ADB Climate Action SOUTH ASIA
Steering Economies Toward Low-Carbon and Climate-Resilient Development
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Economics of Reducing Greenhouse Gas Emissions in South Asia: Options and Costs

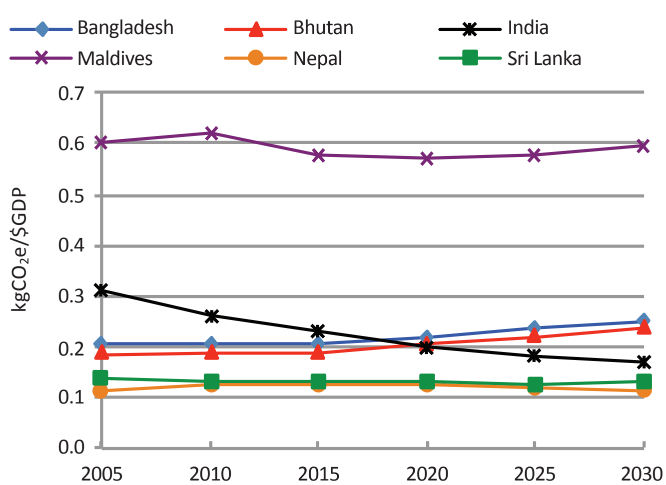
The study Economics of Reducing Greenhouse Gas Emissions: Options and Costs in Bangladesh, Bhutan, the Maldives, Nepal, and Sri Lanka reveals excellent opportunities in low-carbon green growth by pursuing resource- and energy-efficient technologies that would lower emissions of greenhouse gases at low cost (≤ $10 per ton) or even cost saving (benefits). These technologies range from solar cooking utensils to electric and more efficient diesel vehicles and use of solid waste for fuel. They could reduce greenhouse gas (GHG) emissions by a fifth by 2020, relative to base case for that year. Introduction of a climate policy based on stabilizing global GHG concentrations through a carbon tax would further lower emissions, for example, by more than 22% at a carbon price of $41 per ton by 2030. Policy and regulatory barriers, perverse subsidies on conventional fossil fuels, and uncertain future carbon price currently reduce incentives to invest in GHG emission-reducing technologies. However, these barriers can be overcomed through various enabling policies and measures, such as: promoting research and development; building capacity; establishing a sound regulatory framework for renewable energy (RE); providing incentives to clean technology and RE users and producers; promoting industry self-regulation and voluntary arrangements; and enhancing regional energy development and trade.

BACKGROUND

South Asia is expected to bear a significant share of the consequences of global impacts associated with climate change. Sustained and rapid economic growth is necessary for the region to achieve significant poverty reduction, uplift the economic well-being of its people, and increase its resilience to environmental shocks and natural disasters, including those associated with climate change. However, Asian Development Bank (ADB) developing member countries in South Asia may be following resource- and energy-intensive paths of economic development that are not sustainable in the long term.

These countries need a new look at their resource and energy options in order to develop a low-carbon path that can provide sustained, high economic growth and simultaneously abate emissions of greenhouse gases (GHGs) at low or even negative costs (benefits). Already, increased use of cost-effective, clean, and energy-efficient technologies is foreseen in India, as seen in the projected rate of energy-related GHG emissions per unit of its gross domestic product (GDP) over the next 2 decades **(Figure 1)**.

Figure 1: CO_2e Intensity of GDP (Kg per dollar of GDP at PPP, 2005 US$)



CO_2e = carbon dioxide equivalent, GDP = gross domestic product, Kg = kilogram, PPP = purchasing power parity

Source: ADB Regional Economics of Climate Change in South Asia (RECCSA) study (unpublished); The Energy Research Institute and Government of India-Ministry of Environment and Forests simulations

Given the large energy and infrastructure investments being planned in the region over the coming decade, an investigation into the feasibility of designing energy, transport, water, industrial, residential, and agricultural infrastructure systems and processes consistent with green growth principles is very timely. This will allow the countries to assess economy- and sector-wide mitigation options and their costs and benefits, and identify appropriate policies.

THE STUDY

The study, Economics of Reducing Greenhouse Gas Emissions in South Asia: Options and Costs,[1] was carried out for Bangladesh, Bhutan, the Maldives, Nepal, and Sri Lanka[2] to examine low-carbon growth opportunities and GHG abatement potential. Information on India was obtained from existing literature.

