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# Asta-Ja and Energy Security in Nepal

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## **Abstract**

Energy independence and sustainable renewable energy sources are the two main components of energy security for Nepal. More than 2/3rd of energy consumed in Nepal comes from biofuels and waste and about 1/4th of energy consumed comes from coal and petroleum products. With increasing number of motor vehicles and rising demand for cooking gas, Nepal's coal and petroleum import bills in recent years have reached over Rs. 200 billion. With its vast water resources, Nepal has a great potential for energy independence and sustainability and achieve energy security. Nepal's current 1,689 MW hydroelectricity capacity is expected to reach over 5,000 MW in next three to five years, which means Nepal will have a large amount of clean energy in the market. This increased hydropower production will also require an increased domestic consumption by making hydroelectricity affordable, reliable, and high-quality energy by improving its distribution system. Nepal also has a very high potential for solar power, which need to be harnessed and brought to the national grid. Nepal needs to harness all energy sources, which consist of hydropower, solar power, wind power, biofuels, and biogas, in a sustainable way for its energy independence and security. Because Nepal is in a geologically active and natural disasters prone area, it is critical to ensure ecological balance of Asta-Ja elements, Nepali letter, *Jal* (water), *Jamin* (land), *Jungle* (forest), *Jadibuti* (medicinal and

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aromatic plants), *Janashakti* (manpower), *Janawar* (animal), *Jarajuri* (crop plants) and *Jalabayu* (climate) while developing energy resources. Asta-Ja Framework serves as the connecting bridge between the energy resources and the end users. Strategic planning for comprehensive energy development considering ecological balance of Asta-Ja resources, decarbonization and electrification of energy end uses, improvement of energy infrastructures, continuous monitoring and evaluation of energy sector, and development of hydropower plants and alternative energy sources such as solar and wind is suggested for energy security in Nepal.

**Keywords:** Hydroelectricity, alternative energy sources, energy security, Asta-Ja, Nepal.

## Introduction

Energy source, whether it is in the form of human muscles, draft animals, fuelwoods, or modern energy sources such as coals, oil and gas, hydroelectricity, or nuclear, has always been one of the key elements for the development of human society. The conversion of energy form coals to steam engine paved the way for the first industrial revolution. Coal energy started being used for cooking, heating, and lighting. Along with coals, energy generation form hydropower, nuclear, geothermal, and natural gas also started with the passage of the times. The development of internal combustion engine led to the massive production of automobiles which used petroleum products. Together with the coals, the use of oil and gas as energy sources resulted in the generation of greenhouse gases (GHGs), and the accumulation of an increasingly large amount CO<sub>2</sub> in the atmosphere causing global warming. In recent years, clean energy sources such as solar and wind have become the focus of energy generation. Other potential energy sources include hydrogen cells, biofuels, and biogas. Many countries in the world depend on other countries to meet their energy needs. Countries depending on foreign countries for their conventional energy sources are naturally looking for alternative energy sources, seeking their energy independence and security.

Nepal is a landlocked country bordered three side by India and one side by China. Nepal's trade with China is minimal due to lack of reliable transit routes to China owing to High Himalayas and difficult terrain. Nepal's trade is fully dependent on India. Despite historic and very strong cultural, social, and economic relationships between Nepal and India, Nepal has faced at least four declared or undeclared economic blockades from India due to various

political and trade and transit reasons in the past 60 years. Each blockade brought serious hardships to Nepalese people and economy primarily by cutting off the supply of petroleum products, food and medicine, construction materials, and other items that were necessary for daily life. To safeguard Nepal from such unwanted disruptions on energy supplies and subsequent losses in national economy and public hardships, Nepal needs to attain energy independence and energy security.

Nepal is endowed with vast water resources including over 6,000 rivers and streams with excellent geographical gradients and appreciable flow rates throughout the year for hydroelectricity generation across the country. Nepal gave high priority for hydroelectricity development since the onset of Five-Year Plans in 1956. However, Nepal's installed capacity for hydroelectricity generation is struggling with about just 1,689 MW. Since hydropower is a clean energy and there is a large amount of energy generation potential, it is in the advantage of Nepal to focus on small to large size hydropower and generate electricity. Surplus electricity can be exported to its neighboring countries. Although Nepal has a very low per capita energy consumption, the imports of petroleum, coals, and hydroelectricity has been increasing over time with corresponding increase in energy import bills reaching over Rs. 200 billion in recent years. Nepal imports its petroleum products solely from India. In 2018, Nepal's electricity demand was about 1,200 megawatts, about 180 megawatt was imported from India, and monthly LPG demand was about 32,000 tones with an increase by 30–40% in the winter (Pant, 2018).

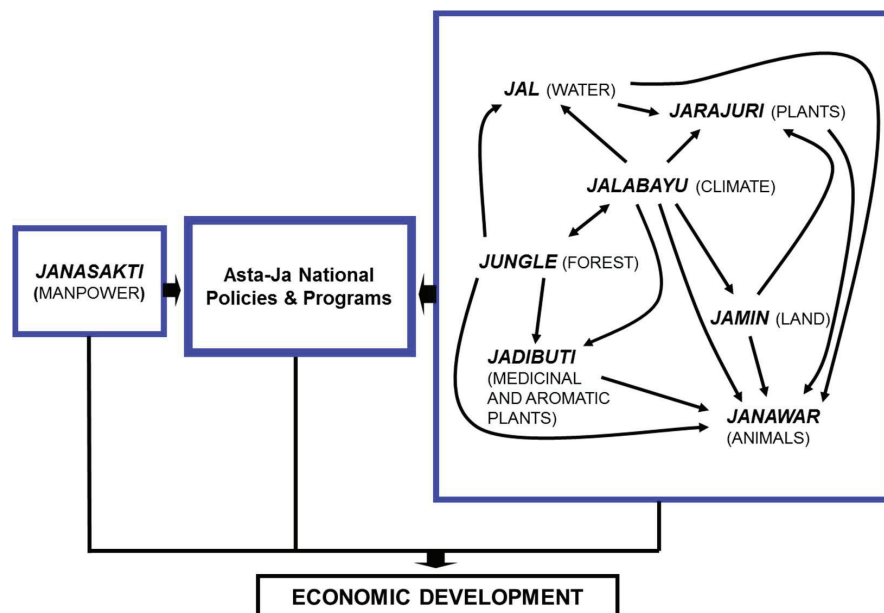
According to Gyawali (2013), water resources harnessing initiatives in Nepal have become major political issues and controversies. In 1950s, the issue of Koshi and Gandak agreements with India became the major issue and still these two projects are often at the center of Nepalese politics. The Arun-3 in 1980s, the Tanakpur issue and Mahakali treaty in 1990s, the West Seti project in 2000s, the Upper Karnali, and the Melamchi projects are some of the examples of such issues and controversies. On September 14, 2017, the Government of Nepal and the US Government signed a \$500 million Millennium Challenge Corporation (MCC) agreement in Washington, DC (MCC, 2017). The Government of Nepal committed additional \$130 million to this compact, making Nepal on the top list of the MCC countries on in-country contributions. Including India as a strategic partner, the MCC's first compact in South Asia grant investment targeted the construction of high voltage power lines aiming electricity trade with India, 300 kilometers of roads maintenance in East-West Highway, and the improved governance of Nepal's power sector. While the MCC funded project has initiated the construction of

a 400 kilometers 400 kV Lapsipedi-Galchhi-Damauli-Sunawal transmission line in the central part of Nepal (NEA, 2019; Ghimire, 2020), the MCC agreement is facing a serious opposition from general public, lawmakers, civil society, and some political parties citing that the MCC agreement is a part of the USA's Indo-Pacific Strategy for countering China and also some of the rules and regulations in the compact contradict with the Constitution of Nepal (Ghimire, 2020). As a result, the Government of Nepal has not been able to ratify the MCC agreement from its parliament as required by the agreement, leaving the compact in full controversy.

