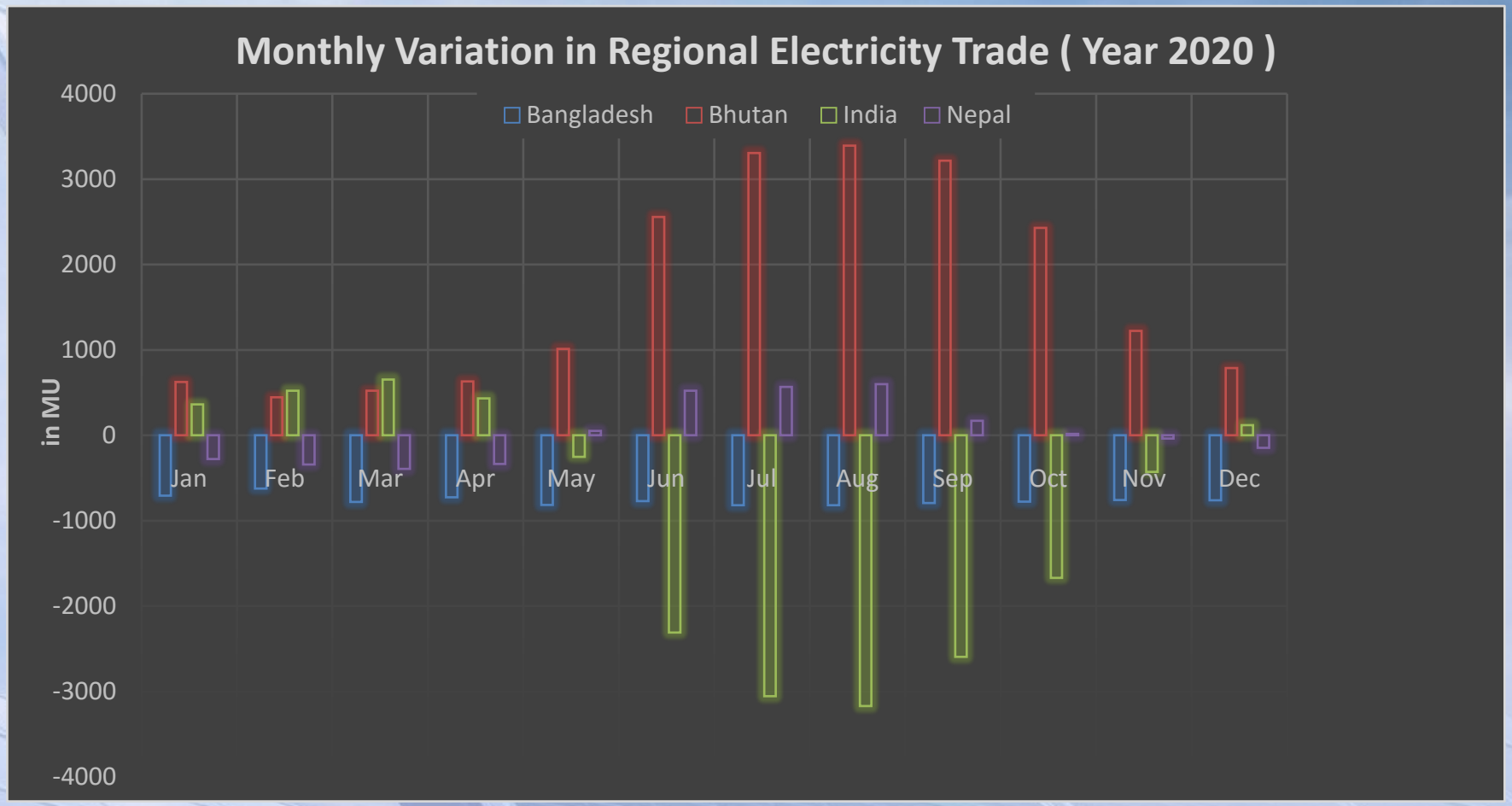
SRI LANKA: Future Perspective

- **Till 2025, we have put the transmission constrained for capturing the realistic view of regional trade potential with Sri Lanka.**
- **Unconstrained transmission is showing small amount of regional electricity trade with Sri Lanka.**

