Development of a Potential Regional Hydropower Plant in South Asia: A Pre-feasibility Study

https://www.google.com.np/#q=South+asia+map

http://www.nccprojects.com/site_media/img/photos/Qatar_2x400kV_DC_OHTL_for_Kahramaa.jpg

Presentation of Pre-feasibility Study Report by

Shyam S. Shrestha

Presentation Outline

- Pre-feasibility study objectives and highlights;
- Methodology;
- Review of electricity laws and regulations in South Asia;
- Power market in South Asia;
- Export oriented hydropower projects in South Asia;
- Economic and financial feasibility;
- Socio-economic and environmental issues;
- Conclusions and recommendations.

Pre-feasibility Study Objective and Scope of Work

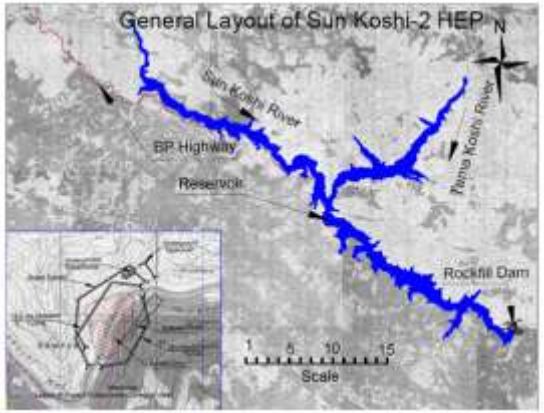
Objective:

- Prepare a pre-feasibility study for the development of a potential hydropower plant in South Asia ;

Scope of Work:

- Identify at least three suitable hydropower project sites; considering Size (in terms of energy), Access and Location (in terms of site and transmission line);
- Prepare project layout drawings and preliminary plant design;
- Prepare feasibility level cost estimates;
- Develop a typical power purchase agreement (PPA);
- Prepare a business model for regional power sharing;
- Assess proposed sites considering cross-border trade;
- Pre-feasibility level economic and financial evaluation of alternatives;
- Evaluate financing options for project construction.

http://www.vmapas.com/Asia/South_Asia_Political_Map_2004.jpg/maps-en.html?map_viewMap=1



Pre-feasibility Study Highlights

Development of a Potential Regional Hydropower Plant in South Asia:

A Pre-feasibility Study

Installed Capacity and Access to Electricity

Population in South Asia:

- 1,649.28 million (1/5th % of world population)

Installed Capacity:

- 276,365 MW (69% is thermal generation);

Access to Electricity:

Afghanistan	15.6%
Bangladesh	41%
Bhutan	60%
India	66.3%
Maldives	100%
Nepal	4 3.6%
Pakistan	62.4%
Sri Lanka	88%

http://apod.nasa.gov/apod/image/0011/earthlights2_dmsp_big.jpg

More than 1/3rd (37.5%) or 618.81 Million population in South Asia have no access to electricity;

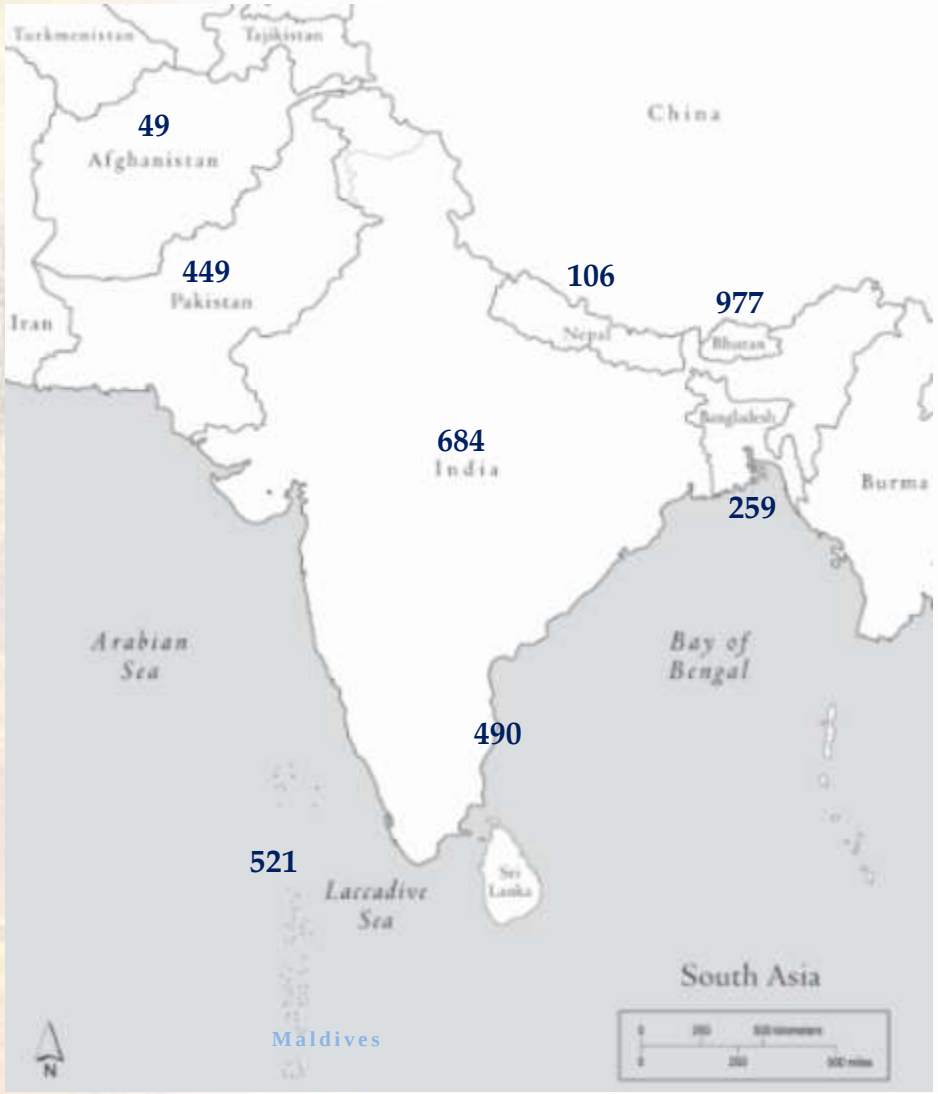
Per Capita Electricity Consumption

Low Per Capita Electricity Consumption:

- Afghanistan - 49 kWh/person/year
- Bangladesh - 259 kWh/person/year
- Bhutan - 977 kWh/person/year
- India - 684 kWh/person/year
- Maldives - 521 kWh/person/year
- Nepal - 106 kWh/person/year
- Pakistan - 449 kWh/person/year
- Sri Lanka - 490 kWh/person/year

South Asian Average 517 kWh/person/year and World Average 2,782 kWh/person/year.

Source: IRENA and World Bank Little Green Data Book 2014



http://alabamamaps.ua.edu/contemporarymaps/world/asia/index2.html

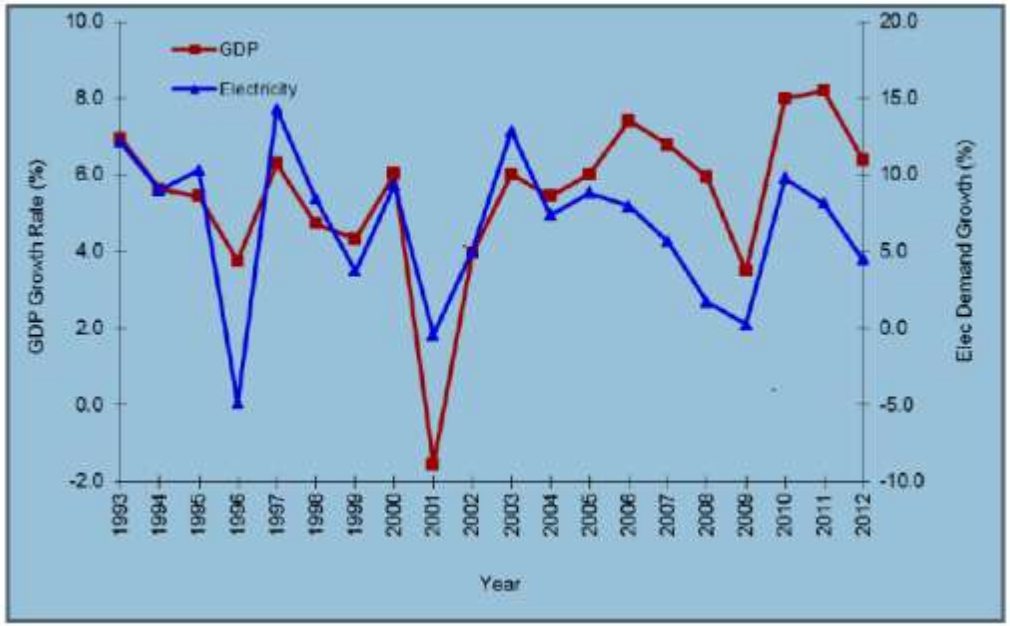
Development of a Potential Regional Hydropower Plant in South Asia: A Pre-feasibility Study

Electricity and its Correlation with Economy

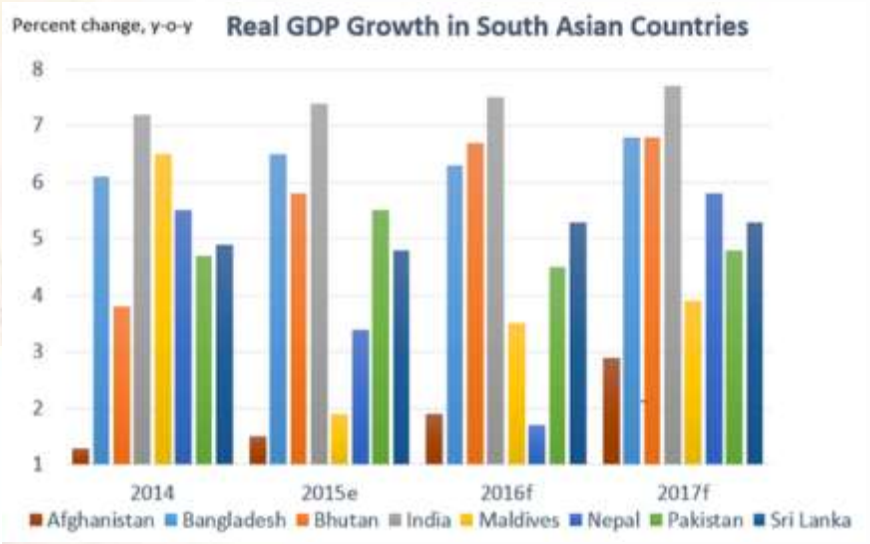
Electricity and Economy:

- Electricity demand growth rate has a direct correlation with the growth rate of the country's economy;

GDP Growth Rate and Electricity Sales:



Source: Long Term Generation Expansion Plan 2013 – 2032 , Ceylon Electricity Board



For example in India - At a GDP growth rate of 8% and 9%, the country needs to add power plant capacity of 203 GW and 275 GW in 2031 and 2032, respectively;

Energy Resources of South Asia

Hydropower Resource:

- 3500 km Hindu Kush Himalaya abut Afghanistan, Pakistan, India, Nepal and Bhutan has huge water resources and the mountain topography with valleys suitable for hydropower development;
- Out of 10 major rivers originating from the Hindu Kush Himalaya, rivers in South Asia are Amu Darya, Indus, Ganga (Padma), and Brahmaputra (Jamuna).

Country	Potential	Techno-economically Feasible	Present Generation	Generation Capacity %
Afghanistan	23,000 MW	18,400 MW	298 MW	1.62%
Bangladesh	1,897 MW	775 MW	220 MW	28.39%
Bhutan	30,000 MW	23,760 MW	1,484 MW	6.25%
India	150,000 MW	84,400 MW	40,195 MW	47.62%
Nepal	83,000 MW	42,130 MW	743 MW	1.76 %
Pakistan	100,000 MW	60,000 MW	6,928 MW	11.54%
Sri Lanka	4,000 MW	2,423 MW	1,628 MW	67.19%
Total	391,897 MW	231,888 MW	51,496 MW	22.21%

http://www.mapsofworld.com/asia/south-asia-geography.html

- The highest percentage is in Sri Lanka (67.19%) followed by India (47.62%)

Development of a Potential Regional Hydropower Plant in South Asia:

A Pre-feasibility Study

Energy Resources of South Asia Cont ..

Hydropower Export Potential :

- India and Pakistan - Huge hydropower potential (but as per the present demand there would not be surplus for export);
- Nepal and Bhutan - Hydropower potential excess of their demand.

Coal:

- India, Pakistan and Bangladesh has signification coal reserves (others do not have viable quantities);
- India and Pakistan combined has 7% of global total coal reserve;

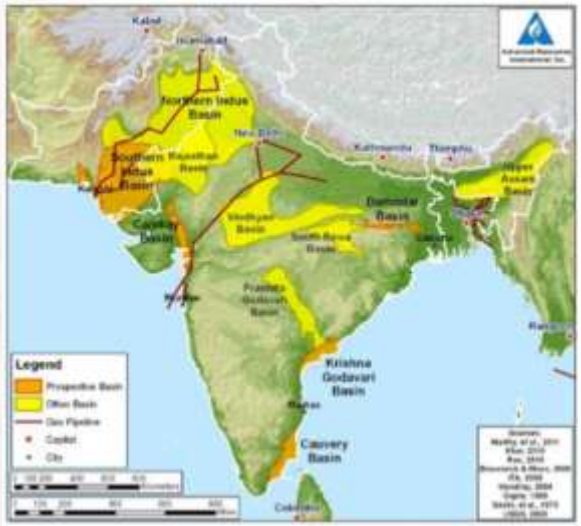
Natural Gas:

- India (0.7%), Pakistan (0.3%) and Bangladesh (0.1%) - 1.1% of the global total reserve;

Oil:

- India - 0.3% of the global total reserve;

Source: World Energy Council 2015



Source: US Energy Information Agency

Energy Resources of South Asia Cont ..

