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ORIGINAL ARTICLE

Linking climate policy across economic sectors: A case for green growth in Nepal

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Abstract

While the energy sector is the largest global contributor to greenhouse gas (GHG) emissions, the agriculture, forestry, and other land use (AFOLU) sector account for up to 80% of GHG emissions in the least developed countries (LDCs). Despite this, the nationally determined contributions (NDCs) of LDCs, including Nepal, focus primarily on climate mitigation in the energy sector. This paper introduces green growth—a way to foster economic growth while ensuring access to resources and environmental services—as an approach to improving climate policy coherence across sectors. Using Nepal as a case country, this study models the anticipated changes in resource use and GHG emissions between 2015 and 2030, that would result from implementing climate mitigation actions in Nepal's NDC. The model uses four different scenarios. They link NDC and policies across economic sectors and offer policy insights regarding (1) energy losses that could cost up to 10% of gross domestic product (GDP) by 2030, (2) protection of forest resources by reducing the use of biomass fuels from 465 million gigajoules (GJ) in 2015 to 195 million GJ in 2030, and (3) a significant reduction in GHG emissions by 2030 relative to the business-as-usual (BAU) case by greater use of electricity from hydropower rather than biomass. These policy insights are significant for Nepal and other LDCs as they seek an energy transition towards using more renewable energy and electricity.

KEYWORDS
climate mitigation, energy loss, GHG emissions, green growth, policy coherence

1 | INTRODUCTION

Although development issues are given more prority in political discourse in least developed countries (LDCs), almost all LDCs are required to implement nationally determined contributions (NDCs) under the Paris Climate Agreement. However, despite the obligation to implement NDCs and focus on socioeconomic development issues, limited studies focus on the links between NDCs and socioeconomic development (Altieri et al., 2016; von Stechow et al., 2016). While recent research on NDCs aims to promote discussions on the nexus between NDCs and socioeconomic development, there is still a lack of appropriate approaches for assessing the linkage between NDCs and economic development, especially for low-income countries and within the government policy landscape. This research uses the concept of green growth as a strategic approach to assess linkage between NDCs and key sectors of an economy in Nepal, which is a case country. Green growth is defined as a way to foster economic growth and development while ensuring access to resources and environmental services from natural capital (OECD, 2017; OECD, 2018a, 2018b). Hallegate et al. (2011) further clarifies that green growth is resource-efficient, clean, and resilient growth. The reference to resource-efficient and clean growth implies that using fewer, renewable, and clean resources will potentially improve carbon and energy productivity.[1] Resilient growth is economic growth amidst economic threats from climate change. In this paper, the green growth approach is viewed as having potential to improve coherence across policies representing different economic sectors in the context of implementing climate mitigation actions as NDCs. This is because green growth is one of the strategies favored by mainstream economists and policymakers in studies related to addressing climate change. They see it as a means of reconciling the conflict between economic growth and environmental protection (Antal & van den Bergh, 2016).

Nepal is deemed as a suitable case country because of three main reasons. First, Nepal is an LDC with minimum levels of climate policy mainstreaming. Saito (2013) notes that the level of mainstreaming of climate change-related policies and actions is minimal in Nepal. This implies that one of the most vulnerable groups of country is yet to fully recognize the importance of climate change policies, particularly by covering the mitigation aspect that has been traditionally ignored in favor of climate adaptation aspect. Second, the Government of Nepal has committed to achieving net zero emissions by submitting a "Long-term strategy to achieving net zero emissions" to the UNFCCC (GoN, 2021). This strategy, along with two NDCs submitted to the UNFCCC, has a strong focus on climate mitigation policies, meaning an intention to have a strong climate mitigation framework in place despite weak climate policy mainstreaming (Saito, 2013). Third, priority should be given to non-climate benefits, such as socioeconomic development, as Nepal is recommended for LDC graduation by the United Nations. NDCs were introduced by the UNFCCC as a policy initiative for countries to declare their intended climate actions post-2020. However, Shockley (2019) states that achieving mitigation and adaptation goals in NDCs depends on the determination of nations, meaning that the LDCs could operate on a business-as-usual basis (BAU) to deliver committed climate actions, especially in the absence of other benefits in delivering NDCs. Therefore, climate policies could also incorporate non-climate objectives (Vogt-Schilb & Hallegatte, 2017). This is important for an LDC like Nepal, where policymakers prioritize addressing their economic and social problems and reducing GHG emissions. The green growth narrative connects discourse on economic and social issues and climate change (e.g., mitigation). Thus, this paper intends to contribute to the literature focusing on climate mitigation discourse tied to economic issues for LDCs, taking Nepal as a case study. The broader climate change discourse in LDCs is generally focused more on adaptation compared to mitigation, as most LDCs contribute least to global climate change compared to non-LDCs (Baniya & Giurco, 2021; Baniya, Giurco, & Kelly, 2021). This paper highlights the economic aspects of climate mitigation and its position in climate policy discourse in the economic sectors for the case country, Nepal.

Nepal contributes 0.027% of total global GHG emissions (MoPE, 2015). The Third National Communication (SNC) report on GHG emissions submitted by the Government of Nepal (GoN) to the United Nations Framework Convention on Climate Change (UNFCCC) in 2017 highlighted the agriculture, forestry, and other land use change (AFOLU) sector as the largest contributor (50%), followed by energy (46%), and others (4%). These figures are similar to aggregated figures from low-income countries, as mentioned in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report, where the AFOLU sector is the major contributor, representing up to 80% of total GHG emissions (Edenhofer et al., 2014). Previous literature has already highlighted the negative impacts of climate change on key economic sectors in Nepal, including agriculture, forestry, energy, and water (Chalise et al., 2017; Devkota & Gyawali, 2015; IDS-Nepal et al., 2014). In 2015, the economy-wide impact of climate change was equivalent to a 1.5%–2% decrease in GDP per year. This impact is expected to increase to 5% per year in the future under extreme conditions. These are high figures by international standards (IDS-Nepal et al., 2014). Effective implementation of committed climate mitigation actions in NDC is therefore essential if future economic losses arising from climate change are to be minimized. It is assumed that climate mitigation actions can be considered effective when, if implemented within a defined period of time, they: (i) do not negatively impact economic growth, and (ii) improve carbon and energy productivity on an economy-wide scale. It has been proposed that these conditions can be achieved by greening economic growth, also called 'green 'growth'. While this approach is not universally embraced mainly, because it typically focuses on efficiency and does not sufficiently consider ecological limits (Ferguson, 2015; Santarius, 2012), it does have a potential to help achieve decoupling of GHG emissions and resource use from economic growth.

The objective of this paper is to study the potential role of the green growth approach in delivering climate mitigation actions identified in the NDC, given the structural change in resource use and GHG emissions at the macroeconomic level. The consideration of structural changes in the economy and resource use in most LDCs (including Nepal), as they undergo the economic modernization process, is often less addressed by climate mitigation policy literature focusing on LDCs, which this paper aims to shed more light on by using the green growth concept. The analysis of projected resource use and GHG emissions is used to discuss a case for better coherence between NDCs and policies across different economic sectors, thus ensuring NDC implementation is effective and well-aligned with other policies. The remainder of the paper is organized as follows: Section 2 describes the methods used. Section 3 presents the main results and discussion from this analysis. Section 4 presents the conclusions.

2 | METHODS

2.1 | Case country

While this paper focuses on Nepal, this case country is explored in the light of issues common to LDCs in the Asia region that have historically focused more on climate change adaptation. Nepal is a low-income country in terms of the World 'Bank's classification of countries by income. It is highly vulnerable to climate change and has a minimum climate policy mainstreaming (Saito, 2013). As with most low-income countries, the AFOLU sector is the major contributor to 'Nepal's total GHG emissions; however, the focus of Nepal's NDC is more on reducing GHG emissions from the energy sector (MoPE, 2016). Nepal's GHG emissions share is about 4% in the total GHG emissions generated from seven LDCs in Asia (Afghanistan, Bangladesh, Bhutan, Cambodia, Lao PDR, Myanmar, and Nepal), despite contributing to about 9% of the population and 6% of the gross domestic product (GDP). However, the per capita energy use of Nepal (18 gigajoules) is the highest amongst the seven Asian LDCs. Green growth was introduced in the government policy landscape in Nepal by the Global Green Growth Institute (GGGI) in 2015, although it is not a mainstream policy agenda yet (GGGI, 2017). Higher energy use per capita, the presence of a green growth program, and an aspiring country to graduate from low-income to middle-income country status of the United Nations make Nepal a good case country to explore the NDC and socioeconomic development linkage.

