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Author: Shrestha, Ram M.

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Energy Use and Greenhouse Gas Emissions in Selected Hindu Kush–Himalayan Countries

Ram M. Shrestha
ram.m.shrestha@gmail.com; ram@ait.ac.th
School of Environment, Resources and Development, Asian Institute of Technology, Pathumthani, Thailand

This article discusses historical patterns of energy supply, electricity generation, and sectoral energy consumption as well as the emission of energy-related greenhouse gases during 1995–2008 in 5 Hindu Kush–Himalayan countries, Bangladesh, Bhutan, India, Nepal, and Pakistan, and reviews major studies that predict energy use and greenhouse gas emissions during 2005–2030 in the absence of climate policy interventions. It presents a range of energy use and greenhouse gas emission projections for the selected countries as a whole, and for the Hindu Kush–Himalayan areas in those countries for 2030. This study shows a need to establish a spatially disaggregated (district-level) energy database in the Hindu Kush–Himalayan countries to enable more accurate estimates of energy use and associated greenhouse gas emissions in the region.

Keywords: *Total primary energy supply; electricity generation; greenhouse gas emissions; Hindu Kush–Himalayan region; Bangladesh; Bhutan; India; Nepal; Pakistan.*

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Introduction

The Hindu Kush–Himalayan (HKH) region, which extends from Afghanistan in the west to Myanmar in the east, is one of the least developed regions in the world. It is spread over 3500 km of distance and involves, partly or entirely, 8 countries from Afghanistan to Myanmar. The region's total estimated area is 3,441,719 km^2. It occupies approximately 60% of Afghanistan, 9% of Bangladesh, 17% of China, 14% of India, 47% of Myanmar, 51% of Pakistan, and all of Bhutan and Nepal (ICIMOD 2013). This study focuses on 5 of those countries, Bangladesh, Bhutan, India, Nepal, and Pakistan, whose HKH mountain areas account for approximately 32% of the land area and 68% of the population of the entire HKH region (WB 2011; ICIMOD 2013). The selection is justified by the near unavailability of relevant studies on Afghanistan, Myanmar, and the HKH regions of China.

The energy economy of the HKH countries considered in this study is characterized by limited access to electricity, low per capita consumption of electricity and modern energy, a relatively high dependence on biomass energy, and a growing dependence on imported fossil fuels, especially petroleum products (ADB 2009). A large percentage of the people in HKH countries lack access to electricity and the cleaner cooking and heating fuels (ADB 2009). However, most of the countries have experienced rapid economic growth in recent years, and access to electricity is also increasing rapidly (see Table 1). With increasing industrialization, urbanization, and economic growth, energy consumption is expected to also grow significantly. Six countries in the HKH region (Bangladesh, Bhutan, China, India, Nepal, and Pakistan) together account for approximately 17% of total global greenhouse gas (GHG) emissions, which is low relative to their size and population. Although the emission of GHGs from the HKH region may not appear significantly high from the global perspective at present, this may change in the coming decades.

Some studies have projected future energy use and GHG emissions in individual HKH countries. However, they vary in terms of the approaches used and assumptions made about key driving forces such as future economic and demographic growth. The number of such studies also varies widely across countries; for example, there is a relatively large number of studies for India and very few for Bangladesh, Bhutan, Nepal, and Pakistan. To the best of the author's knowledge, there is no study that assesses future energy use and GHG emissions in the HKH mountain region.

This article discusses historical patterns of total primary energy supply (TPES), electricity generation, sectoral energy consumption, and energy-related GHG emissions during 1995–2008 in the 5 selected HKH countries. "Primary energy" refers to energy sources as found in their natural state, as opposed to derived or secondary energy, which is the result of the transformation of primary or secondary sources; and TPES is made up of the following formula: indigenous production + imports – exports – international marine bunkers – international aviation bunkers +/– stock changes (IEA 2013). It also reviews the major studies on future energy use and related GHG emissions in those countries and discusses likely changes in energy use and GHG emissions by 2030 in the absence of climate policy interventions. It estimates TPES and carbon dioxide (CO_2) emissions in 2008, and makes a rough projection of the same values for 2030 from the HKH areas of the 5 countries. It also

TABLE 1 Key socioeconomic indicators in selected HKH countries in 1995 and 2008. (Table extended below.)

	Unit	Bangladesh		Bhutan	
		1995	2008	1995	2008
Population[a)]	Million	128.1	160.0	0.5	0.6
Population of the HKH area (2007)	Million		1.5		0.6
Population growth rate[a)]	%	2.0	1.8	−1.0	1.6
Share of urban population[a)]	%	22.0	27.0	21.0	34.0
GDP per capita[a),c)]	US$	1205.0	1952.6	2234.0	4746.0
Access to electricity	%		41.0[e)]	16.8[f)]	27.6[f),g)]

TABLE 1 Extended.

	India		Nepal		Pakistan	
	1995	2008	1995	2008	1995	2008
Population[a)]	932.2	1140.0	21.6	25.3[b)]	124.5	166.0
Population of the HKH area (2007)		72.9		25.3[b)]		38.6
Population growth rate[a)]	1.8	1.3	2.5	1.8	2.5	2.2
Share of urban population[a)]	27.0	30.0	11.0	17.0	23.7	34.5
GDP per capita[a),c)]	1940.7	3781.1	1186.2	1507.7	1557.5[d)]	2400.8
Access to electricity		64.5[e)]	14.1[h)]	44.1[i)]	52.9[j)]	57.6

a) WB (2011).
b) Estimated value was based on MOF (2011) and CBS (2012).
c) IEA (2010a); GDP per capita is given at purchasing power parity.
d) IMF (2000).
e) IEA (2009).
f) ADB (2010).
g) Bhutan's second electrification rate is based on 2002 data rather than 2008 data.
h) CBS (2004).
i) UNDP (2010).
j) IEA (2000).

highlights the need for disaggregated data for the HKH areas and local sectoral case studies to enable more rigorous estimations of energy use and GHG emissions in the mountain areas of the HKH countries.