Lohani and Blakers (2021) report vast potential for solar power in Nepal, much greater solar power potential than hydropower. They estimate 100 times larger solar energy potential than required solar energy for per capita energy consumption at the par of developed nations. Fossil fuels constitute the negligible sources of energy in the country. Emerging technologies on solar and wind power may make these energy sources cost effective. To harness solar energy, activities such as forecasting solar irradiation and establishment of appropriate solar photovoltaic power stations at appropriate locations are necessary. Passive solar energy capture systems such as orientation of house and buildings to capture sunlight, planting trees to conserve electricity during hot months, and other passive solar energy capture techniques should be promoted. Clean and renewable energy sources would naturally be the best route to go for Nepal's energy security. Large hydropower dams and reservoirs cause significant environmental degradation with high risks of failures. Such projects must be very carefully evaluated and approved. The subsequent sections of this article presents Asta-Ja Framework, energy production and consumption, strategic energy planning, ecological balance of Asta-Ja, and conclusions and recommendations.

### **Asta-Ja Framework**

Considering Nepal's vast natural and human resources, great potential for economic development through sustainable conservation and development of natural resources, climate change and community resiliency, and national competitiveness and businesses, Poudel (2008) published a groundbreaking Asta-Ja Framework as a theoretically grounded planning and management approach for Nepal. The Asta-Ja Framework includes a system of strongly interlinked eight elements, i.e., eight *Ja* in Nepali letter, *Jal* (water), *Jamin* (land), *Jungle* (forest), *Jadibuti* (medicinal and aromatic plants), *Janashakti* (manpower), *Janawar* (animal), *Jarajuri* (crop plants) and *Jalabayu* (climate)



**Figure 1** Interrelationships and linkages among Asta-Ja, and the formulation of national policies and programs for economic transformation (adopted from Poudel, D.D. 2008. Management of Eight “Ja” for Economic Development of Nepal, *Journal of Comparative International Management*, 11(1), 15–27; page no. 23, Figure 2).

(Figure 1). The *Jalabayu* (climate) serves as the central element of the Asta-Ja system as any changes on climatic conditions will directly affect all other elements in the system. Asta-Ja Framework identifies eight *Ja* as the foundation for sustainable development and stresses ecological balance of these eight elements for sustainable economic growth and environmental resources. Some of the subsequent publications in relation to Asta-Ja Framework include Asta-Ja policy framework (Poudel, 2009), strategic framework (Poudel, 2011), community capacity-building framework (Poudel, 2012), Asta-Ja system (Poudel, 2016), management of cooperatives focusing on Asta-Ja and globalization (Poudel, 2018a), Asta-Ja planning and development (Poudel, 2018b), Asta-Ja Framework as a peaceful approach (Poudel, 2021) and so on.

As the Asta-Ja Framework contains eight principles, (1) Community awareness, (2) Community capacity-building, (3) Policy decision-making, (4) Interrelationships and linkages, (5) Comprehensive assessment, (6) Sustainable technologies and practices, (7) Institutions, trade and governance, and

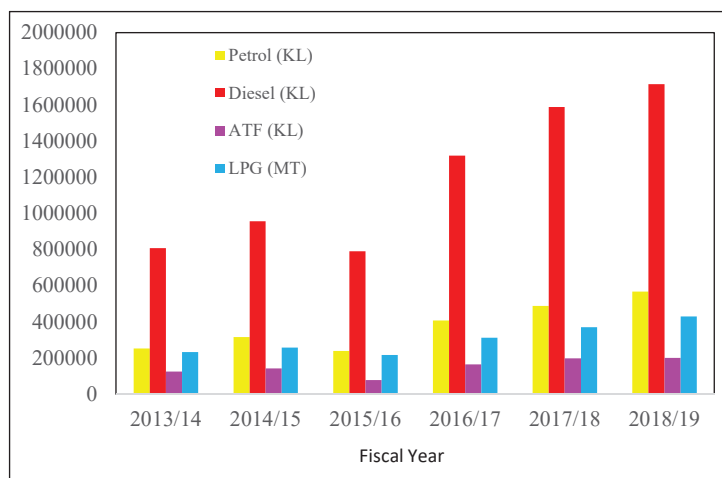
(8) Sustainable community development and socio-economic transformation (Poudel, 2008; 2009; 2011; 2012; 2021), and puts heavy emphasis on the principle of community awareness, this framework is a bottom-up approach to resources planning and development. The principle of community awareness underlines the importance of the understanding of Asta-Ja Framework by local communities. The communities who are educated and are aware of the conditions of their local natural and human resources can better enhance sustainable community development and socio-economic transformation in their localities. A close look of these eight principles reveals that Asta-Ja Framework reaches out to various quarters of the society from local communities to national planning and development authorities. It involves social mobilizers and trainers for community capacity-building, elected officials in policy decision making; scientific communities, academia, and development experts for understanding interrelationships, assessments, and the development of sustainable practices and technologies; business communities, lawmakers, and various local, regional and national institutions for governance and trade; and local communities and all other stakeholders in sustainable community development. Asta-Ja Framework crosscuts disciplines and engages everybody in the society for sustainable conservation, development, and utilization of natural and human resources, sustainable economic growth, and social inclusion.

### **Energy Consumption and Production**

According to IEA (2021), Nepal's total energy consumption from biofuels and waste, oil, coal, hydropower, and solar and wind sources has increased by 138% from 5,794 ktoe in 1990 to 13,787 ktoe in 2018. The order of energy sources contributing to the total energy consumption in 2018 was solar and wind (0.007%) < hydropower (3.05%) < coal (6.1%) < oil (18.72%) < biofuels and waste (72.1%), suggesting that more than 2/3rd of energy consumed in Nepal comes from biofuels and waste and about 1/4th of energy consumed comes from coal and petroleum products. Biofuel and waste sources of energy primarily include firewood, charcoal, biogas, and dry dung fuel. Indoor air pollution due to burning firewood and cow dung cakes is a major public health concern in the country. As compared to 1990, energy consumption from coal and petroleum products in 2018 increased by 1,620% and 958%, respectively, and corresponding increases in energy consumption from hydropower and biofuels and waste, respectively, were 461% and 83.2%. As Nepal lacks its own coal and petroleum sources,

these data clearly show that Nepal is becoming more and more dependent to India for its energy supply. Major energy sources of Nepal include the “dirty energy sources” (e.g., coal, petroleum, and biofuel and waste burning for cooking and heating), which has increased by 134% in 2018 compared to 1990, causing more indoor air pollution and environmental degradation. Heavy reliance on biofuel and waste for energy sources is harmful for the environment, agriculture, ecosystem, and public health as it relates to deforestation, diversion of the farmyard manure from agricultural application to other uses, burning of crop residue and other wastes for energy as opposed to leaving them in the field for carbon sequestration and adding soil nutrients, and degradation of air quality due to biomass burning and related public health issues.