TRADING POTENTIAL OF THE SOUTH ASIAN NATIONS (Base Case)



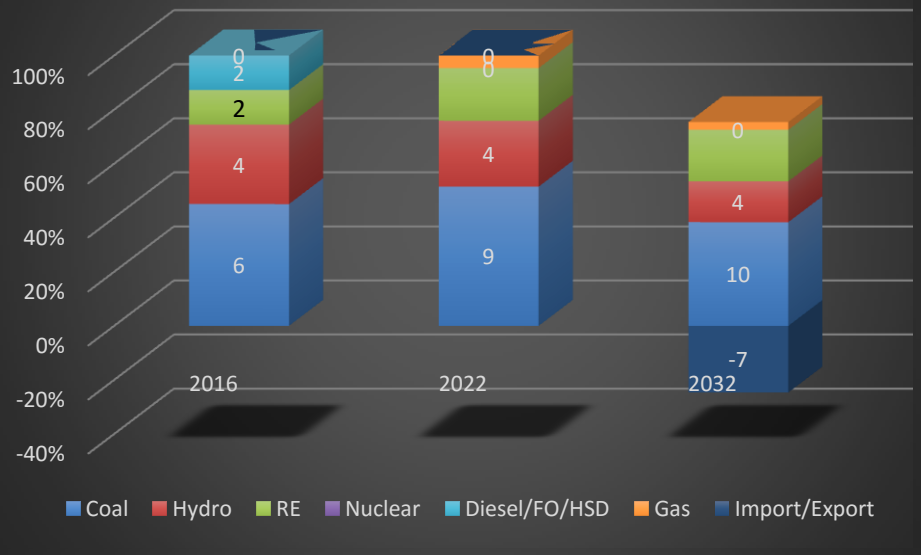
- There exists an annual regional Cross Border Electricity Trade potential of ~6 BU to ~20 BU in the near term (2015 to 2020) and ~108 BU to ~260 BU in the long term (2025 to 2034) among the South Asian countries.
- Negative Values indicate Imports.



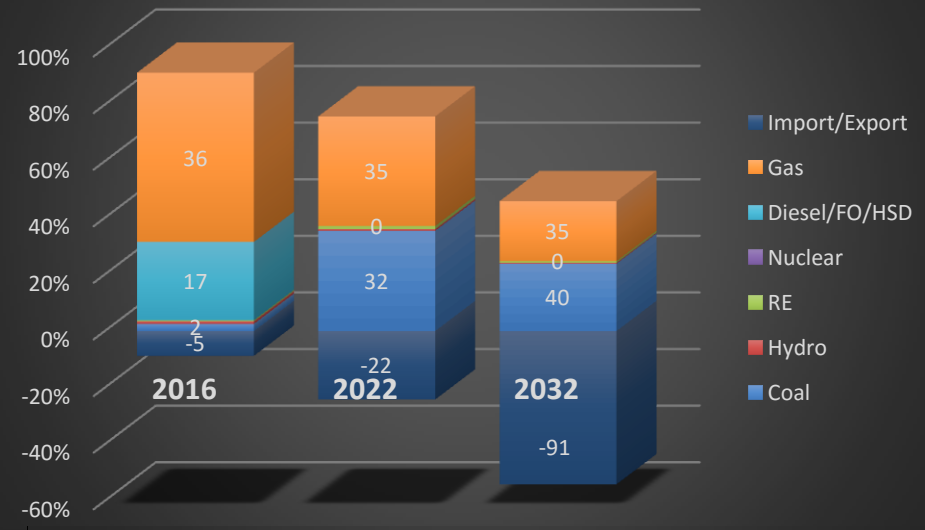
Summary/Key Points:

- Monthly electricity trade fluctuation will be high, due to cyclic nature of hydro resources.
- Import possibility to Bangladesh may be high, however it will be restrict because of the transmission constrained or absence of regional electricity market.