Demographic and economic changes

The HKH countries have undergone significant demographic and economic changes (Table 1), including increasing urbanization. Households in these countries have low access to electricity and to cleaner cooking fuels. Biomass accounted for as much as 86.4% of TPES in Nepal in 2008 (IEA 2010a) and 59.2% in Bhutan in 2005 (Garud and Gurung 2007). Approximately 77.6% of rural households and 20.1% of urban households in India used biomass for cooking in 2007/08 (TERI 2011).

Structure of the primary energy supply

TPES increased by 75% during 1995–2008 in Bangladesh, 85% in India, 45% in Nepal, and 53% in Pakistan (Table 2). The structure of TPES is shown in Figure 1. In 2008, Bangladesh depended most heavily on natural gas (50%), India on coal (42%), Pakistan on oil and natural gas (56.1%), and Nepal and Bhutan on

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TABLE 2 Traditional energy use and total primary energy supply of selected HKH countries in 1995 and 2008.[a)]

	Total primary energy supply (metric tons of oil equivalent)		Share of traditional biomass energy in total primary energy supply (%)[b)]		Per capita traditional biomass energy (tons of oil equivalent)		Per capita total primary energy supply (tons of oil equivalent)	
	1995	2008	1995	2008	1995	2008	1995	2008
Bangladesh	16.00	27.94	45.11	31.11	0.06	0.05	0.12	0.17
Bhutan	—	0.39	—	59.18	—	0.39	—	0.62
India	336.48	620.97	43.22	26.34	0.20	0.14	0.47	0.54
Nepal	6.75	9.80	89.45	86.37	0.28	0.30	0.31	0.34
Pakistan	54.32	82.84	39.61	34.80	0.17	0.17	0.44	0.50

[a)]IEA (2010a); Garud and Gurung (2007).

[b)]Traditional biomass energy refers to combustible renewable and waste biomass energy.

biomass (86.4% and 42.6%, respectively). Although traditional biomass energy plays a major role in the HKH countries, its share in TPES has been declining except in Nepal (Figure 1). In India, the share of biomass showed a substantial decline, that is, from a share of 43.2% in 1995 to 26.3% in 2008. Over the years, the share of natural gas has been increasing in Bangladesh and Pakistan; similarly, the share of oil has been increasing in Nepal and the shares of both coal and gas have been increasing in India. In 2008, petroleum products accounted for 15.8% of TPES in Bangladesh, 23.3% in India, 23.3% in Nepal, 24.1% in Pakistan (IEA 2010a), and 19.6% in Bhutan in 2005 (Garud and Gurung 2007). In 2008, the share of renewable energy sources (including biomass, hydro, wind, solar, and geothermal) in TPES was 31.6% in Bangladesh, 28.1% in India, 89.1% in Nepal, and 37.7% in Pakistan (IEA 2010a); in Bhutan, the share was 73.6% in 2005 (Garud and Gurung 2007).

When using existing documentation of per capita energy consumption (IEA 2010a; WB 2011), this study estimated the TPES of the HKH areas of Bangladesh, India, and Pakistan in 2008 to be 0.27 metric tons of oil equivalent, 39.70 metric tons of oil equivalent, and 19.26 metric tons of oil equivalent, respectively. When considering these figures together with the TPES of

FIGURE 1 Structure of the total primary energy supply. *Bhutan data for 2005 only.