Nepal’s import of petroleum products is increasing rapidly in recent years (Figure 2). As compared to FY 2013/14, the import of petrol, diesel, automatic transmission fluid (ATF), and liquefied petroleum gas (LPG) in FY 2018/19 has increased by 124%, 112%, 59% and 85%, respectively. These sharp increases in the volume of petrol and diesel imports correspond to the rapid increase in the number of automobiles in the country. Using vehicle registration data from the Department of Transport Management (DoTM), Poudel (2018) reported a massive surge in the number of registered vehicles from 1,755,821 in FY 2013/14 to 3,080,000 as of mid-May 2018 of the FY 2017/2018. Almost 300,000 motor vehicles were added in FY 2017/2018.



**Figure 2** Nepal’s import of major petroleum products. Data source: Nepal Oil Corporation, 2020, cited by MoF., 2020. Economic Survey 2019/2020, Table 9(i), page 98.

This increase in the number of automobiles is obviously associated with current worsening of air quality in the cities. The import of kerosene has increased from 18,409 KL in 2013/14 to 25,004 KL in 2018/19 (MoF, 2020).

With increasing volume of oil imports, Nepal's oil import bills are also rising at an alarming rate. As per the Nepal Rastra Bank Statistics compiled and reported by The Kathmandu Post (2018), Nepal's oil import bill was Rs. 131.73 billion in 2013/14, Rs. 110.05 billion in 2014/15, Rs. 65.6 billion in 2015/16 (decreased expenditures due to 2015 Gorkha Earthquake and the 2015 economic blockade), and Rs. 118.91 billion in 2016/17. Expenditures on oil import in 2017/18 and 2018/19 fiscal years, respectively, were Rs. 171.00 billion and Rs. 214.48 billion (Khanal, 2019). These massive increases in oil import bills curtail Nepal's economic development. Therefore, energy security through domestic energy sources is critical for Nepal for its sustainable economic growth.

Nepal ranks as the second richest country in the world on inland water resources. With the total theoretical potential of 83,290 MW, Nepal's economically and technically feasible hydropower potential is estimated between 42,000 MW to more than 50,000 MW (Bhatt, 2017; IFC, 2021). Realizing the great hydropower potential of the country, the Government of Nepal started its hydropower development initiative by establishing its first hydropower station, and South Asia's second hydropower station, as early as in 1911 with an installed capacity of 500 kilowatts in Pharping (Bhatt, 2017; Bhushal, 2021), which is located about 10 km south of Kathmandu. Despite such a huge potential for hydroelectricity generation and with more than 100 years of journey in hydropower development, Nepal had hydroelectricity generation of only 746 MW until the end of FY 2013/14 (Bhatta, 2017). But there is a remarkable jump in the generation of hydroelectricity in recent years due to the completion of several hydroelectric projects and linking them into the national grid (Table 1). However, except for the Kulekhani, almost all hydropower plants in Nepal are run-of-the-river (diversion) type, resulting in big fluctuations in the electricity generation capacity during the high and low flow conditions. It is important to have a balance between the run-of-the-river, storage, and pumped storage hydropower plants to maintain uninterrupted supply of hydroelectricity during the base and peak-loads, and to conserve surplus energy during the base-load and use it to generate electricity during the peak-load. Pumped storage hydropower plants can utilize surplus energy during the low electricity demand period for pumping water to the storage and help meeting peak electricity demand by generating electricity using stored water during the peak-load. Storage hydropower (impoundment) facilities



**Table 1** List of major hydropower stations with their years of commission and installed capacities in Nepal

Commissioned	Hydropower	Capacity	Commissioned	Hydropower	Capacity
1911	Pharping, Kathmandu	0.50 MW	2008	Middle Marsyangdi, Lamjung	70.00 MW
1936	Sundarjal, Kathmandu	0.90 MW	2012	Lower Modi I, Parbat	10.00 MW
1943	Letang Hydropower Plant, Morang	1.80 MW	2013	Ankhu Khola, Dhading	7.00 MW
1965	Koshi-Surajpura, Sunsari and Saptari	20.00 MW	2013	Sipiring Khola, Dolakha	10.00 MW
1965	Panauti, Kavrepalanchok	2.40 MW	2014	Mai Hydropower, Ilam	22.00 MW
1967	Trishuli, Nuwakot	18.00 MW	2015	Nau Gad Khola Hydropower, Darchula	8.50 MW
1969	Phewa Hydropower Station, Kaski	1.00 MW	2016	Upper Marsyangdi A, Lamjung	50.00 MW
1972	Sunkoshi, Sindhupalchok	10.00 MW	2017	Madhya Bhote Koshi, Sindhupalchok	102.00 MW
1979	Gandak, Nawalparasi	15.00 MW	2018	Thapakhola Hydropower, Mustang	11.20 MW
1982	Kulekhani Hydropower Plant I, Makwanpur	60.00 MW	2018	Madkyu Khola Hydropower, Kaski	13.00 MW
1984	Devghat, Nuwakot	14.10 MW	FY 2018/19	Upper Trishuli 3A, Rasuwa	60.00 MW
1985	Seti Hydropower Station, Pokhara, Kaski	1.50 MW	2019	Bagmati Small River Hydro, Makwanpur	22.00 MW
1986	Kulekhani Hydropower Plant II, Makwanpur	32.00 MW	FY 2019/20	Lower Hwa Khola, Panchthar	22.10 MW
1989	Marsyangdi Hydropower Station, Tamahu	69.00 MW	FY 2019/20	Lower Chhote Khola Small Hydro, Gorkha	0.99 MW
1991	Andhi Khola Hydropower Station, Syngja	9.40 MW	FY 2019/20	Upper Madi Hydropower, Kaski	7.00 MW
1994	Jhimruk Khola Hydropower, Pyuthan	12.00 MW	FY 2019/20	Iwa Khola Hydropower, Taplejung	9.90 MW
1996	Chatara Hydropower, Sunsari	3.20 MW	FY 2019/20	Upper Naugarh Gad, Darchula	8.00 MW
1999	Puwa Khola Hydropower, Ilam	6.20 MW	FY 2019/20	Kabeli B1 Hydropower, Panchthar	25.00 MW
2000	Modi Khola, Parbat	14.80 MW	FY 2019/20	Juligad Small Hydropower, Bajhang	0.99 MW
2000	Khimti I Hydropower Plant, Dolakha	60.00 MW	FY 2019/20	Padam Khola, Dailekh	4.80 MW
2001	Upper Bhote Koshi, Sindhupalchok	45.00 MW	FY 2019/20	Rudi B, Lamjung	6.60 MW
2001	Tadi Khola Hydropower, Nuwakot	5.00 MW	FY 2019/20	Ghalemd, Myagdi	5.00 MW
2002	Indrawati Hydropower III, Sindhupalchok	7.20 MW	FY 2019/20	Kulekhani Third, Makwanpur	14.00 MW
2002	Kali Gandaki A, Syangja	144.00 MW	2020	Solu Hydropower Station, Solukhumbu	23.50 MW
2003	Chilime Hydropower Plant, Rasuwa	22.00 MW	2021	Upper Tamakoshi, Dolakha	456.00 MW
		<b>575.00 MW</b>			<b>969.58 MW</b>