Renewable Energy Resources:

Renewable Energy Potential	India	Pakistan	Sri Lanka
Wind	45,000 MW	1,100 - 40,000 MW	24,000 MW
Solar	50,000 MW	Very Large	Large
Biogas plants	15,000 Units	~ 1,000 Units	300 Units
Ocean thermal	50,000 MW	NA	NA
Sea wave	20,000 MW	NA	NA
Tidal	9,000 MW	NA	NA

Source: Regional Energy Security for South Asia, Regional Report, SARI/Energy

NA = Not Availabe

http://www.altenergystocks.com/archives/ocean_power/

http://www.energynext.in/wp-content/uploads/2014/11/csp-Page-62.jpg

http://www.nepcindia.co.in/images/gallery/gujarat/windfarm1.jpg

Development of a Potential Regional Hydropower Plant in South Asia:

A Pre-feasibility Study

Power Supply and Demand Gap

	Afghanistan	Bangladesh	Bhutan	India	Maldives	Nepal	Pakistan	Sri Lanka
Hydropower	298 MW	220 MW	1484 MW	40,195 MW	-	743 MW	6,928 MW	1,628 MW
Nuclear	-	-	-	4,780 MW	-	-	787 MW	-
Renewables	7 MW	-	-	29,463 MW	-	-	50 MW	99 MW
Thermal	285 MW	8,317 MW	-	163,305 MW	245 MW	53 MW	15,852 MW	1,635 MW
Total	590 MW	8,537 MW	1,484 MW	237,743 MW	245 MW	787 MW	23,617 MW	3,362 MW
Grand Total								
Principal Resource	Hydro power	Gas and Coal	Hydro power	Coal	Biomass	Hydro power	Gas and lignite	Wind Biomass
Demand and Supply Gap %	-	About 25%	Significant surplus	>15% Energy Deficit	-	Peak and base deficit	>25% Peak Demand Deficit	Some Deficit

Source: AF-Mercados EMI 2011, CEB Statistical Digest 2013; Annual Report 2012-13, CEA; Pakistan Energy Yearbook 2012; NEA Year in Review, Fiscal Year 2013/2014; Annual Report 2012-13, Bangladesh Power Development Board; Annual Report 2013, Bhutan Power Corporation Limited

- Pakistan - Peak demand deficit >25% (highest in the region).
- Bangladesh - Peak and base deficit is 25%.
- India - Energy deficit >15%.

Electricity Supply Demand Gap (2012):

- India - Peak shortage 12,159 MW;
- Pakistan - Peak shortage 5,500 MW;
- Bangladesh - Peak shortage 1,048 MW.

Cumulative Gap 18,707 MW

https://www.youtube.com/watch?v=Em1crnEt45Q

Development of a Potential Regional Hydropower Plant in South Asia: A Pre-feasibility Study

Identified Projects

Firstly Identified Project:

- 10,800 MW Karnali Chisapani Multi-purpose Storage Project (project was not found financially feasible);

Project	Installed Capacity	Project Scheme	Water Source	Dam Height	Catchment Area
Sunkoshi 2	1,100 MW	Storage	Monsoon and snowfall	166 m	10,221.88 km^2
Budhi Gandaki	1,000 MW	Storage	Monsoon and snowfall	263 m	6,190.24 km^2
Sunkoshi 3	600 MW	Storage	Monsoon and snowfall	160 m	5,005 km^2

- All 3 projects accessible by road;
- Department of Hydrology and Meteorology Nepal river gauging data are available for all 3 projects;
- All 3 projects are located in the middle hills of Nepal.
  - Directly affected population is less (> 15,000 in Sunkoshi 2 Storage Project);
  - 7,000 ha of cultivated land, forest, grassland, barren land will be affected;
  - Resettlement would not be difficult.

http://www.himalayanriverfun.com/information/riversystem.php

Cost Estimate and Electricity Tariff

Cost Estimate and Energy Generation:

Project	Cost Estimate	Energy Generation	Energy per MW	Cost per kW
1,100 MW Sunkoshi 2	US$ 1,639 Million	3,795 GWh/year	3.45	US$ 1,490
1,000 MW Budhi Gandaki	US$ 2,202 Million	4,142 GWh/year	4.14	US$ 1,967
600 MW Sunkoshi 3	US$ 968 Million	2,051 GWh/year	3.42	US$ 1,613

Tariff Determination:

- Electricity tariff was determined by using fixed cost components and standard assumptions;
- Key Assumptions:
  - Debt: Equity Ratio: 70:30;
  - Return on Equity: 20%;
  - Prevailing interest rate: 11%.

Minimum Tariff:

- USc 8.58/kWh (Average for peaking and non-peaking)

Financial Analysis

Objective:

- Verification of project's profitability and sustainability, both of which are evaluated from a strictly financial perspective;

Approach:

- Analysis is based on discounted cash flow (DCF) method;
- Calculation of Project IRR, NPV, B/C Ratio and cash flow;

Data and Assumptions for Financial Analysis (Base Case)			
Description	Sunkoshi 2 Storage Project	Sunkoshi 3 Storage Project	Budhi Gandaki Storage Project
Project Capacity	1,100 MW	600 MW	1,000 MW
Average Power Generation	3,795.09 GWh/year	2,051.22 GWh/year	4,142.41 GWh/year
Debt : Equity Ratio	70:30	70:30	70:30
Interest Rate	11%	11%	11%
Project Cost (at 2015 price level)	US$ 1,485.71million	US$ 877.37 million	US$ 1,996.59 million
Total Project Cost (Including IDC)	US$ 1,638.68 million	US$ 976.70 million	US$ 2,202.15 million
Equity	US$ 494.12 million	US$ 291.25 million	US$ 660.64 million
Debt	US$ 1,152.94 million	US$ 679.59 million	US$ 1,541.51 million
Envisaged COD	2024	2024	2024
Construction (starting 2019)	6 years	6 years	6 years

Financial Indicators:

Indicators	Sunkoshi 2	Budhi Gandaki	Sunkoshi 3
Internal Rate of Return (IRR)	13.76%	11.23%	8.22%
NPV at 10% Discount Rate	US$ 112,283 Million	US$ 5,494 Million	Negative
Benefit Cost Ratio	1.38	1.03	0.62

Economic Analysis

Objective:

- Demonstrate that project implementation justifies efficient use of scarce economic resources;

Approach:

- Analysis is based on discounted cash flow (DCF) method;
- Calculation of Project Economic IRR, NPV, B/C Ratio;

Key Assumptions:

- Emission benefit calculated for 10% electricity use in Nepal and 90% export;
- Carbon reduction revenue at US$ 23.24/tCO_2/year (Syanpse Energy Economics Inc.

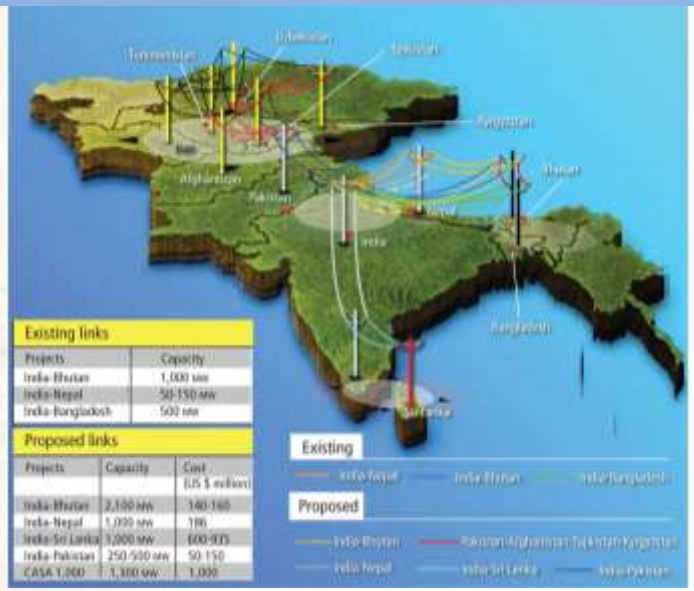
Economic Indicators :

Description/Indicators	Sunkoshi 2	Budhi Gandaki	Sunkoshi 3
Average GHG emission reduction	3.15 Million tCO_2/year	3.44 Million tCO_2/year	1.7 Million tCO_2/year
Carbon reduction revenue	US$ 73.15 Million/year	US$ 79.85 Million/year	US$ 39.54 Million/year
Capital cost of coal plant	US$ 825 Million	US$ 750 Million	US$ 450 Million
Fuel cost	US$ 153.30 Million/year	US$ 139.36 Million/year	US$ 83.62 Million/year
EIRR	30%	16.18%	25.66%
Economic B/C Ratio	1.58	1.12	1.46

Transmission Infrastructure

Power Transmission Infrastructure:

- India - Only country having cross-border inter-connections with Bangladesh, Bhutan, and Nepal;
- India and Sri Lanka - Under sea transmission line is under study;
- India is in a unique position - Can play key role in the promotion of power trade in South Asia.



Source: Vivek Bhardwaj, CSE

Proposed Transmission Infrastructure:

- +/- 500 kV HVDC
  - Transmission losses reduced to 2% for 1,000 km length;
  - Construction cost is less than AC system as right of way is 50 m.

Electricity tariff with transmission cost:

- Feasible - India, Pakistan and Bangladesh;

Per kWh Electricity Tariff and Transmission Line Cost

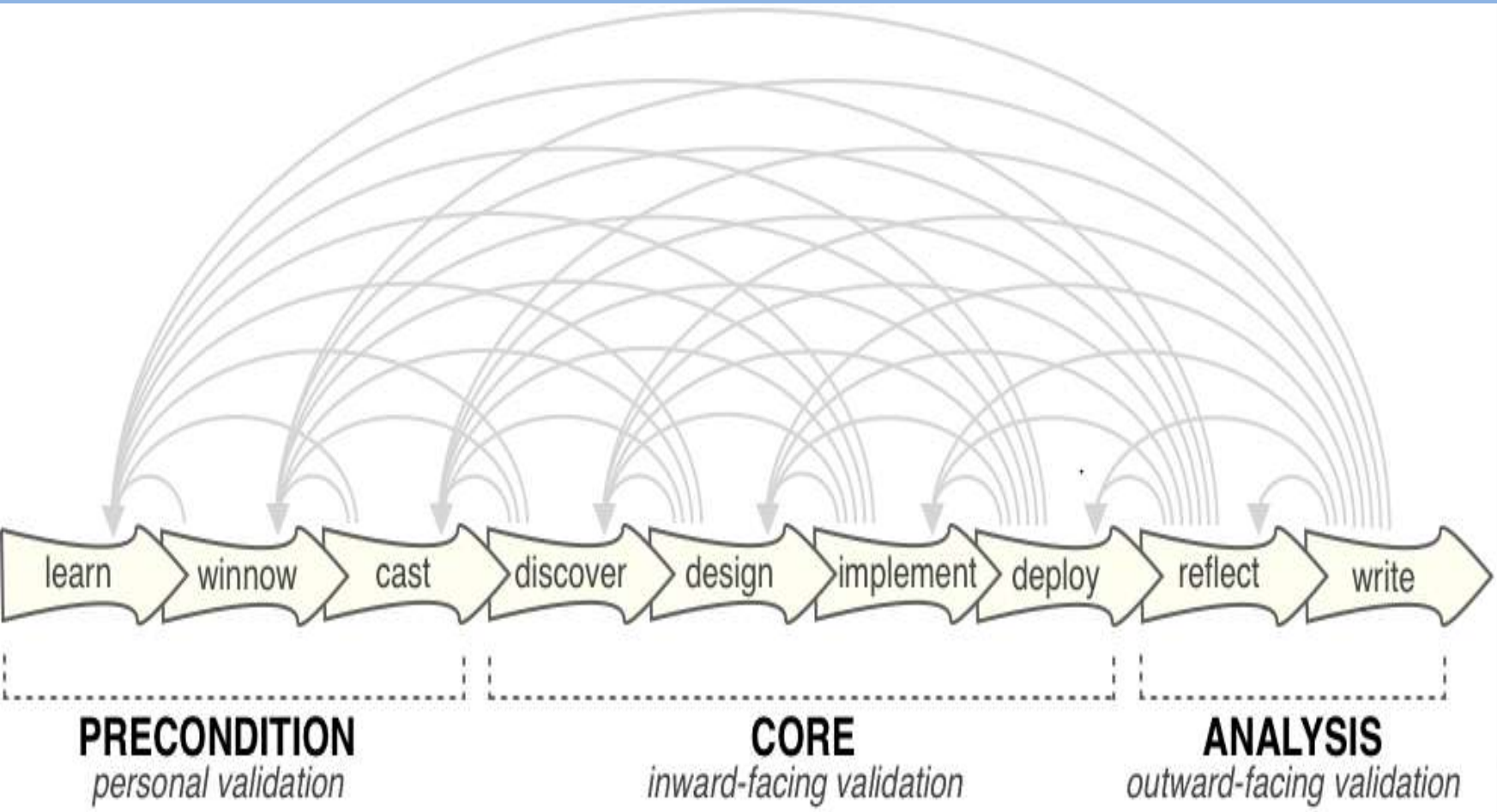
Description	Afghanistan	Bangladesh	India	Pakistan
Distance in km. from Proposed Project	1,850	350	125	1,250
Generation Cost USc/kWh	6.0	6.96	8.0 – 13.6	13.2 (Peaking) 9.2 (Non-peaking)
Electricity Tariff (Proposed Project) USc/kWh	8.58	8.58	8.58	8.58
Transmission Cost USc/kWh	5.38	1.02	0.36	3.63
Final Electricity Tariff USc/kWh	13.96	9.60	8.58	12.21

Sources: FICCI Lack of Affordable & Quality Power: Shackling India's Growth Story, Casa 1000 Study, Casa 1000 Study, Energy Sector in Bangladesh Study by IIDS