2.2 | Model framework

A quantitative approach was used to forecast and analyze energy use and GHG emissions data from Nepal's energy and AFOLU sectors between 2015 and 2030 and to estimate energy productivity and carbon productivity in 2030. High energy productivity is desirable, as it indicates high economic output per unit of energy. High carbon productivity is also desirable and could be achieved by lowering GHG emissions from economic activities. The Long-Range Alternative Energy Planning (LEAP) is used to forecast future energy use and GHG emissions in Nepal, particularly for the energy sector. LEAP is widely used for energy policy analysis and climate change mitigation assessment. At least 32 countries have used LEAP to create energy and GHG emission scenarios to develop their NDCs (Heaps, 2016). However, LEAP does not model non-energy-related GHG emissions from the AFOLU sector, so the IPCC guidelines for national GHG emission inventories (2006 version, volume 4) were used to estimate these emissions.

The LEAP model was used by Sapkota et al. (2014) to study the role of renewable energy technologies in rural communities in Nepal. Similarly, Bhandari and Pandit (2018) used LEAP to model residential sector energy demand in Nepal, and Pradhan et al. (2006) used LEAP to study GHG emissions from transport sector in Nepal. While Pokharel (2007) and Parajuli et al. (2014) used an econometric approach (multivariate regression analysis) to model future energy consumption in Nepal, Baniya, Giurco, Kelly, and Aryal (2021) use machine learning via Python programming to model energy and material consumption for Nepal and Bangladesh. For AFOLU sector, Pradhan et al. (2017) uses "AFOLU-B" model to study GHG emissions abatement in Nepal. This paper builds on previous works on energy use and GHG emissions modeling for both the energy and AFOLU sectors in Nepal to study a case for an effective implementation of NDCs. A focus on economy-wide improvements in carbon and energy productivity via modeling NDCs and by using both the LEAP tool and IPCC guidelines for national GHG emission inventories is deemed to add value to the existing energy and GHG emissions modeling studies pertaining to Nepal.

Four scenarios with different levels of resource use and different GHG mitigation targets were developed, namely: (1) a business-as-usual (BAU) scenario, (2) a nationally determined contribution (NDC) scenario, (3) an 'other policies' scenario (OPS), and (4) a 'beyond NDC' (BNDC) scenario. The BAU scenario is a reference scenario that assumes no sectoral policy interventions and no NDC implementation. The NDC scenario assumes that all climate mitigation actions in Nepal's NDC are implemented. The OPS scenario assumes that the NDC is not implemented but that sectoral policies are implemented on a nationwide scale. The BNDC scenario assumes that the NDC is implemented with an intention to address perceived gaps. Future resource use and GHG emissions data for all scenarios were then used to see how green growth indicators (OECD, 2017), carbon productivity, and energy productivity would change between 2015 and 2030 across all scenarios.

2.3 | Data types, sources, and modeling

Figure 1 depicts the methods used for projecting future GHG emissions from the energy and AFOLU sectors between 2015 and 2030, and for estimating the carbon and energy productivity values in 2030. Data types and sources are also shown in Figure 1. The year 2015 was chosen as the base year for all four scenarios. This was the year when the first NDC for Nepal was submitted to the UNFCCC. Two types of data inputs were used, namely activity data and scenario data. Activity data are socioeconomic data that depend on sectoral and human consumption activities. Scenario data are data generated from climate mitigation commitments made in the NDC and from assumptions made in the scenarios.

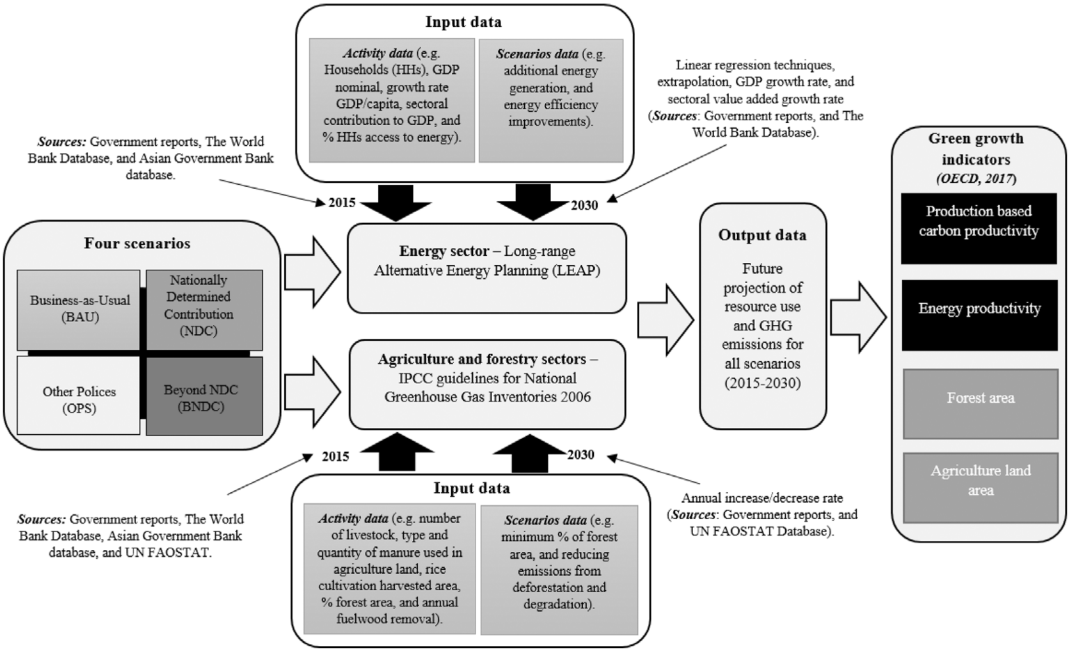

FIGURE 1 Methods used for estimating future energy use and GHG emissions from energy and agriculture, forest, and other land use sectors.

2.3.1 | Base-year activity data

These were taken from reports produced by the Government of Nepal (MoAD, 2016; MoFSC, 2015; MoPE, 2015; MoSTE, 2014) and development indicator databases established by international agencies: the Asian Development Bank (ADB, 2018), the World Bank (WB, 2012), International Energy Agency country statistics for Nepal (IEA, 2018), and the Food and Agriculture Organization of the UN database (FAO, 2018).

2.3.2 | End-year scenario data

LEAP projects future energy consumption and GHG emissions for all years between 2015 and 2030, based on activity data from the base year and scenario data from the end year. However, end-year scenario data such as sectoral value-added data, nominal GDP per capita, and energy consumption by fuel types (all variables affecting energy demand) are difficult to estimate without a proper data modeling technique. Sectoral energy consumption data for 2030 were forecasted by regression analysis of sectoral value-added data between 2005 and 2015. The sectoral energy consumption data for 2030 is used to estimate the factor increase for each of the fuel types between 2015 and 2030. The factor increase is input data under the BAU scenario, which together with socioeconomic data such as increase in number of households, sectoral value-added growth, and increased population with access to energy project total energy demand for each of the four scenarios via the LEAP model. The assumption about the factor increase of each fuel types is explained in detail in Section 2.4 and Table 3.

To forecast sectoral energy consumption in 2030 and to subsequently estimate the factor increase of each fuel type between 2015 and 2030 for the BAU scenario, a linear regression method $y = \beta x + c$, was used. A forecasted sectoral value-added data in 2030 was also used as a predictor variable for the agriculture, service, and mining and

TABLE 1 Estimated sectoral energy consumption values in 2030.

Sectoral energy consumption (million gigajoules (GJ)) (ŷ)	Predictor variable (x)	*β* (coefficient of the linear regression model)	c (constant values)	R^2 (coefficient of determination)	*p*-value (statistical significance)
Residential energy consumption (472)	Gross Domestic Product (GDP) per capita (1475 current USD)	2.67	7327	.62	.004
Agriculture energy consumption (11)	Agriculture value added (15 billion USD)	15.8	23.53	.80	.000
Service and commercial sector energy consumption (15)	Service value added (22 billion USD)	12.5	83.08	.77	.000
Mining and manufacturing sector energy consumption (52)	Mining and manufacturing value added (6 billion USD)	200.5	−23.10	.77	.000
Transport sector energy consumption (72)	GDP per capita (1475 current USD)	1.3	−135.4	.90	.000

manufacturing sectors. Nominal GDP per capita in 2030 was used as a predictor variable for the residential and transport sectors. A linear regression method was preferred over a multiple regression model. This was done to avoid duplication when the LEAP model used the number of households and access to energy services (percentage of households) as additional endogenous variables along with sectoral value-added data to estimate sectoral energy consumption in 2030. Table 1 shows the value of sectoral energy consumption and the values of relevant predictor variables, constants, and R^2.

The limitation of using a simple linear regression method is that it assumes a linear relationship between energy consumption and sectoral value-added data. However, given the available data and recent trends (2005–2015), which were more or less linear with relatively high R^2 values ($.60 < R^2 < .90$), this method was deemed to be suitable for this study. Higher R^2 values imply a better relationship between the observed data and predictor variables. Previous studies have used a similar approach to estimate future energy consumption in Nepal (Bhattarai, 2015; Parajuli et al., 2014; Pokharel, 2007).