Data Sources: Alam et al., 2017; Bhatt, 2017; MoF, 2020; NEA, 2020; MoEWRI, 2021; Wikipedia, 2021. There are a large number of small and medium size hydropower plants generating a total amount of 145 MW hydroelectricity that are not included in this list.

can play multiple roles including flood control, irrigation, recreation, aquaculture, and climate change adaptation. Nepalese should be able to get electricity year-round at a fair price.

With high priority to hydroelectricity generation over the past several decades from the Government of Nepal coupled with substantial bilateral support, aid from multilateral agencies, and the involvement of public entities, private businesses, individuals, and other stakeholders, Nepal has made remarkable progress on hydroelectricity generation in recent years. Nepal generated 1,233 MW of hydroelectricity in addition to 54 MW from thermal plants and 68 MW from renewable sources by the end of the first eight months of FY 2019/20 (MoE, 2020). With the completion of the 456 MW Upper Tamakoshi Hydroelectric Project (HEP) and its full operation, Nepal's hydroelectricity generation reaches 1,689 MW, which is 126% increase in the hydroelectricity generation from FY 2013/14. The Upper Tamakoshi is the largest hydroelectric project under operation until this time in Nepal. Nepal's installed capacity for hydroelectricity generation can be expected to exceed 2,000 MW soon with possibly of exceeding 6,000 MW at not far distant in the future (Table 2). While transmission lines and other necessary infrastructures should be upgraded or built as the hydroelectricity generation continue to increase, increased domestic consumption of hydroelectricity is critical in sustaining the growth of hydropower in Nepal. The successful competition of the Upper Tamakoshi HEP adds a new dimension to hydropower in Nepalese society as it is the largest hydropower plant in the nation, and it is fully funded through domestic resources. Similar funding mechanism can be adopted to the construction of additional large hydropower plants in the country. It is a big step forward for the country's sustainable economic development. However, one of the major issues in hydroelectricity generation in Nepal is the increased cost of the project primarily due to corruption and the delay in construction. Since there is no open market for hydroelectricity in Nepal, it is important to keep the cost of hydroelectricity projects at minimum so that the electricity price for the public will be at a lower level. Energy security in Nepal requires energy independence and sustainable energy resources along with the availability of reliable and quality energy at affordable price for the Nepalese citizens.

## **Strategic Energy Planning**

The concept of planned development in Nepal first started by establishing a national planning committee and developing a Fifteen-Year-Plan for making

**Table 2** Some of the major hydroelectricity projects under construction and planned or proposed in Nepal

Under Construction		Planned or Proposed	
Project	Capacity	Project	Capacity
Tanahu Hydropower Project, Tanahu	140.00 MW	Upper Arun HEP, Sankhuwasabha	335.00 MW
Rahughat HEP, Myagdi	32.00 MW	Upper Modi A HEP, Kaski	47.00 MW
Upper Sanjen, Rasuwa	14.60 MW	Dudh Kosi Storage HEP, Okhaldhunga and Khotang	640.00 MW
Sanjen, Rasuwa	42.50 MW	Tamor Storage HEP, Panchthar and Tehrathum	530.00 MW
Rasuwagadi, Rasuwa	111.00 MW	Uttar Ganga Storage HEP, Baglung	300.00 MW
Upper Trishuli 3 B, Nuwakot and Rasuwa	42.00 MW	Budhi Gandaki HEP, Gorkha and Dhading	1,200.00 MW
Sanjen (Upper) HEP, Rasuwa	14.80 MW	Kimathanka Arun, Sankhuwasabha	450.00 MW
Seti Nadi-3 HEP, Bajhang	65.00 MW	Upper Karnali HEP, Surkhet, Achham and Dailekh	900.00 MW
	<b>461.90 MW</b>		<b>4,402.00 MW</b>

*Data source:* NEA, 2014; Alam et al., 2017; NEA, 2020.

Nepal self-sufficient by the Rana Prime Minister Shree Mohan Shamsheer JBR in 1949 (Wildavsky, 1972). However, the actual planning in Nepal began by establishing Planning Commission in 1956 following the proclamation from His Majesty King Mahendra Bir Bikram Shah Dev on October 9, 1955, stating “the necessity of a five-year plan for Nepal for attaining national self-sufficiency and establishing a welfare state”. The First-Five-Year Plan was launched in September 1956. In all subsequent plans, especially until the end of the Seventh Plan (1985–1990), self-reliant development through the policy of mixed economy remained as the core concept of development in Nepal. Thus, Nepal’s development began through the centralized planning and the establishment of public enterprises for production of goods and services including manufacturing, transportation, telecommunications, and hydroelectricity power plants. Although it is generally perceived that the centralized planning during the Panchayat Era (January 5, 1961 to April 17, 1989) blocked privatization of enterprises in Nepal, a close look of the Five-Year Plans reveals that the Government of Nepal was gradually introducing public-private or private enterprises as early as the beginning of 1960s. Some of these examples include the establishment of various banks with public-private investments, national trading company, and promotion of various

private industries in the country. Nepal started its economic reform more extensively from the beginning of the Sixth-Five-Year plan (1980–1985). The establishment of Nepal Electricity Authority (NEA), a Governmental Corporation, in August 1985, which follows the enactment of Nepal Electricity Authority Act 1984, is an example of public-private-partnership. The NEA consolidated the activities of planning, construction, operation, and maintenance of power infrastructure facilities and distribution of power in the country. Following the political change in 1990 and subsequent enactment of Privatization Act 1994, Nepal's economic development strategy changed largely to privatization and free economy. This resulted in the privatization of over three dozen of public enterprises during the decades of 1990 and 2000.