The study covered energy supply and demand activities as well as non-energy activities in sectors focused on three major kinds of GHGs (carbon dioxide, methane and nitrous oxide).

Energy Supply and Demand Activities

GHG abatement options and costs for energy generation and consumption sectors—power, industrial, residential, commercial, transport, and agriculture—were analyzed using a MARKAL (MARKet ALlocation) model.[3] The MARKAL model selects the least-cost technology and energy resource options to meet the service demands in various sectors in each country during the study period. It includes constraints related to the fulfillment of each type of service demand, availability of energy resources, and limit on power supply capacity. The model was used to analyze energy development and GHG emissions in two scenarios for the period 2005–2030, as well as to estimate incremental abatement cost (IAC) of various cleaner and energy-efficient options in 2020.

The two scenarios were:

- **Base Case**. The base case was energy development without climate policy interventions during 2005–2030. The penetration of cleaner technology options was set to not exceed 50% of the corresponding total service demand in 2030.

- **Carbon Tax**. This scenario included a climate policy (in the form of carbon tax) to achieve the target of stabilizing global GHGs concentration at 550 parts per million by volume (ppmv) of carbon dioxide equivalent (CO_2e).

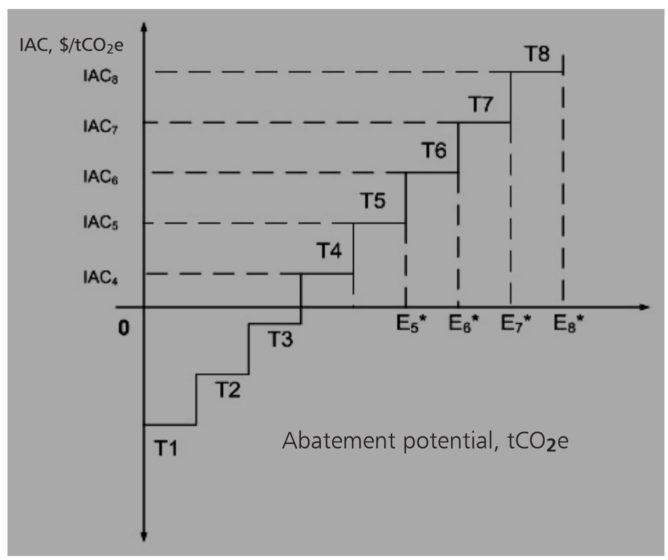
Incremental Abatement Costs

Abatement costs[4] per unit of GHG emission were estimated for each of the technology options along with the total GHG emission reduction potential of the corresponding option **(Figure 2)**. Cleaner technologies with zero or negative IACs (i.e., "no-regret" or win-win options) were identified for each country.

Activities Not Requiring Energy

GHG emissions from activities not using energy were estimated following the Revised 1996 Guidelines of the Intergovernmental Panel on Climate Change (IPCC) for National Greenhouse Gas Inventories. GHG abatement costs of major options for non-energy activities in agriculture, forestry, municipal solid waste, and industrial processes in Bangladesh, Bhutan, Nepal, and Sri Lanka were examined for 2020 using such factors as land-use data, GHG emission factors, non-energy-related activity data, and technology data.

Figure 2: Example of GHG Abatement Cost Curve



GHG = greenhouse gas, IAC = incremental abatement cost

Figure 2 shows a typical IACC, where the width of a block in the horizontal axis is the GHG mitigation (emission reduction) potential of the corresponding option, and the height of the block (vertical axis) shows the option's IAC. For example, in Figure 2, technology option 1 (T1) has the lowest IAC, while technology option 8 (T8) has the highest IAC. The GHG abatement potential of option T8 is given by E_8*-E_7* (the horizontal width of the T8 block), while the option's IAC is given by block height IAC_8.

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1 ADB. 2009. *Regional Economics of Climate Change in South Asia Part 1: Cleaner Technologies and Options* (a subproject funded under RETA 6337: Development Partnership Program for South Asia financed by the Government of Australia through the Australian – ADB South Asia Development Partnership Facility). Manila.

2 The five countries covered in the study, unless otherwise stated.

3 Seebregts, A.J., Goldstein, G.A. and K. Smekens. Undated. Energy/Environmental Modeling with the MARKAL Family of Models. http://www.gerad.ca/fichierspdf/rx01039.pdf

4 Abatement costs are calculated by (i) identifying the sources of GHG emissions in the economy and ways in which these emissions can be reduced, (ii) computing the emission reductions from the measures identified, and (iii) computing the costs of these measures, which may be negative when the measures eliminate waste and save money.