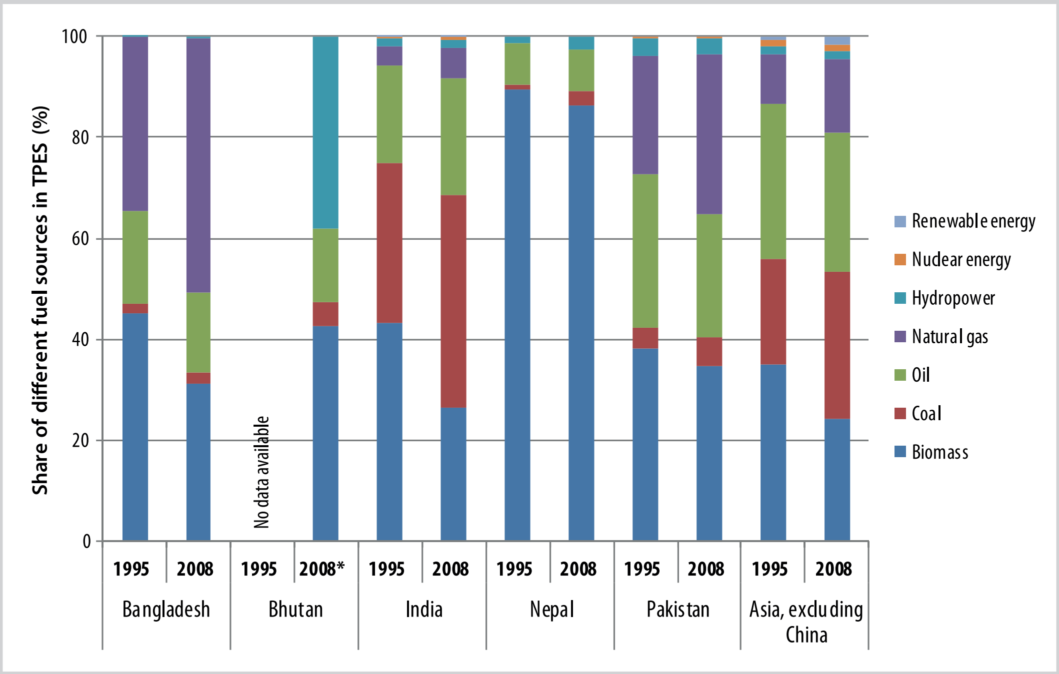

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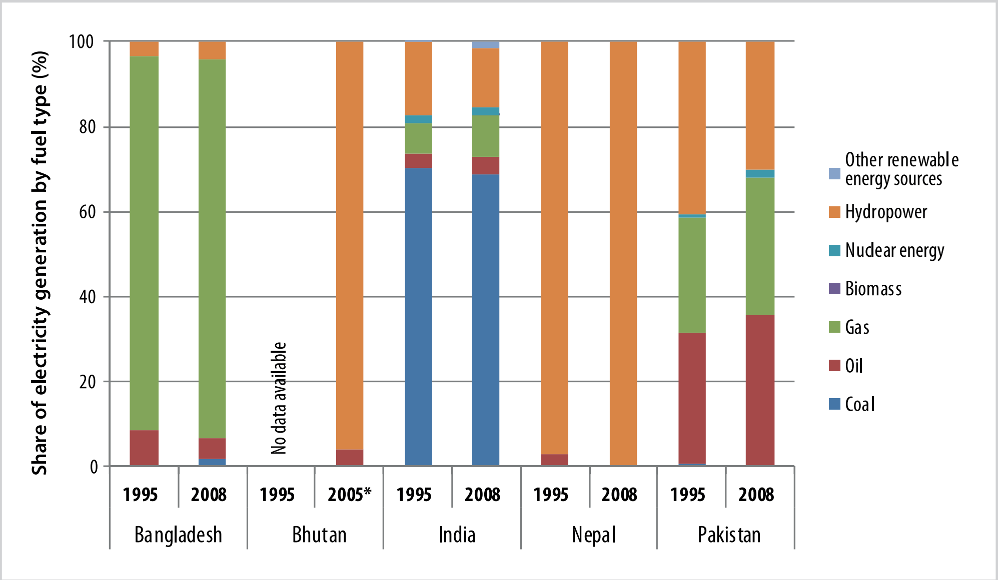
FIGURE 2 Structure of electricity production by fuel type in 1995 and 2008. *Bhutan data for 2005 only.



Nepal in 2008 and the estimated TPES of Bhutan in 2008 (on the basis of per capita energy consumption in 2005), the TPES of the combined HKH areas in the study countries was estimated to be 69.45 metric tons of oil equivalent.

The consumption per capita of traditional biomass energy varies significantly across the study countries, with Bangladesh at the lower end and Bhutan and Nepal at the higher end (Table 2). During 1995–2008, per capita traditional energy consumption declined in all the countries except Nepal and Pakistan, whereas total primary energy consumption increased in all countries.

Electricity generation

Electricity generation per capita in the HKH countries is still relatively low compared with global trends. In 2008, the per capita figure was 218 kilowatt-hours (kWh) in Bangladesh, 728 kWh in India, 108 kWh in Nepal, and 552 kWh in Pakistan compared with 1729 kWh in non-Organization for Economic Co-operation and Development countries as a whole (IEA 2010a; WB 2011). Electricity generation by fuel type in 1995 and 2008 in the countries under study is shown in Figure 2. Electricity generation is predominantly based on coal in India, gas in Bangladesh, hydropower in Bhutan and Nepal, and oil and gas in Pakistan. Dependence on fossil fuels for electricity has been increasing in Bangladesh, India, and Pakistan. Although the share of renewable-energy–based electricity generation other than hydropower is very small, it is increasing in India. As of 2011, the total electricity generation capacity of the selected HKH countries was 188.3 gigawatts (GW): 159.4 GW in India, 19.9 GW in Pakistan, 6.8 GW in Bangladesh, 1.5 GW in Bhutan, and 0.7 GW in Nepal.

The 5 HKH countries under study are endowed with immense hydropower potential (except Bangladesh) and other renewable resources. The total economic hydropower potential of the 5 countries is estimated to be 192,262 megawatts (MW), with 775 MW in Bangladesh (Sankar et al undated), 23,765 MW in Bhutan (DoE 2011), 84,000 MW in India (http://www.nih.ernet.in/rbis/india_information/hydropower.htm), 42,000 MW in Nepal (WECS 2010), and 41,722 MW in Pakistan (MoWP undated). Most of the countries currently have inadequate capacity for electricity supply, which results in load shedding (disconnecting the electric current on certain lines when the demand becomes greater than the supply). For example, the annual energy demand of Nepal was recorded to be 4367.13 Gigawatt hours (GWh) in 2009–2010, of which 3076.69 GWh was met through domestic generation and 612.58 GWh through imports; the rest, 677.86 GWh, was managed by load shedding (NEA 2010).

The total grid-connected power generation capacity installed (which is the present capacity to generate electricity and is different from both the potential capacity and the capacity required to fully meet the demand) in Bangladesh as of 2011 was 6361 MW, whereas the total demand was 6000 MW (with demand-side management, ie through measures to modify energy consumption patterns). However, the maximum average power generated so far in the country is approximately 4724 MW. The shortage of power supply capacity is managed through load shedding during peak periods

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(GoB 2011). In India, the electricity deficit peaked at 11.1% in 2008–2009 and declined to 9.9% in 2009–2010 (TERI 2011). Pakistan's total installed electricity generation capacity of 20,000 MW is not enough to meet the country's electricity demand; its energy shortfall is estimated to be approximately 2500–5000 MW (Khan et al 2011).