In relation to energy sources, the Sixth-Five-Year-Plan (1985–1990) states:

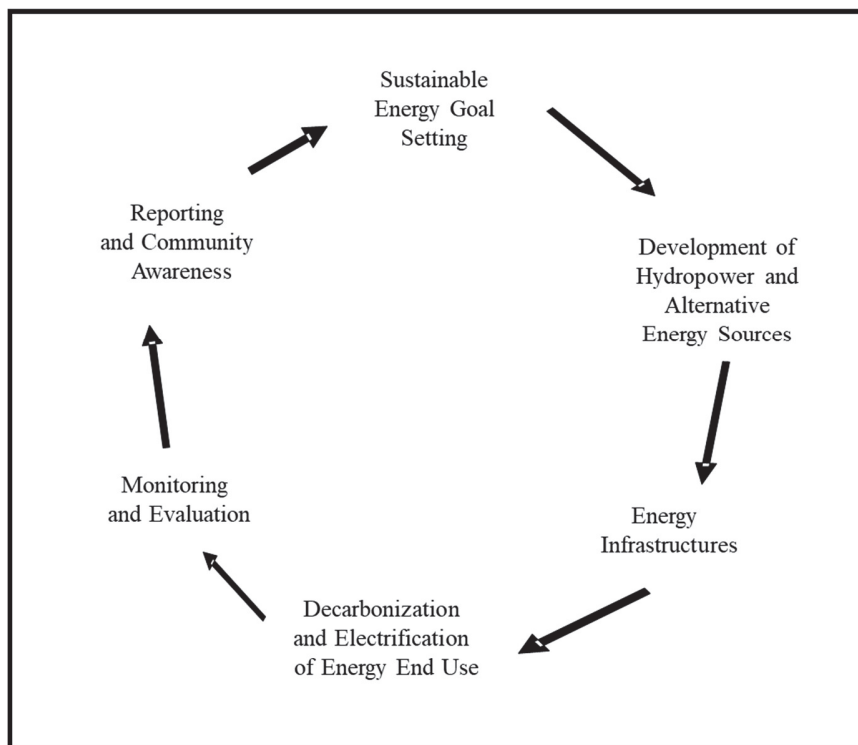
*“The main aims of electricity development in the Sixth Plan are to produce enough electric power to meet the growing demands of the different sectors, to extensively widen the domestic use of electricity with a view to stopping further depletion of the forest wealth, and to supply power required for electrifying the transport system as a substitute of petroleum.”* (NPC, 1980).

The above statement in the Sixth-Five-Year Plan very nicely captures the key issues and the direction for hydropower development in Nepal. It emphasizes hydropower development, massive demand creation for the use of electricity with a view of replacing fossil fuel, protecting forests from degradation, and transformation of fossil fuel-based transportation sector to hydropower-based transportation. These aims resemble well, especially on the decarbonization and electrification of energy end use, with the Paris Agreement that came as an output of the COP 21, November 30 – December 11, 2015 (UNCC, 2021). The main goal of the Paris Agreement is keeping global warming below 2°C while pursuing efforts to limit it to 1.5°C above preindustrial levels. Various mitigation pathways identified for limiting future emissions in 1.5°C pathways include: (1) using carbon budget approaches and reducing global CO<sub>2</sub> emissions to net zero, (2) reductions in non-CO<sub>2</sub> emissions (N<sub>2</sub>O, CH<sub>4</sub>, NH<sub>3</sub>, black carbon, hydrocarbons), (3) Carbon Dioxide Removal (CDR), (4) renewables and clean energy sources including bioenergy, hydropower, wind and solar; reduction in coals, and land transitions resulting in Carbon Capture and Storage (CCS) in soils and biomass, (5) electrification of energy end use, (6) land use changes – reduction in increase in agricultural lands to produce food and feed crops, reduction in pasture land

and converting pasture lands to energy crops, increase in forest areas, and (7) demand-side management including reduction in energy demand and land and GHG-intensity of food production, reducing demand for energy from end-use sectors such as building, transportation, and industry, and sustainable development through increasing efficiency of energy use in the demand-side and changes in lifestyles that limit energy resources and GHG-intensive food demand (Rogelj et al., 2018).

Nepal Electricity Authority has developed a comprehensive five-year (2018/19-2022/23) Corporate Development Plan (CDP) (NEA, 2019). The CDP includes 18 goals and 57 goal-specific activities under three themes: (1) national priorities, (2) capable, modern, and smart utility, and (3) improve customer care. The 18 goals of the CDP relate mainly to the development of hydropower in the country: (1) system improvement, loss reduction and supply of high-quality electricity, (2) use of modern IT system in power delivery, (3) improved project and human resources management, and (4) energy security through increased electricity generation and market integration. Some of the activities in relation to demand side management and energy efficiency include promoting activities to make economy more energy efficient, encourage consumers to change behavior, better manage peak and fill valley of the load curve, and enhance institutional capacity to make the system more efficient.

While there exists a huge possibility of electricity generation from hydropower, solar, wind, geothermal, and biofuels in Nepal, fuelwoods and waste constitute two-third of energy sources and per capita electricity consumption in the country is very low. Strategic energy planning (SEP) is necessary for Nepal to accelerate the development of clean and renewable energy, create demand for clean energy, transfer the society from carbon-based energy to clean energy, electrify end energy uses, and conduct regular monitoring and evaluation of the energy sector. Transformation of Nepalese society from nonrenewable and carbon-based energy sources to decarbonized energy sources not only makes the country energy independent and saves money spent on energy import but also improves public health and environmental quality. It enhances environmental sustainability primarily through controlling deforestation, improvement of soil fertility in agricultural land, soil erosion control, air pollution control, minimization of hazardous waste, and controlling site contamination. Improved air quality and clearance of haze will attract more tourists. Presence of the haze reduces the visibility of snowy Himalayas and the beautiful landscape of the country, frustrating the tourists and local people. Strategic energy planning requires to have a holistic



**Figure 3** Strategic Energy Planning Framework for the energy sector of Nepal.

view of energy resources, economy, energy market, public health, environment, climate change impacts, energy independence, and sustainability. Figure 3 shows the SEP Framework for Nepal's energy sector.

As depicted in Figure 3, the SEP for Nepal can broadly be generalized into six steps: (1) sustainable energy goal setting, (2) development of hydropower and alternative energy sources, (3) energy infrastructures, (4) decarbonization and electrification of energy end use, (5) monitoring and evaluation, and (6) reporting and community awareness. The first step of SEP, goal setting, begins with clear answers to the questions where, when, how, and how much electricity development is going to happen soon and the priority rankings of the hydropower plants. Water resource is the key resource in Nepal and people's lives and other sectors of Nepalese economy such as agriculture, forestry, industrial development, and drinking water supply are intricately linked with water resources. Therefore, it is important to set energy goals and objectives considering the holistic water use environment of the country.

