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Supplementary Information

Mapping Bioenergy Supply and Demand in Selected Least Developed Countries (LDCs): Exploratory Assessment of Modern Bioenergy's Contribution to SDG 7

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Figure S1. LDCs analyzed in the present study.

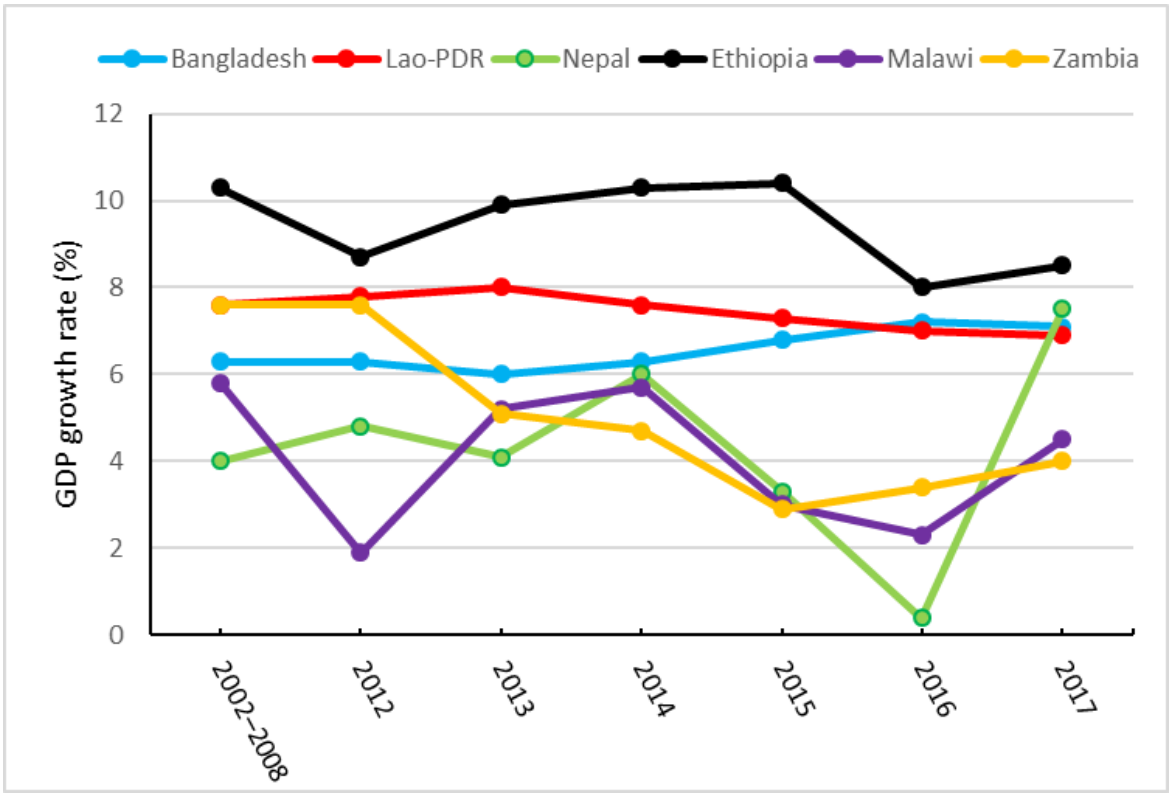

Figure S2. GDP growth rate in the selected LDCs. Source: [1].