Summary

- Wide gap exists between supply of electricity generated and demand in the region;
- The cumulative supply and demand gap in India, Pakistan and Bangladesh is 18,707 MW. This creates huge market for potential power producers such as Nepal and Bhutan;
- The Sunkoshi 2 Storage Project has the highest FIRR of 13.67%, which equals to WACC of 13.7%, and the B/C Ratio is 1.38;
- Similarly, Sunkoshi 2 Storage Project has the highest EIRR at 30%;
- Therefore, Sunkoshi 2 Storage Project is both financially and economically feasible;
- It is envisaged that the pre-construction works require 2 years, and another 6 years is required for project completion;
- Rajasthan Sun Technique Concentrated Solar Project financing model could be useful for replication, where combined debt is from foreign public institutions and local private investment;
- SARPP model regional pool will add value to peaking power generation by matching with the region's peak load demand timings

Study Methodology



Study Methodology Continued …

Major River Basins in Nepal:

- Koshi
- Karnali
- Gandaki
- Mahakali

https://upload.wikimedia.org/wikipedia/commons/3/34/Ganges-Brahmaputra-Meghna_basins.jpg

River Basin	Area (km^2)	River Source	Remarks
Koshi	60,400	Monsoon and snowmelt	In Nepal 27,863 km^2 In China 32,537 km^2
Karnali	43,679	Monsoon and snowmelt	In Nepal 41,058 km^2 In China 2,621 km^2
Gandaki	34,960	Monsoon and snowmelt	In Nepal 29,626 km^2 In China 5,334 km^2
Mahakali	15,260	Monsoon and snowmelt	In Nepal 5,317 km^2 In India 9,943 km^2

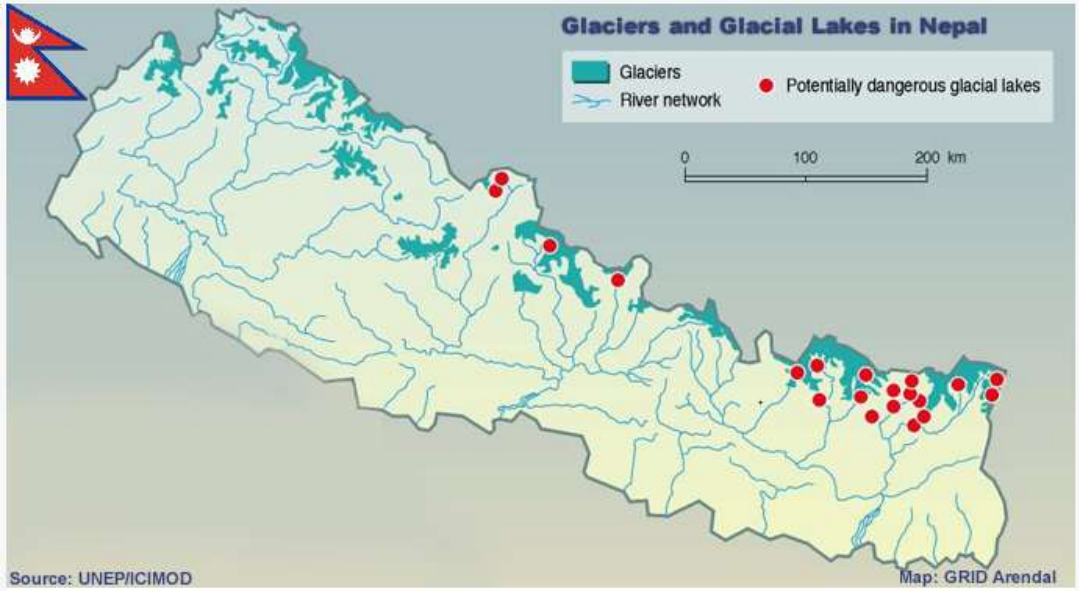
Source: M. R. Gautam & K. Acharya (2012) Streamflow trends in Nepal, Hydrological Sciences Journal

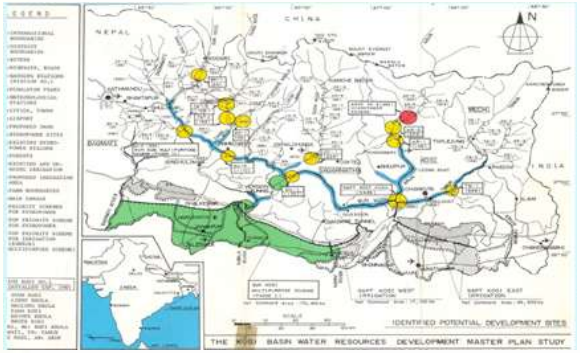
Study Methodology Continued …

Study completely based on published reports, information and maps:

Reports reviewed:

- Master Plan Study on the Koshi River (1985);
- Master Plan Study on Karnali and Mahakali River Basins;
- Master Plan Study on Gandaki River Basin (UNDP Assistance 1979);
- Feasibility Study of Karnali Chisapani Project (1989);
- Nationwide Master Plan Study on Storage Type Hydropower Development in Nepal (2014).





Development of a Potential Regional Hydropower Plant in South Asia:

A Pre-feasibility Study

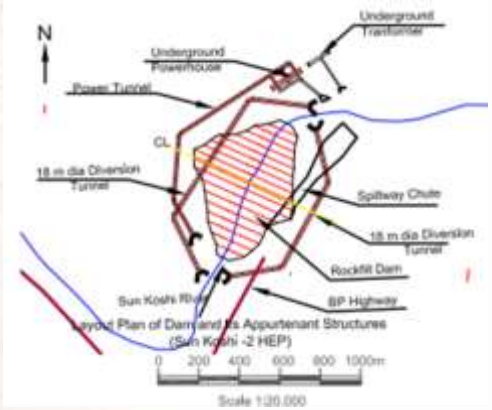
Study Methodology Continued …

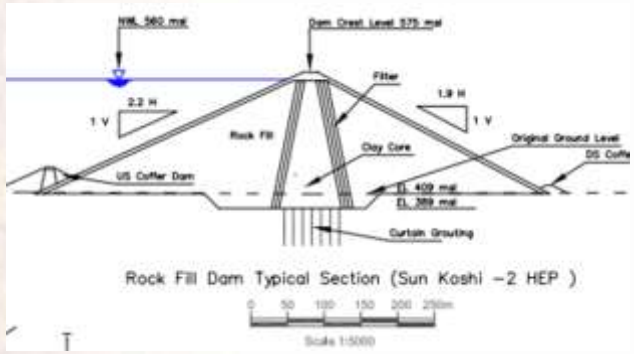
Topographical Maps:

- 1:50,000 scale map produced by the Department of Survey of Nepal Government;

Mapping:

- 1:20,000 scale mapping for layout plan of dam and appurtenant structures;
- 1:5,000 Scale Mapping for design of dam, powerhouse, tunnel, intake etc.



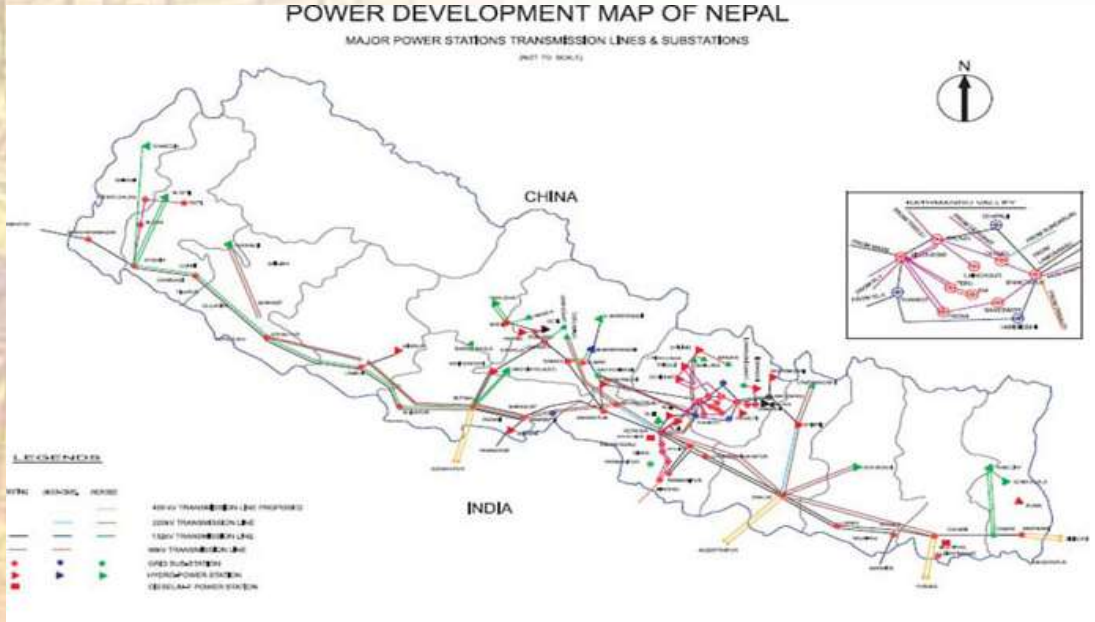


Study Methodology Continued …

Other Maps:

- Google Earth;

- Maps of South Asian countries (Political, rivers, transmission line etc.).



http://www.sari-energy.org/pagefiles/countries/nepal_energy_detail.asp

Study Methodology Continued …

River Source:

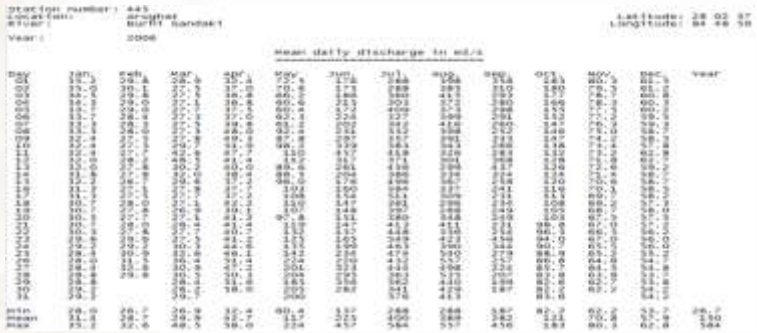
- Summer monsoon contributes about 80% of annual precipitation in Nepal.
- Snowmelt is the primary source of pre-monsoon flow for rivers with catchment above snowline;

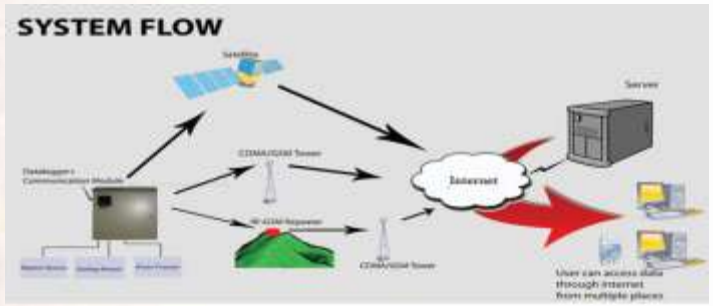
Hydrological and Meteorological Data:

- Data used for the present study are from Department of Hydrology and Meteorology (DHM) of Nepal. The DHM records and publishes meteorological and streamflow data of rivers in Nepal.

Length of Data Stream:

- Budi Gandaki Station at Arughat (from 1963);
- Sunkoshi Station at Khurkot (from 1967);





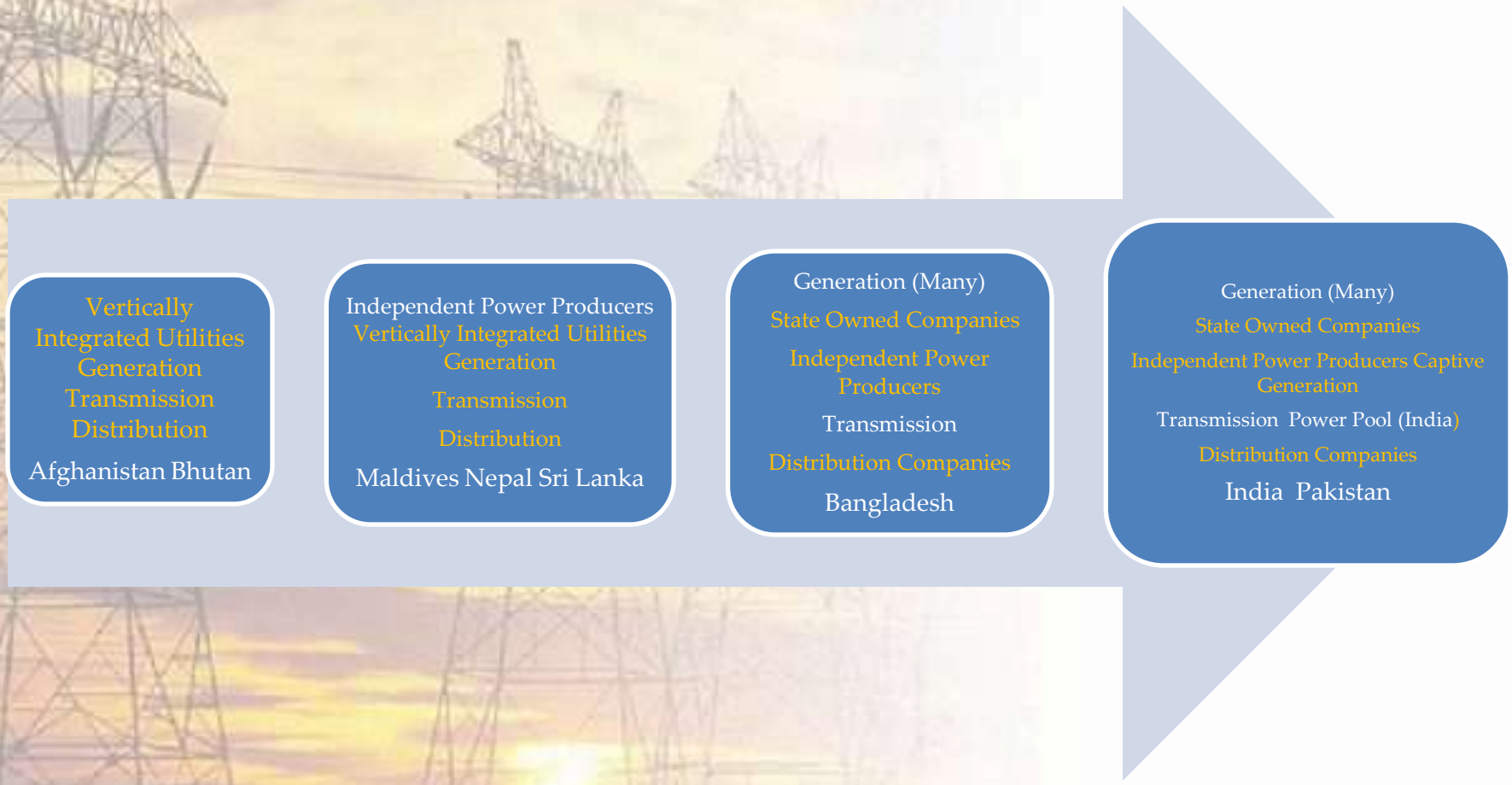
Real time online data collection using Data Logger