The second step in SEP includes the development of hydroelectricity and alternative energy sources. As Nepal has high potential for the generation of a large amount of hydroelectricity, it is important to identify appropriate modality for hydropower development. Micro-hydropower (<100 kW) development was the major emphasis for rural electrification of the country starting in 1960s. Nepal is well-known in South Asia for micro-hydropower plants. Given appropriate terrain and plentiful of water resources in rural areas, smaller expenses for the installment, direct involvement of the communities, and not necessary to relate to national grid, micro-hydropower was viewed as a great approach at least for rural electrification. However, micro-hydropower plants are being dismantled now primarily due to the mandate given to Nepal Electricity Authority to light up every household in the country by 2023 through national-grid (Rai, 2020) and other reasons. Butchers et al. (2021) have identified weak specification of civil components during tendering, poor manufacturing of the equipment, poor quality of construction, and lack of trained manpower as major factors limiting the sustainability of micro-hydropower projects in Nepal. It is urgent for the Government of Nepal to come up with a clear policy of buying electricity from micro-hydropower plants and evacuating it to the national-grid and addressing other management issues to save more than 3,300 micro-hydropower plants scattered all over the country. The current path of hydropower development in Nepal appears to be the construction of many medium size and some large size hydropower plants, connection with high voltage transmission line and export of surplus electricity to India. There are many challenges in power development in the country. Gyawali (2021) have raised several issues with regard to hydropower development in Nepal including (1) the selection, financing, contracting, and the timely completion of hydropower projects, (2) seasonality of hydroelectricity generation and balancing the run-of-the-river and storage projects to address seasonal fluctuations in hydroelectricity generation, (3) institutional restructuring and assignment of duties and responsibilities accordingly, (4) multipurpose reservoirs projects that may include other elements such as irrigation, flood control, waterway, and fishery, (5) policy changes, laws and regulations considering the administrative federalization of the country, and (6) changes on electricity distribution system involving local community groups, cooperatives, and other similar entities. Lohani and Blakers (2021) suggest the development of solar power and off-river pumped hydro-energy-storage as opposed to on-river hydro storage for ecological integrity and investment on battery storage as a possible route for energy security in the country. They believe that the national energy plan developed before 2020

are largely outdated due to recent development in solar power. As the cost of solar power is coming down fast, it is possible that hydropower could be an expensive option for energy supply. In this context, it is necessary for the country to come up with a clear vision and power development strategy for energy security. Since solar power is an emerging technology, Nepal itself should strive in Research and Development of solar energy rather than waiting in line for the import of technologies from other countries.

The third step in SEP is the energy infrastructures. Nepal's high voltage transmission lines and electricity distribution system are relatively weak and cannot handle a large amount of electricity flow. Also, there is a huge amount of electricity loss due to poor quality transmission. Distribution lines are easily affected by windstorms. Overall, the reliability and quality of the electricity availability is a problem. Underground electricity lines activities are underway in Kathmandu, which will not only improve the aesthetics of the city but also increase the reliability of the power supply. Energy infrastructure development initiatives such as high voltage transmission lines, underground distribution lines, trolley buses, charging stations for electric cars, electrification of rural areas, establishment of industrial complexes, etc., are necessary for the development of energy sector in Nepal. Cross border electricity trade, which was a dream for Nepalese policy makers, has slowly becoming a reality, especially with the establishment of the first 400 kV cross border Dhalkebar-Mujaffarpur transmission line between Nepal and India (NEA, 2020). The second cross border 400 kV New Butwal to Gorakhpur transmission line, which was finalized on 14–15 October 2019, and other two cross border 400 kV transmission lines: New Duhabi-Purnia and Lumki-Bareilli between Nepal and India, whose detailed studies are about to be finalized soon, set potential for high volume electricity trade between Nepal and India in the future. Similarly, the potential 400 kV Ratmate-Rasuwadhi-Kerung transmission line, if established, will open electricity trade with China. It is necessary to plan energy development and distribution system considering future energy needs of the country so that the Nepalese society will not have any interruption in energy supply and economic growth.

The fourth step in SEP include decarbonization and electrification of energy end use. Decarbonization and electrification of energy end use is one of the major challenges for sustainable energy in Nepal. As over 72 percent of energy used in the country comes from biomass and wastes such as fuelwoods, cow dung, and crop residue, it is critical to develop comprehensive energy plan for decarbonization of the energy end use in Nepal. According to Pokharel and Rijal (2021), Nepal's current per capita annual



electricity consumption is 330 kWh, which is just one third of per capita energy consumption of India and about 7% of the per capita annual electricity consumption of China. Nepal Electricity Authority sets the goal of 500 kWh per capita annual electricity consumption by the end of FY 2022/2023 (NEA, 2019). Energy dependence on fuelwoods lead to deforestation and use of cow dung and crop residue contradicts with the sustainable land management goal through carbon sequestration and organic matter build-up in agricultural lands. Burning fuelwoods, cow dungs and crop residues as energy sources causes serious respiratory health consequences and air pollution. Programs such as housing development at the local level, subsidized hydroelectricity for cooking and heating and other residential uses, and the promotion of hydroelectricity or clean energy for household uses will stimulate hydropower energy generation in the country. Nepal's current annual import of LPG is Rs. 33 billion, which is 2.5% of the total import bill of Nepal. Replacement of LPG by hydroelectricity at a relatively cheaper price will result a saving of at least Rs. 33 billion on import bills annually. Replacement of LPG will also reduce GHG emissions. Transportation is another sector which has highly potential for decarbonization and electrification of energy end use. Electric vehicles, electric trains, ropeways, and vehicles running with biofuels will promote the development of renewable and clean energy resources in the country. Industrial and commercial sectors also need decarbonization and electrification of energy end use. Replacement of coal-fired and diesel plants with hydroelectricity power plants or alternative energy sources enhances the sustainability of energy supply. The current level of electricity consumption, primarily for lighting and negligible amount for cooking and heating, will not be sufficient to create enough demand for increased production of hydroelectricity, which is expected to the generation of 5,000 MW hydroelectricity in next three to five years. According to NEA (2020), 86% of the total households in Nepal have access to electricity infrastructures and domestic consumers constitute 93.26% of the total electricity consumers suggesting that most electricity consumption in Nepal is for household uses, and largely for lighting. It is important for Nepal to develop strategic energy plan considering not just the conventional goals of development of hydropower, transmission and distribution, and upgrade on planning and development, but also on increasing electricity demand through housing development, agro-industrialization, and decarbonization and electrification of energy end use. It is important to create demand for the increased amount of electricity.

The fifth step in SEP includes monitoring and evaluation of the energy development and supply programs, project costs, electricity demand and

prices, users' preferences, improvement in system reliability, quality of electricity, and environmental conditions. Comprehensive and timely monitoring and evaluation of the energy sector is necessary for sustainable energy supply and security. The sixth and the final step in SEP includes reporting and community awareness. Historically, Nepal's water resource harnessing projects, especially when it comes jointly with India whether in the form of a large-scale irrigation or as a hydropower project, have become politically very sensitive issues. Therefore, it is critical for Nepal to do sufficient homework and EIA while making final decisions on hydropower projects especially on those where foreign interest and involvement exists. Community awareness and participation in the development of hydropower and other alternative energy sources is critical for energy sustainability in the country. Community awareness will not only ease the development of energy production units but also on the protection and long-term vitality of these developmental projects.

### **Ecological Balance of Asta-Ja**

Nepal is one of the most vulnerable countries to climate change impacts in the world. Rising temperatures, changes on precipitation patterns, extreme rain events and environmental pollution due to domestic and transboundary pollution sources are some of the major environmental concerns in Nepal. Nepal is experiencing tremendous effects of global warming including changes on snow cover, hydrological changes, GLOF, droughts, and flooding (Bajracharya et al., 2011; Poudel and Duex, 2017; Corwin et al., 2019). Emissions from fossil fuels, coal-fired plants, biomass burning, and other sources of GHGs are responsible for global warming and climate change. Climate change affects hydropower plants through drought resulting on low water volume in the reservoir, and through extreme rain events resulting in landslides, flooding, sediment deposition, and breaking of the reservoirs and damaging hydropower stations and transmission lines. Bajracharya et al. (2011) identified GLOFs and the variability of river runoff as the two critical impacts of climate change in hydropower development in Nepal. While a few rivers in the Gandaki River Basin were found increasing annual discharges, several rivers had alarmingly declining annual discharges (Bajracharya et al., 2011; Poudel and Duex, 2017).