Table 2 shows the base-year and end-year data for all scenarios. The energy and emission parameters and green growth indicator values shown in Table 2 are the results of the study. Therefore, these are discussed more in the results and discussion section. The impacts of changing economic growth rates on energy demand and supply were not considered. This was because the World Bank database (WB, 2019) showed a linear growth in value-added data, with an average annual growth rate of 4.4% between 1990 and 2018. In addition, the core focus of this study is on the effective implementation of climate mitigation actions, given the submitted NDC and sectoral policies that are already in the delivery phase. However, the impacts of low-to-high growth rates on energy demand and supply are discussed in Section 3.

For the other scenarios (NDC, BNDC, and OPS scenarios), activity data and scenarios data were used as inputs in LEAP to model and estimate energy consumption and GHG emissions between 2015 and 2030. The scenarios and assumptions made are explained in the following sub-section.

TABLE 2 Key socioeconomic parameters, and input and output data for four scenarios (business-as-usual (BAU) scenario, nationally determined contribution (NDC) scenario, 'beyond NDC' (BNDC) scenario and 'other policies' (OPS) scenario.

				2030				
	Key parameters	**Unit**	**2015**	**BAU**	**NDC**	**OPS**	**BNDC**	**Remarks on data**
Socioeconomic parameters (*Inputs*)	Households	million	6	7.7	7.7	7.7	7.7	Forecasted data (CBS, 2018)
	GDP (nominal)	billion USD[b]	21.4	43.6	43.6	43.6	43.6	The scenarios socioeconomic data for 2030 are same for all scenarios.
	GDP/capita	USD/capita	747.2	1475	1475	1475	1475	
	Agriculture sector value added	billion USD	7	15	15	15	15	
	Service sector value added	billion USD	11	22.2	22.2	22.2	22.2	
	Mining and manufacturing sector value added	billion USD	3.3	6.3	6.3	6.3	6.3	
Energy parameters (*Outputs*)	Total energy demand	million GJ	487.9	662.9	544	542.3	481.6	The data for 2030 are generated from energy modeling via LEAP, and by using 2015 activity data and 2030 scenarios data.
	Energy resource requirements, allocated to demand	million GJ	497.3	686	690.3	561.9	595.1	
	Energy loss	million GJ	9.6	23.1	146.3	19.7	113.5	
	Capacity added (electricity)	million GJ	24.1	62.2	436.4	53	416.8	
Emissions parameters (*Outputs*)	GHG emissions (energy)	Mt CO_2e	10.1	16.5	5	13.5	4.4	The data for 2015 and 2030 are generated from energy modeling via LEAP, and by using 2030 scenarios data.
	GHG emissions (agriculture)	Mt CO_2e	25	33.5	33.5	33.5	30	The data for 2015 and 2030 are generated from IPCC guidelines for national GHGs inventories 2006, and by using 2030 scenarios data.
	GHG emissions (forestry)	Mt CO_2e	4.3	4.3	−9.7[a]	−9.7[a]	−9.7[a]	The data for 2015 and 2030 are generated from IPCC guidelines for national GHGs inventories 2006, and by using 2030 scenarios data.
Green growth indicators (*Calculated values*)	Energy Productivity	USD/GJ	43.9	65.8	80	80.6	90	Productivity calculations.
	Carbon productivity (energy sector)	USD/tCO_2e	2.1	2.6	8.7	3.2	9.9	
	Carbon productivity (economy-wide)	USD/tCO_2e	0.5	0.8	1.5	1.2	1.8	

[a] USD (United States Dollar).

[b] Considering a carbon offset of 14Mt CO_2e per year from REDD.

2.4 | Scenarios and assumptions

Table 3 shows the scenarios descriptions, actual and assumed data as inputs, and the model's outputs. The rationale for assumptions is explained in the following paragraphs.

2.4.1 | BAU scenario

The assumption in this case is that economic activity will continue in a similar manner over the next 15 years, and that NDCs and new sectoral policies will not be implemented. We assume that the economic growth rate will average 4.4% per annum, as it has for the last three decades (WB, 2019), and that sectoral contributions to GDP (nominal) will follow the same trends as in the last ten years. Table 2 shows nominal GDP and sectoral contributions in 2015 and the estimated values in 2030. The number of households will rise from 6 million in 2015 to 7.7 million (with an average household size of 4.6) in 2030, in line with the projections of the Government of Nepal (CBS, 2018). Income per capita will almost double, based on the assumption that trends over the last ten years will continue, with 100% of urban and rural households gaining access to electricity as per the recent progress in electrification rate (WB, 2019). In terms of energy use, consumption of all fuel types within each sector is likely to increase by the same factors related to consumption by associated sectors (households 1.16, service and commercial 1.68, agriculture 1.95, mining and manufacturing 1.7, and transportation 2.32). Energy in the households is the energy consumed by residential buildings and houses. Energy in the transport sector is energy consumed by public, private, and logistics vehicles. Energy in the mining and manufacturing sectors refers to energy consumption for mining activities and for the manufacture of goods. Energy in the agriculture sector refers to energy consumption for agricultural activities such as the use of pumps, cool storage, tractors, and other electro-mechanical harvesting equipment. Energy in the service and commercial sectors refers to energy consumption within service organizations and commercial entities like banks, public and private organizations, and restaurants.

For the agriculture sub-sector, the number of livestock will increase, with an annual growth rate for each livestock category as determined by Upadhyay et al. (2017). The area of land under rice cultivation (1.42 million ha/year) will decline by approximately 6% by 2030, relative to 2015 figures (MoAD, 2016). The amounts of nutrients added to the soil will follow the same trends as in previous years. The amount of forested land will remain similar (41% of total land area), based on historical data (MoPE, 2015).

2.4.2 | NDC scenario

While economic performance in this scenario will remain similar to the BAU, there will be changes to the figures for energy demand, energy mix, and the way energy is distributed. This is because the NDC aims to reduce dependence on fossil fuels by 50% by 2050. Fossil fuels contributed only about 11% of total energy consumption in 2015. An additional capacity of 4000 megawatts (MW) is planned to be operationalized by 2020, and 12,050 MW by 2030, in line with the NDC as mentioned in the NDC document. As much as 75% of total energy demand was met by biomass energy in 2015 (MoPE, 2016). An assumption can therefore be made that the dependence on fossil fuels can be reduced by 50% by 2030. In addition to electricity generation in the BAU scenario, there are plans to generate energy from various means in line with the NDC document. This includes 4000 MW of hydroelectricity by 2020 and 12,000 MW of hydroelectricity by 2030, 2100 MW of electricity from solar photovoltaic (PV), 220 MW of electricity from bioenergy, and 50 MW from small and micro hydropower plants (MoPE, 2016).

For agriculture, commitments are subjective. One example is “promoting climate-friendly agricultural practices”. Energy supply and demand in the agriculture sub-sector, as well as measures to reduce agricultural GHG emissions, are already covered in the energy sector. Therefore, the NDC scenario is assumed to be ‘not applicable’ for the

TABLE 3 Scenarios descriptions, model inputs, and model outputs for two main GHG emissions source sectors under study (energy and agriculture, forest, and other land use (AFOLU) sectors).

		Inputs		
	Definition	Actual data	Assumed data	Outputs
BAU scenario	Economic activity will continue in a similar manner	*Energy sector*: Number of households, gross domestic product (GDP) and the annual growth rate, sectoral value-added and the annual growth rate, % of the population with access to energy/electricity, types of energy used and their growth rate, energy transmission and distribution loss in % of total supply, historical and planned production of electricity by energy type (process efficiency, exogenous capacity, maximum availability, capacity credit, and merit order)	*Energy sector*: Consumption of all fuel types within each sector increase by the same factors as the overall sectoral consumption between 2015 and 2030 (households 1.16, service and commercial 1.68, agriculture 1.95, mining and manufacturing 1.7, and transportation 2.32)	Energy use (demand and supply) and GHG emissions for each of the four scenarios
		AFOLU sector: Number of livestock, and the annual growth rate for each of the livestock type, the area of land under rice cultivation and the annual decline rate, amount of nutrients added to the soil.	*AFOLU sector*: The forest land area will remain the same based on historical data	
NDC scenario	All climate mitigation actions in Nepal's NDC are implemented	*Energy sector*: Built on the BAU scenario data. An additional capacity of 4000MW of hydroelectricity by 2020, 12000MW of hydroelectricity by 2030, 2100MW of electricity from solar photovoltaic (PV), 220MW of electricity from bioenergy, and 50MW from small and micro hydropower plants. Increase in the share of biogas up to 10% as energy for cooking. Every households in rural areas have access to improve cook stoves (number and efficiency). Fossil fuels to be reduced by 50% by 2030 relative to 2015, as mentioned in the first NDC		
		AFOLU sector: The NDC scenario is assumed to be 'not applicable' for the agriculture sub-sector. For forestry and other land use change, forests will continue to cover a minimum of 40% of the nation's total land area. This will reduce greenhouse gas emissions by about 14 million tonnes (Mt) CO_2e per year by 2020 as per the NDC document		

(Continues)

TABLE 3 (Continued)

