Integrated
Electricity Generation and Transmission Planning in SAR:
Context of Energy Transition and Cross Border Power Trade

By

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Agendas of Discussion

- Introduction
- Conceptualization of IGTEP
- GTEP in SAARC Grid
- Issues and Outlook

1. Introduction

1.1 Planning (Conventional: VIU)

Separate GEP and TEP:

- > 80% of the total expansion planning cost belongs to GEP.
- Solving the GEP problem first and then using the obtained solution as an initial point for the TEP problem would be a closed optimal solution of the GEP/ TEP combinatory problem;
- Combinatory problem needs such a huge computational effort that the older computer architectures could not support it
- A simple and Practicable Solution

1. Introduction

Planning (Vertically Integrated Utilities): Steps

Input:

- ✓ Time, size and location of load consuming point (Load centers)
- ✓ Other data: market, priority, investment options

- Get Output: Time, size, type, technology and location of generating stations
- Execute Transmission Expansion Plan

Methods

- ✓ GEP: Nonlinear Optimization Problem
- ✓ TEP: Mixed Integer Linear Programming

Nature

- ✓ Deterministic Approach: All data were available and handled by single entity
- ✓ Sale of Service: state responsibility

1. Introduction

1.2 Planning (Unbundled Power Market)

- Assumptions
  - Cheaper Generation cost with least cost optimization
  - Transmission lines are adequate to cater the generated load
- New Scenario
  - ✓ Multiple GENCOs: try to optimize GEP individually
  - ✓ Multiple TRANCOs: try to optimize TEP individually
  - ✓ Distributed and diverse loads
  - ✓ Penetration of intermittent renewables
- Challenges
  - ✓ High Risk: Investment has to recovered from the market
  - ✓ Uncertainty: generations (reneawles), market price, etc
  - ✓ Probabilistic Approach

1. Introduction

1.2 Planning (Unbundled Power Market)

Further Challenge in TEP

- Lack of incentive to built Infras
- Lack of Proper cost recovery mechanism

Result

- Delayed Development of Transmission Infras
- Bottleneck in Power supply ecosystem

Therefore, Regulation needs to be restored to an extent for

- Avoiding the market manipulation
- Open access
- Promoting the Construction of Transmission Infras

1. Introduction

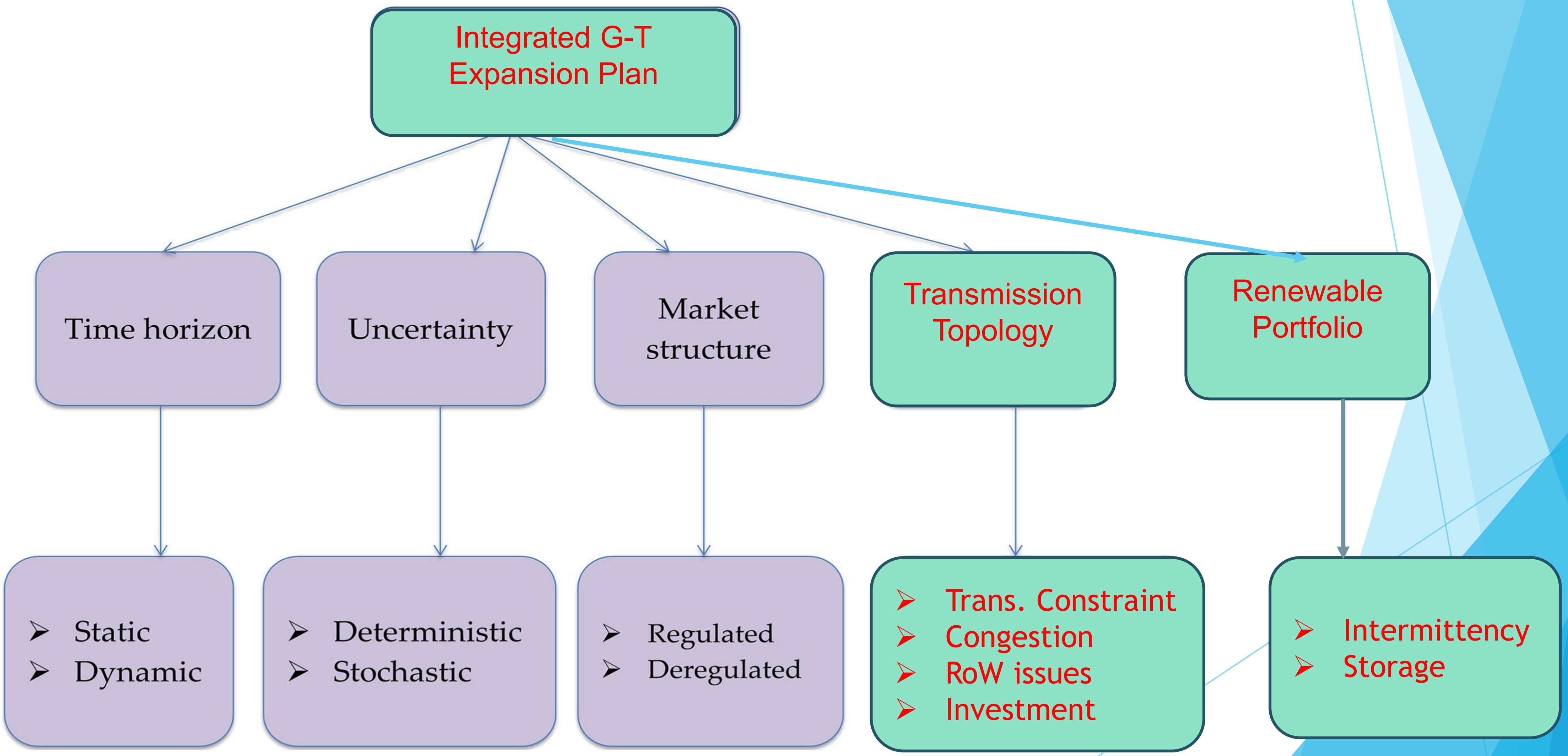
1.2 Planning (Unbundled Power Market)