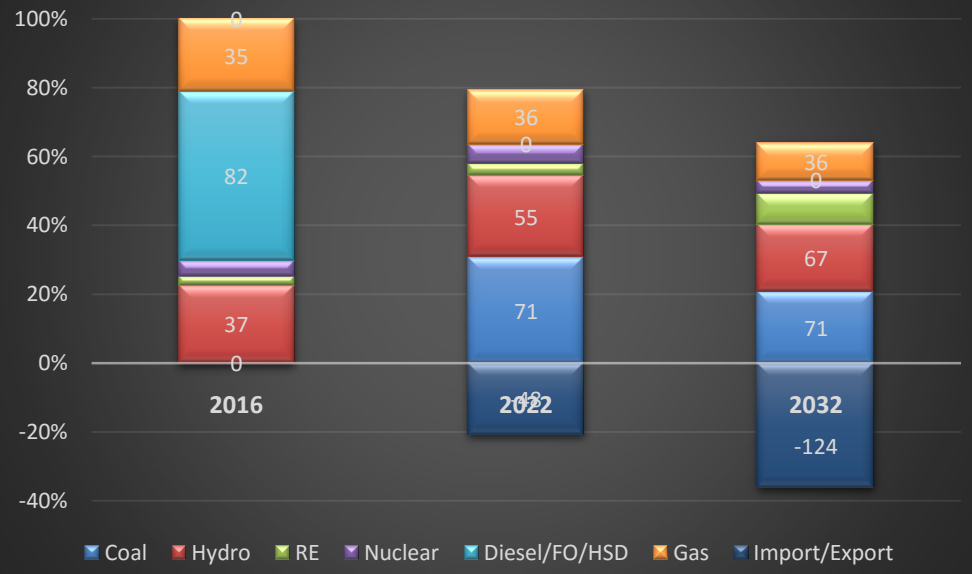
Sri Lanka Fuel Mix (In MU)



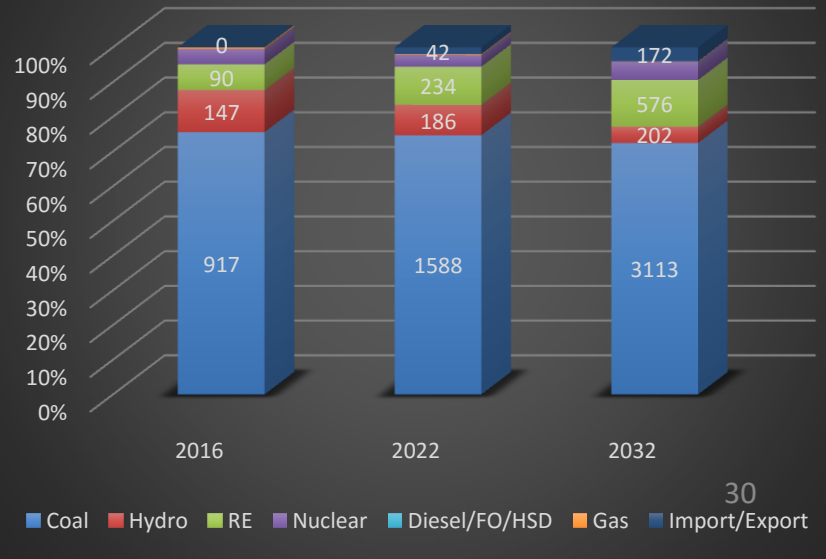
Bangladesh Fuel Mix (In MU)



Pakistan Fuel Mix (in MU)



India Fuel Mix (In MU)



CONCLUSION –REGIONAL CBET POTENTIAL

BANGLADESH:

- Transmission constraints to force Bangladesh to run expensive units like FO/HSD/LNG in near term.
- In medium to long-term: Bangladesh may import cheaper power from neighbouring countries instead of power from expensive FO/HSD units.
- Imports and coal-based capacity to meet base load requirement, whereas gas capacity based on domestic gas to be used as mid-merit or for meeting peaking load.
- CBET to reduce with (i) Increased RE addition, and (ii) strategic capacity addition as they add internal generation capacity to Bangladesh.
- Monthly electricity demand variation is very high in Bangladesh (around 50%)

BHUTAN:

- Exporter in all seasons which are expected to increase with capacity additions.
- RTC exports throughout the year with heavy exports during wet season.
- CBET to increase with (i) Increased RE addition, and (ii) Higher imported coal prices as they provide better signal for hydro development in country.