Final energy consumption

The total final energy consumption (TFEC) by sector and fuel type in the study countries in 1995 and 2008 are presented in Table 3. During 1995–2008, TFEC increased by 73% in Bangladesh, 10% in India, 45% in Nepal, and 49% in Pakistan. The residential sector accounts for the highest share of TFEC in all countries (in Nepal, it is more than 90%), whereas the industrial sector has the second highest share. In Pakistan and Bangladesh, consumption is more evenly distributed across sectors. The residential sector's share is decreasing in all countries, whereas that of the industrial sector has been increasing in Nepal, India, and Bangladesh.

The structure of TFEC by fuel type varies among the countries. In Bhutan, 91% of the residential sector energy demand is met by biomass and the rest by liquefied petroleum gas, electricity, and kerosene (DoE 2011). More than two thirds (68.4%) of households in Nepal use fuelwood as the main source of energy for cooking; this is followed by liquefied petroleum gas (12.3%), animal waste (10.7%), biogas (2.4%), and kerosene (1.4%) (MoE/GoN 2011). The demand for commercial fuels has risen drastically in all 5 countries. None of them has oil reserves, except India, which has a relatively small oil deposit. Bangladesh and Pakistan have modest natural gas reserves, the use of which has significantly increased in recent years. India is the only country in this region that uses coal in substantial amounts and has made significant progress in exploiting renewable energy resources.

As can be seen in Table 3, biomass had the largest share in TFEC in 2008 in all countries, followed by gas and oil in both Bangladesh and Pakistan and by oil and electricity in India. Coal was the fourth largest contributor to TFEC in India. The share of biomass in TFEC has been increasing in all countries; the share of natural gas has been increasing in Bangladesh and Pakistan but decreasing in India. The share of electricity has also been increasing in all countries.

Based on per capita final energy consumption figures for the countries as a whole and for their HKH mountain areas, the TFEC of the combined HKH area of the selected countries was estimated to be 47.98 metric tons of oil equivalent in 2008, of which Bangladesh, Bhutan, India, Nepal, and Pakistan account for 0.19, 0.39, 22.70, 9.70, and 14.98 metric tons of oil equivalent, respectively. Partly because of the high level of biomass use, dependence on imported energy is relatively low. In 2008, energy import dependency (defined as the share of imported energy in TPES, including biomass) was the highest in India (31.9%), followed by Pakistan (25.9%), Bhutan (24.1%), Bangladesh (18.1%), and Nepal (11.8%). The share of imported energy in TPES, excluding biomass energy, was, however, much higher in all countries, with Nepal having the highest share (86.3%), followed by Bhutan (56.7%), India (43.3%), Pakistan (39.8%), and Bangladesh (26.3%) (Garud and Gurung 2007; IEA 2010a). This clearly indicates the importance of energy security measures for these countries.

There is a wide variation in electricity consumption per capita in the selected countries. In 2008, it varied from 84 kWh in Nepal to 949 kWh in Bhutan, with the corresponding figures in Bangladesh, Pakistan, and India being 199 kWh, 424 kWh, and 528 kWh, respectively (Garud and Gurung 2007; IEA 2010a; WB 2011). Per capita electricity consumption in Bhutan appears to be higher because more than 66% of the country's total electricity consumption is concentrated in power-intensive industrial units.

GHG emissions

The shares of energy-related and nonenergy-related GHG emissions in the study countries in 1994–1995, as stated in each country's report to the United Nations Framework Convention on Climate Change (NEC 2000; MoEF 2002; MoE 2003; MoEF 2004; MoPE 2004), are shown in Table 4. The share of energy-related GHG emissions in 1994–1995 was lowest in Nepal (8.3%) and highest in India (60.4%). The share of energy-related CO_2 emissions, however, was significantly higher: 15% in Nepal, 62.5% in Bangladesh, 81% in Pakistan, and 86.2% in India. In Bhutan, due to relatively low fossil fuel use and effective forestry and plantation management, there was a net CO_2 removal (NEC 2000).

As discussed earlier, Bhutan and Nepal are only 2 of the 5 study countries whose entire area lies in the HKH region. Due to a lack of spatially disaggregated data, it was not possible to precisely estimate GHG emissions for the countries' HKH areas. Instead, a simplified approach was used that assumed that GHG emissions per capita in each country's HKH mountain area were the same as those for the country as a whole. This yielded an estimate for 2008 of 127 metric tons of CO_2 emissions from the HKH areas of the study countries. CO_2 emissions from the HKH parts of Bangladesh, India, and Pakistan were estimated at 0.4 metric tons, 91.3 metric tons, and 31.1 metric tons, respectively (estimated by the author by using per capita national emission based on Garud and Gurung 2007; IEA 2010a; WB 2011), whereas the emissions from Bhutan and Nepal were 0.4 metric tons and 3.3 metric tons, respectively.

For CO_2 emissions intensity, measured as kg CO_2 per US$ of gross

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TABLE 3 Structure of total final energy consumption in selected HKH countries.[a] (Table extended below.)

	Bangladesh		Bhutan		India	
	1995	2008	1995[b]	2005	1995	2008
Sector						
Agriculture (%)	3.6	4.9		1.2	2.3	4.6
Commercial (%)	1.1	1.6		10.3	1.7	3.9
Industrial (%)	13.1	22.3		25.2	24.2	32.3
Residential (%)	73.6	59.5		48.9	60.3	46.4
Transport (%)	8.6	11.7		14.4	11.5	12.8
Total (metric tons of oil equivalent)	**11.4**	**19.6**		**0.4**	**323.1**	**355.1**
Fuel type						
Coal (%)	2.8	2.0		7.1	11.5	12.1
Oil (%)	18.0	17.1		19.9	19.9	26.6
Gas (%)	9.3	22.9		0.0	2.3	1.8
Biomass (%)	63.6	44.3		59.4	58.4	45.8
Electricity (%)	6.2	13.7		13.6	7.9	13.8
Total (metric tons of oil equivalent)	**11.4**	**19.6**		**0.4**	**323.1**	**355.1**

TABLE 3 Extended.