Also, it is felt that

- Deregulation good for Power Sector Planning?
- Planning needs to be centralized,

So, Integrated G-TEP is essential

1. Introduction: Complexity of Integrated TGEP



1. Introduction: Summary of Planning

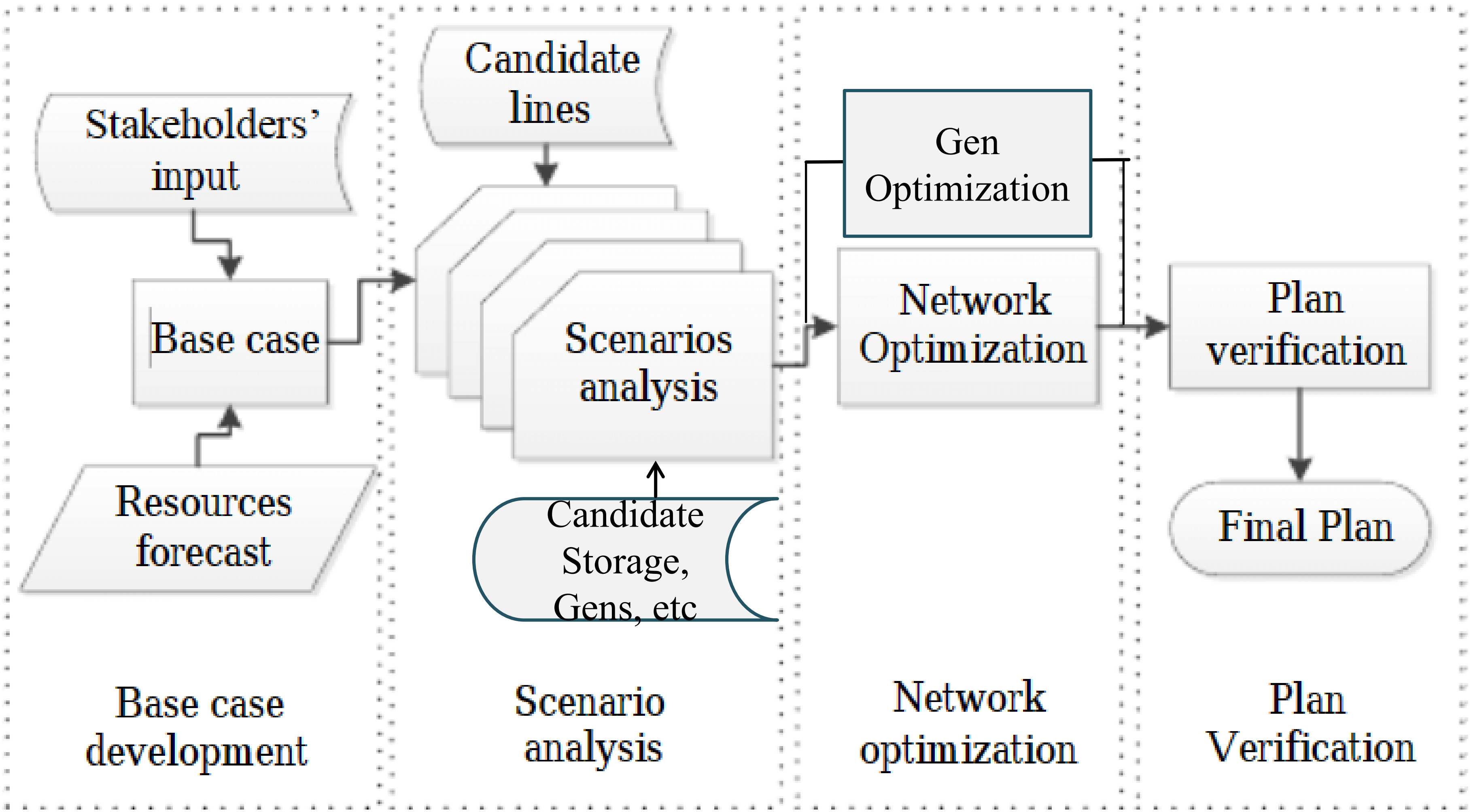


Fig. 1 Next generation transmission expansion planning process

2. Integrated G-T Expansion Planning

2.1 IGT Expansion Planning (with Renewables, CBET, Environmental Concerns)

Moving Beyond Production Cost Savings to Assess a Wider Range of Benefits

Benefit	Description
Production cost benefits	Quantification of fuel cost savings, reduced curtailment, variable operations and maintenance costs, reduced cycling of thermal power plants.
Emissions reduction benefits	The reduction in emissions of environmental pollutants, including CO_2, NOx, SOx.
Generation capital cost benefits	Reduced capital costs of new generating capacity and lower costs of achieving a renewable energy target from being able to access lower-cost renewable regions that are associated with better resource quality, lower land cost, and easier development.
Risk mitigation benefits	Production cost savings across a range of uncertain future conditions associated with varying gas prices, load growth, renewable build-out and thermal plant retirements.
Resource adequacy benefits	The reduction in loss-of-load expectation attributed to the transmission line, compared to the net cost of a new combustion turbine(s) necessary to achieve the same level of reliability.
Resilience benefits	The reduction in unserved energy attributed to the transmission line during the loss-of-load events remaining after resource adequacy improvements, valued at the ERCOT loss-of-load assumption of $20,000/MWh.