CONCLUSION –REGIONAL CBET POTENTIAL

INDIA

- To emerge as a net exporter of power and will continue to remain a predominantly coal-based economy.
- Does not need to set up additional capacity to meet the additional requirement to export to neighbouring countries; improvement in capacity factor of coal plants by ~1% - 2% would be sufficient.
- India monthly average electricity demand variation is lowest(around 9%). However due to size of the Indian market , it may have huge impact on the regional market.

NEPAL:

- Nepal to depend on high cost units like diesel/FO etc. to meet its demand, in absence of sufficient transmission links with neighbouring countries
- Once Dhalkebar- Muzzafarpur line is fully operational, Nepal to have sufficient transmission capacity to import electricity from neighbours and not run diesel to meet its demand
- Net importer till 2018 and then likely to become a net exporter. RTC imports during deficit season and RTC exports during surplus season
- CBET to increase with (i) Increased RE addition, and (ii) Higher imported coal prices as they provide better signal for hydro development in country.
- Coal-based generation capacity remains on the margin for the system and any capacity having lower price would receive priority for dispatch.

CONCLUSION –REGIONAL CBET POTENTIAL

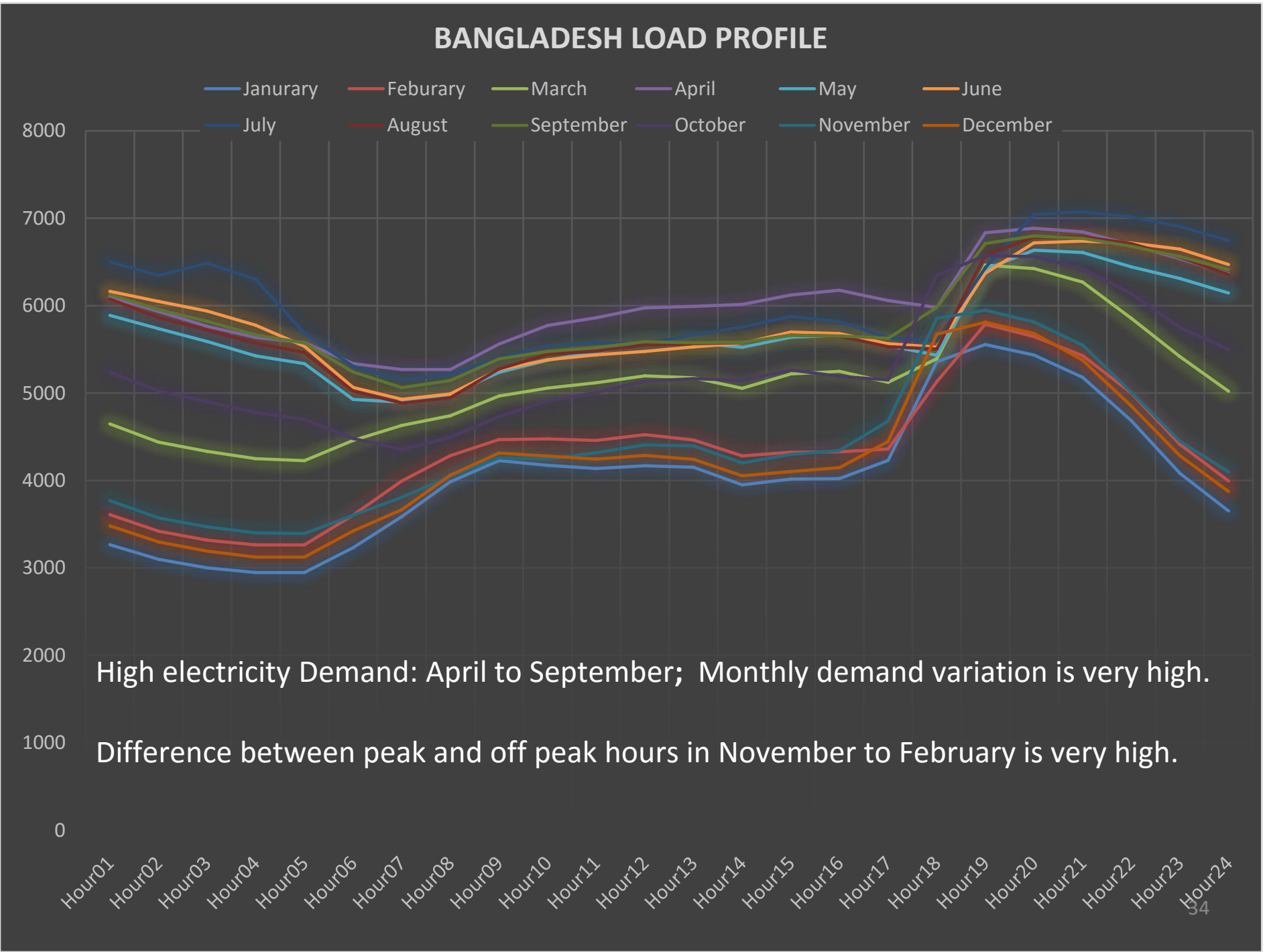
PAKISTAN

- In medium to long-term: Pakistan should import cheaper power from neighboring countries instead of power from expensive FO/HSD units. This will be helpful for country to reduce its power crunch/deficit.

- Constrained capacity addition/ strategic addition scenario push Pakistan to use its own costlier power/build up their own generation capability and reduce the dependency on regional power market.

SRI LANKA:

- In long-term: Sri Lanka may import cheaper power from neighboring countries instead of power from expensive imported coal based power plants.