Review of Electrical Laws and Regulations

Review of Electricity Laws and Regulations

Country	Key Policy	Act	Regulatory Institution
Afghanistan	Electricity Sector Policy 2003	Law "For Using Electricity" 1986	Draft Electricity Law has proposed Afghanistan Electricity Regulatory Authority (AEFA)
Bangladesh	National Energy Policy, 2005	Electricity Act, 1910; Private Sector General Policy, 1996; Bangladesh Energy Regulatory Commission Act 2003	Bangladesh Energy Regulatory Commission (BERC)
Bhutan	Bhutan Sustainable Hydropower Development Policy, 2008	Electricity Act, 2001	Bhutan Electricity Authority (BEA)
India	National Electricity Policy, 2005	Electricity Act, 2003	Central Electricity Regulatory Commission (CERC), and Electricity Commissions in most States
Maldives	National Energy Policy & Strategy, 2010	Electricity/Energy Act, yet to be formulated	Maldives Energy Authority
Nepal	Hydropower Development Policy, 2001	Electricity Act, 1992	Draft Nepal Electricity Regulation Commission Act, 2065
Pakistan	National Power Policy, 2013	Electricity Act 1910; Regulation of Generation, Transmission, and Distribution of Electric Power Act 1997	National Electric Power Regulatory Authority (NEPRA)
Sri Lanka	National Energy Policy & Strategies of Sri Lanka, 2008	Sri Lanka Electricity Act, 2009; Public Utilities Commission Act, 2009	Public Utilities Commission of Sri Lanka (PUCSL)

Evolution of Power Market in South Asia



Regional Power Integration

Legislative and Institutional Barriers:

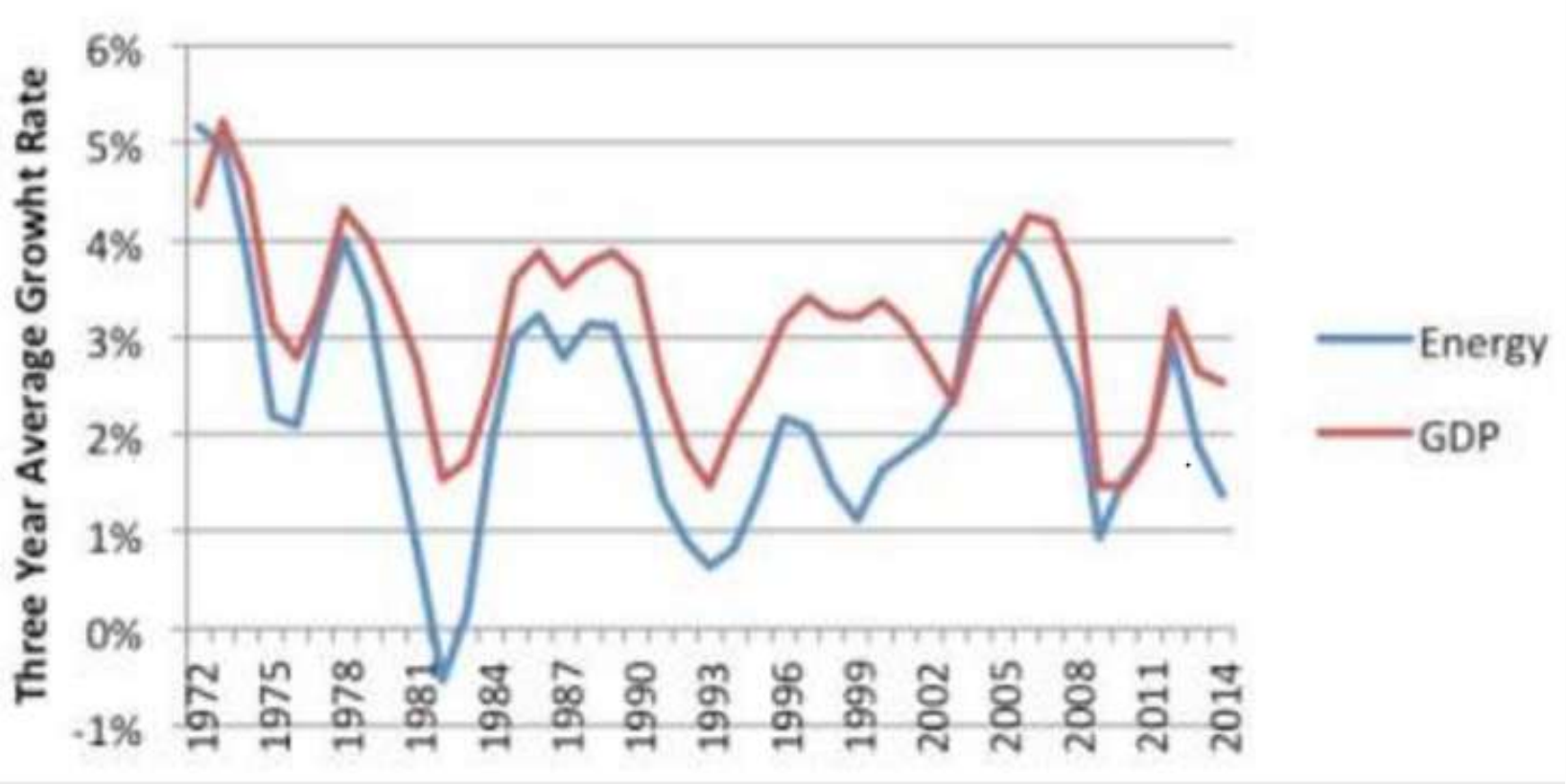
- Lack of legal provisions governing cross-border electricity trade (except in Nepal and Bhutan);
- Ad hoc bilateral agreements (instead of contractual arrangement). Long term policy needs to be in place for sustainability;
- All SAARC member countries except Afghanistan and Nepal have fully functional autonomous regulators to govern electricity sector.

Infrastructure Constraints:

- Lack of cross-border transmission line in the region as a whole. India has bilateral links with Bhutan, Nepal and Bangladesh. However, volume of trade is minuscule compared to their potential (except in Bhutan);

Thank You

Power Market in South Asia

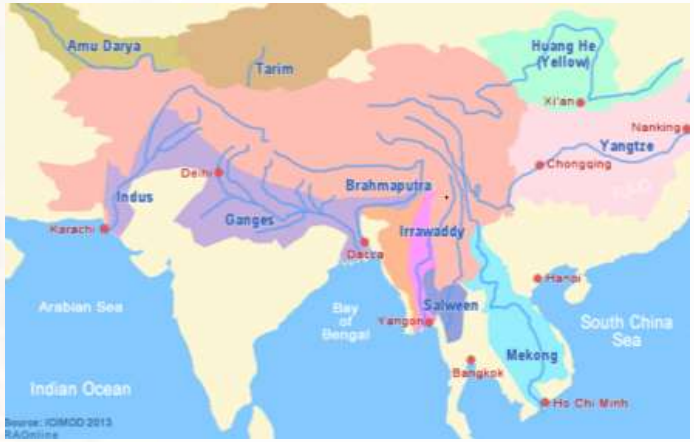


http://cdn.oilprice.com/images/tinymce/ada3065-min.jpg

Energy Resources of South Asia

Energy Resources:

- **Hydropower Resource:**
  - Huge water resource potential - Himalaya abut Afghanistan, Bhutan, India, Nepal and Pakistan;
- **Coal Resource:**
  - Significant coal reserves - In India, Pakistan and Bangladesh (other's do not have viable quantities);
  - Proved reserve in India - 60,600 Million Tonnes (6.8% of global total) and Pakistan – 2,070 Million Tonnes (0.2% of global total) BP Statistical Review of World Energy (2015);
  - India - 3rd largest producer of coal in the world (400 million tons) after China (2,000 million tons) and the US (1,000 million tons);
  - Pakistan - Strategic plan to exploit Thar coal and build power plants in nearby areas;
  - Bangladesh - Limited coal reserve compared with India and Pakistan. Plans to exploit coal (Power System Master Plan 2010);



http://www.raonline.ch/pages/np/visin/np_rivers1301.html

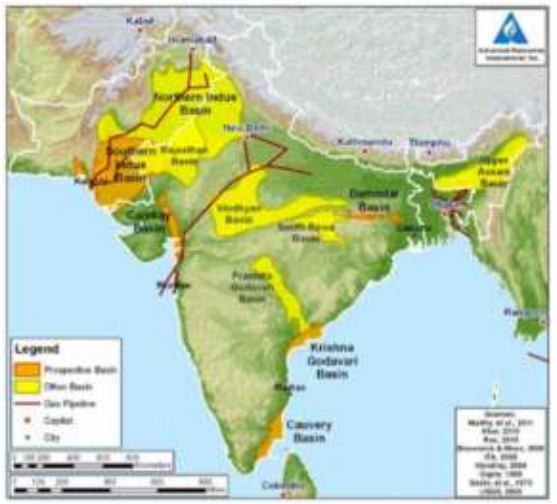
Development of a Potential Regional Hydropower Plant in South Asia:

Pre-feasibility Study

Energy Resources of South Asia

- **Natural Gas Resource:**
  - Proved reserves - Bangladesh (0.3 trillion m^3), India (1.4 trillion m^3), Pakistan (0.6 trillion m^3) BP Statistical Review of World Energy 2014);
  - Bangladesh (0.1%), India (0.7%) and Pakistan (0.3%) combined - 1.1% of global total;
- **Oil Resource:**
  - Proved reserve - India, 5.7 Thousand million barrel (0.3% of global total);
- **Renewable Energy:**

  India - Gird interactive power is 38,453 MW (Ministry of New and Renewable Energy 2015)
  - 26,744 MW (Wind) >50% of potential
  - 6,763 MW (Solar) >12% of potential
  - 4,831 MW (Biomass)
  - 115 MW (Waste to energy)

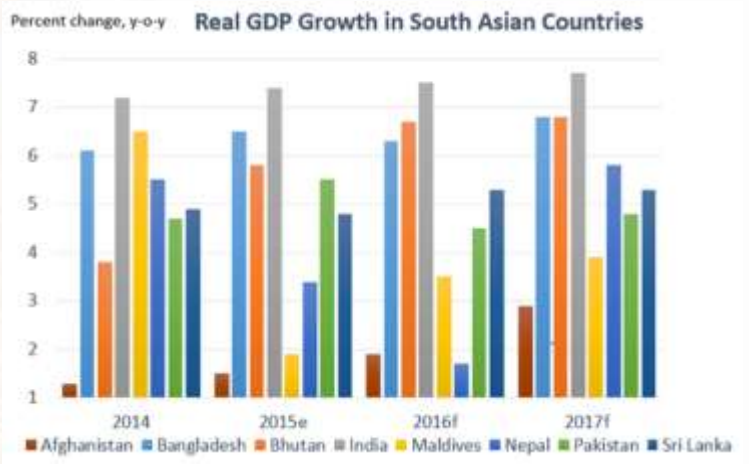


Wind Farm in Jaisalmer, Rajasthan India

Status of Electricity Sector in South Asia

Status of Electricity Sector:

- Insatiable demand for electricity - India, Bangladesh, Sri Lanka, and Pakistan;
  - South Asia - Fastest growing region in the world;
  - > 35% (618 million) population without access to electricity;
  - Low electricity consumption (517 kWh/capita/year);
- Black out "Load shedding" prevalent (except Bhutan);
- Indigenous resources are being used at faster rate;
- Member countries exploring options to import electricity to meet demand;



http://www.worldbank.org/en/news/press-release/2016/04/09/south-asia-fastest-growing-region-world-vigilant-fading-tailwinds

Power Exchange Opportunities: South Asia

- Nepal and Bhutan's wet season hydropower surplus matches with India, Pakistan and Bangladesh's summer peak demand.
- Coal power in India can supply base load.
- Pakistan and India has sizable flexible gas fired generation.

http://www.struggle.com.pk/pakistan-loadshedding-cartoon/

Status of Electricity Sector in Afghanistan

Afghanistan

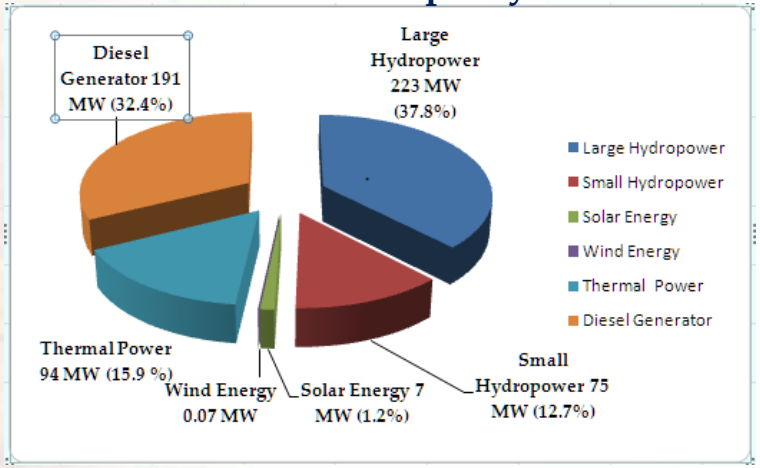
- Population - 29.8 Million
- Area - 652,225 km^2
- Low Population Density - 46 people/km^2

Status of Electricity Sector:

- Low access to electricity - 15.6%;
- Low per capita electricity consumption - 49 kWh/year;
- Major indigenous energy resource is hydropower. 18,400 MW techno-economically feasible hydropower potential of which 1.62% or 298 MW exploited;
- Power generating capacity is beginning to grow - After a long period of decline;
- Electricity Import (> 250 MW) - Uzbekistan, Tajikistan, Turkmenistan and Iran.8
- Da Afghanistan Breshna Sherkat (DABS) national electric utility manages, operates and maintains the national power system.

http://static.lonelyplanet.com/worldguide/maps/wg-afghanistan-1-400x300.gif

Total Power Installed Capacity (590.07 MW)

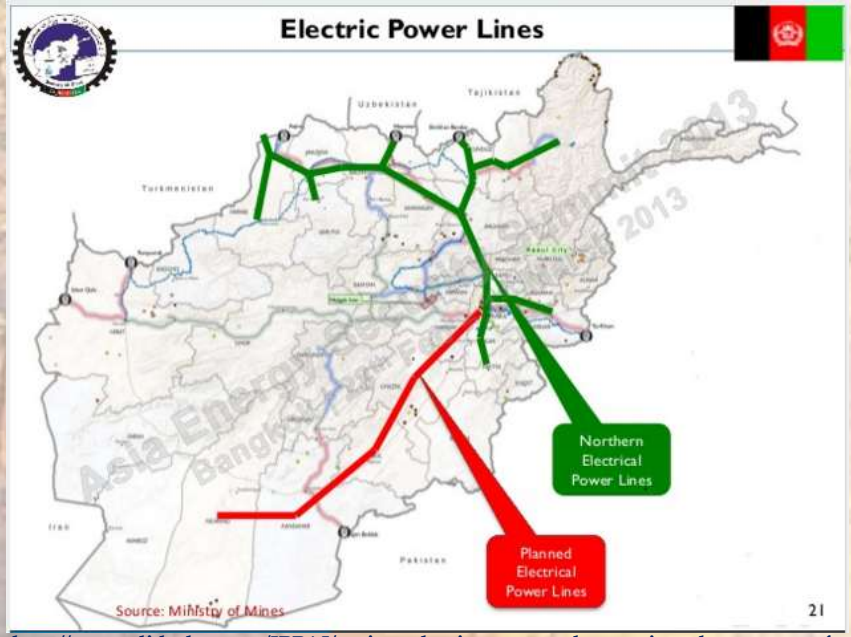


Development of a Potential Regional Hydropower Plant in South Asia:

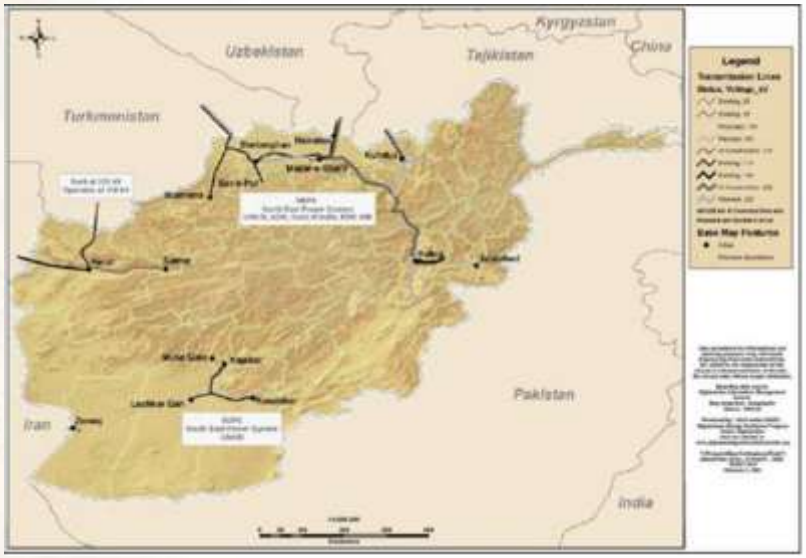
Pre-feasibility Study

Transmission System of Afghanistan

- North East Power System (NEPS) – Linking Kabul, Mazar-e-Shariff, Jalalabad with Uzbekistan (220kV) and Tajikistan (220 kV);
- South East Power System (SEPS) – Linking Kajaki and Kandhar (110 kV);



http://www.slideshare.net/IPPAI/an-introduction-to-petroleum-mineral-resources-of-afghanistan



http://www.sarienergy.org/images/content/countries/afghanistan/Afghanistan_Energy_Overview_clip_image002_0000.jpg

- Herat System – Linking Herat with Iran (132 and 110 kV);
- Turkmenistan System – Linking Herat, Aquina, Andkhoi, Shirin, Tagab, Mimana, Khoka Doko, Sarepul, Shibirghan and Mazar-e-Sharif (110 kV).

Status of Electricity Sector in Bangladesh

Bangladesh

- Population – 154.7 Million;
- Area – 147,570 km^2
- Population Density - 1049 person/km^2

Status of Electricity Sector:

- Access to electricity - 41%;
- Low per capita electricity consumption - 259 kWh/year;
- Rich in water resource. Rivers Jamuna, Padma and Meghna. Flat terrain, limited hydropower potential;
- 775 MW techno-economically feasible hydropower potential of which 220 MW or 29.32% exploited);
- Heavy reliance on indigenous natural gas for power generation (above 85%);
- Supply Demand Gap - < 1,000 MW;
- Electricity to all by 2021;

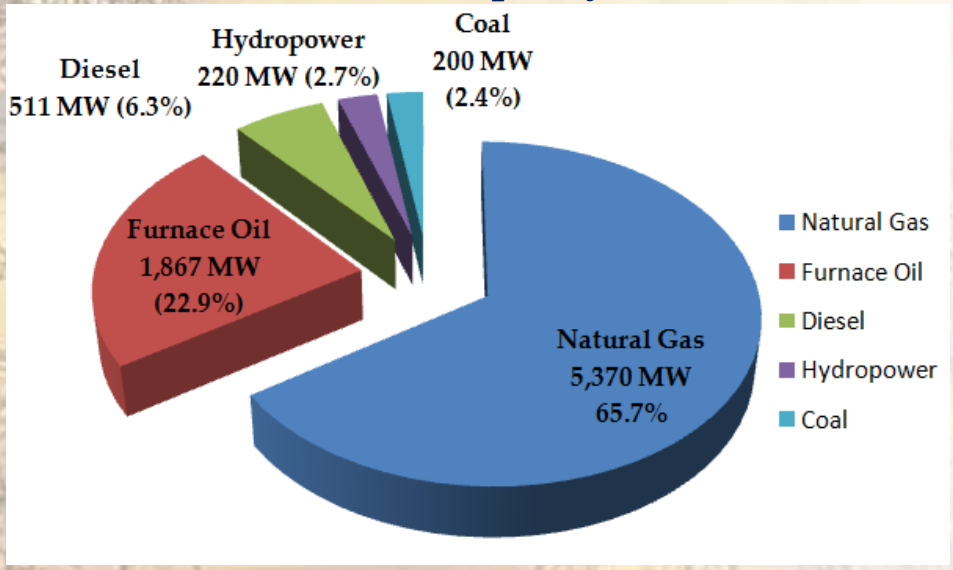
http://dlca.logcluster.org/download/attachments/853200/Bangladesh%20power%20map.jpg?version=1&modificationDate=1380639847000&api=v2

Power Sector Structure of Bangladesh
Apex Body ▪ Power Division, Ministry of Power, Energy & Mineral Resources (MPEMR)
Regulator ▪ Bangladesh Energy Regulatory Commission (BERC)
Generation ▪ Bangladesh Power Development Board (BPDB) ▪ Ashuganj Power Station Company Ltd. (APSCL) ▪ Electricity Generation Company of Bangladesh (EGCB) ▪ North West Power Generation Company Ltd. (NWPGCL) ▪ Independent Power Producers (IPPs)
Transmission ▪ Power Grid Company of Bangladesh Ltd (PGCB)
Distribution ▪ Bangladesh Power Development Board (BPDB) ▪ Dhaka Power Distribution Company (DPDC) ▪ Dhaka Electric Supply Company Ltd (DESCO) ▪ West Zone Power Distribution Company (WZPDC) ▪ Rural Electrification Board (REB) through Rural Co-operatives

http://dlca.logcluster.org/download/attachments/853200/Bangladesh%20power%20map.jpg?version=1&modificationDate=1380639847000&api=v2

Power Generation in Bangladesh

Total Power Installed Capacity (9,151 MW)



Source: Bangladesh Power Development Board, Annual Report 2012-13

https://en.wikipedia.org/wiki/Electricity_sector_in_Bangladesh

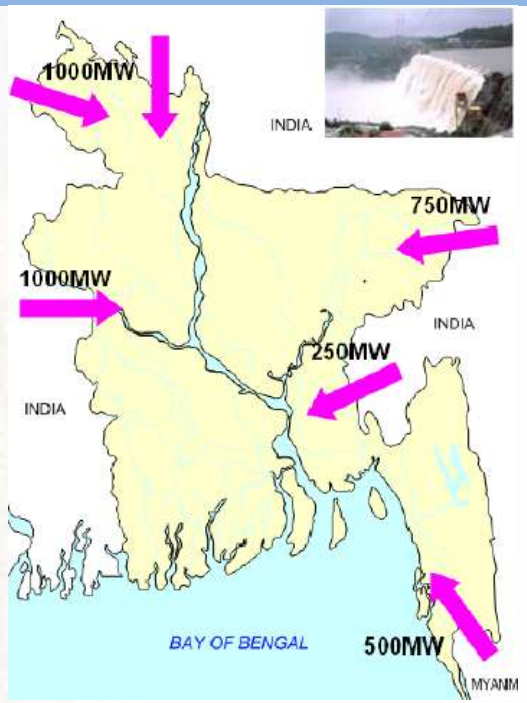
Installed Capacity, Maximum Demand, Maximum Peak Generation and Maximum load Shedding

Year	Installed Capacity (MW)	Addition of Installed Capacity (MW)	Present Capacity MW (Derated)	Maximum Demand (MW)	Maximum Peak Generation (MW)	Maximum Load Shedding (MW)
2008-09	5,719	518	5,166	6,066	4,162	1,269
2009-10	5,823	104	5,271	6,454	4,606	1,459
2010-11	7,264	1,441	6,639	6,639	4,890	1,335
2011-12	8,716	1,452	8,100	7,518	6,066	1,058
2012-13	9,151	435	8,537	8,349	6,434	1,048

Source: Bangladesh Power Development Board, Annual Report 2012-13

Transmission System in Bangladesh

- Transmission system - Jointly owned by parastatal organization (Bangladesh Power Development Board 75%) and general public;
- Cross-border connection with India
  - 125 km long 400 kV DC line Bheramara and Baharampur in West Bengal, India (capacity up to 1,000 MW);
- Power System Master Plan 2010 - Envisages power import from Bhutan (1,000 MW), India additional 1,000 MW, Nepal (1,000 MW) and Myanmar 500 MW);



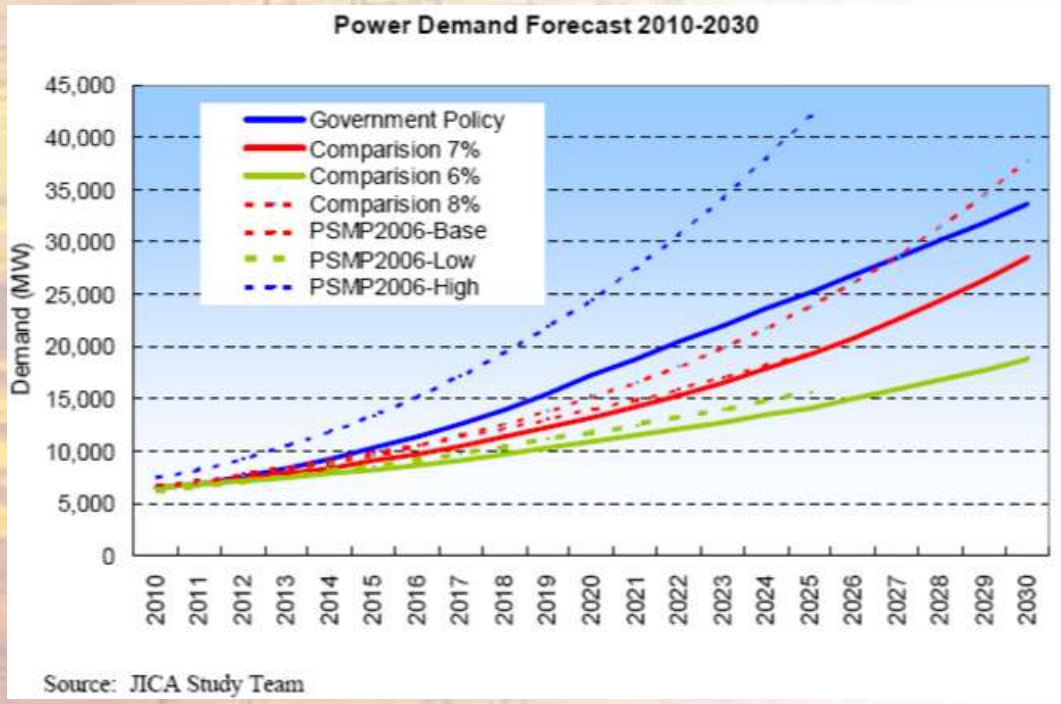
Source: Cross-border Power Trading Plan (Power System Master Plan 2010)

Bangladesh - Transmission System			
Transmission System Type	Voltage (kV) level	Unit	Length
AC Transmission Lines	400	c.km	165
	230	c.km	3,066
	132	c.km	6,125
Total		c.km	9,356
AC Substation	400	Number	1
	230/132	Number	88
	132/33	Number	88
Total			177

Source: Power Grid Company of Bangladesh, 2013

Power Planning in Bangladesh

- Bangladesh plans to set up 2,000 MW Ruppur Nuclear Power Plant at Rooppur, 200 km northwest of Dhaka in 2018. It is planned to go into operation by 2020; (https://en.wikipedia.org/wiki/Electricity_sector_in_Bangladesh)
- Bangladesh has prepared a comprehensive Power Sector Master Plan (PSMP) in 2010.
  - As per PSMP peak demand is 17,500 MW (year 2020) and 34,000 MW (year 2030);
  - To meet the peak demand, suggested installed capacities 22,500 MW (year 2020) and 39,000 MW (year 2030).