Ecological balance of Asta-Ja elements is critical for sustainable energy resources in Nepal. As depicted in Asta-Ja Framework (Figure 1), climate serves as the central element for all Asta-Ja elements, and the changes on

climatic conditions affect all other elements. Energy sector which is primarily the hydropower (*Jal*), biomass and waste (*Jungle, Jarajuri, Janawar*), and solar and wind (*Jalabayu*) are directly affected by climate change. Sustainable hydropower development initiatives need to keep factors such as the fragile environment of the country, geology, ecology, climate change, and other sectors such as agriculture, forestry, and rangelands into consideration while energy planning and development. Sedimentation of hydropower facilities due to soil erosion from agricultural lands, landslides, or debris flow is always a big environmental concern. Large-scale hydropower projects are often associated with environmental degradation and socio-economic disturbance largely due to displacement of people, land inundation, loss of forest, destruction in river ecology, and production of a large amount of methane due to decomposition of organic matter in the reservoir (Lohani and Blakers, 2021). A thorough environmental impact assessment (EIA) of hydropower projects should be accomplished and the recommended EIA measures should be implemented.

Nepal belongs to a geologically active region of the world and constitutes five major fault zones which require full consideration while developing hydropower projects. Regarding the development of Nepalese landscape and the fault zones, Corwin et al. (2019) write:

*“One hundred twenty-five million years ago (Ma) during the Cretaceous period, the Indian plate rifted apart from Antarctica and began moving north until colliding with the Eurasian plate in the Eocene period around 40–50 Ma (Gibbons et al., 2013). The continent-continent convergent boundary resulted in the collision of the Indian plate with the Eurasian plate and the onset of the Himalayan orogeny, which continues to grow to this day. Five major fault zones are recognized as a result of this ongoing collision (Upreti, 1999). A much more complex network of smaller faults exists that were formed to relieve the immense pressure associated with Indo-Eurasian plate boundary (Martin et al., 2010). Thus, geologically, Nepal is located in an active tectonic setting where two lithospheric plates collide. Nepal is divided into five zones, each of which are separated from one another by thrust faults (Arita et al., 1982). These five zones from south to north are the Indo-Gangetic Plain (also called the Terai), the Siwaliks, the Lesser Himalaya, the Higher Himalaya and the Tibetan Tethys Zone (Upreti, 1999).”*

Frequent occurrence of high magnitude earthquakes is another major physical process in Nepal. The 7.8 Magnitude 2015 Gorkha Earthquake that killed more than 9,000 people and nearly 25,000 injuries affected almost one third of country's population destroying millions of houses, over 500 temples, many historic buildings and monuments, and damaging roads, bridges, and other infrastructures. Another incidence related to the fragility of Nepal's physical environment include the flood devastation of the Melamchi river on June 15, 2021. This landslide-induced dam outburst flood killed at least 20 people, displaced more than 600 people, destroyed 260 houses, and damaged several infrastructures along the road corridor and agricultural lands. This landslide-induced flood disaster also partly destroyed the Headworks of the Melamchi Water supply project. The glaciated fragile landscape coupled with the stresses caused by the 2015 Gorkha Earthquake and large amount of precipitation in a relatively short duration seems to have caused this landslide-induced flood disaster. A close monitoring of the catchment area with respect to possible upcoming landslides and taking necessary remedial actions is necessary to prevent similar disasters in the future. Fragile geology, poor land management, and lack of enough consideration for environmental conditions in infrastructural development constitute some of the obvious reasons for the Melamchi disaster. There are many incidences of flooding, landslides, debris flow, and GLOF disasters resulting in loss of lives and massive destruction of infrastructures in recent years in Nepal (NEA, 2019; Poudel, 2021). It is necessary to assess environmental, socio-economic, and ecological risks of any developmental project thoroughly and take necessary mitigation measures accordingly. Development of local technical expertise, comprehensive assessment of all risks, and impact mitigation should be an integral part of project planning. For resiliency and sustainability of hydropower projects, they should fit well with the physical environment and have ecological integrity with *Asta-Ja* elements.

## **Conclusion and Recommendations**

Nepal has a huge potential for energy independence and security through the development of its vast water resources, solar energy, and other alternative energy sources. Nepal's energy development initiatives should aim decarbonization and electrification of energy end use and enhance energy security. With increasing installed capacity for hydroelectricity, Nepal urgently needs to focus on increasing its domestic consumption which depends largely on the reliability and quality of electricity and its cost. Various strategies for

increasing domestic energy demand include expansion in household electricity consumption, increased industrial and commercial uses, and the transformation of transportation sector to electric vehicles. Governmental programs such as housing development, industrialization, and city lighting will increase electricity consumption. Energy infrastructures should be developed primarily considering domestic supply. In developing energy infrastructures, it is important to keep in mind the country's future developmental initiatives such as railway lines, cable cars, highways, urban centers, and others. Climate change affects river flows, water levels of the reservoirs, and cause flooding, and GLOFs. Sufficient consideration should be given to changing climatic conditions while developing hydropower plants in the country. Sustainable hydropower development in Nepal requires a comprehensive consideration on geology, agriculture, forestry, wildlife and habitat, water resources use, natural disasters, and climate change impacts. Strategic energy planning (SEP) which revolves around appropriate goal setting, the development of hydropower and alternative energy resources, development of energy infrastructure, decarbonation and electrification of energy end uses, monitoring and evaluation, reporting, and community awareness is necessary for sustainable energy development and energy security. Asta-Ja Framework that contains eight elements, *Jal, Jamin, Jungle, Jadibuti, Janashakti, Janawar, Jarajuri*, and *Jalabau*, serves as a strong connecting bridge between energy resources and end users in Nepal.

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### **References**

- Alam, F., Alam, Q., Reza, S., Khurshid-ul-Alam, SM., Saleque, K., and Chowdhury, H., 2017. A review of hydropower projects in Nepal, *Energy Procedia* 110 (2017) 581–585, Elsevier Ltd., Available at: <https://www.sciencedirect.com/science/article/pii/S1876610217302187>

