Options for Development and Meeting Electric Power Demand in South Asia

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There are a number of reasons for focusing on what will propel development in South Asian Countries (SAC). The most compelling to me is the intersection of demographics and poverty. The region is defined geographically by the Himalayan mountain chain in the North and the Indian Ocean in the South. SAC considered here (Afghanistan, Pakistan, India, Nepal, Bangladesh, Bhutan, Myanmar, and Sri Lanka)[1] are home to about 24% of the world population, and this fraction is predicted to grow to 26.5% by 2050. Most monitoring agencies estimate that about 70% of the total population of SAC (1150 out of about 1640 million in 2009) lives below the poverty line (on less than US2_{ppp}/day). Demographically, SAC consist of a number of ethnic communities that are widely distributed and, in many cases ethnic and religious affiliations remain stronger than even national identity. While there is significant emigration to developed countries, especially of highly trained people, the numbers are comparatively tiny. Mass migration out of the sub-continent is an unlikely scenario as there are no new frontiers nor are there enough other countries that need hundreds of million untrained immigrants. Contemplating the future of this large population, and whether the region possesses adequate resources to develop, and what development means to each of these countries, therefore, remain very timely issues.

Governance will play a pivotal role at every level of the development process and determine the outcomes. There are large variations in governance between and within SAC, ranging from repressive to dysfunctional to barely functional. Each of the eight countries has a different political system, and all SAC except Bhutan are facing issues of civil and political unrest with multiple insurgencies. Nevertheless, faced with widespread poverty and inadequate individual resources their best option forward is cooperation and trade so that all their resources can be devoted to development. This paper examines long-term and sustainable options for each of the eight countries to provide adequate (0.5 kW per capita will be used as the development goal) electric power to its citizens, opportunities for collaboration and the challenges involved.

The path forward in the liquid-fuel based transportation sector is far less clear since all SAC countries import oil and have very limited reserves. They have yet to develop sustainable transportation options and find the balance between individual owned and public transport. Most of these countries are beginning their phase of rapid urbanization, so they have the opportunity to develop cities planned around efficient and effective transportation systems. Unfortunately, current growth of cities is organic rather than planned and development of public transport systems are responding to the demand rather than driving the planning. There are no significant collaboration opportunities for oil trade as all SAC countries except Myanmar (44%) already meet 70-100% of their demand through import. The supply for Nepal and Bhutan goes through India, while Afghanistan and Pakistan have yet to benefit from trade with their oil and gas rich neighbor Iran. In short, if oil remains the long-term energy source for personal and public transport, all eight countries have no option but to import it and pay the market price.

This paper concentrates on electric power generation. To make the discussion of opportunities, options and challenges concrete, some of the key indicators of development as well as a 2008/2009 summary of energy resources relevant to this study are given in Table 1. Before examining individual countries, it is useful to state a number of common features:

- The current estimates of fossil-fuel resources show that none of the SAC is rich in fossil fuels. SAC already import 75% of oil to meet demand from their transportation and other sectors. Myanmar has adequate gas reserves to fuel its own development, however, most of its production for the foreseeable future is earmarked for export. India has adequate reserves of domestic coal to develop up to about 300 GW of coal-fired generation but that would increasingly need to be supplemented by imports. The most likely scenario, if India develops this coal-fired capacity, is it will need to import over 50% of coal consumed by 2040. Pakistan can develop using indigenous energy resources and imports from Iran.

- All eight countries are facing severe power shortages and there are daily power cuts that persist for hours. All industries, and individuals who can afford them, have therefore installed diesel generator sets to overcome the daily load shedding, indicating there is a large market willing to pay 3-4 times the current utility price if firm power could be guaranteed.
- Large fractions of the populations and geographical regions are without electric connections. There is dire need for developing the generating capacity to meet growing demand and for equal (if not more) investment in the associated transmission and distribution infrastructure to reach the entire population.
- Transmission and distribution losses are high—typically in the 20-30% range—compared to <10% in developed countries.
- The power demand in all SAC is growing at 7-10%. This is faster than the economic growth and the demand-supply gap is widening.
- To provide adequate electric power (0.5 kW per capita) to all their citizens, all SAC countries require a factor of 5-20 increase in generating capacity and energy delivered.
- Bhutan can be energy independent based on its hydroelectric resources alone. The same is true of Nepal and Myanmar if their populations stabilize below the projections in Table 1. To develop these resources, they are forging strong collaborations with neighboring countries and international companies: Nepal and Bhutan predominantly with India and Myanmar with China. For long-term planning they, however, must take into account large seasonal and annual fluctuations in water flow, possible impacts of climate change on precipitation, and deforestation and its impact on erosion and silting of water reservoirs.