		Inputs		
	Definition	**Actual data**	**Assumed data**	**Outputs**
OPS scenario	NDC is not implemented, but sectoral policies are implemented	*Energy sector*: Built on the BAU scenario data	*Energy sector*: Sectoral energy consumption will be reduced by 20% between 2015 and 2030 if the sectoral policies are implemented but NDCs are not delivered	
		AFOLU sector: There is no OPS scenario for agriculture. The intention to reduce GHG emissions has already been covered by the OPS for the energy sector. The REDD strategy aims to reduce emissions from forestry by approximately 14Mt CO_2e per year by 2030		
BNDC scenario	NDC is implemented with an intention to address perceived gaps	*Energy sector*: Built on the BAU scenario data	*Energy scenario*: The electricity transmission and distribution loss is assumed to decrease to 10% by 2030. The consumption of non-renewable fuels will decrease by a further 20% due to improvements in energy efficiency as the NDC does not mention energy efficiency improvements. Adding a further 2500MW capacity to the targeted 12,500MW in the NDC scenario seems reasonable based on Nepal's immense hydropower potential	
			AFOLU sector: Non-energy GHG emissions are not covered by the NDC scenario, and therefore the BNDC scenario assumes that GHG emissions could be reduced by 10% by 2030 compared to a BAU scenario. Forests already cover about 41% of Nepal's total area, so the BNDC scenario does not change assumptions in terms of the forestry sector	

agriculture sub-sector. For forestry and other land use changes, the NDC states that Nepal's forests will continue to cover a minimum of 40% of the nation's total land area. This will reduce greenhouse gas emissions by about 14 million tonnes (Mt) CO_2e per year by 2020 (MoPE, 2016).

Nepal submitted its second NDC in December 2020 to the UNFCCC. While the GHG emissions-related commitments across the energy and AFOLU sectors remain almost the same as in the first NDC, transport sector-related commitments are added in the second NDC. These are discussed in the results section and are covered largely by the energy demand analysis within the energy sector. The exclusion of the commitments related to the transmission and distribution losses and the energy efficiency targets is still missing in the second NDC. These are also discussed in the results section.

2.4.3 | OPS scenario

The assumption in this scenario is that instead of the NDC, almost all relevant government policies are implemented. These policies are the Climate Change Policy (2011), the National Energy Strategy (2013), the Agriculture Development Strategy (2015–2035), the Forest Sector Development Strategy (2016–2025), Nepal Reducing Emissions from Deforestation and Forest Degradation (REDD) Strategy (2015), and the Industrial Policy (2011). These policies include some statements on reducing energy demand and the use of renewable energy, but they do not currently have any quantitative targets. In terms of modeling via LEAP, it is therefore assumed that sectoral energy consumption will be reduced by 20% between 2015 and 2030 if the abovementioned policies are implemented but NDCs are not delivered. The value of 20% has been assumed based on improvements in the energy intensity (unit megajoules [MJ] of energy used per unit GDP) of Nepal, which had improved by 20.5% in 2015 (7.4 megajoules [MJ]/GDP) compared to 2000 (9.3 MJ/GDP) (WB, 2019). While it is understood that there might be relatively little potential to improve energy intensity between 2015 and 2030 in comparison to the past 15 years before 2015, the energy intensity of Nepal is still one of the highest in the Asia-Pacific region (WB, 2019). A comparison of the energy intensity of Nepal with other South Asian countries such as Bangladesh shows that a further reduction of 20% by 2030 is a reasonable estimate. In addition, biomass is the main energy source that comprises almost three-quarters of Nepal's total energy demand (MoPE, 2016). A transition from low-intensity biomass to high-intensity energy sources such as electricity could reduce energy consumption per unit of GDP generated (Nag & Parikh, 2000).

There is no OPS scenario for agriculture. The intention to reduce GHG emissions has already been covered by the OPS for the energy sector, assuming a reduction of energy consumption by 20% by 2030. The REDD strategy aims to reduce emissions from forestry by approximately 14Mt CO_2e per year by 2030 (MoPE, 2016).

2.4.4 | BNDC scenario

We developed this scenario to investigate how the NDC will perform if its perceived gaps are resolved. For example, losses from the transmission and distribution of electricity were not addressed in the NDC scenario but would be in the BNDC scenario. In the base year 2015, 32% of the total dispatched electricity was lost during transmission and distribution (WB, 2019). While the aggregate electricity transmission and distribution loss has been reported to be about 15% in 2020 (NEA, 2020, p. 74), in the BNDC scenario, this loss is assumed to decrease to 10% by 2030. The implementation of energy-efficiency improvement targets is not explicitly mentioned in the NDC, so the BNDC scenario assumes that the consumption of non-renewable fuels will decrease by a further 20% due to improvements in energy efficiency. The share of renewable fuels could also be increased by the addition of another 2500 MW of hydropower. Nepal has the potential to develop about 54,000 MW more hydropower even under Q40 (40% exceedance) water discharge and with a production efficiency of 80% (Jha, 2013). In addition, the electricity demand forecast report of the GoN states that approximately 15,000 MW of electricity will be required by 2030 under a GDP growth rate of 4.5% (WECS, 2017). Therefore, adding a further 2500 MW to the targeted 12,500 MW in the NDC scenario seems reasonable.

The agriculture sub-sector offers fewer areas for improvement in terms of reducing GHG emissions other than effective manure management and management of soil and nutrients (MoSTE, 2014). However, there could be other options, such as no-till farming, crop management, and supply chain management of agriculture products (Cole et al., 1997; Wollenberg et al., 2016). Non-energy GHG emissions are not covered by the NDC scenario, and therefore the BNDC scenario assumes that GHG emissions could be reduced by 10% by 2030 compared to a BAU scenario. Forests already cover about 41% of Nepal's total area, so the BNDC scenario does not change assumptions in terms of the forestry sector.

3 | RESULTS AND DISCUSSION

3.1 | Energy sector

3.1.1 | Change in energy demand and supply

Nepal's total energy demand (TED) in 2015 was 488 million gigajoules (GJ). By 2030, TED will be significantly higher in the BAU scenario at 663 million GJ, representing an increase of 36% (Figure 2). The NDC and OPS scenarios also show an increase in TED. In both scenarios, it increases to 545 million GJ by 2030, representing an increase of 11%. On the other hand, in the BNDC scenario, the TED value drops to 482 million GJ in 2030 from 488 million GJ in

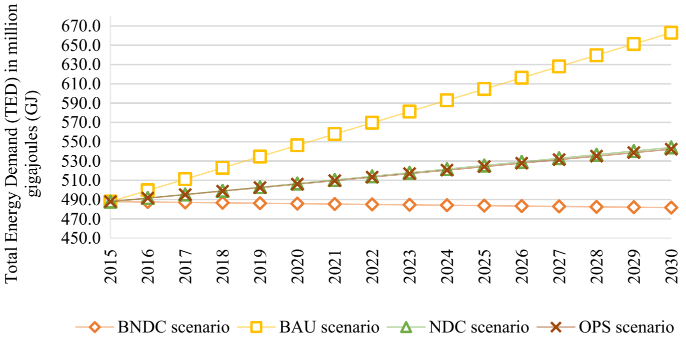

FIGURE 2 Change in Total Energy Demand (TED) in million gigajoules (GJ) for four different scenarios between 2015 and 2030.

TABLE 4 Percentage change in total energy demand (TED) and greenhouse gas (GHG) emissions between 2015 and 2030.

Scenarios	Total energy demand (TED) per cent change (%)	GHG emissions per cent change (%)
Business-as-usual (BAU) scenario	35.9	63.4
Nationally determined contribution (NDC) scenario	11.5	−50.0
'Other policies' (OPS) scenario	11.1	23.8
'Beyond' NDC (BNDC) scenario	−1.3	−56.8

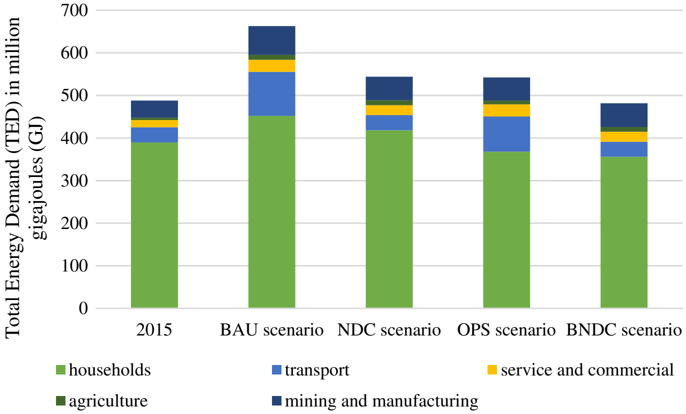

FIGURE 3 Changes in the total energy demand (TED) in million gigajoules (GJ) between 2015 and 2030 for four scenarios, and the change in demand for major energy consuming sectors: households, transport, service and commercial, agriculture and mining and manufacturing between 2015 and 2030.