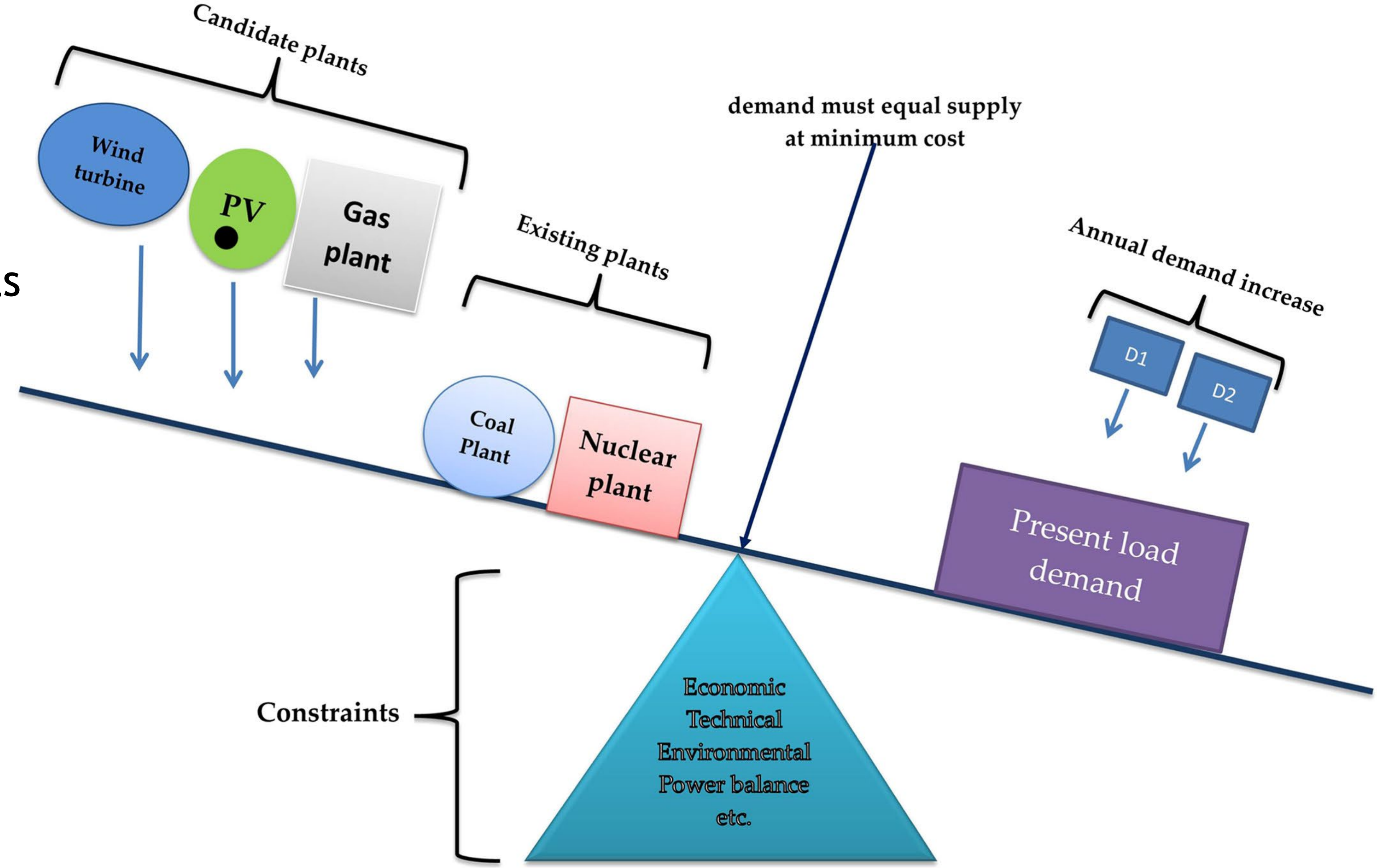
Source: Energy Systems Integration Group.

2. Integrated G-T Expansion Planning

2.2 Moving Beyond Production Cost Savings: Assess a Wider Range of Benefits

Steps:

- Include all the Benefit and Constraints in one Place
- Use Advance Computational tools
  - MILP, AI
  - Network Analysis tool (PSSE, ETAP etc)
- Get the result
- Verify for the applicability



3. Integrated GTEP: Illustration

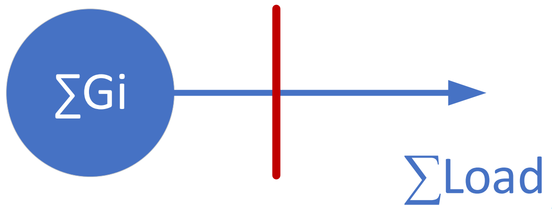
3.1 Generators and Load lumped in one bus

Optimization Problem

Min: $TC = \sum_{i=1}^{n} \left(Gcost_{i,cap} + Gc_{i,OM} \right) + Out_C$

Constraints:

- Network constraints
- Generation constraints
- Power balance
- ..