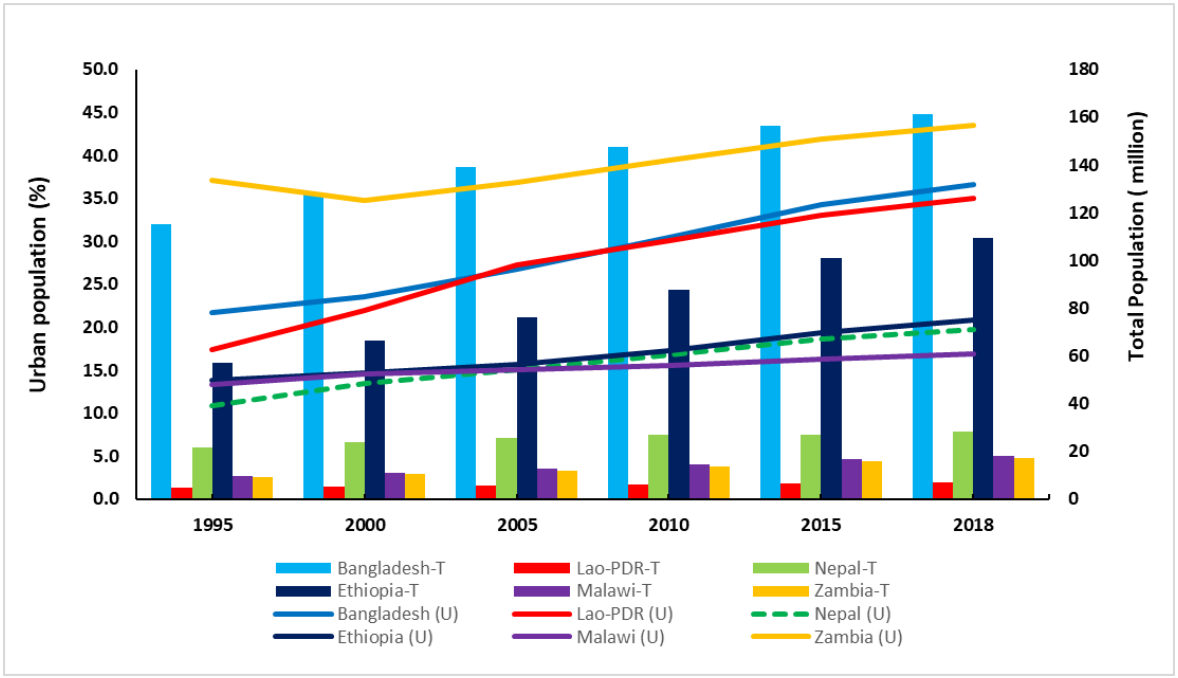

Figure S3. Population and urbanization pattern in the selected LDCs; Note: primary y-axis shows the urban (U) population (%) while second axis presents total (T) population in million; Source: [2].

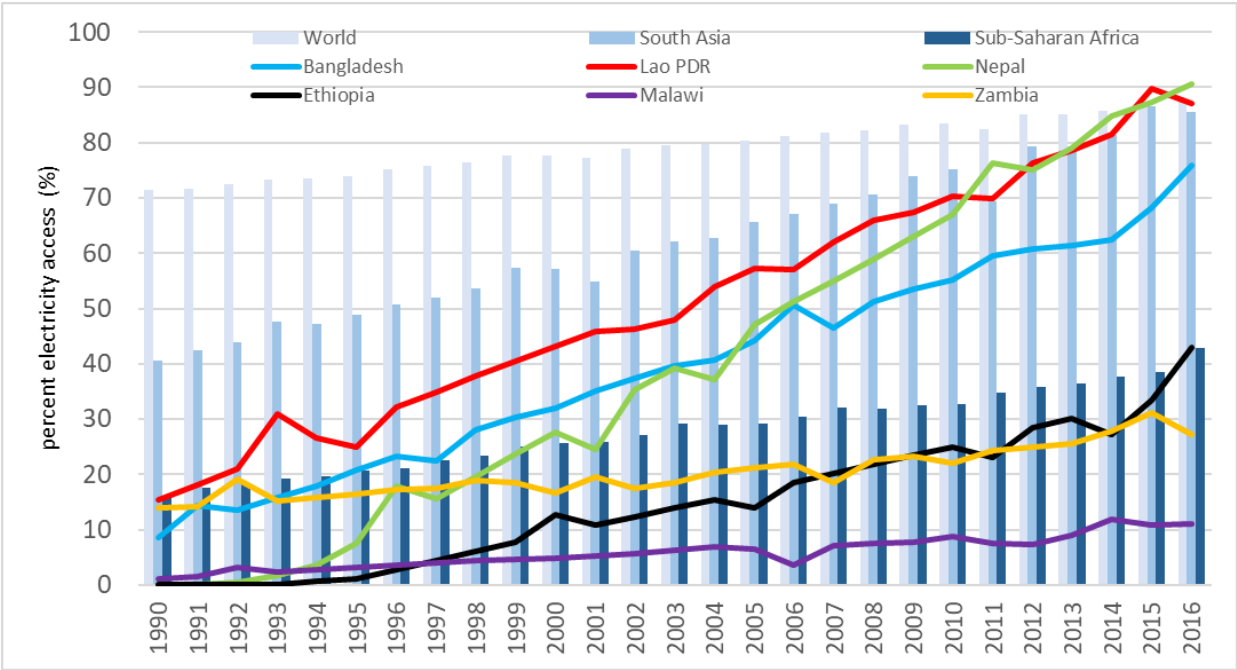

Figure 4. Electricity access from 1990 to 2016 in the world, South Asia, SSA and selected DCs; Source: [2].