	AFG	PAK	IND	NPL	BGD	BTN	MMR	LKA
Population 2009 (million)	28.4	181	1171	27.5	162.2	0.7	50	20.5
Population per sq km	44	227	356	187	1127	15	74	312
Rate of Increase (%)	2.1%	2.3%	1.6%	2.1%	1.6%	1.7%	1.1%	1.2%
Population 2025 (million)	39.4	246	1445	36	195	0.9	58	23
Population 2050 (million)	53.4	335	1748	46	222.5	1.0	63	25
Literacy (%) M/F	43.1/12.6	63/36	73.4/47.8	62.7/34.9	54/41.4	60/34	93.9/86.4	92/89.1
Life Expectancy Years M/F	44/44	66/67	63/65	63/64	64/66	67/68	59/63	67/75
GDP (Billion $)	14	166	1235	12.6	95	1.27	28	41
GDP PPP (Billion $)	21.3	440	3526	32	225	3.4	68	92
GDP per Capita (US$)	493	917	1055	458	586	1814	560	2000
Real GDP growth rate (%)	3.4%	2.7%	8.5%	4.7%	6.4%	5%	1%	3.5%
% Population living on less than US2_{ppp}$/day		60%	76%	78%	81%	50%		40%
Oil Proven Reserves Mbbl	0	289	5625		28	0	50	100
Oil Production Mbbl/yr	0	21.6	321	0	2.09	0	6.72	0
Oil Consumption Mbbl/yr	1.66	136.2	1088	6.44	35.7	0.476	15.2	32.72
Coal Reserves MT (short)	73	2185	62278	0.013				
Coal Production MTA/yr	0.039	3.8	568			0.108	1.455	
Coal Consumption MTA/yr	0.039	12.174	637.5	0.454	0.772	0.090	0.302	0.101
Gas Reserves (BCM)	50	885	1075	0	141.5	0	283	0
Gas Production BCM/yr	0.03	37.5	32.2	0	17.9	0	12.4	0
Gas Consumption BCM/yr	0.03	37.5	43	0	17.9	0	3.85	
Generation Capacity GW	0.489	19.44	159	0.617	5.245	1.486	2.5	3.0
Hydro resource tapped GW	0.26/0.75	6.7/53	40/80	0.6/43	0.23/0.75	1.5/23	1.4/39	1.25/9
Electricity Generated TWh	0.825	90.43	787.5	2.78	23	4.475	6.286	9.507
Electricity Consumed TWh	1.01	72.2	568	2.243	21.38	0.529	4.403	7.95
% Population Connected	26%	60%	56%	40%	32%	40%	27%	73.4%

Table 1: The population data are from PRB[2]. Literacy, life expectancy and GDP data are from CIA World Factbook[3]. Oil, coal, gas and electricity data are from US EIA[4], CIA[3], 2010 BP statistical review[5], and individual country statistics. Estimates of population living below poverty line, literacy and percent population connected to the grid have large uncertainties. Also, the criteria used to measure these hide the full extent of the deficit. Blank spaces indicate that reasonable estimates are not available.

India, by strength of its large population, land area and economy, is the largest energy market in South Asia. If its GDP (and energy demand) continues to grow at ≥8%, it will need about 4000TWh per

year by 2032[6]. Exploiting the full 80 GW of hydroelectric potential will provide only 280TWh annually assuming the current 40% plant load factor (PLF). The only large fossil-fuel reserve it has is coal. Assuming 50 billion tonnes of coal can be extracted in total, coal plants would generate 83000TWh at an efficient rate of 0.6kg/kWh for Indian coal that has 30-50% ash content. This resource, therefore, translates into a twenty-year supply at 4000TWh per year. In addition to impacts of coal-fired generation on the environment and the climate, and imminent international pressure to reduce CO_2 emissions, India faces major impediments to mining the required volumes of coal—the almost total erosion of infrastructure and human resource needed for underground mining that is necessary to extract majority of the reserves, and growing public opposition to surface mining. Conventional fossil-fuel based development, therefore, cannot be sustained for much more than 20 years and during this time supply will continue to lag behind demand. For the long-term India's planners are banking on the success of its three stage nuclear program with the goal of installing 500-600 GW of nuclear capacity by 2060[7]. Until that happens India can absorb, and will bid for, all surplus energy resources in the region.