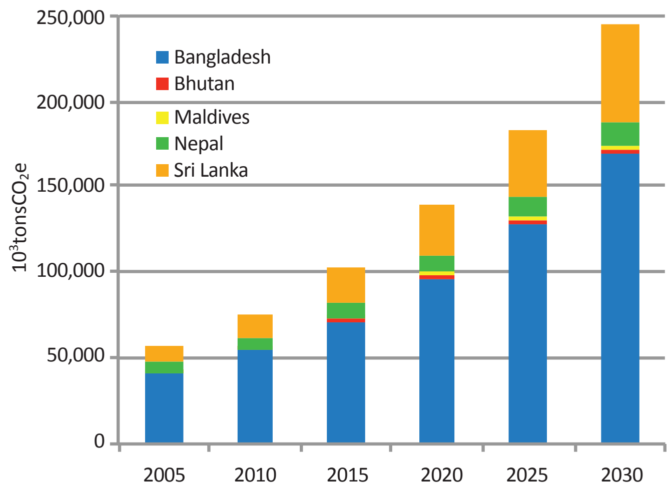
RESULTS

Energy Supply and Demand Sectors

GHG Emissions

Base Case Scenario. Energy-related GHG emissions are estimated to increase by four- to sixfold, from 58 million tons of carbon dioxide equivalent (CO_2e) in 2005 to 245 million tons of CO_2e in 2030 in the five countries as a whole **(Figure 3)**.

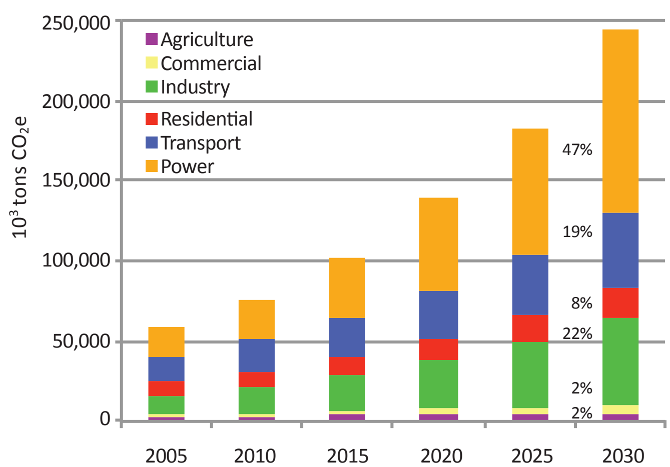
Figure 3: Total GHG Emissions by Country, 2005 to 2030



CO_2e = carbon dioxide equivalent, GHG = greenhouse gas

Total GHG emissions are progressively increasing from 2005, with the power sector constituting the biggest share at 47%, followed by industry (22%) and transport (19%) sectors in 2030 **(Figure 4)**.

Figure 4: Total GHG Emissions in Five Countries by Sector, 2005 to 2030



CO_2e = carbon dioxide equivalent, GHG = greenhouse gas

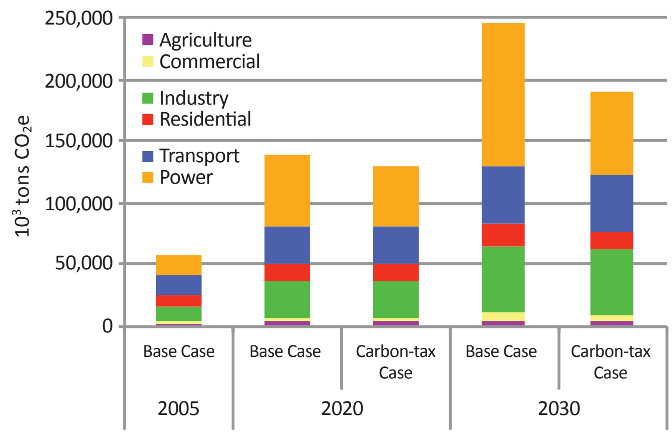
Carbon-tax Scenario. A carbon price profile was included, corresponding to a global GHG concentration stabilization target at 550 ppmv starting at \$15 per ton CO_2 (at constant 2005 prices) in 2010 and attaining a value of \$41 per ton CO_2 by 2030.