Table S1. Total Primary Energy Supply (TPES) in LDCS by fuel source (in ktoe).

Items	Bangladesh		Lao-PDR		Nepal		Ethiopia		Malawi[a]		Zambia	
	2017	%	2015	%	2017	%	2017	%	2008	%	2017	%
By fuel source												
Coal	1984	4.9	1801	37.8	791	6.0	357	0.8	98.68	2.4	470	3.9
Oil product (petroleum)	5829	14.4	930	19.5	2298	17.3	3678	8.7	280.07	6.8	1452	12.0
Natural gas	23071	56.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biofuel and waste	9534	23.5	1619	34.0	9778	73.7	37215	87.7	3640	88.2	9106	75.4
hydroelectricity	90	0.2	415	8.7	398	3.0	1114	2.6	104.82	2.5	1049	8.7
Other (wind, solar, etc.)	16	0.04	0.0	0.0	1	0.0	84	0.2	2.4	0.1	0.0	0.0
Total (ktoe)	40524		4765		13266		42448		4125.97		12077	

Source: [3][4][5] [a] Latest information is not available, but there is no significance change in the energy mix in Malawi [5].

Table S2. Land covered by agricultural and forest land (% of the country's land area).

Country	Forest area (% of land area)						Agricultural land (% of land area)					
	1995	2000	2005	2010	2015	2016	1995	2000	2005	2010	2015	2016
Bangladesh	11.4	11.3	11.2	11.1	11	11	72	72.2	71.5	71	70.4	70.6
Lao-PDR	74	71.6	73.1	77.2	81.3	82.1	7.4	7.8	8.6	9.6	10.3	10.3
Nepal	30.5	27.2	25.4	25.4	25.4	25.4	29.3	29.6	29.3	28.8	28.7	28.7
Ethiopia	14.4	13.7	13	12.3	12.5	12.5	30.5	30.7	33.6	35.7	36.3	36.3
Malawi	39.6	37.8	36.1	34.3	33.4	33.2	45.4	50.2	54.9	60.3	61.4	61.4
Zambia	69.9	68.8	67.7	66.5	65.4	65.2	28.9	30.3	30.6	31.5	32.1	32.1

Source: FAO-STAT [6].

Table S3. Targets and indicators for measuring SDG7.

Targets by 2030	Indicators
7.1: Ensure universal access to affordable, reliable and modern energy services	7.1.1: Access to electricity - measured as the share of people with electricity access at the household level
	7.1.2: Access to clean fuels for cooking - measured as the share of the total population with access to clean fuels and technologies for cooking
7.2: Increase the share of renewable energy in the energy mix	7.2.1: Renewable energy share in the total final energy consumption - measured as renewable energy as a share of final energy consumption
7.3: Double the rate of improvement in energy efficiency	7.3.1: Energy efficiency - it is energy intensity measured in terms of primary energy and GDP (kWh or MJ per 2011 int-US$)
7.A: Facilitate access to clean energy research and technology	7.A.1: Access and investments in clean energy - financial flows to developing countries to promote RE production
7.B: Expand modern and sustainable energy in developing countries	7.B.1: Expanding energy services for developing countries - investments in energy efficiency and foreign direct investment in sustainable energy infrastructures

Source: UN [7].

Table S4. Access to electricity – Indicator 7.1.1 in the rural and urban population in LDCs, 2000–2016, selected years.

Country	Total			Urban			Rural		
	% of total population			% of total population			% of total population		
	2000	2010	2016	2000	2010	2016	2000	2010	2016
Bangladesh	32	55	76	81.2	90.1	94	20.5	42.5	68.9
Lao-PDR	43	70	87	96	97	97	28.3	57.2	80.3
Nepal	28	67	91	84	93	95	18.8	61.8	85.2
Ethiopia	13	25	43	76.2	85	85.4	0.4	12.5	26.5
Malawi	5	9	11	28.7	34.7	42	1	3.5	4
Zambia	17	22	27	44.1	49.8	62	2.2	3.1	2.7

Source: UNCTAD [1].