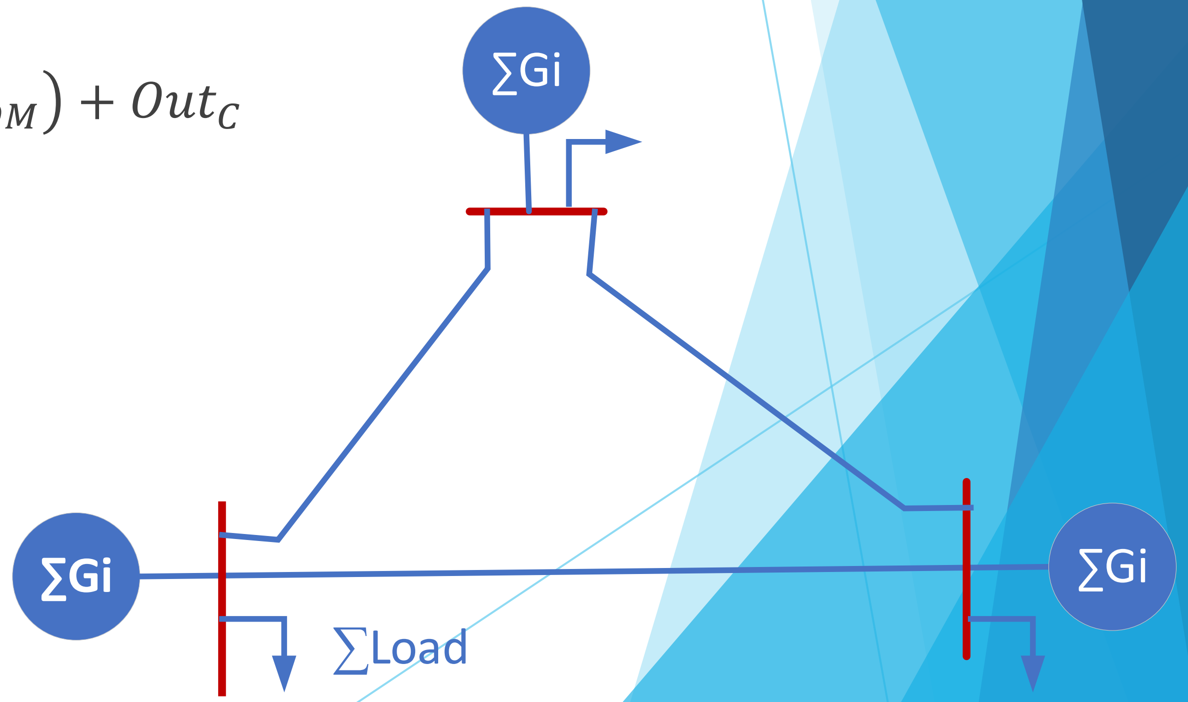
3. Integrated GTEP: Illustration

3.1 Generators and Load Connected with TLs

Optimization Problem

Min:

$$Total\ C = \sum_{i=1}^{n} (GC_{i,cap} + GC_{i,OM}) + (TC_{i,cap} + TC_{i,OM}) + Out_C$$



Constraints:

- Generation constraints
- Power balance
- Network Constraint

3. Integrated GTEP: Illustration

3.1 Integrating the Renewables on Existing System

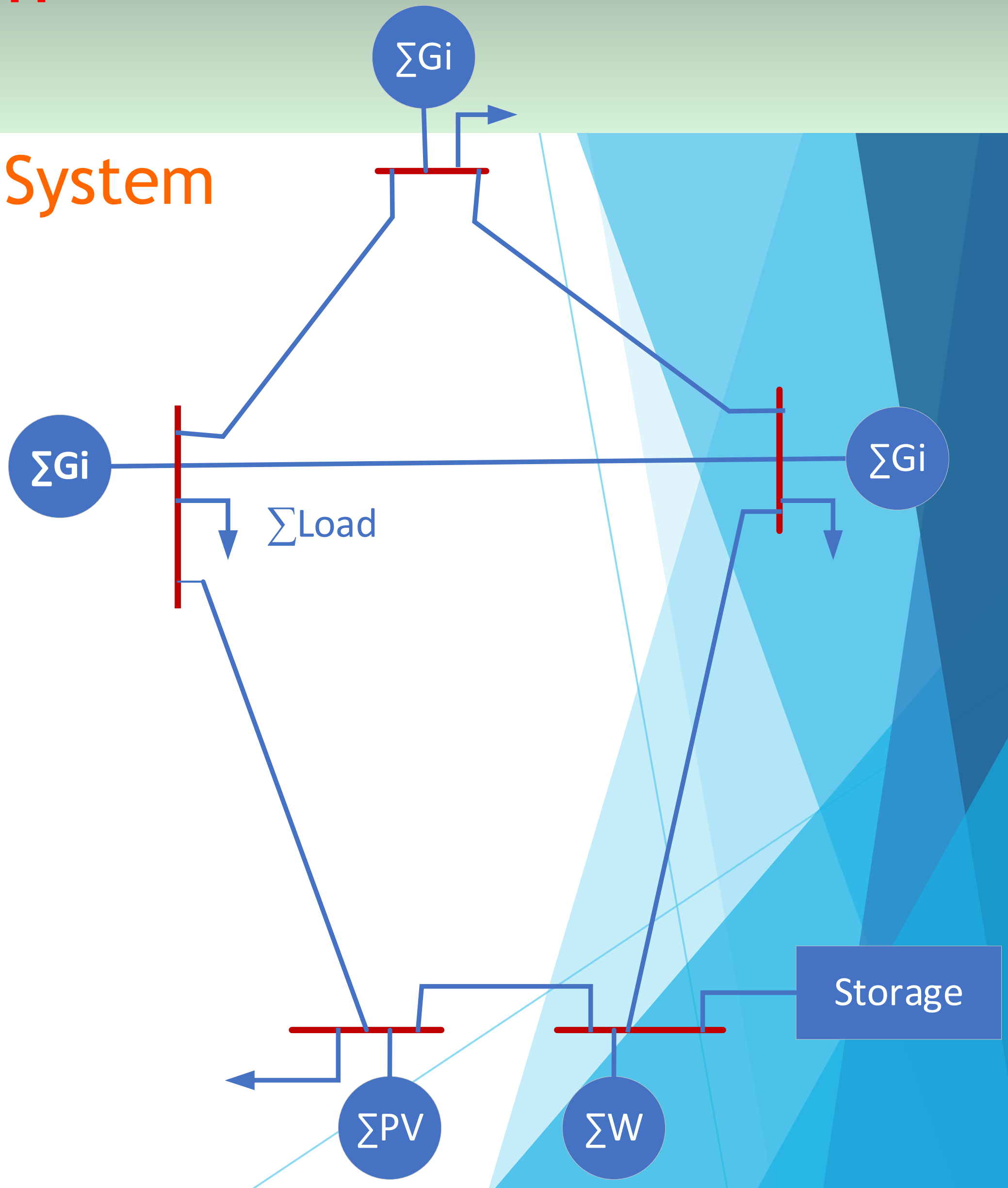
Optimization Problem

Min:

$$Total\ C = \sum_{i=1}^{n} (GC_{i,cap} + GC_{i,OM}) + (TC_{i,cap} + TC_{i,OM}) + EC + ESS + OutC$$