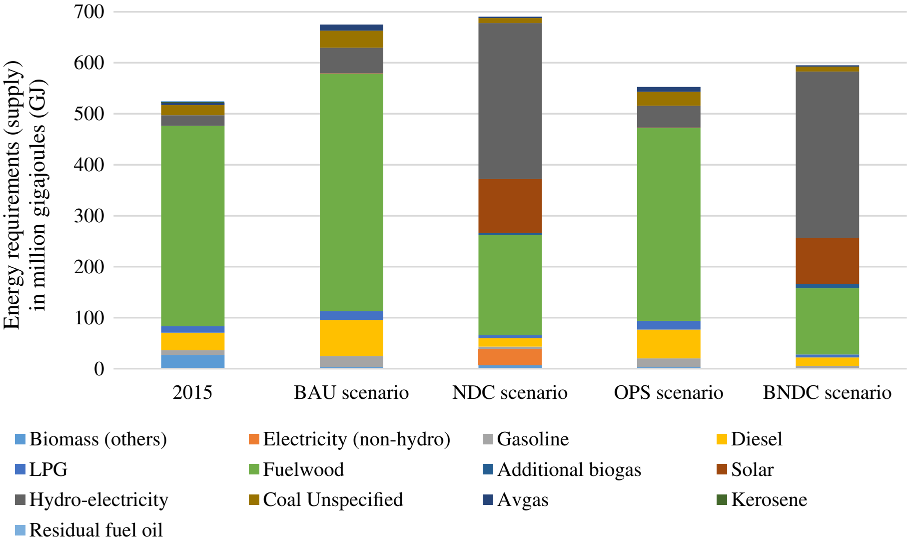

FIGURE 4 Energy resource requirements in million gigajoules (GJ) allocated to demands for four scenarios between 2015 and 2030 based on fuel type. The fuel type and the composition of fuels variy between 2015 and 2030 as the energy mix changes based on intended actions for each of four scenarios.

2015, representing a decrease of 1.3% (Table 4). Although there are similarities between the NDC (544 million GJ) and OPS (542.3 million GJ) scenarios in terms of the TED, the NDC scenario is favored because of the higher per cent of renewable energy in the energy mix (Figure 4). Thus, the total CO_2 emissions will be lower. The quantity of GHG emissions will drop by almost 50% in the NDC scenario by 2030 compared to 2015, whereas in the OPS scenario, GHG emissions will increase by almost 24% (Table 4). In the BAU scenario 2030, the projected 663 million GJ is almost 17% higher than the findings (549 million GJ in BAU) of Parajuli et al. (2014), who used the econometric method to project Nepal's 2030 energy consumption. Likewise, it is 4% less than the finding (691 million GJ in BAU) of Baniya, Giurco, and Kelly (2021), who used machine learning models (e.g., Ridge and Lasso regression) to forecast Nepal's 2030 energy consumption across various scenarios.

The energy demand for all key sectors will also change by 2030, as shown in Figure 3. In all scenarios, the energy demand for the household sector will account for the largest share of TED in 2030, which was also the case in 2015. However, between 2015 and 2030, the household sector will have the lowest growth in energy demand. Energy demand by households accounted for almost 80% of total energy demand in 2015. This figure is likely to drop to 70% by 2030, owing to the growth in demand from other sectors. In the BNDC and OPS scenarios, total household energy demand will decrease by 8.7% and 5.6% respectively. In the BAU and NDC scenarios, household energy demand will increase by 16% and 7.3% respectively. The transport sector shows the highest percentage increase in energy demand. In the BAU scenario, the increase is 190% and in the OPS scenario, it is 132%. A rapid increase in the number of vehicles, driven by improvements in overall GDP and per capita income in recent years, has contributed to the highest per cent increase in the transport sector energy demand. The second NDC submitted to the UNFCCC in December 2020 mentioned the upscaling of electric vehicles and targets their share up to 25% by 2025 and 90% by 2030. While achieving the electric vehicle target may be practically challenging given the current share of less than 5% in 2020, a focus on climate mitigation-oriented actions in the transport sector is a positive step given the notable increase in the private vehicles in recent years. In the BAU scenario, energy demand in the mining and manufacturing, agriculture and service, and commercial sectors increases by 70%, 95%, and 68%, respectively. In the NDC scenario, energy demand for agriculture shows the highest percentage increase (93%), followed by the mining and manufacturing sector (39.6%) and the service and commercial sector (37.7%).

Energy sector transformation and efficiency are key elements of green growth, which advocates resource efficiency and a clean environment (Hallegate et al., 2011). A drop in TED in the NDC, OPS, and BNDC scenarios compared to the BAU scenario suggests a transition towards energy-efficient growth. The GDP of Nepal is expected to double by 2030 relative to 2015, with an annual growth rate of 4.4%. During the same period, TED and sectoral energy demand are expected to grow much more slowly across all scenarios, at rates ranging from 0.8% (NDC scenario) to 2.2% (BAU scenario) per annum. These figures suggest a partial decoupling of energy demand from economic growth.

The energy resource requirements allocated to demand (Figure 4) give an insight into the energy mix needed (supply) to meet TED. In 2015, fuelwood was the major source of energy, representing almost 79% of total energy supply. This will change in each of the scenarios. In the BAU and OPS scenarios, fuelwood (465.5 million GJ) will still continue to be a major energy source, followed by diesel (70.8 million GJ) and electricity (61 million GJ). In contrast, in the NDC and BNDC scenarios, electricity from hydropower becomes the major energy source. However, unlike TED figures, the energy requirements will be highest for the NDC scenario and increase in the BAU, BNDC, and OPS scenarios. This is because electricity will be a major energy source in 2030, and electricity loss in transmission and distribution will be almost 15% of total generation capacity. Electricity loss will consume almost 21% of the energy requirements (supply) due to losses in transmission and distribution and electricity theft. This is a significant gap in Nepal's NDC, and the NDC does not identify actions to reduce electricity loss. The GoN (2011) reports that large-scale hydropower plants with an accumulated capacity of 8150 MW are likely to be commissioned by the end of 2030. Despite focusing on the large-scale development of hydropower plants to generate electricity as the primary source of renewable energy in 2030, both the first and the second NDCs submitted to the UNFCCC have not included any actions to target reductions in the transmission and distribution losses.

3.1.2 | GHG emissions from the energy sector

Total GHG emissions from the energy sector will continue to increase in the BAU and OPS scenarios. However, they will decrease in the NDC and BNDC scenarios. If the NDC is not implemented, GHG emissions could reach

TABLE 5 Energy loss and potential value loss in four scenarios between 2015 and 2030.

Scenarios	Energy loss (million gigajoules (GJ))	Potential value loss (billion USD)	% of gross domestic product (GDP) in 2030
BNDC scenario	34	3.1	7%
BAU scenario	19	1.3	3%
NDC scenario	54	4.3	10%
OPS scenario	16	1.3	3%

16.5 Mt of CO_2e per year by 2030. This is approximately 18% less than the energy section-related emissions in the reference scenario (similar to BAU) in the long-term net zero emissions strategy developed and submitted by the Government of Nepal to the UNFCCC (GoN, 2021). If the NDC is implemented, GHG emissions from the energy sector could be reduced by up to 47% relative to the base year of 2015. A further reduction of up to 64% can be achieved under the BNDC scenario relative to the base year. This will contribute to the pursuit of low-carbon development in Nepal, mainly because the NDC document prioritizes aggressive development of hydropower to add to existing capacity.

3.1.3 | Green growth in the energy sector

Green growth in the energy sector implies an increased share of renewable energy, increased energy productivity and carbon productivity, and reduced electricity losses (OECD, 2017). While renewable energy's contribution to TED will increase in the NDC scenario, electricity loss is emerging as one of the most important gaps in the nation's NDC (both first and second) as the energy requirements allocated to demand is maximum (690 GJ) in the NDC scenario (Figure 4). The additional allocation for demands in the NDC scenario is to offset the electricity loss. The losses, which occur during the transmission and distribution of electricity, will challenge the energy sector's capacity to meet energy demands and potentially impact the overall efficiency of the economy. The World Bank (WB, 2019) reports a high transmission and distribution loss for Nepal, which was 32% of total electricity generated in 2015. The high loss is attributed to the poor transmission and distribution infrastructure and low power factors in electricity-intensive industries. In contrast, the Nepal Electricity Authority reports significant progress in the last five years and states that the transmission and distribution losses have been reduced to 15% in 2020 from 32% in 2015 (NEA, 2020).