	Nepal		Pakistan	
	1995	2008	1995	2008
Sector				
Agriculture (%)	0.9	0.8	2.0	1.3
Commercial (%)	0.9	1.8	2.4	3.1
Industrial (%)	2.4	4.7	24.7	27.4
Residential (%)	92.2	89.5	54.3	51.4
Transport (%)	3.6	3.2	16.6	16.8
Total (metric tons of oil equivalent)	**6.7**	**9.7**	**43.2**	**64.4**
Fuel type				
Coal (%)	1.1	2.9	4.0	6.5
Oil (%)	7.6	7.3	23.7	16.7
Gas (%)	0.0	0.0	15.2	23.6
Biomass (%)	90.3	88.1	48.8	43.8
Electricity (%)	1.0	1.7	8.4	9.4
Total (metric tons of oil equivalent)	**6.7**	**9.7**	**43.2**	**64.4**

[a] IEA (2010a); Garud and Gurung (2007).
[b] Left blank due to data unavailability for Bhutan in the year 1995.

TABLE 4 CO_2 emissions in the 5 studied HKH countries in 1994–1995 (millions of tons).[a)]

	Nepal	Bangladesh	Bhutan[b)]	India	Pakistan
Energy use	3266.0	15,210.1	95.8	743,820.0	83,269.1
Nonenergy use	35,999.0	38,553.3	−2353.0	488,091.9	83,859.2
Total	**39,265.0**	**53,763.4**	**−2257.0**	**1,231,911.9**	**167,128.3**
Share of energy use in GHG emissions (%)	8.3	28.3	—	60.4	49.8

[a)]MOEF (2002); NEC (2000); MoEF (2004); MoPE (2004); MoE (2003).

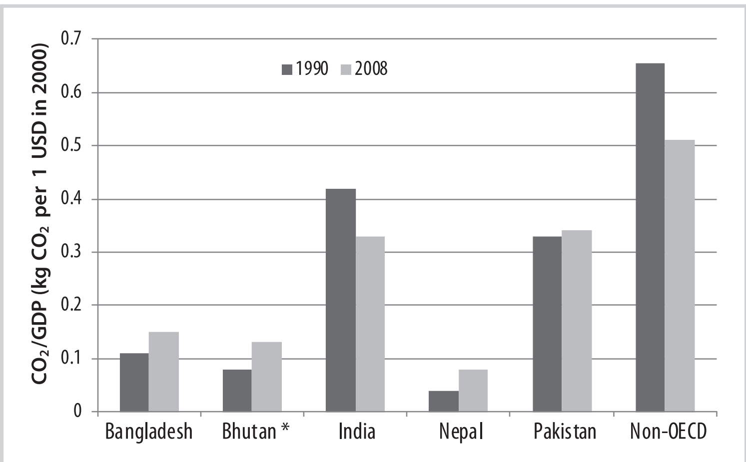
[b)]Bhutan experienced a net removal of CO_2.

domestic product (GDP) (at 2000 prices) (Figure 3), there were wide variations across the study countries for 1990 and 2008: above 0.3 kg CO_2 per US$ for India and Pakistan, and below 0.15 kg CO_2 per US$ for Bangladesh, Bhutan, and Nepal. During 1990–2008, CO_2 intensity increased by 37% in Bangladesh, 59% in Bhutan, 71% in Nepal, and approximately 1% in Pakistan, whereas it decreased by 21% in India. CO_2 emissions per capita increased by 80% in India during 1990–2008, by 147.4% in Bangladesh, 151.6% in Nepal, 47.3% in Pakistan, and 244% in Bhutan compared with 32% in non–Organization for Economic Co-operation and Development countries as a group (Figure 4).

The sectoral contributions to total energy-related CO_2 emissions in the study countries in 1990 and 2008 are shown in Figure 5. The power sector was the largest source of energy-related CO_2 emissions in Bangladesh and India, and the second largest source in Pakistan in 2008, which accounted for 43.3% of total CO_2 emissions in Bangladesh, 56.3% in India, and 30.9% in Pakistan. The sector's share in total CO_2 emissions increased in Bangladesh, India, and Pakistan during 1990–2008, whereas it was almost negligible in Bhutan and Nepal, due to the predominance of hydropower in those countries.

In 2008, the manufacturing and construction sector was responsible for the largest share (33.3%) of total energy-related CO_2 emissions in Pakistan, and the second largest in Bangladesh, India, and Nepal. The sector's share in total CO_2 emissions decreased in Bangladesh, India, and Pakistan, and increased in Nepal during 1990–2008. The transport sector ranked third in energy-related CO_2 emissions in 2008 in Bangladesh, Nepal, and Pakistan, and fourth in India. The sector's share in total CO_2 emissions increased in Bangladesh and Pakistan, and decreased in India and Nepal.

FIGURE 3 CO_2 intensity in 1990 and 2008. Sources: IEA (2010a, 2010b); NEC (2000); UNDP (2007). *Data for Bhutan are from 1994 and 2005.