Constraints:

- Generation constraints
- Power balance
- RPO constraints



3. Integrated GTEP: Illustration

3.1 Adding the EBET in Planning

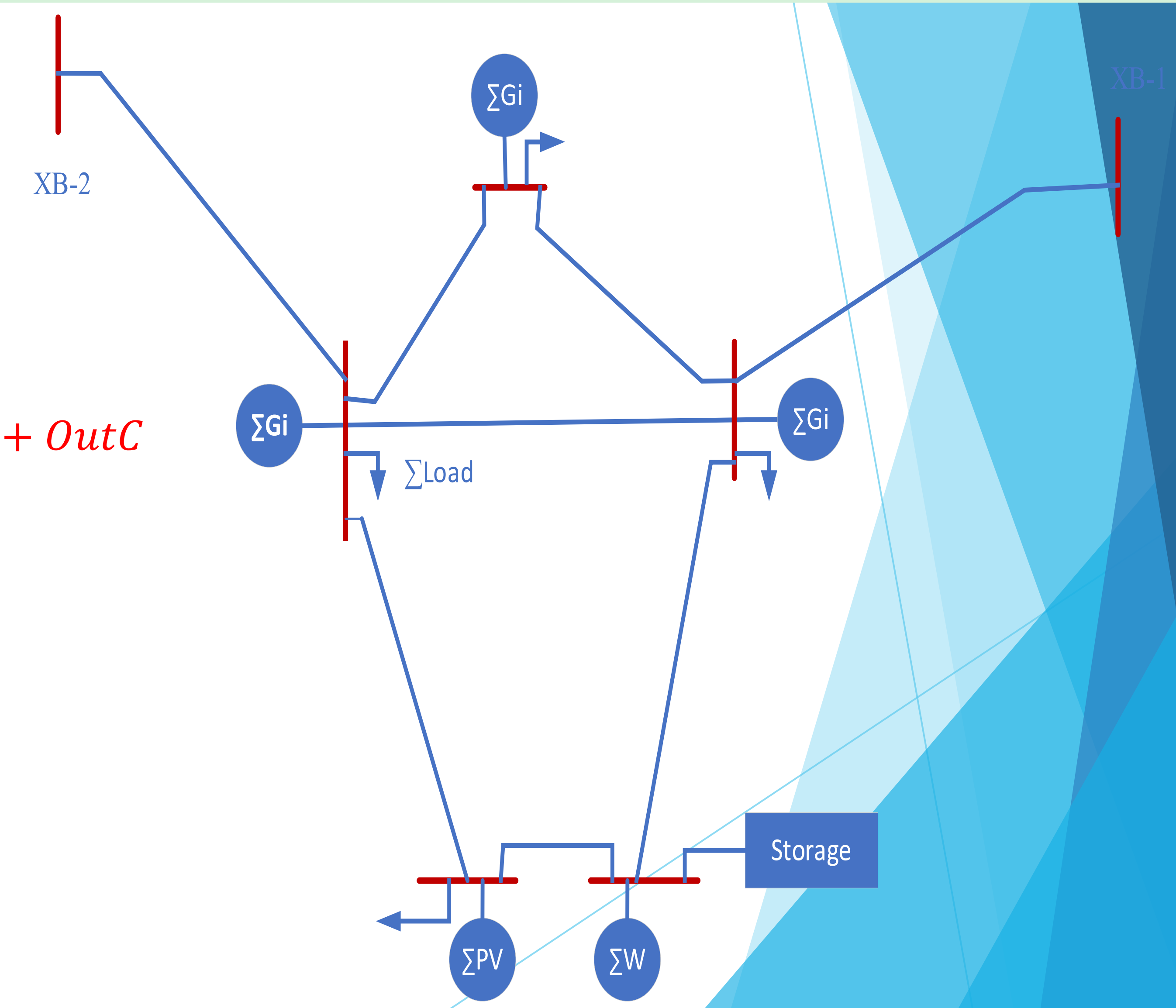
Optimization Problem

Min:

$$Total\ C = \sum_{i=1}^{n} \begin{matrix} (GC_{i,cap} + GC_{i,OM}) \\ +(TC_{i,cap} + TC_{i,OM}) + EC + ESS + OutC \end{matrix}$$

New Constraints:

- RPO constraints
- CBET constraints
- Ramping Up Constraints
- Ramping Down Constraints
- Export and Import Constraints



3. Integrated GTEP: Illustration

Results of Planning

- Solution for the TEP may not be cost effective
- Cross subsidy and/or other incentive required to promote the TEP

3. Integrated GTEP: Nepal

Load Forecast

Table 6: Total load demand in different scenarios[5]