In the NDC scenario, the loss of potential value-adding as a result of transmission and distribution losses is likely to be approximately 10% of the total GDP in 2030 (Table 5), if the value of energy productivity in 2030 is considered as an indicator to measure the productive use of energy. The potential loss under the BNDC scenario is almost 7% of GDP in 2030. While it might be difficult in practical terms to keep transmission and distribution losses below 10% as assumed under the BNDC scenario, the loss of approximately 1.2 billion USD in value-adding potential could be avoided under the BNDC scenario by better energy management. For example, by ensuring transmission and distribution losses of no more than 10%, and by end-use efficiency measures that remain excluded in the NDC. In addition, minimizing energy loss could ensure that latent energy demand is met, as the NDC, OPS, and BAU scenarios assume that almost 100% of households will have access to electricity by 2030, while the utility of energy consumption is likely to place stress on supply and demand as incomes increase. In 2015, approximately 87% of the population had access to electricity in Nepal (WB, 2019). This figure is likely to increase and reach up to 100% in 2030 as more rural people have access to off-grid and locally distributed micro-hydro and solar home systems.

Energy productivity will have similar values (80 USD/GJ) in 2030 under the NDC and OPS scenarios (Table 2 and Figure 5). However, the carbon productivity of the energy sector under the NDC scenario is likely to be almost 2.5 times greater than under the OPS scenario in 2030. The energy loss (and value loss) that results

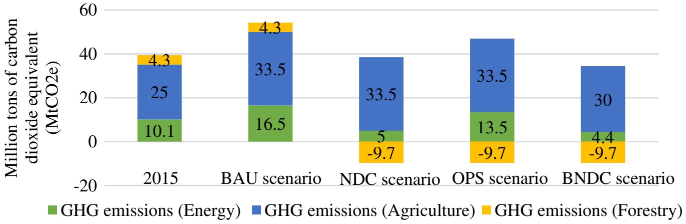

FIGURE 5 Carbon productivity (Energy sector), carbon productivity (Economy-wide), and energy productivity values for base year (2015) and four scenarios in 2030.

from an inefficient electricity transmission and distribution system in the NDC scenario is about three times the corresponding loss in the OPS scenario. Despite this, the NDC scenario looks better from the point of view of carbon productivity improvement. However, the implementation of climate mitigation actions in the NDC does not seem to simultaneously satisfy the three green growth conditions (resource-efficient, clean, and resilient growth), as explained by Hallegate et al. (2011), especially for the energy sector in Nepal. Under the BNDC scenario, carbon productivity and energy productivity are far better than in any other scenario in 2030. Energy loss and value loss are marginally higher than in the OPS scenario; however, the significant improvements in carbon and energy productivity show a potential to offset energy loss. Energy and carbon productivity are projected to improve, mainly because of the use of high-intensity and commercial energy sources (electricity) instead of low-intensity biomass and partly because of changes in the structure of an economy. The change in the structure of an economy refers to the change from an agro-based economy to a services-based economy in Nepal (WB, 2019). Regardless of the different scenarios, less energy and a less carbon-intensive service sector will continue to generate more than half of Nepal's GDP in 2030 (GoN, 2011; WB, 2019). Service sector-based economic growth is a key indicator of green growth (OECD, 2017; UNDESA, 2019).

The four scenarios provide TED estimates for different sectors based on the assumption that the average annual economic growth rate of 4.4% will remain the same until 2030. However, TED could change with a change in the annual economic growth rate. A causal relationship between economic growth and energy consumption has already been identified for Nepal in previous empirical studies (Dhungel, 2008; Nepal & Paija, 2019). This means that energy consumption is a critical production factor for economic growth in Nepal. This study analyzed future TED based on a single growth rate. With a view to providing further analytical insights, we compared our TED estimates, especially in the NDC scenario, with estimates from previous studies that used different annual growth rates to estimate future TED. It has been estimated that in 2030 TED will be at least: 700 million GJ at a high growth rate (10% per annum), 550 million GJ at a medium growth rate (6.4%–7% per annum), and 520 million GJ at a normal-growth rate (3.3%–5% per annum) (GoN, 2011; Parajuli et al., 2014). If medium and high growth rates are to be considered for the NDC scenario, energy loss seems to be an even more significant issue that must be resolved. Eliminating the energy loss of approximately 33 million GJ, even after considering a transmission and distribution loss of 10% could enable the energy sector to meet the extra demand coming from increased economic activities. Additionally, the higher scale of decoupling of energy use and GHG emissions from economic growth under a transmission and distribution loss of 10% as in the BNDC scenario means a step towards achieving green growth. Decoupling energy use and GHG emissions from economic growth is an important condition to achieving green growth (OECD, 2017).

Energy transition appears to be another important contribution to delivering energy-related climate mitigation actions, as the NDC scenario aims for a nationwide clean energy transition. The percentage of electricity in the energy mix is projected to be only approximately 11% at a maximum in 2030, considering all normal-to high-growth rates (Parajuli et al., 2014). GoN (2011) projected that the share of hydropower-based electricity in the energy mix will reach up to 25% in 2030. Contrastingly, in the NDC scenario, even at the normal

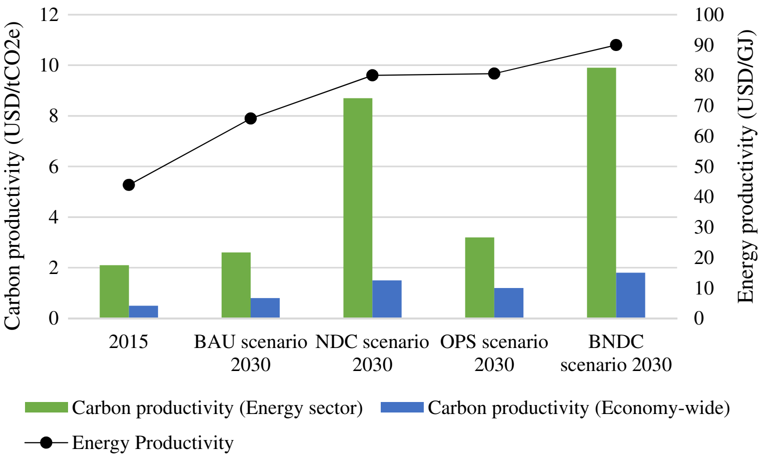

FIGURE 6 Greenhouse gas (GHG) emissions in million tons of carbon dioxide equivalent from the Agriculture sector in 2015 and in 2030 for four different scenarios.

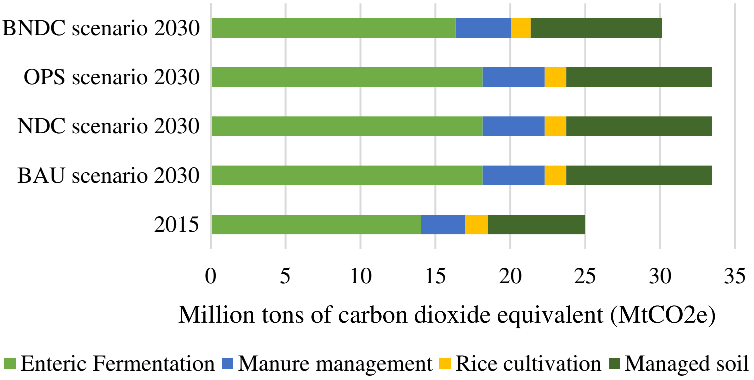

FIGURE 7 Greenhouse gas (GHG) emissions in million tons of carbon dioxide equivalent from energy sector and AFOLU sector (expressed in terms of agriculture sub-sector and forestry sub-sector) in 2015 and in 2030 for four different scenarios.

growth rate of 4.4% per annum, the share of electricity will be more than 50% of total energy supply in 2030. However, the efficiency of the transmission and distribution system must be managed. Energy efficiency improvements and the integration of renewable energy into the existing energy supply system have been identified as critical drivers of green growth (Jouvet & de Perthuis, 2013; Jupesta et al., 2011; van Vuuren et al., 2017). While the integration of renewable energy (hydro-based electricity) into the existing energy system is an important climate mitigation action in the NDC scenario in Nepal, energy efficiency targets are missing in both of the first and the second NDC. We considered the lack of energy efficiency measures in the NDC as the major gap and modeled the potentially feasible energy efficiency measures under the BNDC scenario. The finding is that energy productivity in the BNDC scenario is approximately 11% greater than it is in the NDC scenario. Similarly, the economy-wide carbon productivity is 20% greater in the BNDC scenario than it is in the NDC scenario.

3.2 | Agriculture, forestry, and other land use change sector

3.2.1 | GHG emissions from the AFOLU sector

GHG emissions from agriculture in Nepal come primarily from enteric fermentation, manure management, managed soil, rice cultivation, and field burning (MoSTE, 2014). The GHG emissions from these sources within the agriculture sector are shown in Figure 6. In the BAU, NDC, and OPS scenarios (Figures 7 and 6), total GHG emissions from the agriculture sector will increase by almost 36% by 2030 (33.5 Mt CO_2e) compared to 2015 (25 Mt CO_2e). The third national communication submitted by the Government of Nepal to the UNFCCC projects the AFOLU sector emissions reaching 40 Mt CO_2e in BAU scenario 2030 (MoFE, 2021), which is almost 19% more than the project BAU AFOLU sector emissions (33.5 Mt CO_2e). The NDC document and the Agriculture Development Strategy (2015–2035) of Nepal do not specifically mention about reducing GHG emissions from the agriculture sector. Therefore, GHG emissions from the agriculture sector under BAU, NDC, and OPS scenarios are similar. In the base year, enteric fermentation (14Mt CO_2e) from livestock was the highest contributor to GHG emissions. This figure will increase steadily to 18 Mt CO_2e per annum by 2030. This will be mainly because of an increasing number of livestock.