Box 1: Stabilization Targets

The stabilization target of 450 parts per million by volume (ppmv) is for carbon dioxide (CO_2) concentration only. In terms of total greenhouse gas (GHG) concentration (i.e., CO_2 as well as other GHGs), the carbon price profile corresponds to the stabilization target of 550 ppmv carbon dioxide equivalent (CO_2e). In the present study, this carbon price profile is reflected in the model by considering carbon tax values of the same amount as the carbon price.

Under the carbon-tax scenario, total GHG emissions would be 131 and 191 million tons of CO_2e in the five countries in 2020 and 2030, showing a decrease by 6% and 22%, respectively, compared to their corresponding base case. In 2030, the power sector would have the biggest share of these reductions **(Figure 5).**

Figure 5: Sectoral GHG Emissions under the Base and Carbon-tax Cases

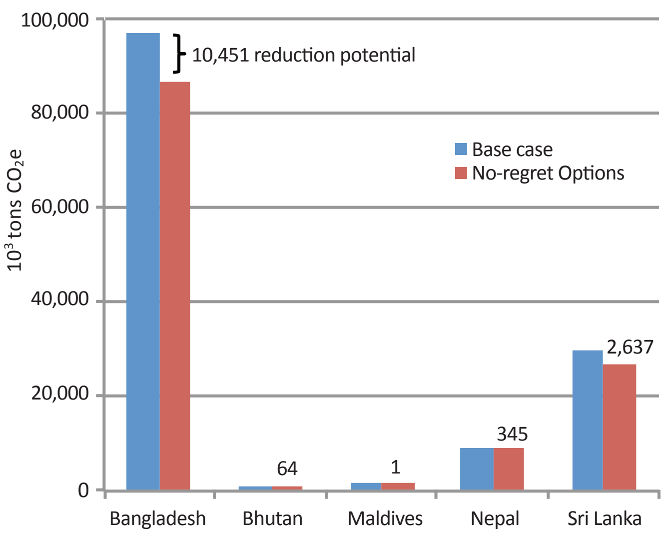


CO_2e = carbon dioxide equivalent, GHG = greenhouse gas

Abatement Costs and Benefits

Many GHG mitigation options can be implemented in each country at no or negative costs ("no-regret" options). In aggregate, no-regret options would reduce GHG emissions by about 13.5 million tons of CO_2e in 2020 across the five countries, a reduction of about 9.71% relative to the base case. The potential for GHG emissions reduction appears highest in Bangladesh and Sri Lanka **(Figure 6)**. It should be noted that across all the countries, most reduction would be provided by the residential sector (50%).

Figure 6: Total Reduced GHG Emissions of 2020 Base Case vs No-regret Options



CO_2e = carbon dioxide equivalent, GHG = greenhouse gas

The potential set of no-regret options is specific to a country's socioeconomic and energy supply characteristics. The following no-regret cleaner and energy-efficient technologies are available at no additional cost in each country.

- **Bangladesh:** Efficient lamps, i.e., compact fluorescent lamps in the residential sector; energy efficient boilers, brick kilns, paddy rice parboiling, and milling in the industry sector; efficient irrigation pumps in the agriculture sector; fuel switching of car transport to compressed natural gas (95%) and gasohol (5%); efficient passenger and freight water transport systems; and partial modal shift of road freight to railways in the transport sector.

- **Bhutan:** Use of electric cooking to replace liquefied petroleum gas and kerosene-based cooking in the residential and commercial sectors, increase in the share of electric buses, and replacing light diesel vehicles by light electric vehicles in the transport sector.

- **Maldives:** Solar cooking stoves to replace 10% of kerosene stoves in the residential sector, and use of municipal solid waste to replace 50% of diesel-based power generation in Thilafushi Island.