Table S5. Status of SDG7 – Indicators: clean cooking (7.1.2), share of renewable energy (7.2.1) and primary energy intensity (7.3.1) in the LDCs (in 2016).

Country	Access to clean cooking (% of population)	RE (% of TFEC)	Primary energy intensity (MJ per 2011 USD-PPP)
Bangladesh	19	34	3.10
Lao-PDR	6	52	5.90
Nepal	29	79	8.10
Ethiopia	3	92	13.10
Malawi	2	79	4.20
Zambia	16	89	7.70

Source: World Bank [8].

Table S6. Trend in primary energy intensity in LDCs, 1990-2016, selected years.

Country	Primary energy intensity (MJ per 2011 USDPPP)						
	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**
Bangladesh	3.90	3.90	3.60	3.50	3.40	3.10	3.10
Lao-PDR	8.20	6.50	4.40	3.80	3.80	4.40	5.90
Nepal	10.80	9.70	9.30	8.90	8.00	7.40	8.10
Ethiopia	30.60	34.70	32.30	27.50	19.00	13.70	13.10
Malawi	9.10	8.00	6.60	6.40	4.80	4.20	4.20
Zambia	12.10	13.20	11.90	10.50	8.00	7.80	7.70

Source: World Bank [8] .

Table S7. Projection of peak load (load capacity) and electricity generation in the LDCs[a,b.]

Year	Bangladesh		Lao-PDR		Nepal		Ethiopia		Malawi		Zambia	
	MW	**GWh**	**MW**	**GWh**	**MW**	**GWh**	**MW**	**GWh**	**MW**	**GWh**	**MW**	**GWh**
2015	9 036	52 193	1 056	5 212	1 292	6 335	2 657	14 637	352	1 997	2 504	15 355
2016	9 479	57 276	1 349	6 789	1 468	6 912	3 156	17 415	388	2 208	2 574	15 784
2017	10 958	62 678	1 608	8 188	1 644	7 490	3 748	20 720	427	2 432	2 647	16 231
2020	13 746	79 533	2 723	14 378	2 638	12 018	6 279	34 906	571	3 249	2 893	17 740
2025	20 056	118 288	4 395	24 057	4 519	20 585	9 989	53 132	925	5 268	3 401	20 855
2030	29 264	175 926	5 892	32 923	7 542	34 355	14 372	73 709	1 500	8 541	4 066	24 933

Authors' compilation based on the results of projection; [a] Refer to Section 3.2 (future projection of electricity generation) for data sources and method of the projection; [b] GWh represents the total electricity generation whereas capacity (MW) represents peak load.

Table S8a. Production of major crops by country in 2017.

Country	Crop production (Million tonnes, Mt)												
	Barley	Cassava	Jute	Maize	Millet	Potatoes	Rice, paddy	Seed cotton	Sugar cane	Sweet potatoes	Tobacco*	Wheat	Total
Bangladesh	0.0	0.0	1.5	3.0	0.0	10.2	49.0	0.1	3.9	0.3	0.1	1.3	69.4
Lao-PDR	0.0	2.3	0.0	1.2	0.0	0.0	4.0	0.0	1.8	0.1	0.0	0.0	9.4
Nepal	0.0	0.0	0.0	2.3	0.3	2.7	5.2	0.0	3.2	0.0	0.0	1.9	15.6
Ethiopia	2.0	0.0	0.0	8.1	1.1	0.9	0.1	0.0	1.4	2.0	0.0	4.8	20.4
Malawi	0.0	5.0	0.0	3.5	0.0	1.2	0.1	0.0	3.0	5.5	0.1	0.0	18.4
Zambia	0.0	1.0	0.0	3.6	0.0	0.0	0.0	0.1	4.5	0.2	0.1	0.2	9.7

*unmanufactured; Source: FAO-STAT [6].

Table S8b. Residue to grain ratio for major crops in the LDCs.