Annual emissions from agricultural soil were 6.5 Mt CO_2e in 2015 and will increase to 9.8 Mt CO_2e by 2030. This will be due to increasing use of fertilizers because of a potential reduction in the amount of agricultural land (MoAD, 2016). Emissions from manure management will be almost 1.4 times higher in 2030 (4 Mt CO_2e) than they were in 2015 (2.9 Mt CO_2e). The contribution of rice cultivation to GHG emissions will be slightly lower in 2030 (1.4 Mt CO_2e) compared to 2015 (1.5 Mt CO_2e). This is because of changes in the annual harvested area, which is likely to decrease from 1.42 million hectares in 2015 to 1.34 million hectares in 2030, based on the continuation of the harvested area reduction rate of approximately 6% in the 15-year period between 2001 and 2015 (FAO, 2018; MoAD, 2016). However, given a significant increase in rice consumption in the future and the limited ability to increase the amount of harvested land, the yield has to increase from 3 tonnes/hectare in 2012 to 6–7 tonnes/hectare in 2035 (Tripathi et al., 2019). Increasing the intensity of rice cropping has been proposed as a measure to improve yield, but this could increase energy consumption and GHG emissions in the agriculture sub-sector. In the BNDC scenario, which aims to strengthen the case for the implementation of the NDC by addressing its gaps, the GHG emissions from the agriculture sector increase slightly from 25 Mt CO_2e in 2015 to 30 Mt CO_2e in 2030.

With regard to forestry and other land use, forest soil, deforestation, and forest degradation are responsible for emissions of approximately 4.5 Mt CO_2e per year (MoSTE, 2014). Other sources of GHG emissions include the use of limestone to neutralize the acidity of soil, but their contribution is negligible. Forty-one percent of Nepal is forested, so the existing biomass stock of the Nepalese forest has the potential to sequester approximately 30 Mt CO_2e per year (MoPE, 2015). If this were to be considered and if the REDD strategy were to be implemented as stated in the NDC scenario, net GHG emissions from the forest sub-sector could be less than zero (Figure 7).

3.2.2 | Green growth in AFOLU sector

Achieving green growth in the AFLOU sector via improving non-energy carbon productivity appears to be challenging for Nepal. On the one hand, the nation's agriculture and forest sector strategies aim to improve productivity and value outputs in absolute terms to meet food and biomass demands in the future (MoAD, 2016; MoFSC, 2015); on the other hand, the AFOLU sector is a major contributor to national GHG emissions. The AFOLU sector of Nepal is also reported as having a minimum potential to reduce GHG emissions, except for the forest as a carbon sink (MoPE, 2016). Therefore, much of the economy-wide carbon productivity improvement is mainly because of the carbon productivity improvement in the energy sector (Figure 5). This corresponds to the reluctance of the policymakers in explicitly stating GHG emissions reduction measures related to the AFOLU sector in the NDC and the relevant government policies. In developing countries, a significant proportion of non-energy GHG emissions are generated from agriculture, but their climate mitigation commitments are weakly related to agriculture because this could jeopardize food security (Amjath-Babu et al., 2019). Efforts to reduce GHG emissions are focused more on the energy sector.

In the agriculture sub-sector, the use of nutrients, rice cultivation, and livestock farming for dairy and meat products (including mechanization in agriculture) will likely lead to efficiency gains and increased emissions in the future. Similarly, in the forestry and other land use sub-sector, biomass will continue to be used as a source of energy in the future, especially in the BAU and OPS scenarios. The percentage of energy coming from biomass sources decreases from 80% in 2010 to less than 30% in 2030 in the NDC and BNDC scenarios. This means that the aim of the REDD strategy (i.e., to reduce emissions from deforestation and forest degradation) is also likely to be met in the NDC and BNDC scenarios. In these circumstances, and despite not having an explicit statement on GHG emissions reduction from the AFOLU sector in the NDC, the implementation of NDC that focuses more on energy sector seems to be a practical way to continue improving economy-wide carbon productivity. However, the significant energy loss and potential value loss associated with NDC implementation, coupled with added pressure on the energy sector to improve economy-wide carbon productivity, mean that a sustainable supply of energy and reduction in GHG emissions cannot be guaranteed under this scenario. Consequently, the sustainable management of forest resources and the target forest area (40%) could be at risk. Forest resources (i.e., the percentage of a nation's total land area covered by forest) represent one of the important green growth indicators that measure the natural asset base of a country (OECD, 2017). In 2030, economy-wide carbon productivity will be twice as high in the NDC scenario (1.5 USD/tCO_2e) and the BNDC scenario (1.8 USD/tCO_2e) than it will be in the BAU scenario (0.8 USD/tCO_2e), while the forest is likely to remain at least 40% of the total area in 2030. The improvements in economy-wide carbon productivity can be attributed to the transition from a biomass-based energy source to a commercial energy source (electricity). Even if agricultural emissions do not decrease, implementing the climate mitigation actions of the NDC and, more importantly, the REDD strategy could ensure that economy-wide carbon productivity improves.

3.3 | Green growth for policy coherence and delivery of climate mitigation actions

3.3.1 | Maximizing the policy outcomes for effective climate mitigation actions

Previous studies (Choi et al., 2016; Gazheli et al., 2016) note that achieving green growth could be costly due to the monetary expenditure required to create structural change in the economy. Amidst this challenge, are there any benefits in incorporating a green growth approach in NDC implementation? For a low-income country such as Nepal, which is likely to double its GDP over the 15-year period between 2015 and 2030 (even at a current average annual growth rate of 4.4%), there are areas within the scope of the NDC scenario for which it is worth considering green growth as an approach for delivering climate mitigation actions. The green growth approach can link NDC and other policies to maximize outcomes for NDC and other policies. Potential outcomes include (1) improved energy productivity (by addressing energy losses that could cost the economy up to 10% of GDP in 2030), (2) protection of forest resources through a reduction in the use of biomass fuels from 465 million GJ in 2015 to 195 million GJ in 2030, which will potentially help to ensure that the forest area is at least 40% of land area (as mentioned in the NDC scenario), and (3) doubling carbon productivity by 2030 relative to the business-as-usual case by energy transition (from biomass-based fuel to a hydropower-based economy).

The NDC implementation scenario analysis showed that the implementation of Nepal's NDCs would be able to reduce GHG emissions in the energy sector (16.5 Mt CO_2e to 5 Mt CO_2e) in 2030 and significantly increase the carbon sink potential of the nation's forests (−4.3 Mt CO_2e to 9.7 Mt CO_2e) in 2030 with reference to the business-as-usual (BAU) scenario in 2030. However, GHG emissions from the agriculture sector appear to remain the same (33.5 Mt CO_2e) in the NDC scenario in 2030 with reference to the BAU scenario in 2030. The agriculture sector is the primary GHG emissions source in Nepal, and it contributes to about half of total national GHG emissions as of 2020, which means that the existing NDCs of Nepal may not result in GHG emissions reductions at an economy-wide scale. The research found that the potential to reduce GHG emissions from the agriculture sector was limited, apart from reducing the burning of agriculture residues that contributes to GHG emissions. The reduction of non-energy GHG emissions by using other options such as no-till farming and the supply chain management of agricultural products could potentially further reduce GHG emissions from the agriculture sector (Wollenberg et al., 2016). However, they are not a part of Nepal's NDCs. Therefore, the limited opportunities in the agriculture sector of Nepal (MoSTE, 2014), coupled with insufficient agriculture-specific climate mitigation actions in the NDC, mean that other policy areas may have to offset GHG emissions from the agriculture sector. Therefore, a strong linkage between climate mitigation-related objectives in the NDC and sectoral policy goals is necessary for an economy-wide GHG emissions reduction in Nepal. Kok and de Coninck (2007) state that strengthening the linkages between sectoral policies and climate action plans (e.g., NDCs) via policy coherence is critical for improving the effectiveness of climate actions across different policy areas (and sectors)—for example, agriculture, forestry, energy, and other industries.

With regard to the energy sector, the scenario analysis found that total energy demand will decrease significantly in the NDC scenario in comparison to the BAU scenario by 2030 (663 million GJ to 545 million GJ). However, the implementation of NDCs will put stress on energy supply because of the significant amount of transmission and distribution loss in the energy sector (21% of the energy supply). The energy loss is primarily due to the planned shift in the energy system from biomass-based energy to hydroelectricity-based energy, which is mentioned by the NDC document of Nepal. The energy loss may reach up to USD 4.3 billion per annum in 2030 if the current level of electricity transmission and distribution losses persists. In case the country fails to maintain the transmission and distribution loss of about 10%, which is a South Asian regional average, a loss of USD 1.3 billion per annum is likely to result in the NDC scenario in 2030. The estimated economic loss due to energy loss will range from 3 to 10% of GDP in 2030 if the current value of GDP growth rate is considered to project the 2030 GDP value. Therefore, the study finds that the NDCs should not be a standalone plan of climate action for reducing GHG emissions. Instead, an economic growth approach, such as green growth, that emphasizes both economic and environmental imperatives should be used as part of improving policy coherence between NDCs and sectoral policies.