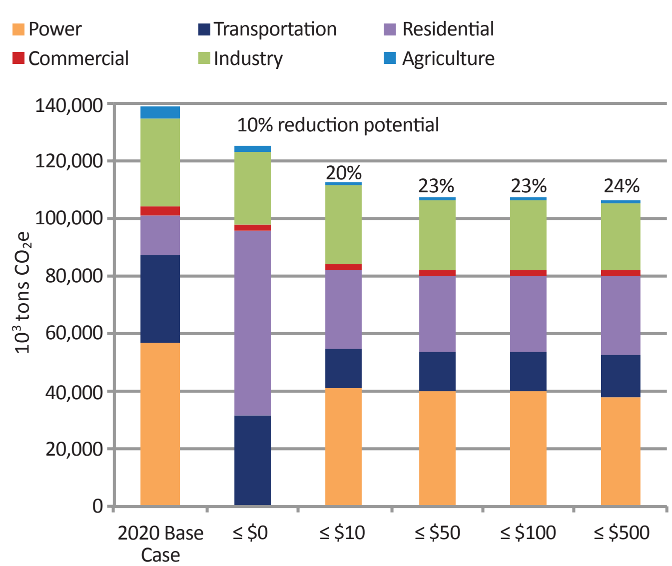
- **Nepal:** Improved fuel-wood cooking stoves and electric cookers, and electric water heaters in the residential and commercial sectors; and use of efficient diesel boilers replacing conventional boilers in the industry sector.

- **Sri Lanka:** Efficient refrigerators and compact fluorescent lights in the residential sector, efficient air conditioners in the residential and commercial sectors, energy-efficient electric motors and advanced fuel oil boilers in the industry sector, efficient diesel tractors and biodiesel fishing boats in the agriculture sector, and adoption of efficient, diesel heavy trucks and diesel buses in the transport sector.

At a cost of less than or equal to \$10 per ton CO_2e, the total GHG emission would be reduced to 111 million tons of CO_2e, one fifth (20.1%) reduction, relative to the base case (139 million tons of CO_2e) by 2020. At a cost of less than or equal to \$50 per ton of CO_2e, the total GHG emission reduction would be 31.6 million tons of CO_2e. At this price, GHG emissions would fall by 22.7% relative to the base case. In all five countries, the potential for GHG emissions reduction at the cost of \$10 per ton of CO_2e is highest in the power sector followed by the residential and industry sectors **(Figure 7).**

Furthermore, controlling GHG emissions may also offer co-benefits in the form of reduced emissions of other pollutants, such as sulfur dioxide (SO_2) and nitrogen oxides (NO_x), that are both locally and regionally damaging to the environment. Emissions of SO_2 from the five South Asian countries under the carbon-tax scenario would be 5.4% lower in 2020 and 37% lower in 2030 than the emission levels in the base case. However, while NO_x emissions from the five countries would be marginally lower (by 0.3%) in 2020 under the carbon-tax scenario, they would be 3% higher than in the base case by 2030.

Figure 7: Total GHG Emissions in Five South Asian Countries at Selected Incremental Abatement Costs in 2020



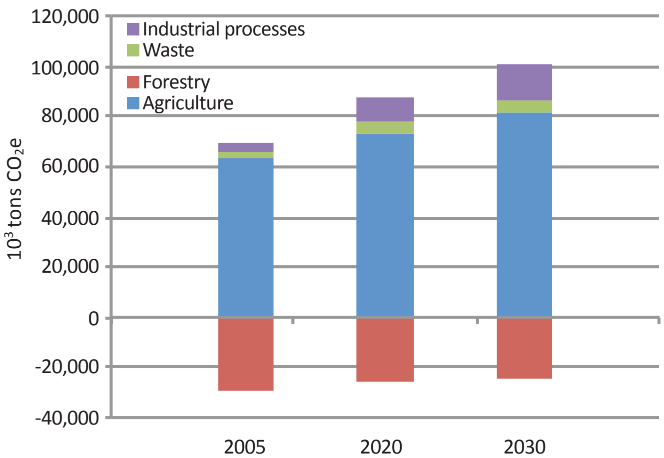
CO_2e = carbon dioxide equivalent, GHG = greenhouse gas

Activities Not Requiring Energy

GHG Emissions

The total GHG emissions for activities not requiring energy in the agriculture, industrial process, and waste generation sectors in Bangladesh, Bhutan, Nepal, and Sri Lanka have been estimated to nearly double in 2030 from the 2005 level of 69.82 million tons of CO_2e. Agriculture alone represents the largest share of GHG emission in all periods. For the forestry sector, the carbon sink capacity shrinks to 24.9 million tons of CO_2e in 2030 from 29.3 million tons of CO_2e in 2005 **(Figure 8)**.