Crop	Type of residue	Residue to product ratio	Sources
Barley	Straw	1.3	[9][10]
Cassava	Stalk	0.88	[11][12]
	Stalk	3.8	[13][14][15]
Cotton	Husk	1.1	[13]
	Boll shell	1.1	[13]
Jute	Stalk	2	[16][17]
Maize	Stalk + cobs	2.5	[18][14]
Millet	Straw	1.2	[13]
Potatoes	Root and Stubble residues	0.25	[19][20]
Rice, paddy	Straw + husk	1.8	[21][22][18][23]
Sugar beet	Residue	0.7	[15]
Sugar cane	Bagasse + leaves	0.4	[18][14]
Sweet potatoes	Residues	0.25	[20]
Tobacco, unmanufactured	Tobacco refuse	0.2	[24]
Wheat	Straw	1.6	[18][23]

Table S9a. Technical potential of agricultural residues for bioelectricity.

Year	Gross agri-residues availability (Mt)						Biomass power potential (GW)					
	Bangladesh	Lao-PDR	Nepal	Ethiopia	Malawi	Zambia	Bangladesh	Lao-PDR	Nepal	Ethiopia	Malawi	Zambia
2002	75.9	4.9	14.9	12.7	7.8	4.0	9.0	0.6	1.8	1.5	0.9	0.5
2003	74.6	5.1	15.4	13.2	8.3	4.9	8.8	0.6	1.8	1.6	1.0	0.6
2004	73.3	5.3	16.0	13.7	8.8	5.8	8.7	0.6	1.9	1.6	1.1	0.7
2005	80.0	5.8	16.1	17.2	7.5	5.2	9.5	0.7	1.9	2.1	0.9	0.6
2006	81.6	6.2	16.0	17.9	12.0	6.5	9.7	0.7	1.9	2.1	1.4	0.8
2007	86.8	7.0	15.5	16.1	14.1	6.4	10.3	0.8	1.8	1.9	1.7	0.8
2008	94.5	8.6	16.9	17.3	13.1	6.0	11.2	1.0	2.0	2.1	1.6	0.7
2009	95.5	8.9	17.1	19.3	15.9	8.4	11.3	1.1	2.0	2.3	1.9	1.0
2010	99.8	8.9	16.5	22.0	15.4	10.6	11.8	1.1	2.0	2.6	1.8	1.3
2011	102.5	9.5	18.1	24.5	16.5	11.3	12.1	1.1	2.2	2.9	2.0	1.4
2012	102.9	10.5	19.8	26.1	18.0	11.9	12.2	1.2	2.4	3.1	2.1	1.4
2013	105.8	10.7	18.4	28.2	17.9	10.4	12.5	1.3	2.2	3.3	2.1	1.3
2014	107.8	13.0	19.6	31.0	18.0	12.1	12.7	1.5	2.3	3.7	2.1	1.4
2015	108.4	14.1	19.5	33.0	14.6	10.2	12.8	1.7	2.3	3.9	1.7	1.2
2016	106.3	14.4	20.1	32.6	13.5	11.0	12.6	1.7	2.4	3.8	1.6	1.3
2017	111.4	14.6	20.6	33.8	16.5	13.0	13.2	1.7	2.5	4.0	2.0	1.6
2018	116.5	14.8	21.1	35.2	18.1	13.4	13.8	1.8	2.5	4.2	2.2	1.6
2019	119.2	15.5	21.5	36.8	18.8	14.0	14.1	1.8	2.6	4.3	2.2	1.7
2020	121.9	16.2	21.8	38.4	19.4	14.6	14.4	1.9	2.6	4.5	2.3	1.8
2021	124.6	16.8	22.2	39.9	20.0	15.2	14.7	2.0	2.6	4.7	2.4	1.8
2022	127.3	17.5	22.5	41.5	20.6	15.8	15.0	2.1	2.7	4.9	2.5	1.9
2023	130.0	18.2	22.9	43.1	21.2	16.5	15.3	2.2	2.7	5.1	2.5	2.0
2024	132.7	18.9	23.3	44.7	21.8	17.1	15.7	2.2	2.8	5.3	2.6	2.1
2025	135.4	19.5	23.6	46.2	22.5	17.7	16.0	2.3	2.8	5.5	2.7	2.1
2026	138.1	20.2	24.0	47.8	23.1	18.3	16.3	2.4	2.9	5.6	2.7	2.2
2027	140.8	20.9	24.3	49.4	23.7	18.9	16.6	2.5	2.9	5.8	2.8	2.3
2028	143.5	21.6	24.7	50.9	24.3	19.5	16.9	2.6	2.9	6.0	2.9	2.3
2029	146.2	22.2	25.0	52.5	24.9	20.2	17.3	2.6	3.0	6.2	3.0	2.4
2030	148.9	22.9	25.4	54.1	25.5	20.8	17.6	2.7	3.0	6.4	3.0	2.5

Table S9b. Economic potential of agricultural residues for bioelectricity.