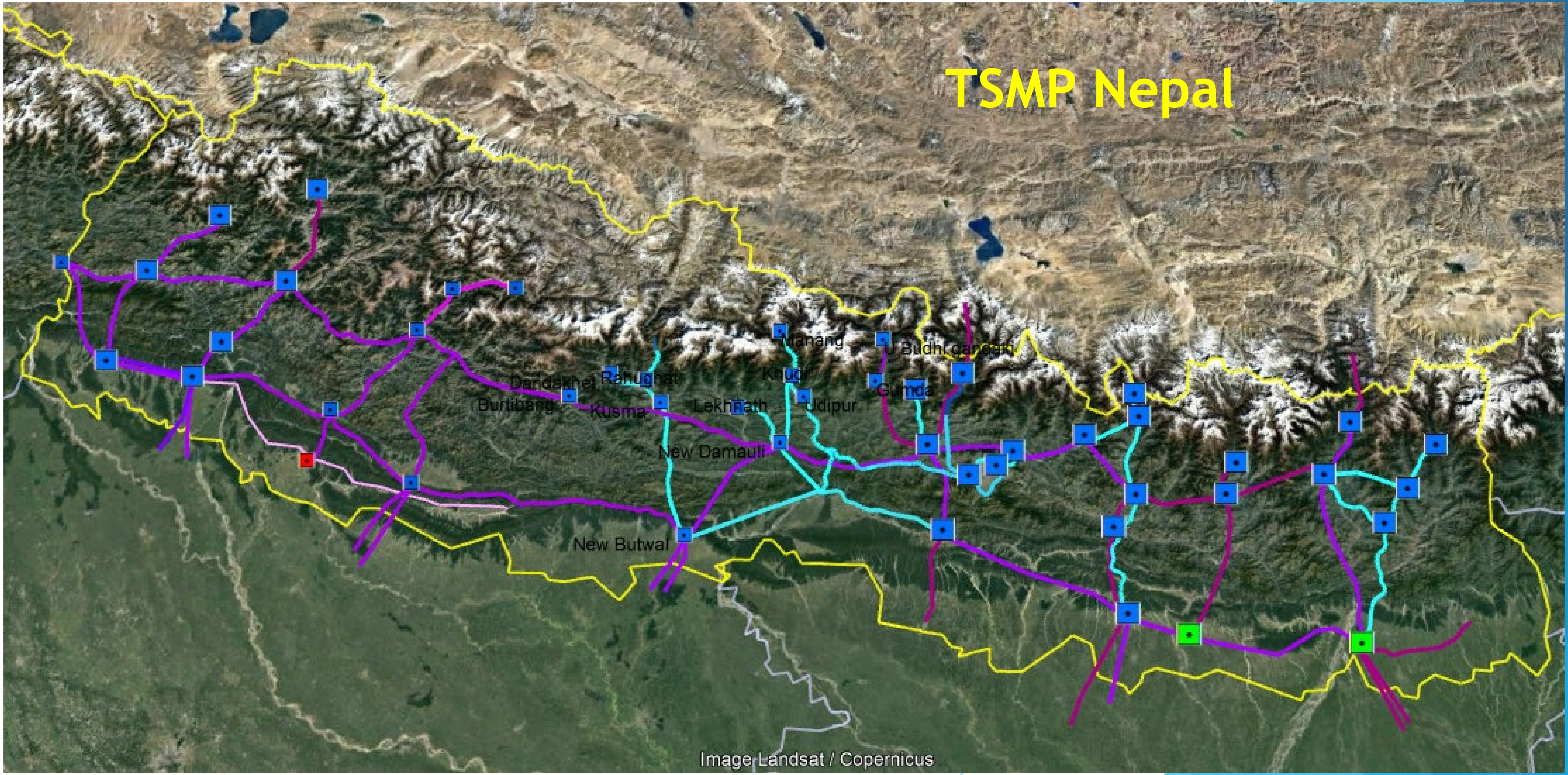
	BAU 4.50%	Reference Scenario 7.20%	High Scenario 9.20%	7.2% growth with policy intervention	9.2% growth with policy intervention
2020	4338.32	2225.65	2338.80	4080.75	4199.67
2025	7419.09	4078.60	4540.37	6155.51	6658.61
2030	11457.67	6848.43	8195.05	9696.24	11323.55
2035	16977.56	11171.23	14539.20	14206.80	18017.18
2040	24552.9	18137.67	26028.24	22490.50	31638.14

3. Integrated GTEP: Nepal

Expected generation Expansion: 2030-2035

Item	Capacity in MW
Installed Capacity	2550
Applied for PPA	11000+
Application for Survey	7600+
IBN Projects	4200
Expected Installed (2030-2035)	17000
Available for Export	10000+
Solar PV (Survey+UC)	900