Future energy use and GHG emissions: methodological limitations

An overview of existing studies on the 5 countries included in this study is presented in Table S1 (*Supplemental data*, http://dx.doi.org/10.1659/MRD-JOURNAL-D-12-00103.S1), including their models or methodologies and their assumptions about the key drivers of future energy use and GHG emissions, such as GDP and population growth. Their differences in these regards yielded significant variation in their estimates.

Primary energy supply in 2030

Different projections of TPES and GHG emissions for the 5 study countries for 2030 are presented in Table 5. Projected TPES for India varies from 920 metric tons of oil equivalent to 2149 metric tons of oil equivalent; this is partly due to different assumptions about GDP and population growth rates, and partly due to differences in the way total energy consumption is reported. Projections of the total 2030 TPES for the 5 study countries vary from 1164 metric tons of oil equivalent to 2585 metric tons of oil equivalent compared with 742 metric tons of oil equivalent in 2008. To estimate the level of energy consumption in the HKH mountain

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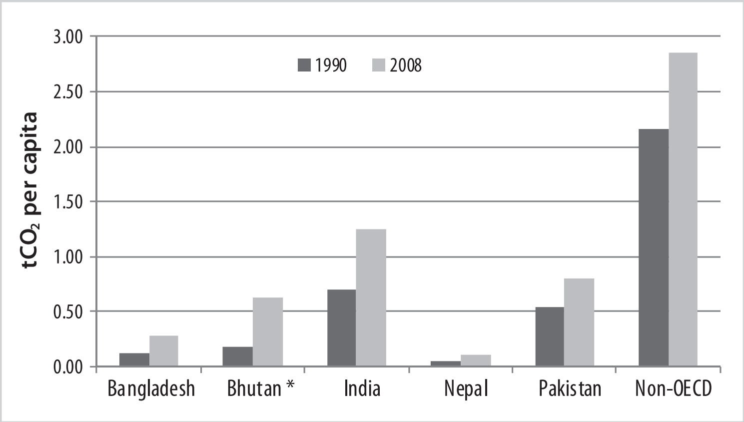
FIGURE 4 Per capita CO_2 emissions in 1990 and 2008. Sources: IEA (2010a, 2010b); NEC (2000); UNDP (2007). *Data for Bhutan are from 1994 and 2005.



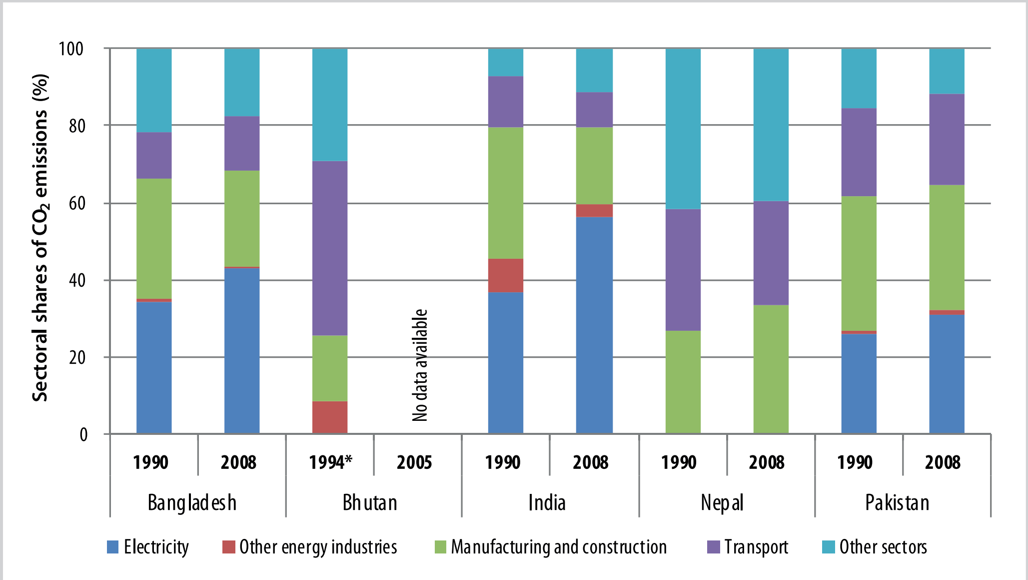
areas of the selected countries, which is not addressed in the existing literature, a simple approach was used again, based on national-level estimates and the proportion of those national populations living in the HKH regions, which was assumed to remain the same as it was in 2007. Based on this calculation, the combined TPES of the HKH mountain areas of the 5 countries in 2030 was projected to be between 114 metric tons of oil equivalent and 240 metric tons of oil equivalent, a significant increase over the estimated 69 metric tons of oil equivalent in 2008.

Energy mix patterns, 2005–2030

Projections of fossil fuel use in the study countries as a whole in 2030 vary from 811 metric tons of oil equivalent to 1388 metric tons of oil equivalent compared with 513 metric tons of oil equivalent in 2008. Renewable energy use projections vary from 299 metric tons of oil equivalent to 344 metric tons of oil equivalent compared with 224 metric tons of oil equivalent in 2008. Nuclear energy use is projected to increase to 22–48 metric tons of oil equivalent from 4 metric tons of oil equivalent in 2008. Projections for India were 331–923 metric tons of oil equivalent for coal, 184–453 metric tons of oil equivalent for oil, and 93–120 metric tons of oil equivalent for natural gas. The projected total fossil fuel consumption in India in 2030 varied from 635 metric tons of oil equivalent (Rout 2011) to 1469 metric tons of oil equivalent (Parikh and Parikh 2011). Use of renewable energy, including hydropower, in India is projected to be 82–276 metric tons of oil equivalent. Total consumption of fossil fuels has been projected to increase 2.9-fold in Bangladesh and 4.0-fold in Bhutan between 2005 and 2030 (ADB 2009), between 2.6 and 2.9 times in Nepal (ADB 2009; Shakya et al 2011), and between 4.0 and 4.8 times in Pakistan (ADB 2009; Khan et al 2011).