Given India's large energy market, the question is which SAC countries can profit from it? We examine four of India's neighbors, Pakistan, Nepal, Bhutan and Myanmar, that possess excellent hydroelectric resources. Two of them, Bhutan and Nepal, are land-locked and can mostly export power to India and Bangladesh (another energy deficient country). Pakistan is unlikely to export its resources to India and is also key to transport of oil and gas from Iran and Central Asian countries. A status report on opportunities and obstacles to energy trade and cooperation between SAC countries is as follows:

Bhutan-India Cooperation[8]: The Government of India is funding the development of hydroelectric power projects in Bhutan that will provide revenue to Bhutan and much needed power to India. There are three operating plants, Chhukha (336 MWe), Kurichhu (60 MWe) and Tala (1020 MWe)[9], and seven more are under development with design capacity of 10.616 GW as part of the "10GW by 2020" plan. Bhutan has 30 GW of hydro potential of which, it is estimated, 23 GW is technically and economically feasible. Once the full 23 GW is developed Bhutan can export the output of 20 GW (about 80 TWh of energy per year assuming 50% PLF) to India and Bangladesh and keep the remaining 3 GW to meet internal demand. This export would provide an annual income of about $4 billion (about $4000 per capita) at the current tariff rate of US$0.05 per kWh. Thus, export of hydropower can fund the development of Bhutan, and provide long-term revenue.

Nepal also possesses excellent hydroelectric resources with an estimated 43 GW of technically and economically realizable capacity[10]. The current total generating capacity is small (690 MW) but about 22 GW of hydropower is in planning or proposed stages, most of it in the western part of the country near the Indo-Nepal border and demand centers in India[11]. Its own long-term needs are, however, much larger than Bhutan's (40 times the population) so it is targeting only large projects (over 500 MW) for export of power to India. The micro, small and medium scale resources are distributed across the country and exploiting them for domestic consumption requires less investment in transmission and distribution infrastructure. Thus, Nepal's policy of promoting independent power providers (IPP) and working with multiple international organizations for developing its hydroelectric sector is prudent as it balances internal growth with export of power to India in the near-term. In practice, both aspects of the plan are proceeding slowly. The public opposition to large dams in wake of the World Commission on Dams report 2000, and exporting power before Nepal's needs are met is strong and the government has to address these issues. The uncertain political situation is compounded by the inability of state utility monopoly, Nepal Electricity Authority, to add capacity or to facilitate entry of the IPP fast enough to meet demand. In the long-term, assuming the population stabilizes at 50 million, Nepal would need 50 GW of hydroelectric capacity operating at 50% PLF to provide 0.5 kW per capita. Thus, as it develops, export of hydroelectric power will need to decrease and eventually a developed domestic market will demand the full resource.

Pakistan can fuel its development from indigenous resources. In addition to hydro, it has significant unexploited reserves of coal and gas as shown in Table 1. If all 2 billion tonnes of Thar coal reserves (mostly lignite) are used for power, it would generate about 2000TWh. Similarly, the 800 BCM of gas reserves could generate about 3000TWh, but gas has many other critical uses such as fertilizers and chemicals. These resources, about 40 years supply at current rate of generation, reduce to 25 years if Pakistan's demand and capacity continues to grow at ≥7%. By simultaneously developing the 53 GW of hydroelectric potential[12], this window of opportunity can be stretched to 50 years. Pakistan can further extend this window by importing oil and gas from Iran via pipelines. In June 2010, it finally signed a bilateral agreement with Iran to start importing gas by 2014[13] as the exploration and development of its own fields has been very slow. The challenges Pakistan faces are (i) governance and security, (ii) generating revenues to fund this development, and (iii) its rate of growth of population. Solving the first problem would pave the way for exports to energy-hungry India, and help address the second. Development would help address the second and third. Our conclusion is that, unfortunately, politics, social unrest, political instability, security, the Kashmir issue, and lack of financial resources will prevent Pakistan from developing its resources sufficiently fast to meet demand and grow at ≥7%, much less export power to India.

Clear examples of the lack of cooperation and inaction, even when they would have benefited all countries involved, are three proposed international gas pipelines:

Iran-Pakistan-India (IPI) Gas Pipeline[14]: The 2775 km long and 1.22m diameter dual pipeline would carry 55 billion cubic meters (BCM) of natural gas per year from the South Pars Field in Iran to both Pakistan and India. The expected price tag, US$7.5 billion, is financially viable. The three major challenges to its construction have been (i) guaranteeing security through Pakistan; (ii) Pakistan's share of gas, and transit fee paid by India; and (iii) pressure on India and Pakistan to support international sanctions against Iran. The first two can be resolved by bilateral negotiations between India and Pakistan; the third is a larger issue given the international standoff vis-à-vis Iran's Nuclear ambitions. After over ten years of negotiations, Iran and Pakistan finally signed an agreement in June 2010, for the time being without India[13].