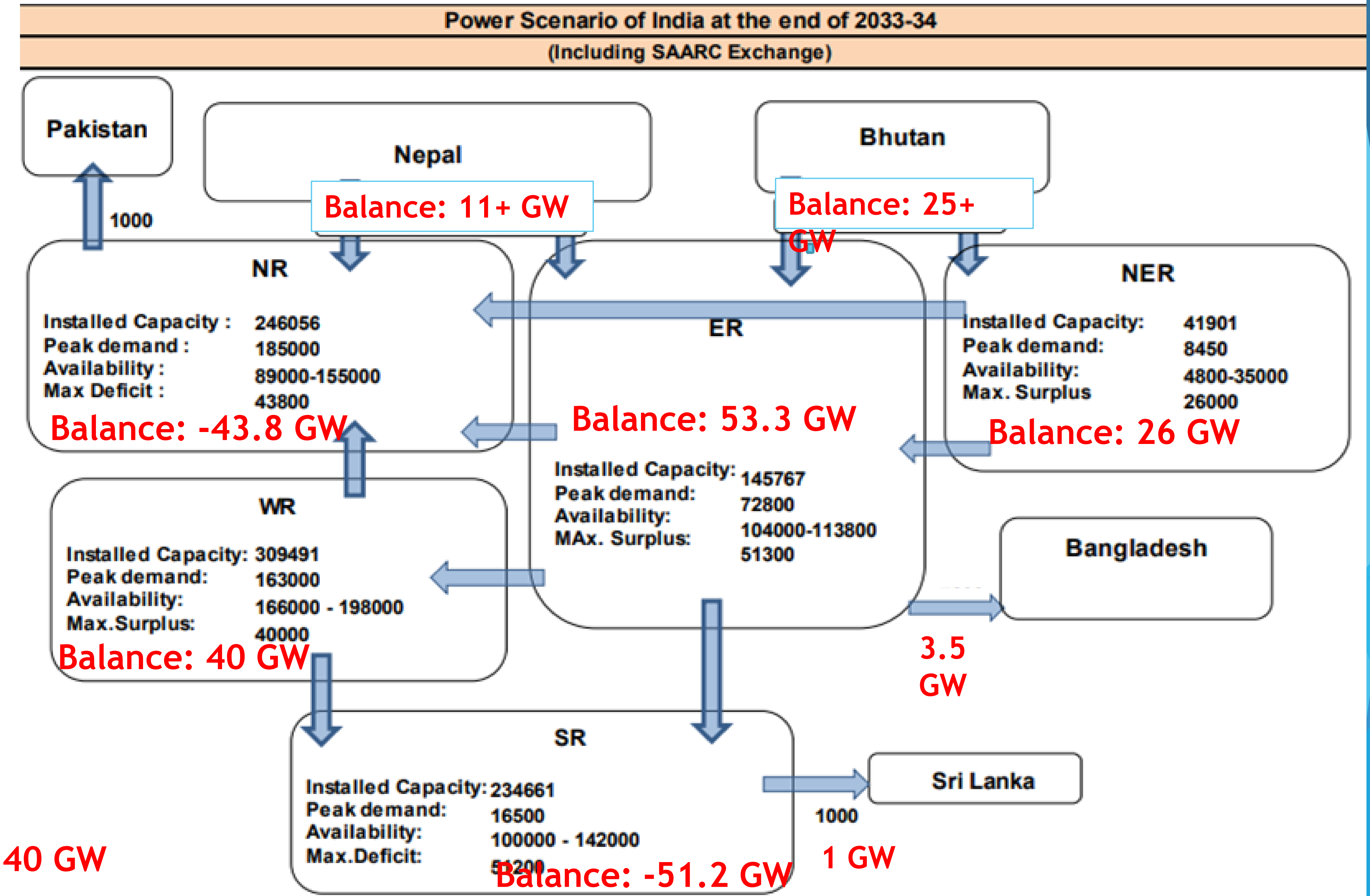
4. Integrated GTEP in SAR



4. Integrated GTEP in SAR

Tap the Benefits from the Features:

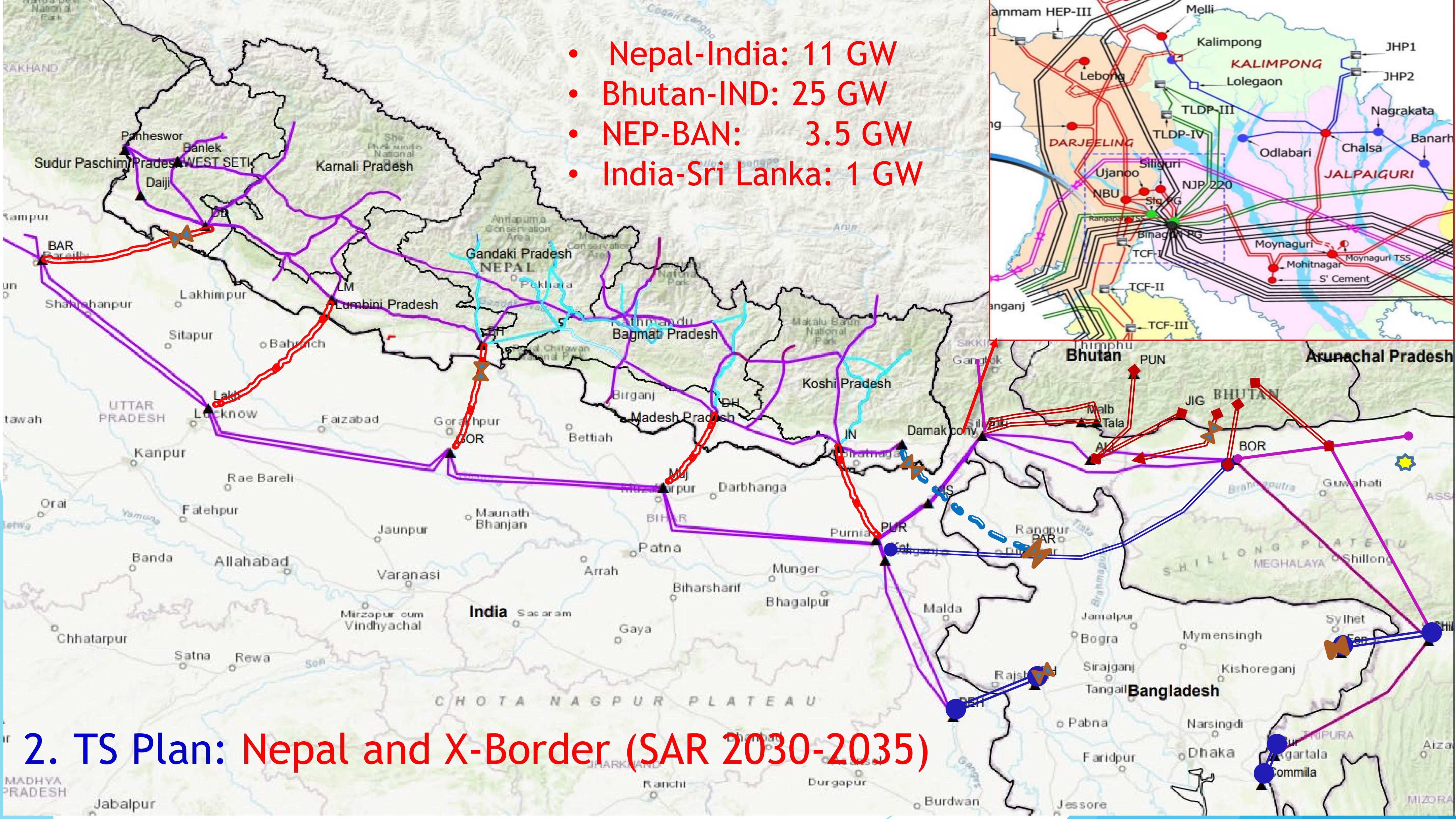
- ✓ Complement the Power use pattern
- ✓ Complement the Energy Generation pattern
- ✓ Complement the Geography
- ✓ Decrease the Carbon Emission
- ✓ Decrease the reserve obligation
- ✓ Increase the quality and reliability of supply
- ✓ Facilitation of Renewable integration
- ✓ Economic Benefit