- High imported coal price may push Sri Lanka for reaping the regional electricity benefits.
- Sri Lanka peak and off peak hour electricity demand variation is highest in the region (range of 100%).


BANGLADESH LOAD PROFILE
Janurary
Feburary
March
April
May
June
July
August
September
October
November
December
8000
7000
6000
5000
4000
3000
2000
1000
0
Hour01
Hour02
Hour03
Hour04
Hour05
Hour06
Hour07
Hour08
Hour09
Hour10
Hour11
Hour12
Hour13
Hour14
Hour15
Hour16
Hour17
Hour18
Hour19
Hour20
Hour21
Hour22
Hour23
Hour24
High electricity Demand: April to September; Monthly demand variation is very high.
Difference between peak and off peak hours in November to February is very high.



Way Forward

INTEGRATED PLANNING MODEL® (IPM®):

New and Existing Power Plants
- Coal
- Oil & Gas Steam
- Combustion Turbine
- Combined cycle
- Nuclear
- Hydro
- Renewables
- Cogeneration
- Other

Operational Factors
- Maintenance
- Outages
- Must Run

Renewable
- Solar/Wind/S-Hydro/Biomass
- Generation profiles and potentials

Transmission
- Transmission capacity
- Line loss and charges

Environmental Scenario
- Regulatory Scenario
- Policy Scenario

Environmental Compliance Choice
- Compliance Technology
- Technology Cost

POWER PLANT DISPATCH AND GRID OPERATIONS

PROJECTIONS
- Power Prices
- Supply Stack
- Allowance Prices
- Asset Values
- Fuel consumption mix
- Generation/Capacity mix
- Dispatch Decision
- Capacity build Decision
- Emission
- Compliance Cost
- Plant retirement Decision

Existing Power Plant Variable Cost
- Fuel Transportation
- Fuel Cost
- Heat Rates
- O & M Costs

New Power Plants
- Capital Cost
- Financing Cost

Electricity Demand
- Hourly Demand
- Peak and Electricity Growth
- Reserve Margins

Resource Supply and prices
- Gas Supply and prices
- Coal Supply and prices