Figure 8: Total GHG Emissions from Non-energy Using Activities (excluding India and the Maldives), 2005 to 2030



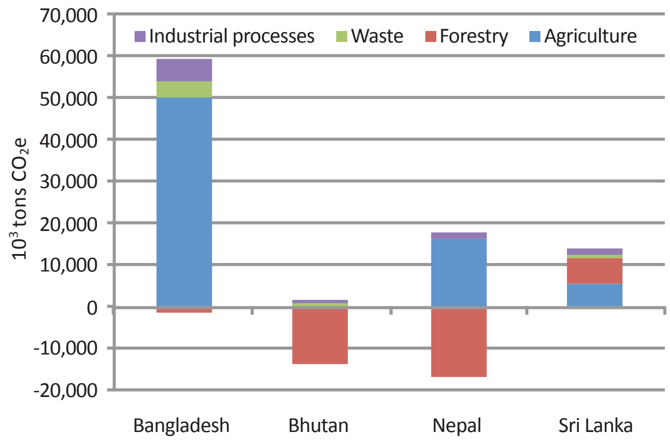
CO_2e = carbon dioxide equivalent, GHG = greenhouse gas

Of the four countries, Bangladesh has the biggest share of 79% (57.96 million tons of CO_2e) out of the total GHG emissions of 73.26 million tons of CO_2e in 2020 originating from the agriculture, industrial process and waste sectors. The Bangladesh share of the carbon sink is 5% (1.3 million tons of CO_2e) of the total carbon sink capacity of 25.6 million tons of CO_2e. Nepal is seen to have the biggest carbon sink capacity at 16.6 million tons of CO_2e **(Figure 9)**.

Abatement Costs and Benefits

The forestry sector showed the highest GHG abatement potential at 23.5 million tons of CO_2e out of the total GHG abatement potential of 29.1 million tons of CO_2e. The GHG abatement potential of conserving existing forests is nearly twice that from expanding carbon sinks, and with a much lower IAC per ton of CO_2e than the latter. In the industrial process-related mitigation

Figure 9: Total GHG Emissions from Non-energy Using Activities by Country in 2020



CO_2e = carbon dioxide equivalent, GHG = greenhouse gas

options, the post-combustion carbon capture and storage (CCS) has a significantly larger GHG abatement potential but with a slightly higher IAC per ton of CO_2e than the oxy-combustion CCS option. For agriculture, the abatement potential for crop production through multiple aeration is highest with a low IAC of \$3.01 per ton of CO_2e. Abatement cost in the waste sector specifically on composting municipal solid waste is the lowest among the options across the four countries **(Table 1)**.

Table 1: Sectoral GHG Abatement Potential and Costs from Activities not Requiring Energy (excluding Maldives), 2020

Sector/Abatement Option	GHG Abatement Potential (ton CO_2e)	Incremental Abatement Cost[a] (\$/ton CO_2e)
Agriculture	**1,369,565**	
– Livestock	161,403	13.51–45.99
– Crop production	1,208,162	3.01 – 25.03
Forestry	**23,562,699**	
– Conserving existing carbon pools/sinks	15,440,512	0.58–194.79
– Expanding the amount of carbon stored (stocks)	8,122,187	14.71–642.96
Waste Generation	**1,519,329**	
– Recycling	620,263	1.18–5.48
– Composting of municipal solid wastes (MSW)	899,066	0.42–1.98
Industrial Processes	**2,605,542**	
– Post-combustion carbon capture and storage (CCS) in cement production	1,555,246	139.05–155.78
– Oxy-combustion CCS in cement production	1,050,296	137.24–153.74
Total	**29,057,135**	

CO_2e = carbon dioxide equivalent, GHG = greenhouse gas
[a] Indicates range of costs across countries.

IMPLICATIONS OF THE STUDY

Constraints and Barriers

Several constraints and barriers continue to hinder the rapid deployment, replication, and promotion of large-scale initiatives on low-carbon cleaner technologies in South Asia, especially in the five countries covered by the study. These are related to technology, financing, and policy and regulatory aspects. A lack of effective cross-border energy development initiatives is also a significant barrier to RE development.

Technology Related. RE technologies, especially those generating electricity, are relatively sophisticated, and most countries in the region are still in a technology-learning phase. Associated issues are the (i) lack of technical expertise and facilities for design, manufacture, promotion, and sale of RE projects; (ii) lack of trained personnel for training, demonstration, maintenance, and operations; (iii) lack of awareness and information programs for technology dissemination; and (iv) lack of technical support and follow-up services for maintenance.