In Bangladesh, the share of renewables in TPES is projected to decline from 30.3% to 18.9% from 2005 to 2030 and, that of oil, from 20.2% to 15.9%, whereas the natural gas share is projected to rise from 47.4% in 2005 to 63.0% in 2030 (ADB

FIGURE 5 Sectoral shares in CO_2 emissions in 1990 and 2008. Sources: IEA (2010b); NEC (2000). *Bhutan data for 1994 only.



2009). In Nepal, the share of renewable energy (especially biomass) in TPES is projected to shrink (from 86.8% in 2005 to 78.0% in 2030), whereas that of oil is projected to rise (from 8.6% in 2005 to 14.0% in 2030) (ADB 2009). The share of renewable energy (including hydropower) in TPES in Pakistan is projected to decline to 24.7% in 2030 from 39.1% in 2005 (ADB 2009), or even to 13.3% (Khan et al 2011). In Bhutan, the renewable energy share in TPES is projected to decline to 76.5% in 2030 from 91.7% in 2005 (ADB 2009).

Electricity generation in 2030

Total electricity generation is projected to quadruple from 2005 to 2030 in Bangladesh, from 22.6 terawatt hours (TWh) in 2005 to 87.5 TWh in 2030, with natural gas remaining the dominant fuel (ADB 2009). Another projection is significantly higher, at 146.3 TWh in 2030 (Mondal et al 2010). Electricity generation in Bhutan is projected to grow at a compounded annual growth rate of 6.8% from 2.4 TWh in 2005 to 12.3 TWh in 2030, with hydropower, the dominant energy resource for electricity generation. Electricity generation in India is projected to increase 2.5-fold during 2005–2030, with a continuing dominant share for coal (63.9%), followed by natural gas (11.1%), hydropower (10.4%), nuclear energy (8.9%), renewable energy (3.7%), and oil (2.0%) (ADB 2009). Net electricity demand is projected to increase from 645 TWh in 2000 to 1910 TWh in 2030 (Rout 2011). Power generation in Nepal is projected to increase nearly 3-fold during 2005–2030, with hydropower having a 99.6% share in 2030 (ADB 2009). This figure is higher than the 96.1% projected by Shakya et al (2011). In Pakistan, electricity generation is projected to increase at a compounded annual growth rate of 4.8% during 2005–2030, from 93.9 TWh in 2005 to 302.5 TWh in 2030, with natural gas having the largest share (40.7%), followed by hydropower (32.3%), oil (15.5%), coal (7.1%), and nuclear energy (4.4%) (ADB 2009).

GHG emissions in 2030

Based on national CO_2 emission projections (Table 5), total 2030 CO_2 emissions from the 5 study countries are likely to reach 2441–3733 million tons compared with 1612 million tons in 2008, for an increase of 1.5 to 2.3 times. According to ADB (2009), the total CO_2 emissions in the 5 countries are projected to more than double during 2005–2030, for an increase of 1867 million tons by 2030 and that CO_2 emissions are projected to increase by 4.5% in Bangladesh, 6.6% in Bhutan, 3.7% in India, 4.0% in Nepal, and 4.1% in Pakistan during the period. Total annual GHG emissions in Bangladesh, Bhutan, and Nepal in 2030 are projected to be 168.3 million tons of CO_2 equivalent (CO_2e), 2.9 million tons CO_2e, and 13.5 million tons CO_2e, respectively (Shrestha et al 2013).

For India, Garg and Shukla (2009) project the total annual CO_2 emissions in 2030 to be 3084 million tons, 2.5 times those in 2005. GHG emissions in India in 2031 were projected to be 4000–7300 million tons CO_2e by a study that used 5 different models (MoEFI 2009); accordingly, India's per capita GHG emissions in 2030–2031 are projected to vary from 2.77 tons to 5 tons of CO_2e. This highlights the likelihood that even 2 decades from now, India's per capita GHG emissions will be well below the global average (4.22 tons per capita in 2005). India was the fifth largest emitter of energy-related CO_2 in 2005, releasing 4% of total world CO_2 emissions (IEA 2007). India is projected to become the third-largest CO_2 emitter in 2015 and to account for 8% of global emissions by 2030 (IEA 2007). Coal burning for power generation is expected to produce almost two thirds of India's emissions. Annual GHG emissions in Nepal are projected to double by 2030, from 5.7 million tons CO_2e in 2005 to 10.3 million tons CO_2e in 2030 (Shakya et al 2011). Total energy-related GHG emissions in Pakistan are projected to increase 3.6-fold during 2008–2030, from 157 million tons CO_2e in 2008 to 560 million tons CO_2e in 2030 (Khan et al 2011).

It would also be of interest to be able to project total 2030 CO_2 emissions from energy use in the combined HKH mountain areas of the study countries. To the author's knowledge, there are no existing studies that address this question, and there are no disaggregated district- or village-level data available for these areas on which to base such a projection; therefore, this study used the same simplified approach described earlier (based on 2030 per capita GHG projections for each country as a whole and the proportion of that country's population living in its HKH areas). The result, a rough projection of GHG emissions in 2030 for the HKH areas of the 5 countries, suggests that total GHG emissions for those areas will likely be 213–296 million tons CO_2.