Year	Net agri-residues availability (Mt)						Biomass power potential (GW)					
	Bangladesh	Laos	Nepal	Ethiopia	Malawi	Zambia	Bangladesh	Lao-PDR	Nepal	Ethiopia	Malawi	Zambia
2002	15.2	1.0	3.0	2.5	1.6	0.8	1.8	0.1	0.4	0.3	0.2	0.1
2003	14.9	1.0	3.1	2.6	1.7	1.0	1.8	0.1	0.4	0.3	0.2	0.1
2004	14.7	1.1	3.2	2.7	1.8	1.2	1.7	0.1	0.4	0.3	0.2	0.1
2005	16.0	1.2	3.2	3.4	1.5	1.0	1.9	0.1	0.4	0.4	0.2	0.1
2006	16.3	1.2	3.2	3.6	2.4	1.3	1.9	0.1	0.4	0.4	0.3	0.2
2007	17.4	1.4	3.1	3.2	2.8	1.3	2.1	0.2	0.4	0.4	0.3	0.2
2008	18.9	1.7	3.4	3.5	2.6	1.2	2.2	0.2	0.4	0.4	0.3	0.1
2009	19.1	1.8	3.4	3.9	3.2	1.7	2.3	0.2	0.4	0.5	0.4	0.2
2010	20.0	1.8	3.3	4.4	3.1	2.1	2.4	0.2	0.4	0.5	0.4	0.3
2011	20.5	1.9	3.6	4.9	3.3	2.3	2.4	0.2	0.4	0.6	0.4	0.3
2012	20.6	2.1	4.0	5.2	3.6	2.4	2.4	0.2	0.5	0.6	0.4	0.3
2013	21.2	2.1	3.7	5.6	3.6	2.1	2.5	0.3	0.4	0.7	0.4	0.3
2014	21.6	2.6	3.9	6.2	3.6	2.4	2.5	0.3	0.5	0.7	0.4	0.3
2015	21.7	2.8	3.9	6.6	2.9	2.0	2.6	0.3	0.5	0.8	0.3	0.2
2016	21.3	2.9	4.0	6.5	2.7	2.2	2.5	0.3	0.5	0.8	0.3	0.3
2017	22.3	2.9	4.1	6.8	3.3	2.6	2.6	0.3	0.5	0.8	0.4	0.3
2018	23.3	3.0	4.2	7.0	3.6	2.7	2.8	0.4	0.5	0.8	0.4	0.3
2019	23.8	3.1	4.3	7.4	3.8	2.8	2.8	0.4	0.5	0.9	0.4	0.3
2020	24.4	3.2	4.4	7.7	3.9	2.9	2.9	0.4	0.5	0.9	0.5	0.4
2021	24.9	3.4	4.4	8.0	4.0	3.0	2.9	0.4	0.5	0.9	0.5	0.4
2022	25.5	3.5	4.5	8.3	4.1	3.2	3.0	0.4	0.5	1.0	0.5	0.4
2023	26.0	3.6	4.6	8.6	4.2	3.3	3.1	0.4	0.5	1.0	0.5	0.4
2024	26.5	3.8	4.7	8.9	4.4	3.4	3.1	0.4	0.6	1.1	0.5	0.4
2025	27.1	3.9	4.7	9.2	4.5	3.5	3.2	0.5	0.6	1.1	0.5	0.4
2026	27.6	4.0	4.8	9.6	4.6	3.7	3.3	0.5	0.6	1.1	0.5	0.4
2027	28.2	4.2	4.9	9.9	4.7	3.8	3.3	0.5	0.6	1.2	0.6	0.5
2028	28.7	4.3	4.9	10.2	4.9	3.9	3.4	0.5	0.6	1.2	0.6	0.5
2029	29.2	4.4	5.0	10.5	5.0	4.0	3.5	0.5	0.6	1.2	0.6	0.5
2030	29.8	4.6	5.1	10.8	5.1	4.2	3.5	0.5	0.6	1.3	0.6	0.5

Table S9c. Technical and economic potential of agricultural residues for bioelectricity.