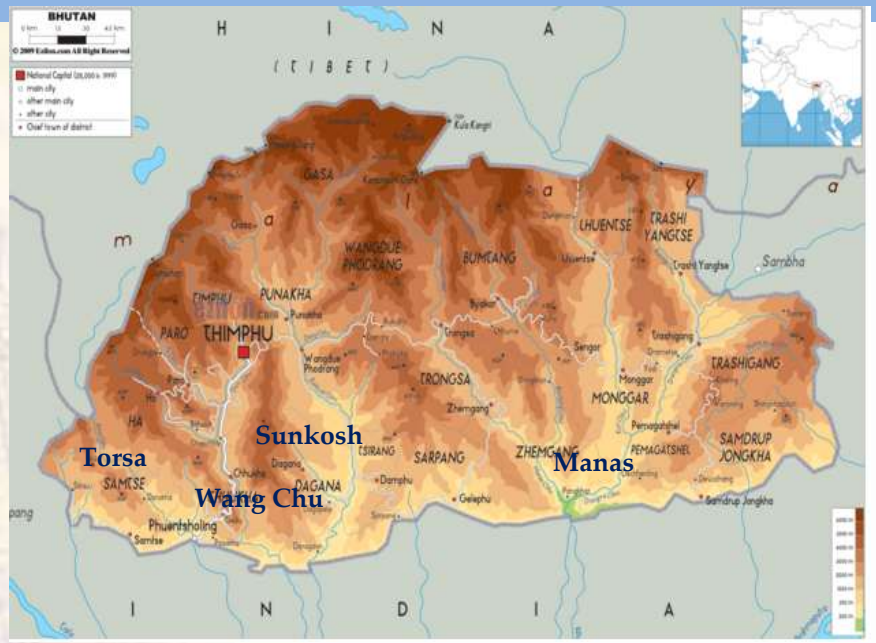
Status of Electricity Sector in Bhutan

Bhutan

- Population - 742 Thousand
- Area - 38,364 km^2
- Low Population Density - 20 person/km^2

Status of Electricity Sector:

- Access to electricity - 60%;
- Highest per capita electricity consumption in South Asia - 977 kWh/year;
- Huge hydropower potential - Himalayan rivers and large altitudinal variations (Techno-economically feasible 23,760 MW of which 6.25% or 1,484 MW exploited);
- Virtually all electricity hydropower based;
- Policy Goal - Achieve additional 10,000 MW installed capacity by 2020, Tap the remaining by 2030;
- Presently Bhutan - Exports 75% of its total electricity generation to India. During winter it import electricity from India;



http://www.ezilon.com/maps/images/asia/Bhutan-physical-map.gif

4 Major rivers in Bhutan

- Torsa (shortest)
- Sunkosh (longest)
- Wangchu
- Manas

Hydropower Projects under Operation in Bhutan		
Project	Generation 2013	Installed Capacity
Chukha	1,907.44 GWh	336 MW
Kurichhu	378.60 GWh	60 MW
Basochhu - I	331.77 GWh	24 MW
Basochhu - II		40 MW
Tala	4,913.63 GWh	1,020 MW
Micro/Mini	20.00GWh	4 MW
Total	7,551.45 GWh	1,484 MW

Source: Annual Report 2013, Druk Green Power Corporation Limited, Bhutan

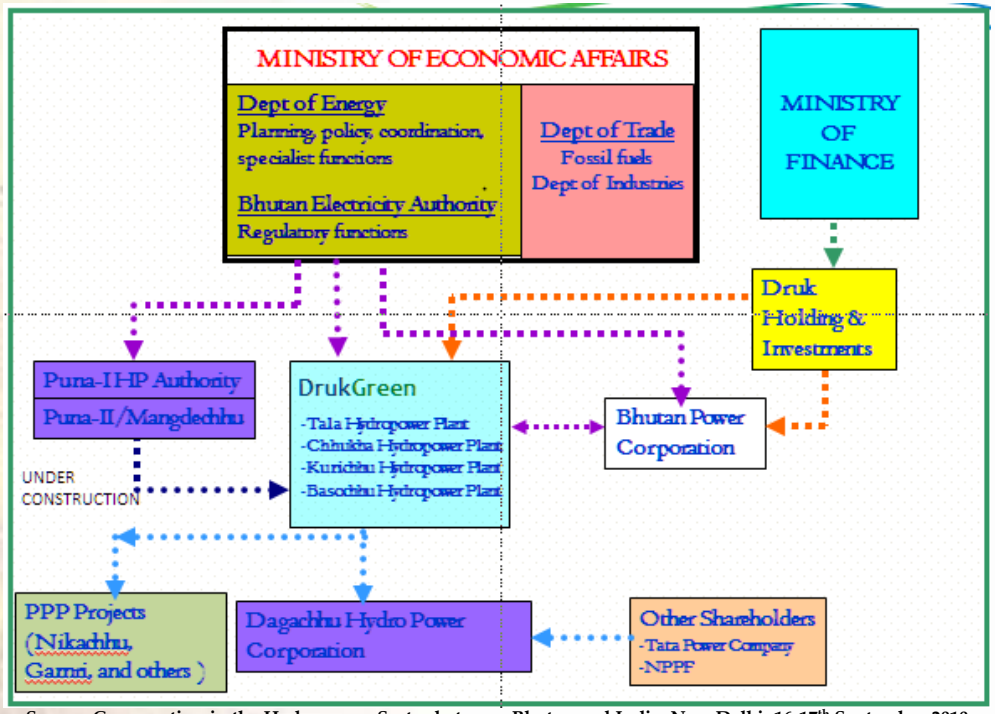
Development of a Potential Regional Hydropower Plant in South Asia:

Pre-feasibility Study

Transmission System and Power Sector Structure in Bhutan

- Transmission system circuit length - 1,015 km;
- Internal transmission system - 66 kV and 132 kV
- Cross-border connection with India.
  - 220 kV line - 336 MW Chukha HEP and Birpara in West Bengal, India;
  - 132 kV line - 60 MW Kurichu HEP and Salakati in Assam, India;
  - 400 kV DC line - 1,020 MW Tala HEP and Siliguri in West Bengal, India.

Power Sector Structure of Bhutan.



Source: Co-operation in the Hydropower Sector between Bhutan and India, New Delhi, 16-17th September 2010 by Rinzin Dorji, SE, Chhukha HydroPower Plant, Druk Green

Existing Transmission Line Between Bhutan and India

Project	Capacity	Connection Locations
336 MW Chukha HEP	220 kV	Chukha (Bhutan) – Birpara (West Bengal, India)
60 MW Kurichu HEP	132 kV	Kurichu (Bhutan) – Salakati (Assam, India)
1020 MW Tala HEP	400 kV	Tala (Bhutan) – Siliguri (West Bengal, India)

Source: National Transmission Grid Master Plan for Bhutan, CEA India, 2012

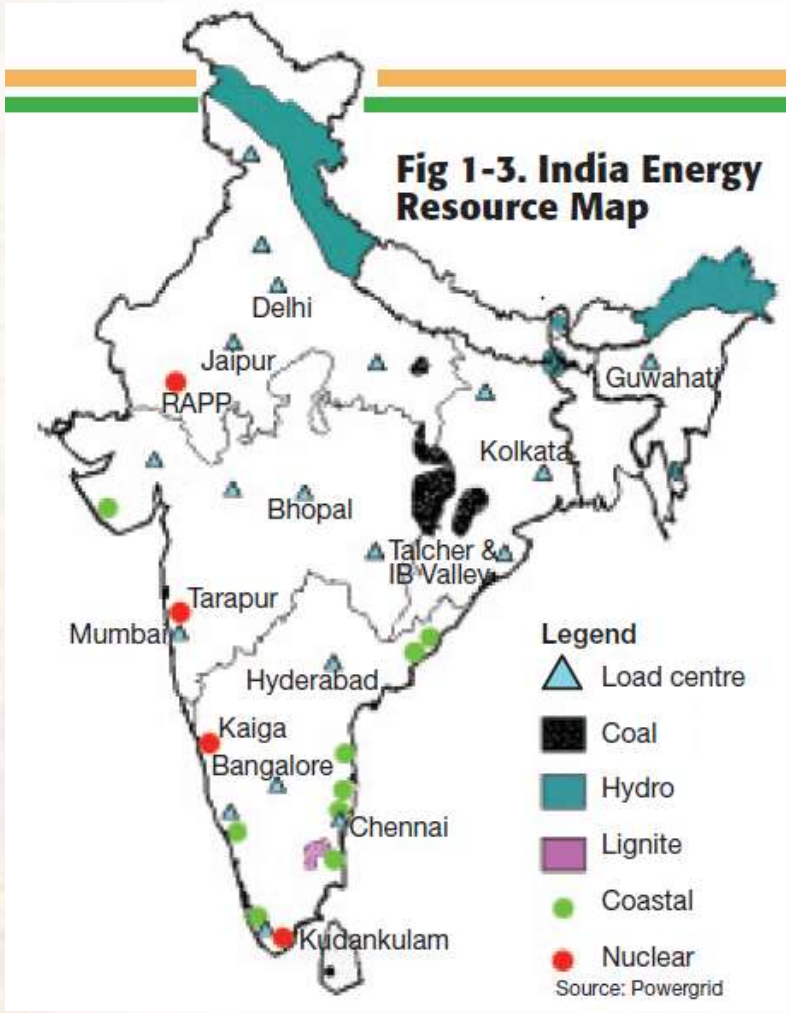
Status of Electricity Sector in India

India

- Population - 1,236.7 Million (17% of world)
- Area - 3,287,240 km^2
- Low Population Density - 377 person/km^2

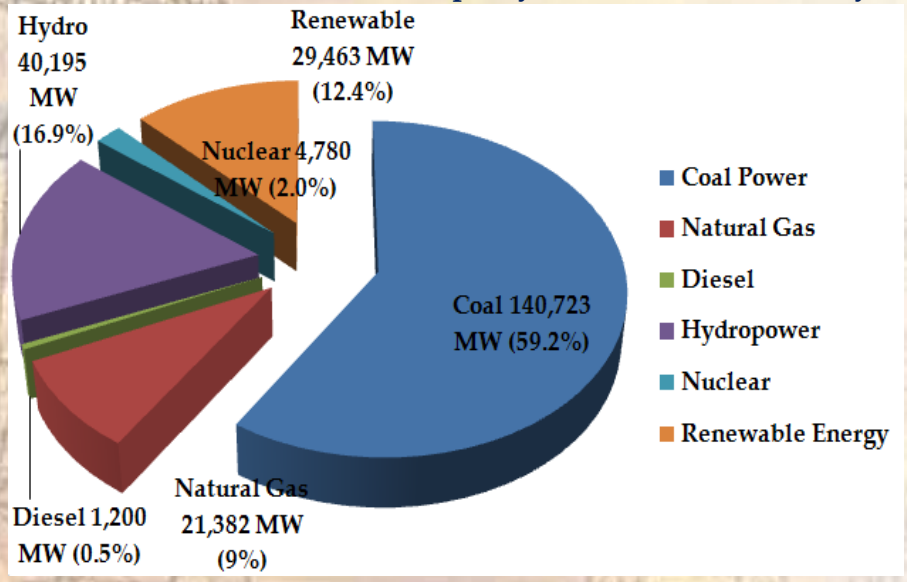
Status of Electricity Sector:

- Access to electricity - 66.3%;
- Per capita electricity consumption - 684 kWh/year;
- India's power market 4th largest in Asia and 6th largest in the world;
- Dominant fuel for power generation - Coal 140,723 MW (about 60%). Coal shortage;
- Techno-economically feasible hydropower potential 84,400 MW of which 47.62% (40,195 MW) exploited;
- Peak power shortage - 12,159 MW in 2012-13;
- Demand Forecast at 8% growth - 425,000 MW (2021-22) and 778,000 MW (2031-32);
- Cross-border interconnection with Bangladesh, Bhutan and Nepal.



Power Generation and Power Sector Structure in India

India's Total Power Installed Capacity is 237,743 MW (February



Source: Central Electricity Authority of India, Summary, February 2014

Power Sector Structure of India
Apex Body ▪ Ministry of Water and Power
Statutory Organization ▪ National Electric Power and Regulatory Authority (NEPRA)
Generation ▪ Water and Power Development Authority (WAPDA) responsible for water and hydropower development ▪ Pakistan Electric Power Company (PEPCO) ▪ NTPC Ltd. (Public Sector Utility) ▪ North Eastern Power Corporation Limited (NEEPCO) ▪ SJVNL ▪ State Level Electricity Boards ▪ Neyveli Lignite Corporation (NLV) ▪ Independent Power Producers (IPPs)
Transmission ▪ Power Grid Corporation of India (Responsible for inter-state transmission) ▪ Private sector
Distribution ▪ State Electricity Boards ▪ Distribution privatized in Kolkata, Mumbai, Delhi, Greater Noida (UP), Ahmedabad, Surat and Orissa etc.

http://www.niticentral.com/2014/11/02/solar-energy-german-technology-can-help-india-235578.html

http://www.tatapower.com/services/power-projects.aspx

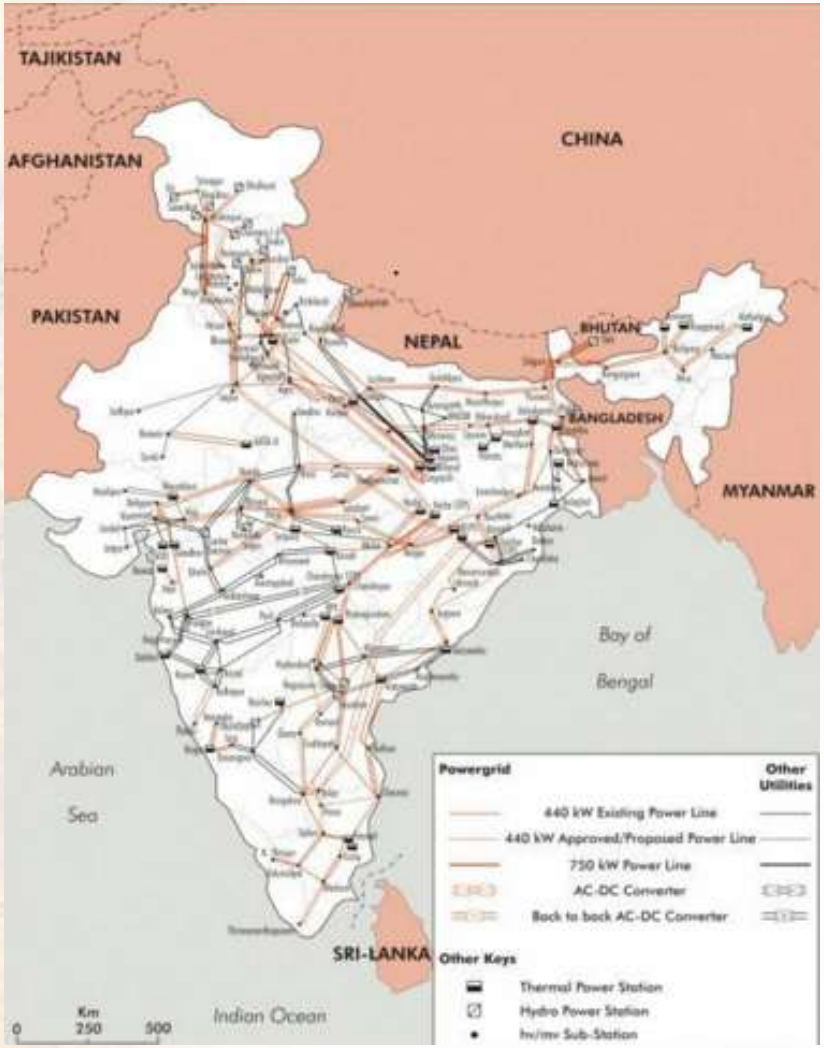
Lately, renewables such as Solar and Wind power are picking up in India.