Financing. Public financing is scarce in the region while private sector financing is not forthcoming due to several risks factors. The risks related to new RE technologies, such as solar thermal, are high, and the expected performance under specific country conditions is unknown.

The high initial cost of cleaner energy technologies constrains their large-scale promotion. In most countries of the region, mainstream financial institutions are not yet prepared for financing individual loans to buy or install clean energy devices or for making investments in small-scale clean energy projects.

Furthermore, uncertainties associated with the future price of carbon, partly resulting from the continued absence of international binding commitment to reduce GHG emissions, and the future direction of the carbon market act as barriers to attracting investment in the clean energy sector.

Policy and Regulatory. Pricing of fossil fuels and retail electricity in many countries is not conducive to the promotion of cleaner energy technologies due to the presence of direct and indirect subsidies. A direct subsidy on the cost of grid-supplied power and indirect subsidy on fuels like coal and natural gas make conventional power supply more attractive and affordable than cleaner, RE-based electricity.

Regulatory barriers exist in various forms in the region. The lack of legal provisions requiring utilities to provide network access to RE projects as in the case of Bangladesh and Nepal, and lack of standardized power purchase agreements for power generation from RE technologies as in the case of Bangladesh, hinder the development of RE projects. The dependency of many RE activities on national budgets creates uncertainties and time delays. The lack of defined polices for establishing/locating biomass plants can result in these plants being in close proximity to each other, affecting the availability of fuel, and thus making them unviable.

Cross-border Energy Cooperation. Despite the huge hydropower potential, cooperation between and among countries for large-scale energy project development and cross-border power trade and transmission have largely remained unexplored. So far only Bhutan has cross-border energy cooperation with India, which is ensuring the development of a high-voltage (400 kilovolt [kV]/220 kV) transmission network for power evacuation to India and supply of the load centers in Bhutan in parallel with implementation of a 10,000- megawatt hydropower program.

Enabling Conditions

Several enabling policies and measures could be adopted in the pursuit of low-carbon and sustainable development in the region. These include: (i) promoting research and development (R&D); (ii) building capacity; (iii) establishing a sound RE

regulatory framework; (iv) providing incentives to users and producers of clean technology and RE; (v) promoting industry self-regulation and voluntary arrangements; and (vi) enhancing regional energy development and trade.

Research and Development

Basic R&D for technology development and technology transfer efforts will be important in promoting the use of clean energy. Researchers, engineers, entrepreneurs, and funding agencies have to work together to develop solutions that address the energy needs and climate change concerns in South Asia. Various technologies have to be developed for implementing and integrating RE resources, such as wind, solar, and tidal power, to satisfy the enormous energy demands. Another potential R&D area related to clean energy technology is carbon sinks. The forest ecosystem plays a significant role in the carbon cycling process; forests are considered the most important carbon sinks and can mitigate climate change at low cost. South Asia has been strengthening its R&D in clean energy technologies and effectively promoting the overall development of the energy sector, but needs to do more.

Capacity Building

International and regional organizations should continue their catalytic role in capacity building and promoting regional and subregional cooperation, particularly for technology transfer initiatives. The countries' access to information also needs to be improved, especially for end users to better understand energy systems and apply that knowledge in making daily decisions.

Sound Regulatory Framework for RE

A strong legal and regulatory framework is essential for the development of RE. For example, utilities should be required to give RE producers access to the transmission/distribution network to ease the difficulty of accessing RE resources that are remote from demand centers. The use of a standard power purchasing agreement between the utility and RE producers would strengthen the financial position of RE producers.

Images: ADB

Incentive Mechanisms and Schemes for RE and Clean Technologies

Incentive mechanisms are measures that would help reduce the up-front costs of cleaner technologies and promote their wider adoption, promote the use of RE, and motivate enterprises to use energy efficiently **(Box 2)**. RE certificates can be issued to producers of RE-based electricity that they generate and inject into the distribution grid. The certificate is a market-based instrument; it enables companies that intend to purchase RE-based power or are required to meet their renewable purchase obligations, to do so by buying the certificates from sellers in the market. Feed-in tariffs provide RE producers access to the electricity distribution system and market, and help RE developers to overcome the barriers of high cost of RE-based power generation and distribution.