Year	Technical potential (in TWh)						Economic potential (in TWh)					
	Bangladesh	Lao-PDR	Nepal	Ethiopia	Malawi	Zambia	Bangladesh	Lao-PDR	Nepal	Ethiopia	Malawi	Zambia
2002	62.2	4.0	12.1	10.4	6.3	3.1	12.4	0.8	2.4	2.1	1.3	0.6
2003	61.1	4.2	12.6	10.7	6.7	3.8	12.2	0.8	2.5	2.1	1.3	0.8
2004	60.0	4.3	13.0	11.1	7.1	4.6	12.0	0.9	2.6	2.2	1.4	0.9
2005	65.6	4.7	13.1	14.0	6.0	4.1	13.1	0.9	2.6	2.8	1.2	0.8
2006	67.0	5.1	13.1	14.6	9.7	5.1	13.4	1.0	2.6	2.9	1.9	1.0
2007	71.3	5.8	12.6	13.2	11.5	5.1	14.3	1.2	2.5	2.6	2.3	1.0
2008	77.7	7.1	13.7	14.1	10.6	4.8	15.5	1.4	2.7	2.8	2.1	1.0
2009	78.5	7.3	13.9	15.8	12.9	6.7	15.7	1.5	2.8	3.2	2.6	1.3
2010	82.1	7.3	13.4	17.9	12.5	8.4	16.4	1.5	2.7	3.6	2.5	1.7
2011	84.4	7.7	14.8	20.0	13.4	9.1	16.9	1.5	3.0	4.0	2.7	1.8
2012	84.7	8.6	16.1	21.4	14.7	9.5	16.9	1.7	3.2	4.3	2.9	1.9
2013	87.1	8.8	15.0	23.2	14.6	8.3	17.4	1.8	3.0	4.6	2.9	1.7
2014	88.8	10.6	16.0	25.5	14.6	9.6	17.8	2.1	3.2	5.1	2.9	1.9
2015	89.3	11.5	15.9	27.2	11.8	8.1	17.9	2.3	3.2	5.4	2.4	1.6
2016	87.5	11.7	16.3	26.8	10.9	8.7	17.5	2.3	3.3	5.4	2.2	1.7
2017	91.8	11.9	16.8	27.8	13.4	10.3	18.4	2.4	3.4	5.6	2.7	2.1
2018	96.0	12.1	17.2	29.0	14.8	10.7	19.2	2.4	3.4	5.8	3.0	2.1
2019	98.2	12.6	17.5	30.3	15.3	11.2	19.6	2.5	3.5	6.1	3.1	2.2
2020	100.5	13.2	17.8	31.6	15.8	11.7	20.1	2.6	3.6	6.3	3.2	2.3
2021	102.7	13.7	18.1	32.9	16.3	12.2	20.5	2.7	3.6	6.6	3.3	2.4
2022	105.0	14.3	18.3	34.2	16.8	12.7	21.0	2.9	3.7	6.8	3.4	2.5
2023	107.2	14.8	18.6	35.5	17.3	13.2	21.4	3.0	3.7	7.1	3.5	2.6
2024	109.5	15.4	18.9	36.8	17.8	13.6	21.9	3.1	3.8	7.4	3.6	2.7
2025	111.7	15.9	19.2	38.1	18.3	14.1	22.3	3.2	3.8	7.6	3.7	2.8
2026	113.9	16.5	19.5	39.4	18.8	14.6	22.8	3.3	3.9	7.9	3.8	2.9
2027	116.2	17.0	19.8	40.7	19.3	15.1	23.2	3.4	4.0	8.1	3.9	3.0
2028	118.4	17.5	20.1	42.0	19.8	15.6	23.7	3.5	4.0	8.4	4.0	3.1
2029	120.7	18.1	20.4	43.3	20.3	16.1	24.1	3.6	4.1	8.7	4.1	3.2
2030	122.9	18.6	20.7	44.6	20.8	16.6	24.6	3.7	4.1	8.9	4.2	3.3

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