Transforming the energy mix requires phasing out non-renewable energy while at the same time progressing climate-sensitive design and installing hydropower plants at a rapid pace (Shakya et al., 2012). However, a dependence on hydropower plants as a future source of energy raises some concerns. Climate change-induced temperature rises in high-altitude Himalayan regions could have an impact on the generation capacity of hydropower plants (Bhutiyani et al., 2010; Gippner et al., 2013). In the AFOLU sector, the intended climate targets can only be achieved by improving productivity and implementing the REDD strategy. Again, improving agriculture productivity by increasing the yield from a limited and gradually shrinking area of agricultural land entails increased energy consumption and GHG emissions. Improving the productivity of forests by sustainably managing forest resources (e.g., biomass) could have a negative impact on energy access for the majority of the rural population. Protecting forest resources and croplands while simultaneously utilizing them requires both policy and technological changes, which inevitably have financial implications. This is challenging not only for Nepal but also for most LDCs. Barbier (2016) argues that green transformation is possible in developing countries, but only where growth can reconcile the structural features of natural resource use and poverty reduction. In the case of Nepal, green growth appears to enable structural changes in resource use while at the same time supporting the livelihood of the rural population by energy transition.

Charley and Taerup (2018) analyze the NDCs of 71 emerging markets and argue for a better process of technology need assessment that could fill gaps in the existing NDC scenario and promote conditions for diffusing technologies to low-income countries. While this study calls for narrowing financial and technology gaps, NDCs can leverage the existing policy landscape (e.g., by utilizing policy instruments), but there must be policy coherence if outcomes and impacts of NDCs are to be maximized. NDC implementation in isolation appears to be ineffective, with the value proposition being relatively weak. This is one of the reasons why the NDC scenario should incorporate a green growth approach, as it links the NDC to sectoral policies. In addition, reducing GHG emissions is one of the main goals of the NDC scenario. However, as can be seen from the above analysis, focusing solely on reducing GHG emissions cannot ensure improved sectoral productivity. Incorporating the conditions for achieving green growth (e.g., resource-efficient, clean, and resilient growth) into an NDC will ensure that the NDC and sectoral policies are not seen as different sets of standalone policies with different kinds of goals. Instead, the idea is to leverage common goals while implementing the NDC.

3.3.2 | Improving policy coherence

The focus of NDCs is primarily on reducing GHG emissions. Approximately 175 countries who are party to the Paris agreement have declared their intention of reducing their GHG emissions in the energy sector (Senshaw & Kim, 2018). The energy sector has been emphasized in studies more frequently than the AFOLU sector (Siagian et al., 2017; Tran et al., 2016; Wu et al., 2017) in relation to the NDCs of Asian countries. This could be because, on a global scale, GHG emissions from the energy sector are significantly greater than emissions in any other sector, including the AFOLU, industry, buildings, and transport sectors. In accordance with the IPCC's Fifth Assessment Report, this is true for upper-, middle-, and high-income countries (Edenhofer et al., 2014). However, for low-income countries (i.e., LDCs), the AFOLU sector is the main contributor of GHG emissions. Therefore, it is clear that policies focusing on reductions in AFOLU emissions have to be linked with NDCs, especially for LDCs. NDCs do not have direct connections with other policies (mostly sectoral), especially in terms of objectives, actions, and impacts. Therefore, green growth has been introduced as an approach to linking two seemingly disparate policy goals, namely climate action and economic growth, by means of policy coherence. Green growth is the only strategy to which mainstream economists and policymakers refer when aiming to address climate change (Antal & van den Bergh, 2016). Policy coherence entails non-conflicting signals and converging opinions on certain policy actions that could promote synergy between different policy areas (Mickwitz et al., 2009; Nilsson et al., 2012). This implies that, for NDC and sectoral policies to be coherent, there should be synergistic effects and objectives, and intended actions should create complementary immediate and end goals. While the objectives of the NDC and sectoral policies are different, intended actions inevitably focus on the productive use of resources (e.g., forest biomass and energy). The means/tools required for the productive use of biomass and energy resources, such as technological change and financial flows, are probably limited in LDCs, which means that there could be conflicts in priorities (e.g., between NDCs and sectoral policies) when there is limited access to technology and financial resources. However, as mentioned above in the OPS scenario section, sectoral policies contain subjective statements regarding reductions in resource use and emissions. Therefore, opportunities exist to align sectoral policy goals with NDCs, for example, by mentioning quantitative targets to reduce GHG emissions. The green growth approach can help policymakers align sectoral policy goals that could include addressing energy and GHG emissions issues by balancing structural change in resource use.

While achieving absolute policy coherence may be difficult because of policy actors' conflicting priorities and the institutional and technocratic hegemony prevalent in Nepal (Baniya, Giurco, Kelly, & Aryal, 2021), policy coherence via green growth showed there was potential to contribute to low GHG emissions. This potential exists for two reasons. First, the research (Section 3.3.1) on policy coherence between climate and sectoral policies identified the synergy between the agriculture and forest sectors to offset the GHG emissions from the agriculture sector. The agriculture sector of Nepal has limited potential to reduce GHG emissions despite being a major contributor to the national GHG emissions (MoSTE, 2014). Therefore, enhancing carbon sink capacity by maintaining the forest area at 40% of the total land area is found to offset about 9.7 Mt CO_2e per annum by 2030, while GHG emissions from the agriculture sector are likely to increase by 8.5 Mt CO_2e in 2030 in comparison to 2015.

4 | CONCLUSION

Addressing losses from the transmission and distribution of electricity and reducing the use of forest resources (fuelwood) as an energy source have emerged as important issues for the NDC of Nepal. Under the NDC scenario, the loss in GDP as a result of electricity loss could be almost 4.3 billion USD per year by 2030. However, if transmission and distribution losses of 10% are considered acceptable, as in the BNDC scenario, the loss in GDP would be approximately 1.3 billion USD per year. The loss of value-added potential in the NDC scenario is approximately one and a half times greater than in the BNDC scenario and more than three times what it is in the BAU and OPS scenarios. However, GHG emissions under the NDC and BNDC scenarios would be lower than under the BAU scenario. This suggests that commitments in the NDC might be sufficient in terms of reducing GHG emissions, but future economic losses associated with NDC implementation would be significant for a low-income country. To offset non-energy-related GHG emissions from the agriculture sub-sector, to improve the carbon productivity, and to leverage the CO_2 absorption capacity of existing forest resources, the REDD strategy must also be implemented.

Cross-sectoral collaboration between government agencies is therefore needed for economy-wide implementation of sectoral policies. This could improve the productivity and efficiency of sectors of the economy, and it could also address the gaps in the NDC by meeting conditions needed to achieve green growth. A green growth approach has not been extensively used in Nepal and other LDCs, probably because there are other similar competing and aligned concepts such as sustainable development and low-carbon economy approaches. However, a green growth approach seems to offer an attractive value proposition for policymakers, especially in improving policy coherence between the NDC and sectoral policies. By improving policy coherence, policymakers could align sectoral policy goals with the NDC by introducing objective targets for GHG emission reductions and resource use in the energy and AFOLU sectors. In LDCs, the most significant sources of GHG emissions are found in the AFOLU sector, mainly because of their dependence on biomass fuels as their main energy source. The priority for LDCs, especially from the viewpoint of climate mitigation, seems to be a renewable energy-based, efficient energy transition. However, given the critical role of biomass as an energy source in LDCs, there appears to be a strong energy-AFOLU nexus that remains unexplored, especially in studies focusing on NDC implementation in LDCs.

Additionally, this research generated three main policy insights that could be useful for policymakers and climate policy researchers focusing on Nepal and other LDCs. First, there is the need to create a coherent climate policy landscape that addresses energy losses that could cost up to 10% of gross domestic product (GDP) by 2030. Second, an integrative climate policy framework targeting the protection of forest resources by reducing the use of biomass fuels from 465 million gigajoules (GJ) in 2015 to 195 million GJ in 2030. Obviously, the climate policy framework looking at the energy and forest sectors needs to be integrative, considering forest resource flow across these two important sectors in Nepal. Finally, an energy transition strategy targeting a significant reduction in GHG emissions by 2030 relative to the business-as-usual (BAU) case by greater use of electricity from hydropower rather than biomass.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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ENDNOTE

[1] Carbon productivity is expressed in terms of a unit dollar of gross domestic product (GDP) generated per unit ton of carbon dioxide equivalent emission. Energy productivity is expressed in terms of a unit dollar of GDP generated per unit consumption of energy resources.

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