Industry Self-Regulation and Voluntary Agreements

Key industries can contribute significantly in achieving low-carbon development by adapting programs that promote conservation and sustainable use of energy. In the commercial sector, building design codes can be adapted to provide guidelines for new commercial buildings to consider different climatic conditions for optimal energy use. In the transport sector, the promotion of clean-energy vehicles and modal shift to mass public transport (e.g.,

Box 2: Examples of Ongoing Initiatives on Clean Energy and Energy Efficiency in South Asia by the Asian Development Bank

Clean and RE: Projects include those that develop and facilitate access to renewable sources of energy, such as solar and hydropower for the technical assistance (TA) on Green Power Development Project in Bhutan (TA 7157), Gujarat Solar and Smart Grid Development Investment Program in India (TA 8055), and the Scaling Up RE Project in Nepal (TA 8081). TA 8081 aims to address the constraints on scaling-up RE by leveraging the Strategic Climate Fund with Asian Development Bank and other donor-assisted funds, to set up both credit and subsidy windows for mini-micro hydropower and solar home systems under the Capital Region Energy Forum.

Energy efficiency improvement: Projects include those that address improving operational efficiency, specifically energy from renewable sources and their transmission/distribution network capacity. Examples are the loan project on Power System Efficiency Improvement in Bangladesh and TA on Clean Energy and Access Improvement Project in Sri Lanka (TA 7267, 7266, and 7265).

urban metro railway, bus rapid transport system, and inter-city railway) are some major options for energy-efficient low-carbon transport development in South Asia.

Regional Energy Development and Trade

South Asian countries are endowed with significant cleaner energy resources that are untapped and have huge potential for regional energy development and trade. For example, hydropower resources are mainly concentrated in Bhutan **(Box 3)**, India, and Nepal, while limited natural gas reserves exist in Bangladesh and India. Negotiation between Bangladesh and India on energy trade is ongoing. In addition, there is potential for large-scale wind power development in Sri Lanka for regional trade; the country is reported to have wind power potential of 24,000 megawatts. Development of cleaner energy resources and regional trade of such energy are important tools for the region's move toward low-carbon and green development.

Box 3: Bhutan's Dagachchu Hydropower Project

The 114-megawatt Dagachhu hydropower project in Bhutan was registered in 2010 as the first cross-border hydropower under the Clean Development Mechanism (CDM) in the world. The project is supported by the Asian Development Bank (ADB) and the governments of Austria and Japan. The project will enable Bhutan to export clean energy to India. It will also encourage cross-border power trade in South Asia by benefitting from the CDM.

The project is expected to reduce greenhouse gas (GHG) emissions by about 50,000 tons per year, mainly through power exports to India. Bhutan also benefits by generating additional revenue from the CDM.

Total cost of the project is $153 million, of which $80 million is a loan from ADB. The National Pension and Provident Fund of Bhutan and Raiffeisen Zentralbank Osterreich (RZB) of Austria co-financed the project. The Austrian Government provided engineering support through the Austrian Development Agency. Project structuring was promoted with assistance from the Japan Special Fund established by the government of Japan and administered by ADB.

Source: ADB. Green Power Development Project (TA 7157), 2010.

ACTIONS AND RECOMMENDATIONS

- Significant emissions reduction can be achieved by prioritizing investments in technologies across sectors with low IAC. These technologies will also generate co-benefits that range from reducing emissions of locally damaging pollutants to economic opportunities for communities, such as those demonstrated by Clean Development Mechanism projects for waste management.

- The scope of investments can cover (i) promotion of energy efficiency and development of RE, (ii) low carbon transport infrastructure, (iii) urban services, including employing of cost effective and income-generating waste management mechanisms, (iv) energy efficient buildings and other infrastructure, and (v) energy efficient irrigation pumps, including use of solar pumps.

- Technology access, policy and financing issues will continue to influence the development of clean technology. Large-scale development of clean energy resources is crucial for South Asian countries to reduce energy-related GHG emissions per unit of its GDP over the next two decades. Regional energy cooperation and trade as well as south-south and north-south cooperation on technology and knowledge sharing will pave the way for a move towards low-carbon and green development in South Asia.

In an era of accentuated climate risks, resource- and energy-intensive paths of economic development are not sustainable. A paradigm shift pursuing opportunities in low-carbon green growth through resource- and energy-efficient technologies will not only lower greenhouse gas emissions but will also be at no cost to the countries.

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