Development of a Potential Regional Hydropower Plant in South Asia:

Pre-feasibility Study

Transmission System in India

- Five grids - Northern grid (NR), Eastern Grid (ER), Western Grid (WR), Southern (SR), North Eastern (NER);
- All five regional grids connected to the central grid through 765 kV transmission line;
- Power transmission and distribution grid in India - Three-tier (Distribution networks, State Grids and Regional Grids;
- Private sector allowed participation in transmission line development (National Electricity Policy 2006) - 3,239 circuit km transmission line commissioned in 2011-12 (Central Electricity Authority).



Source: Global Energy Network Institute (GENI)

Power Demand and Planning in India

Power Peak Demand and Peak Shortage

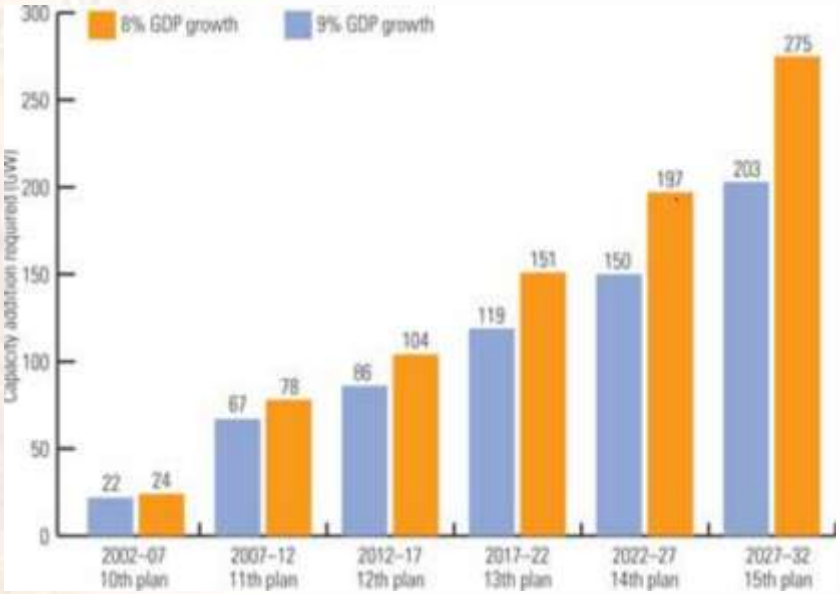
Description	Year 2011-12	Year 2012 -13	Change 2012 -13 over 2011 -12
Peak demand	130,006 MW	135,453 MW	4.2% (Increase)
Peak demand met	116,191 MW	123,294 MW	6.1% (Increase)
Peak shortage	13,815 MW	12,159 MW	10% to 9% (Decrease)

Source: Central Electricity Authority of India, Annual Report, 2012-13.

Planning Commission of India Projections for Power Demand based on Falling Elasticities

Year	Electricity (Falling elasticities)	Total Power Demand Billion kWh		Projected Peak Demand (GW)		Installed Capacity Required (GW)		Installed Capacity Addition (GW)	
		GDP Growth		GDP Growth		GDP Growth		GDP Growth	
		8%	9%	8%	9%	8%	9%	8%	9%
2011-12	0.95/0.85	1097	1167	158	168	220	233	67	78
2016-17	0.85	1524	1678	226	250	306	337	86	151
2021-22	0.85/0.78	2118	2438	323	372	425	488	119	151
2026-27	0.78	2866	3423	437	522	575	685	150	197
2031-32	0.78	3880	4806	592	733	778	960	203	275

Source: Integrated Energy Policy 2006, Planning Commission of India



Development of a Potential Regional Hydropower Plant in South Asia: Pre-feasibility Study

Status of Electricity in the Maldives

Maldives

- Population - 338 Thousand
- Area - 300 km^2 (spread over 859,000 km^2 area 1,190 coral island and 19 atolls)
- Population density - 1,127 person/km^2

Status of Electricity Sector:

- Access to electricity - 100%;
- Per capita electricity consumption - 521 kWh/year;
- Lack of oil, natural gas or coal reserves;
- Largest consumer of fuel - Electricity sector;
- Cannot cost effectively import electricity from neighboring countries ;
- Plans for renewable energy resources;
  - ➢ Solar ➢ Wind ➢ Ocean ➢ Biomass
- Ensure 50% of power generation in 2025 - Using renewable sources;
- Road map - Iegrating diesel based generation with PV and wind to cut generation cost. But, limitations has been land availability and grid stability.

The State Electric Company Limited (STELCO) is an entirely State owned organization responsible for the generation and distribution and sale of electricity to consumers through out the North Central Province (NCP) of the Republic of Maldives

Source: Maldives SREP Investment Plan (2013-17), Ministry of Environment and Energy, Republic of Maldives

Types	Installed Capacity (MW)
Inhabited Islands	120
Tourism Resorts (estimated)	105
Industrial Islands	20
Total	245

Source: Modeling Energy System in the Maldives, Julie Camerlynck

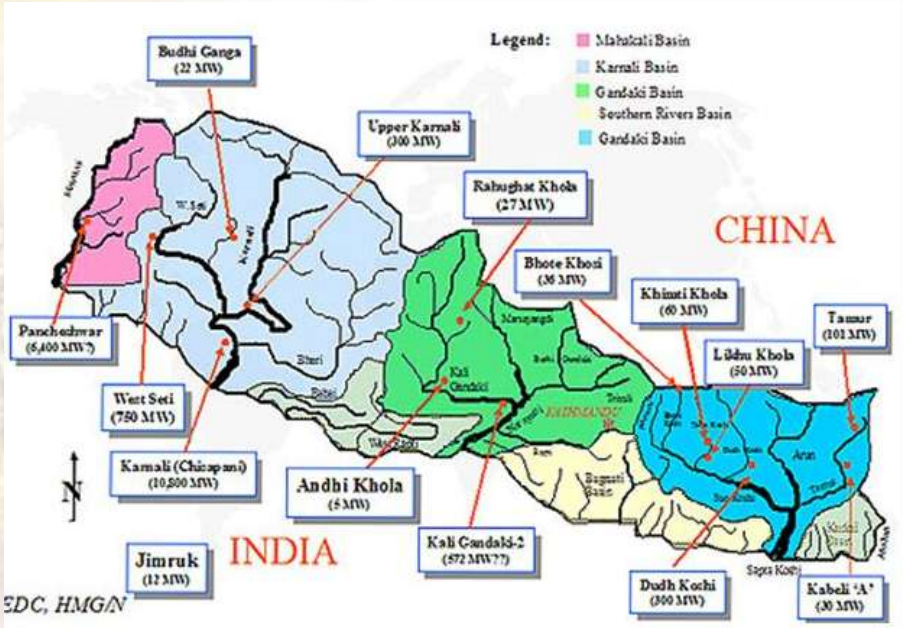
Status of Electricity Sector in Nepal

Nepal

- Population – 27.5 Million
- Area - 147,181 km^2
- Low Population Density - 187 person/km^2

Status of Electricity Sector:

- Access to electricity – 43.6%;
- Per capita electricity consumption - 106 kWh/year;
- Huge hydropower potential - Large altitudinal variations and 6,000 rivers;
- Low hydropower utilization - About 1.76% (787 MW of 42,130 MW techno-economically feasible hydropower potential);
- Major source of electricity - Hydropower;
- Nepal experiences severe power shortage;
- Power sector bundled, NEA manages generation, transmission and distribution. IPPs involved in hydropower generation.

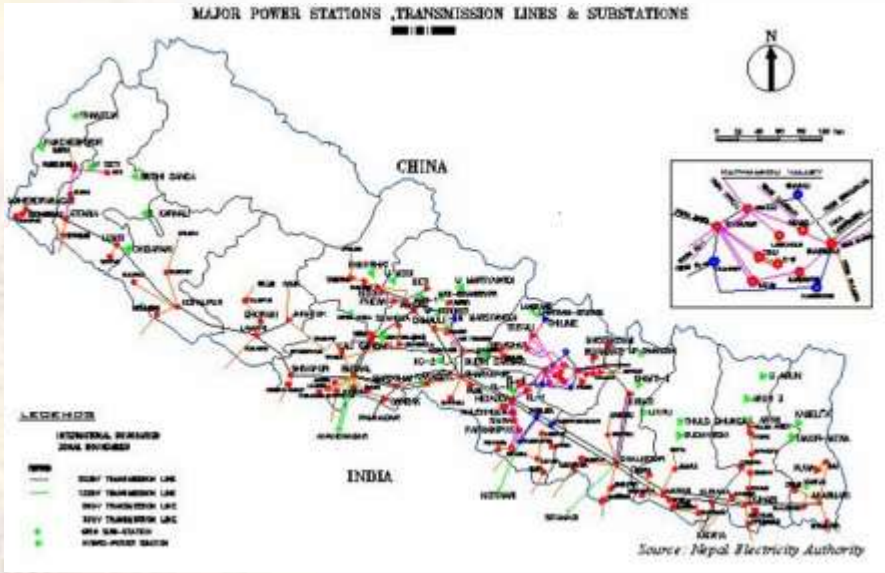


Installed Capacity of Power Plants in Nepal	
Plant Type and Owner	Installed Capacity (MW)
NEA's Major Hydropower Stations (11 Nos.)	459.15
NEA's Small Hydropower Stations (28 Nos.)	14.24
NEA's Plants (Isolated)	4.54
NEA's Hydropower (Total)	477.93
IPPs Hydropower (39 Nos.)	255.64
Total Hydropower in Nepal	733.57
NEA's Thermal	53.41
NEA's Solar	0.10
Total Installed Capacity	787.08

Source: A Year in Review 2013-2014, Nepal Electricity Authority

Transmission System in Nepal

- Total transmission system circuit length - 2,640 km, of which 132 kV is 2,130 km long and remaining 511 km is 66 kV.
- 132 kV circuit length - 2,130 km;
- Major internal transmission system - 66 kV and 132 kV
- Cross-border connection with India.
  - Recently completed 440 kV line between Dhalkebar in Nepal and Muzaffarpur in India;



- Transmission line for power evacuation has been a bottle neck for hydropower project construction in Nepal.
  - Nepal Electricity Authority (NEA) has concluded PPA with 83 private hydropower developers to construct a total of 1,521 MW installed capacity. These are in different stages of construction;
  - In addition, NEA has concluded PPA with 33 private hydropower developers and are in different stages of development;
- NEA is preparing a river basin wise Nepal Transmission System Master Plan for 2015 to 2035.