Conclusion

This article has reviewed projections of future energy use and GHG emissions, assuming the absence of climate policy interventions, in 5 countries of the HKH region. Only a few such studies exist for any country except India. The studies vary widely in their economic and demographic growth scenarios as well as the methodologies used. Based on their country-level results, it has been projected that the TPES in the 5 countries as a group will vary from 1164–2585 metric tons of oil equivalent in 2030 compared with 742 metric tons of oil equivalent in 2008. Similarly, the CO_2 emissions of the 5 countries as a whole in 2030 are projected to be 2441–3733 million tons compared with 1612 million tons in 2008.

In the absence of projections and data that are specific to the HKH areas of the 5 study countries, this study projected total energy use and GHG emissions in those areas on the basis of per capita energy use and GHG emissions in each of the 5

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TABLE 5 Total primary energy supply and GHG emissions projected for 2030. (Table extended on next page.)

Country/study	Primary energy supply (metric tons oil equivalent)				
	Coal	Oil	Natural gas	Hydro	Nuclear
Bangladesh					
ADB (2009)	1.1	9.0	35.6	0.1	—
Shrestha et al (2013)	24.3	7.9	20.1	—	—
Bhutan					
ADB (2009)	0.2	0.2	—	1.1	—
Shrestha et al (2013)	0.2	0.6	—	0.7	—
India					
ADB (2009)	456.6	316.4	97.4	21.5	56.3
IEA (2007)	620.0	328.0	93.0	22.0	33.0
Garg and Shukla (2009)	—	—	—	—	—
Shukla (2006)	—	—	—	—	—
Parikh and Parikh (2011)	923.0	453.0	93.0	—	—
Parikh et al (2009)	—	—	—	—	—
MoEFI (2009)[g)]	—	—	—	—	—
Rout (2011)	331.2	184.0	119.6	27.6	18.4
Nepal					
ADB (2009)	0.6	2.3	—	0.7	—
Shakya et al (2011)	—	—	—	—	—
Shrestha et al (2013)	0.2	2.7	—	1.5	—
ADB (2009)	16.1	41.0	70.0	8.4	3.5
Khan et al (2011)	66.8	68.6	162.6	38.9	15.1

[a)] Estimates at 8% GDP growth rate.
[b)] Others include geothermal, solar, wind, biomass, and electricity exports and imports.
[c)] Others include hydroelectricity and nuclear and renewable energy.
[d)] Total primary commercial energy supply; does not include biomass.
[e)] Estimates for 2031–2032.
[f)] Estimates at 9% GDP growth rate.
[g)] See Table S1 (*Supplemental data*, http://dx.doi.org/10.1659/MRD-JOURNAL-D-12-00103.S1) for definition of modeling studies (MS) 1–5.
[h)] Estimates for 2030–2031.
[i)] Total commercial primary energy.
[j)] Total commercial energy, including secondary forms.

countries and the proportion of each country's population living in the HKH areas (when assuming that these areas' population shares would remain the same as they were in 2007). This yielded a projection of total primary energy use in those areas of 114–240 metric tons of oil equivalent in 2030 compared with 69 metric tons of oil equivalent in 2008, and of total CO_2 emissions in those areas of 213–296 million tons compared with 127 million tons in 2008. These projections are rough estimates and should not be treated as the results of rigorous analysis. Their limitations include the following:

- Energy use and GHG emissions patterns in the mountainous areas are likely to be different from overall national patterns, especially for countries such as Bangladesh, India, and Pakistan.
- The population shares of the HKH areas are unlikely to remain constant over time.

TABLE 5 Extended. (First part of Table 5 on previous page.)

Country/study	Others	Total primary energy supply	Emissions (million tons CO_2) [a]	
			CO_2	All GHGs
Bangladesh				
ADB (2009)	10.7[b]	56.5	99.6	—
Shrestha et al (2013)	11.2	63.5	167.7	168.3
Bhutan				
ADB (2009)	0.2[b]	1.6	1.5	—
Shrestha et al (2013)	0.6	2.1	2.8	2.9
India				
ADB (2009)	223.6[b]	1171.7	2689.2	—
IEA (2007)	203.0	1299.0	3314.0	—
Garg and Shukla (2009)	—	—	3084.0	—
Shukla (2006)	—	—	—	3507.0
Parikh and Parikh (2011)	82.0[c]	1553.0[d]	—	—
Parikh et al (2009)	—	1514.0[a),e]	—	—
		1823.0[e),f]		
MoEFI (2009)[g]	—	MS1: 1087.0[h),i]	—	MS1: 4000.0[h]
		MS2: 1567.0[h),j]		MS2: 4230.0[h]
		MS3: 1042.0[h),i]		MS3: 4900.0[h]
		MS4: 2149.0[h),j]		MS4: 5700.0[h]
				MS5: 7300.0[h]
Rout (2011)	248.4	920.0	2022.0	—
Nepal				
ADB (2009)	12.8[b]	16.4	9.5	—
Shakya et al (2011)	—	12.9	—	10.3
Shrestha et al (2013)	8.9	13.8	11.0	13.5
ADB (2009)	34.4[b]	173.4	308.6	—
Khan et al (2011)	9.2	361.3	—	560

- GDP growth rates in the HKH areas may be different from those in other areas.
- Use of technology and energy resources in the HKH areas could differ from that in other areas.
- Because there usually are fewer fossil-fuel-intensive industrial and commercial activities in mountain areas, basing projections of fossil fuel use and GHG emissions in an HKH area on those for the country as a whole is likely to result in an overestimation.

There is clearly a major gap in knowledge about energy use and GHG emissions in the HKH region. In the absence of disaggregated district- or village-level data on energy use in different sectors and of HKH-area–specific case studies, this knowledge gap is expected to persist. Further research, therefore, is imperative to better understand likely future trends in energy use and

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GHG emissions in this important ecological region.

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Supplemental data

TABLE S1 Models and assumptions used in different projections.

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