The Turkmenistan-Afghanistan-Pakistan-India (TAPI) Pipeline[15]: The 1680 km long 1.42m diameter pipeline would have transported 27 BCM (eventually 33 BCM) annually from Dauletabad gas field in Turkmenistan to Afghanistan (2 BCM), Pakistan (12.5BCM) and India (12.5 BCM). This US$7.6 billion pipeline requires guarantees of security from both Afghanistan and Pakistan, certification of reserves from Turkmenistan, and has the geo-political consequences of providing an alternate evacuation route for Caspian resources that does not go through Russia, isolating Iran and providing much-needed revenue to Afghanistan. Unfortunately, the lack of security in Afghanistan, and failed tariff negotiations between Pakistan and India continue to prevent this pipeline from being built.

Myanmar-Bangladesh-India (MBI) Pipeline[16]: The 900 km long US$1 billion pipeline was to carry gas from Shwe gas fields off the coast of Arakan in Myanmar to Bangladesh and India. The main hurdles pre-2008 were the conditions put forward by Bangladesh to India regarding trade tariffs and free-trade corridors to Nepal and Bhutan. In June 2008, China National Petroleum Corporation (CNPC) negotiated with Myanmar government to purchase the gas and build an 1800 km pipeline (12 BCM per year capacity) from Kyauk Phyu in Arakan to Kunming, China[17]. Subsequently, Bangladesh came back to the negotiating table, especially since it is now facing a growing need for gas supplies as its production declines and demand soars. With the continued delay in reaching an agreement, it is now no longer clear whether the MBI pipeline is an attractive option for India since China has secured exclusive rights on all known export capacity of the Arakan belt and is already constructing the pipeline to evacuate it.

Afghanistan lacks any significant resources of fossil-fuels or hydropower and is land locked. In a perfect world it could, nevertheless, meet all its energy needs by importing oil and gas via pipelines from Iran and/or Turkmenistan, and electric energy from Uzbekistan and Tajikistan. A number of donor countries have helped build the transmission lines and enhanced the North East Power System connecting Afghanistan to Uzbekistan and Tajikistan[18]. To sustain this trade will, however, require the political and security situation to improve dramatically in all three countries. Compounding this problem is the larger reality that Afghanistan does not have sufficient revenue generating potential to pay for these imports, at least not until the recently announced mineral wealth is tapped[19]. In the near-term Afghanistan will need very significant international help to develop.

Bangladesh lacks significant hydroelectric or coal potential and estimates of gas reserves vary widely between 150-600 BCM. Note that 150 BCM of gas can generate 750TWh, which is one year's energy demand at 0.5kW per capita, and thus not sufficient to power the development of the anticipated 200 million people. The reality is worse: Bangladesh's gas fields and transmission infrastructure are highly underdeveloped and gas exploration and foreign investment has stalled[20]. Its power plants are facing gas shortages and electric supply is not keeping up with the 10% growth in demand. It is also unlikely that it will be able to import significant electric energy from either Nepal or Bhutan given India's needs and India's role in developing those resources. Its neighbor to the East, Myanmar, is going with the highest bidder and its military junta has established a very disturbing but mutually beneficial relationship with China[21] against which cash poor Bangladesh cannot compete, not to mention its lack of clout to provide protection to Myanmar's military junta. Bangladesh's best hope is that its gas reserves are much larger than estimated.

Sri Lanka aims to double its generation capacity to about 6 GW by 2020 and has a long-term target of 15 GW[22]. With the completion of Upper Kotmale hydroelectric project, Sri Lanka will have exploited 1.355 GW of the easy-to-develop 2 GW hydroelectric resource, therefore, in the short-term the government owned Ceylon Electricity Board (CEB) is mainly rehabilitating existing hydro plants. Ongoing and future development targets coal and LNG and fuel oil based gas turbine power plants, in which both CEB and Private Power Producers (PPP) will participate. To realize this growth, CEB is working with CMC (China) and Mitsubishi Corporation (Japan) for respectively developing the coal and LNG handling infrastructure. It is unlikely to import any significant power from India by building the proposed Madurai (in Tamil Nadu, India) to Anuradhapura (in central Sri Lanka) HVDC link of up to 1000 MW capacity at least until India develops excess capacity, presumably nuclear, in its Southern regional grid. The current strategy increases Sri Lanka's reliance on fossil fuels for power generation and it will need to generate the revenues to import all the fuels it consumes.