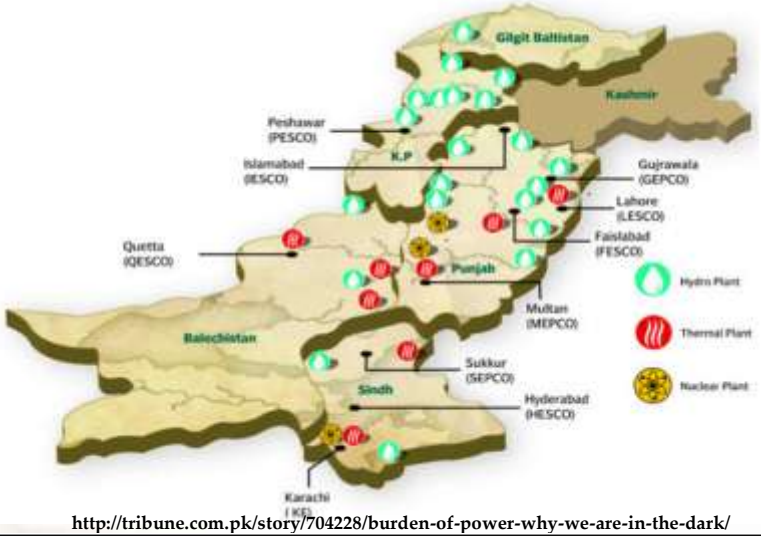
Status of Electricity Sector in Pakistan

Pakistan

- Population – 179.2 Million (17% of world)
- Area - 881,913 km^2
- Low Population Density - 204 person/km^2

Status of Electricity Sector:

- Access to electricity - 62.4%;
- Per Capita Electricity Consumption - 449 kWh/year;
- Dominant fuel for power generation - Gas 9,175 MW (about 40%)
- 11.4% or 6,928MW of 60,000 MW techno-economically feasible hydropower potential exploited;

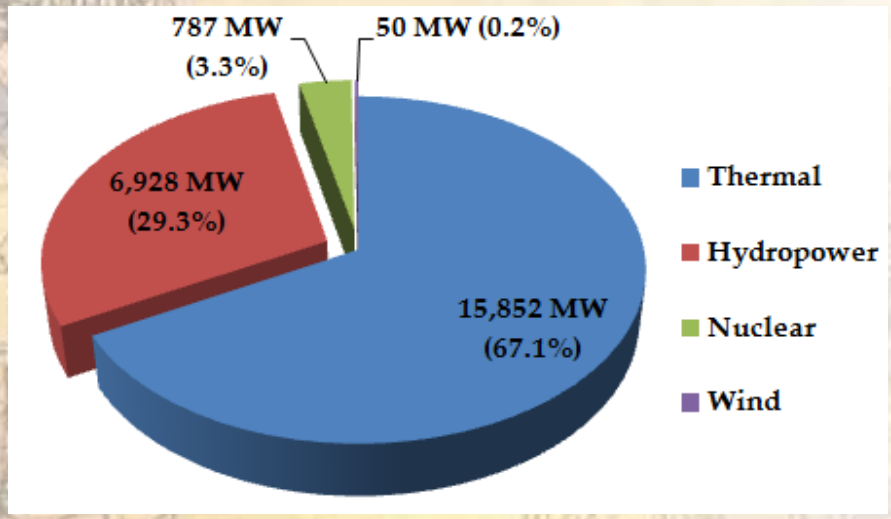


http://tribune.com.pk/story/704228/burden-of-power-why-we-are-in-the-dark/

Power Sector Structure of India
Apex Body ▪ Ministry of Water and Power
Statutory Organization ▪ National Electric Power and Regulatory Authority (NEPRA)
Generation ▪ Water and Power Development Authority (WAPDA) responsible for water and hydropower development ▪ Pakistan Electric Power Company (PEPCO) ▪ IPPs ▪ PAEC ▪ KESC
Transmission ▪ National Transmission and Power Dispatch Company (NTDC) ▪ KESC Transmission
Distribution ▪ LESCO ▪ GEPSCO ▪ IESCO ▪ MEPCO ▪ PESCO ▪ HESCO ▪ QESCO ▪ TESCO

Power Generation in Pakistan

Pakistan's Total Power Installed Capacity is 23,617 MW (2012-13)



3,478 MW Tarbela Dam Largest Hydropower Project in South Asia
(US$ 1,497 Mil.)

http://www.adb.org/news/photo-essays/winds-change-pakistans-zorlu-wind-farm

http://www.skyscrapercity.com/showthread.php?t=1685017&page=7
100 MW Quaid-e-Azam Solar Park in Bahawalpur, Pakistan

Development of a Potential Regional Hydropower Plant in South Asia: Pre-feasibility Study

Power Planning in Pakistan

- Although, the total installed capacity in the country is 23,617 MW, power plants are so old that they generate about 15,000 MW.
- Pakistan is a huge market for power as it currently has a power deficit of 5,550 MW.
- As a part of Mid Term Development Framework 2005 - 10, Pakistan has prepared an Energy Security Action Plan (ESAP) 2005.

Energy Security Action Plan (ESAP) 2005

Year	Hydropower	Nuclear	Coal	Renewable	Gas	Oil	Total	Cumulative
2005	6,460	400	160	180	5,940	6,400	19,540	
2010	1260	-	900	70	4,860	160	7,880	27,420
2015	7,570	900	3,000	800	7,550	300	20,120	39,693
2020	4,700	1,500	4,200	1,470	12,560	300	24,730	72,720
2025	5,600	4,000	5,400	2,700	22,490	300	38,490	110,760
2030	7,070	8,800	6,250	3,850	30,360	300	51,830	162,590
Total	32,660	8,800	19,190	9,700	83,760	7,760	162,590	

Source: Energy Security Action Plan (ESAP) 2005

- Projected Installed Capacity target for 2030 is 162,590 MW.

Transmission System in Pakistan

- Main transmission system - 500 kV north south longitudinal line;
- National Transmission Development Company (NTDC) - Purchases power from Generation Companies (GENCOs);
- NTDC operates - 12 (500 kV), 29 (220 kV) grid stations and 5,077 circuit km of 500 kV and 7,359 circuit km of 200 kV networks;

Pakistan - Transmission System in Pakistan			
Transmission System Type	Voltage Level	Unit	As on 30 June 2013
AC Transmission Lines	500 kV	c.km	5,143.73
	220 kV	c.km	8,309.20
	132 kV	c.km	14,483.00
	66 kV	c.km	4,153.00
Total		c.km	32,088.93

Source: NTDC, Power System Statistics 2012-13

Status of Electricity Sector in Sri Lanka

Sri Lanka

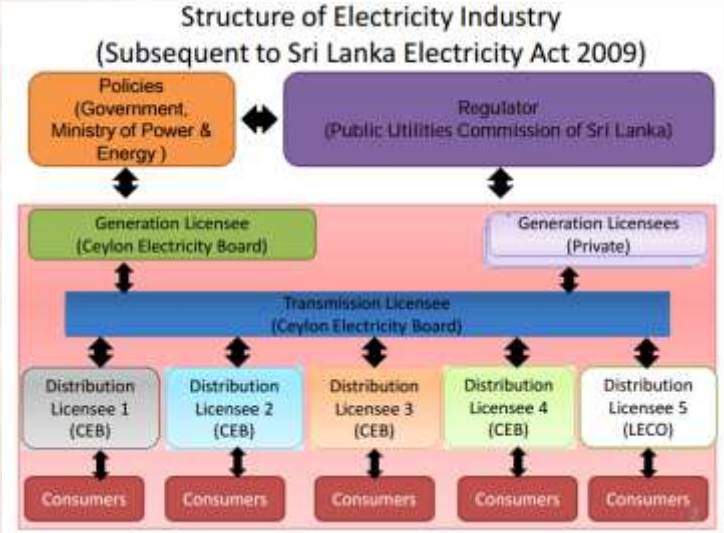
- Population – 20.3 Million
- Area - 65,610 km^2
- Low Population Density - 310 person/km^2

Electricity Sector Overview:

- Access to electricity - 88%;
- Per capita electricity consumption - 490 kWh/year;
- 67.19% or 1,628 MW techno-economically feasible hydropower potential 2,4023 MW exploited;
- Heavy reliance on liquid fuel - Plans for relatively less expensive coal power and renewable energy (wind and Solar);
- Study underway for India-Sri Lanka undersea HVDC cable (Capacity 500 - 1,000 MW);

Source: Ceylon Electricity Board

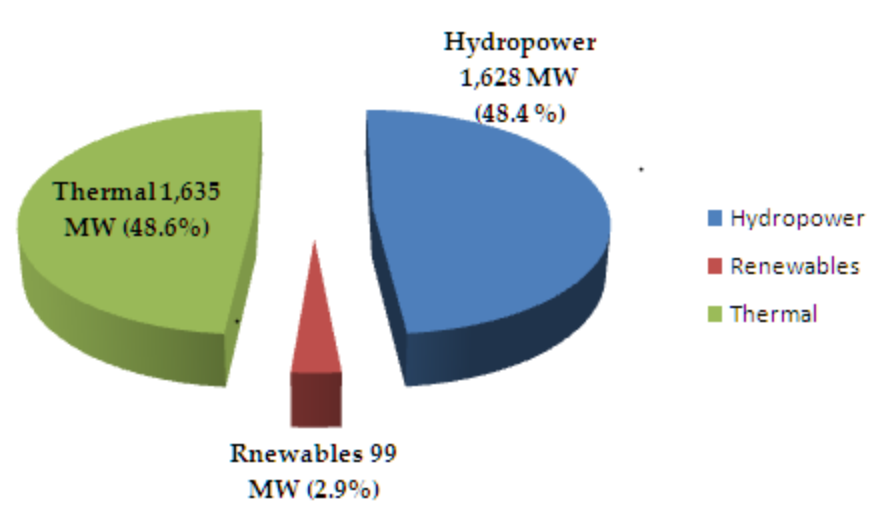
Power Sector Structure in Sri Lanka



http://lirneasia.net/wp-content/uploads/2013/03/Introduction-Electricity-sector-Read-Only.pdf

Power Planning in Sri Lanka

Sri Lanka's Total Power Installed Capacity is 3,362 MW:



Generation Expansion Plan

Type of Plant	2013 - 2017	2018 - 2022	2023- 2027	2028- 2032	Total capacity addition	
	(MW)	(MW)	(MW)	(MW)	(MW)	%
Major Hydro	155	76			231	3.8%
NCRE	287	158	140	135	720	11.9%
Coal	600	1700	1200	1200	4700	78.0%
Gas Turbines	330				330	5.5%
Medium Diesel	44				44	0.7%
Total	1,416	1,934	1,340	1,335	6,025	100.00%

- As per the generation expansion plan, 4700 MW coal based plant will be the major source of power for future;
- 231 MW hydropower potential will be exploited by 2022;
- 330 MW Gas based electricity generation will be commissioned before 2017;
- Investment in 720 MW of Non-conventional renewable energy is envisaged before 2032;
- Costly diesel power is least prioratized.

Transmission System Wind & Solar Resource in Sri Lanka

Transmission System:

- Transmission system circuit length - 2,436 km;
- Internal transmission system - 220 kV (501 km) and 132 kV (1,935 m).

Proposed Link Sri Lanka - India:

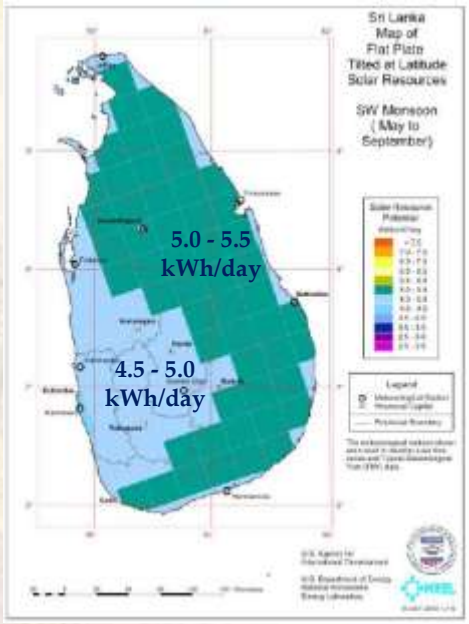
http://indiaenergy.gov.in/docs/ISGF_CBT%20Documentation.pdf

Wind Resource:

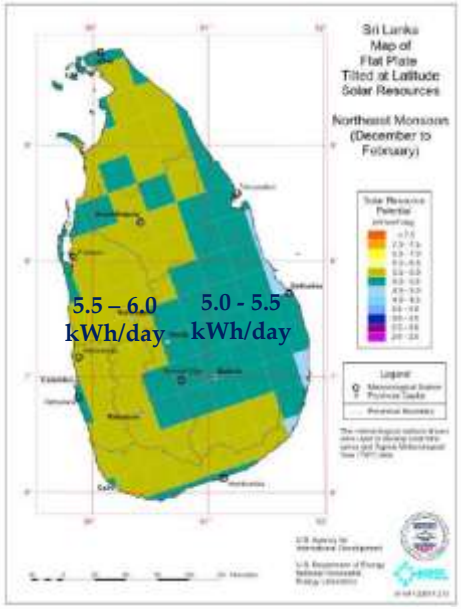
Good-to-Excellent Wind Resource at 50 m

Wind Resource Utility Scale	Wind Class	Wind Power at 50 m W/m^2	Wind Speed at 50 m m/s*	Land Area km^2	Lagoon Area km^2	Total Area km^2	Percent Windy Land	Total Capacity Installed MW
Good	4	400 - 500	7.0 – 7.5	2,341	664	3,005	3.6	15,000
Excellent	5	500 - 600	7.5 – 8.0	788	41	829	1.2	4,150
Excellent	6	600 - 800	8.0 – 8.8	517	0	517	0.8	2,600
Excellent	7	> 800	> 8.8	501	0	501	0.8	2,500
Total				4,147	705	4,852	6.4	24,250

Presentations on Land of Solar and Wind Potentials by Klthsiri Dassanayaka PhD, Sri Lanka Sustainable Energy Authority, Sri Lanka



South West Monsoon (May to September



North East Monsoon (December to February

Development of a Potential Regional Hydropower Plant in South Asia: Pre-feasibility Study

Summary of Power Market in South Asia

Projected Peak Demand and Generation Capacity in South Asia						
Country	Present Generation	Peak Shortage (2012)	Peak Demand 2020	Projected Generation 2020	Peak Demand 2030	Projected Generation 2030
Afghanistan	590 MW		1,750 MW	NA	3,000 MW	NA
Bangladesh	8,537 MW	1,048 MW	17,500 MW (8%)	22,500 MW	34,000 MW (8%)	39,000 MW
Bhutan	1,484 MW	NA	1,500 MW	11,814 MW (Generation)	2,500 MW	26,534 MW (Generation)
India	237,743 MW	12,159 MW	323,000 MW (8%) (2022)	425,000 MW (8%) (2022)	592,000 MW (8%) (2032)	778,000 MW (8%) (2032)
Maldives	245 MW		NA	NA	NA	NA
Nepal	787 MW		2,204 MW	NA	4,614 MW	NA
Pakistan	23,617 MW	5,500 MW	54,400 MW	72,720 MW	113,700 MW	162,590 MW
Sri Lanka	3,362 MW	NA	4,000 MW	5,296 MW	7,250 MW	9,378 MW
Total	276,365 MW	18,707 MW	404,354 MW	525,516 MW	757,064 MW	988,968 MW

Compiled by the author using PSMP 2010 of Bangladesh; Integrated Energy Policy 2006 of India; NEA Annual Report 2014, Nepal; Energy Security Action Plan 2005 of Pakistan etc.

Surplus Export of 10,000 MW from Bhutan would be 1.9% of combined South Asian demand. Similarly Surplus export of 24,000 MW would be 2.5%;

Thank You

Shyam S. Shrestha