Power Scenario of India at the end of 2033-34
(Including SAARC Exchange)
Pakistan
Nepal
Bhutan
1000
Balance: 11+ GW
Balance: 25+ GW
NR
Installed Capacity : 246056
Peak demand : 185000
Availability : 89000-155000
Max Deficit : 43800
Balance: -43.8 GW
ER
Balance: 53.3 GW
Installed Capacity: 145767
Peak demand: 72800
Availability: 104000-113800
MAx. Surplus: 51300
NER
Installed Capacity: 41901
Peak demand: 8450
Availability: 4800-35000
Max. Surplus 26000
Balance: 26 GW
Bangladesh
3.5 GW
WR
Installed Capacity: 309491
Peak demand: 163000
Availability: 166000 - 198000
Max.Surplus: 40000
Balance: 40 GW
SR
Installed Capacity: 234661
Peak demand: 16500
Availability: 100000 - 142000
Max.Deficit: 51200
Balance: -51.2 GW
Sri Lanka
1000
1 GW

CBET: 40 GW

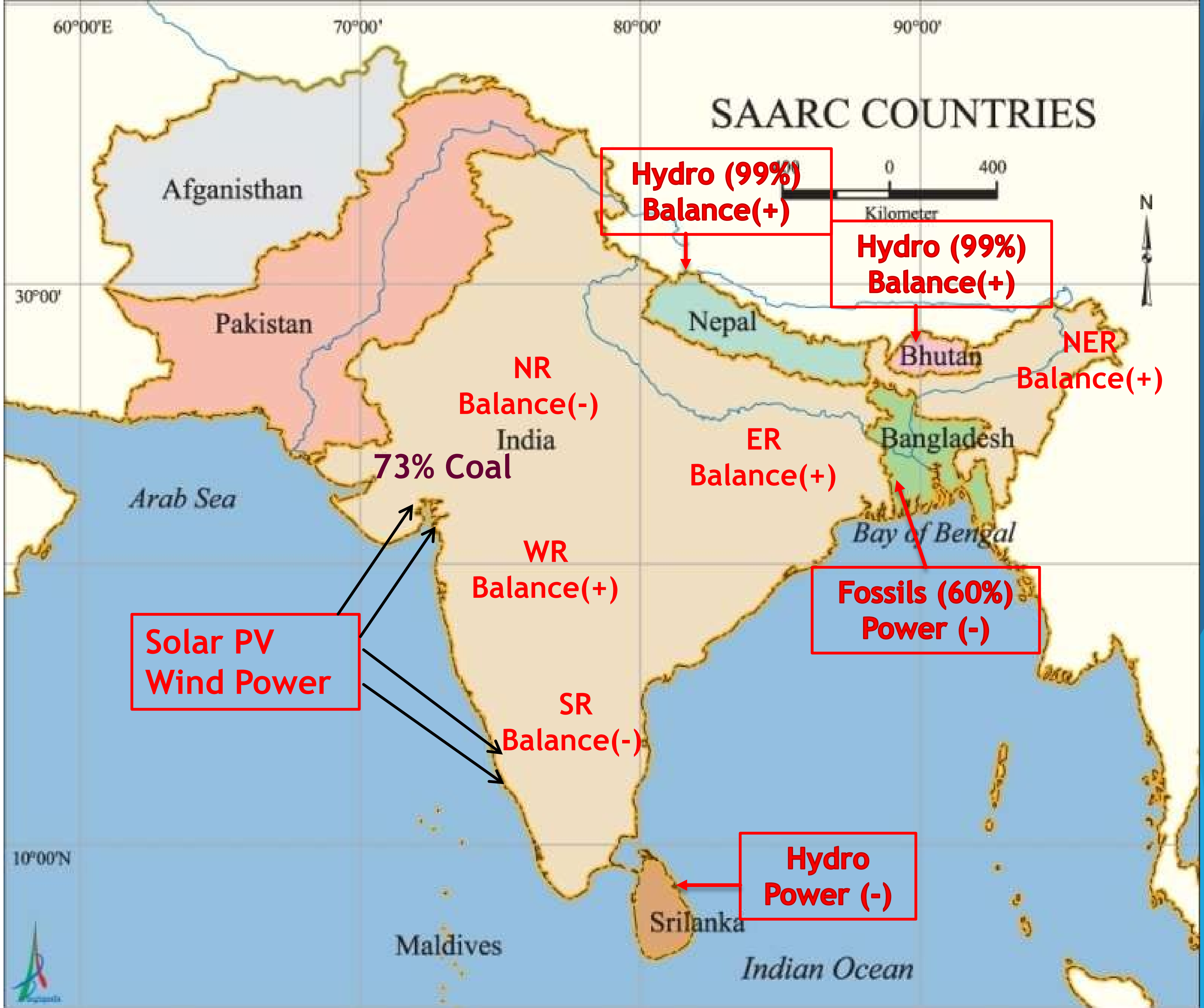
2. TS Plan: Nepal and X-Border (SAR 2030-2035)

- Nepal-India: 11 GW
- Bhutan-IND: 25 GW
- NEP-BAN: 3.5 GW
- India-Sri Lanka: 1 GW



Integrating Other Renewables

- Energy Mix in SAR
- Hydro in Nepal and Bhutan support
  - Grid Sustainability
  - Increase Penetration level of Wind Solar in SAR



4. Outlook and Way forward

- Go beyond Minimum G&T costs and implement a multi-value benefit framework;
- Plan for the long term and Diverse Perspective;
- Embrace uncertainty and adopt established methods to deal with it;
- Quantify resource adequacy and resilience benefits;
- Reap the benefits of Demand and Generation Complements in SAR
- Plan interregional projects: Low Reserve, Low Storage, Smoothening the intermittency.