Based on the trends of the last decade, civil unrest, political differences and power demands varying by orders of magnitude between India and its neighbors, the most probable scenario is that each country will remain focused on its own development. Looking ahead, could they overcome their misgivings and plan to integrate their grids to enhance overall grid stability? In the long-run Nepal, in particular, will not be able to meet demand only using hydropower and will need to import power during low water season. The magnitude of such trade would require grid synchronization at major interconnect sites between Nepal, Bhutan, India and China and these interconnects could serve as regional test-beds until each country's grid matures to the point when full synchronization can be contemplated. Such links would also be valuable demonstration cases for friendship and cooperation for the whole region.

The above discussion makes it clear that, except for Afghanistan, the planning for the development of electric power is constrained but economically reasonable within each country and proceeding at a rate the economy and the overall infrastructure can bear. Issues of governance, security and corruption are undermining the rate at which this development is proceeding. Only Bhutan and Nepal have credible paths to development based on hydroelectric power alone. Myanmar too will develop

adequate hydroelectric generation capacity, mostly with China's help, but 85% of the electric output is targeted for export and the revenues are unlikely to be utilized by the military junta to achieve national development[21,23]. A stable Pakistan can develop using indigenous resources and collect transit royalty on oil and gas export via pipelines from Iran/Central Asia to India. Bangladesh, India and Sri Lanka will be increasingly dependent on imports of fossil-fuels for sustaining development. Export of hydropower from Nepal and Bhutan will be significant and very beneficial but seasonal and not adequate to meet the growing demand of Bangladesh and India.

This discussion has not considered impacts on the environment and the climate of such a business-as-usual, albeit efficient, fossil-fuel based development. The reason is that until CO_2 emissions are priced and/or taxed the development of renewable and conventional systems are proceeding in parallel but at very different scales and with different drivers. Growth of solar and wind is mainly driven by incentives and subsidies; investors are waiting for technology maturation, development of supporting infrastructure, and experience based learning. What this article highlights is: (i) three countries, Nepal, Bhutan and Myanmar, can underwrite their development using hydroelectric power, which over the long-term will be vulnerable to seasonal variations and environmental and climate changes. (ii) The populations and needs of three countries, Pakistan, India and Bangladesh, are too large to, today, plan around renewables, so their coal and gas based development will have very significant impacts globally. We also show that their fossil-fuel reserves are inadequate to sustain development in the mid- to long-term, thus it is in their interest to develop the knowledge and experience to be able to quickly scale up deployment of solar and wind technologies as they become cost-effective. (iii) At this point India's long-term options are to accelerate the development of its nuclear power program, and of the infrastructure to import coal and LNG. (iv) Creating and maintaining the right balance between short-term development and long-term sustainability and climate change mitigation goals require maintaining high GDP growth rate for holistic development, political and financial stability, careful planning and enlightened leadership. (v) In the long-term large-scale development of nuclear power by India and export to the other countries will become increasingly important, especially if solar and wind generation do not scale or do not meet base load demand cost-effectively. This long-term need for trade should motivate governments to work towards a synchronized regional grid by 2050.

As discussed here, each country has options but which of the SAC countries will actually achieve the electric supply-demand goals will depend on governance, implementation, financial stability and resources, and anticipating and resolving the social and political challenges. As these countries develop, people will demand more transparency and will be more vigilant of practices (land acquisition, resource exploitation, emissions, impacts on the environment, etc.) of both the government and private corporations. Governments anticipating these challenges and willing to address them in a transparent and timely manner will meet fewer obstacles and develop faster.

The discussion raises many important questions that are not easy to quantify—what will be the cornerstones of the economies of these countries that will fund development and support 1.65→2.5 billion people as they develop? Will it remain tourism for Bhutan and Nepal, and will they use their energy export revenues for broad-based development? Will India's niche in software, service sector, and the recent rapid growth in the manufacturing sector, buffered by its large domestic market, persist? Will handicrafts, textiles and garments, the traditional export items from SAC countries, grow in scale or are they too fungible and are there too many countries competing to provide a lasting niche? Will Pakistan achieve stability and focus on development? Will Afghanistan achieve peace and unity to even contemplate development, and will the military junta of Myanmar use revenues from oil transport, gas export, and hydroelectric energy sales to seed holistic development or to mainly enrich itself? Will population stabilization occur faster than projected? Hopefully, the answer to many of these questions will be a definite YES.

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