- Arita, K., Hayashi, D., and Yoshida, M. (1982). Geology and structure of the Pokhara-Piuthan area, central Nepal. *Jour. Nepal Geol. Soc.*, 2, 5–29.
- Bajracharya, T.R., Acharya, S., and Ale, B.B., 2011. Changing climatic parameters and its possible impacts in hydropower generation in Nepal (A case study on Gandaki River Basin), *Journal of the Institute of Engineering*, Vol. 8(1):169–173. Available at: <https://www.nepjol.info/index.php/JIE/article/view/5108>
- Bhushal, R., 2021. The forgotten tale of Nepal's first hydro project, The Third Pole, Available at: <https://www.thethirdpole.net/en/energy/the-forgotten-tale-of-nepals-first-hydro-project/>
- Bhatt, R.P., 2017. Hydropower development in Nepal- Climate change, impacts and implications, Intechopen.com. Available at: <https://www.intechopen.com/books/renewable-hydropower-technologies/hydropower-development-in-nepal-climate-change-impacts-and-implications>, DOI:10.5772/66253. pp. 75–98.
- Butchers, J., Williamson, S., and Booker, J., 2021. Micro-Hydropower in Nepal: Analysing the Project Process to Understand Drivers that Strengthen and Weaken Sustainability, *Sustainability*, 13, 1582. <https://doi.org/10.3390/su13031582>.
- Corwin, H., Eddings, K., Bailey, G., Braun, A., Mann, A., Gomez, V., Heafner, H., Faulk, W., Immel, L., Hingdon, A., Stelly, B., Brousard, B.N., Willis, L., Martin, T.C., Mizelle, T.J., Baker, A.J., Duex, T., and Poudel, D.D., 2019. Enriching college students through study abroad: A case of Nepal Field Experience Part 1, *ASEJ* 23(4):24–29. DOI:10.5604/01.3001.0013.6832 (online).
- Ghimire, B., 2020. Why the MCC compact courted controversy in Nepal, published by the Kathmandu Post on January 9, 2020. Available at: <https://kathmandupost.com/national/2020/01/09/why-the-mcc-compact-court-ed-controversy-in-nepal>
- Gibbons, A. D., Whittaker, J. M., and Müller, R. D. (2013). The breakup of East Gondwana: Assimilating constraints from Cretaceous ocean basins around India into a best-fit tectonic model. *Journal of geophysical research: solid earth*, 118(3), 808–822.
- Gyawali, D., 2013. Reflecting on the Chasm between Water Punditry and Water Politics, *Water Alternatives* 6(2): 177–194, Available at: <https://www.water-alternatives.org/index.php/tp1-2/1882-vol6/237-issue6-2>
- Gyawali, D., 2021. *Bijuli Bikas Sahi Margama Doryauna Chahine Abashyak Sudhar*, Published on August 10, 2021 in Setopati-Nepal's Digital

- Newspaper, Setopati Sanchar, Pvt. Ltd., Available at: <https://www.setopati.com/opinion/245677> (In Nepali language).
- IEA (International Energy Agency). 2021. Total energy supply (TES) by source Nepal 1990–2018, Available at: <https://www.iea.org/countries/Nepal>.
- IFC (International Finance Corporation). 2021. Harnessing Nepal’s Hydropower for Energy Starved South Asia, Available at: [https://www.ifc.org/wps/wcm/connect/news\\_ext\\_content/ifc\\_external\\_corporate\\_site/news+and+event\\_s/news/nepal+hydropower](https://www.ifc.org/wps/wcm/connect/news_ext_content/ifc_external_corporate_site/news+and+event_s/news/nepal+hydropower)
- Karki, K., KC. H., 2020. Nepal-India Relations: Beyond Realist and Liberal Theoretical Prisms, *Australian Journal of International Affairs*, DOI: 10.3126/joia.v3i1.29085, Available at: [https://www.researchgate.net/publication/342165968\\_Nepal-India\\_Relations\\_Beyond\\_Realist\\_and\\_Liberal\\_Theoretical\\_Prisms](https://www.researchgate.net/publication/342165968_Nepal-India_Relations_Beyond_Realist_and_Liberal_Theoretical_Prisms)
- Khanal, R., 2019. Oil import bill soared 25 percent to Rs214.48 billion in last fiscal, *The Kathmandu Post*, Published on August 6, 2019, Available at: <https://kathmandupost.com/money/2019/08/06/oil-import-bill-soared-25-percent-to-rs214-48-billion-in-last-fiscal>
- Lohani, S.P., and Blakers, A., 2021. 100% renewable energy with pumped-hydro-energy storage in Nepal, *Clean Energy*, Volume 5, Issue 2, June 2021, Pages 243–253, Available at: <https://academic.oup.com/ce/article/5/2/243/6275217>, <https://doi.org/10.1093/ce/zkab011>
- Martin, A. J., Ganguly, J., and DeCelles, P. G. (2010). Metamorphism of Greater and Lesser Himalayan rocks exposed in the Modi Khola valley, central Nepal. *Contributions to Mineralogy and Petrology*, 159(2), 203.
- MCC (Millennium Challenge Corporation). 2017. MCC Acting CEO Jonathan Nash’s Remarks at the Nepal Compact Signing, September 14, 2017, Washington D.C., Available at: <https://www.mcc.gov/news-and-events/speech/speech-091417-nash-nepal-compact-signing>
- MoEWRI (Ministry of Energy, Water Resources and Irrigation). 2021. Construction License: Hydro (>1 MW), Ministry of Energy, Water Resources and Irrigation, Government of Nepal, Available at: <http://www.doed.gov.np/license/66>
- MoF (Ministry of Finance). 2020. Economic Survey 2019/20, Ministry of Finance, Government of Nepal, Singh Durbar, Kathmandu, Available at: [https://mof.gov.np/uploads/document/file/Economic%20Survey%202019\\_20201125024153.pdf](https://mof.gov.np/uploads/document/file/Economic%20Survey%202019_20201125024153.pdf)
- NEA (Nepal Electricity Authority). 2014. A Year in Review- Fiscal Year 2013/2014, Nepal Electricity Authority, Durbar Marg, Kathmandu, Nepal.

- Available at: [http://www.nea.org.np/images/supportive\\_docs/AnnualReport-2014.pdf](http://www.nea.org.np/images/supportive_docs/AnnualReport-2014.pdf)
- NEA (Nepal Electricity Authority). 2019. Nepal Electricity Authority Corporate Development Plan 2018/19 – 2020/23, Nepal Electricity Authority, Durbar Marg, Kathmandu, Nepal. Available at: [https://energypedia.info/images/c/c7/NEA\\_Corporate\\_Development\\_Plan.pdf](https://energypedia.info/images/c/c7/NEA_Corporate_Development_Plan.pdf)
- NEA (Nepal Electricity Authority). 2020. A Year in Review- Fiscal Year 2019/2020, Nepal Electricity Authority, Durbar Marg, Kathmandu, Nepal. Available at: [https://www.nea.org.np/annual\\_report](https://www.nea.org.np/annual_report)
- NPC (National Planning Commission). 1980. The Sixth Plan, National Planning Commission, Singh Durbar, Kathmandu, Nepal, Available at: [https://www.npc.gov.np/images/category/sixth\\_eng.pdf](https://www.npc.gov.np/images/category/sixth_eng.pdf)
- Pant, B., 2018. Socio economic impact of undeclared blockade of India on Nepal, Research Nepal Journal of Development Studies, Volume I, Issue 1, 2018 May, pp. 18–27, Available at: <https://www.nepjol.info/index.php/rnjds/article/view/21270>
- Pokhrel, T.R., and Rijal, H.B., 2021. Energy transition toward cleaner energy resources in Nepal, Sustainability, 13(8) 4243, Available at: <https://www.mdpi.com/2071-1050/13/8/4243>
- Poudel, D., 2018. 3.1 million motor vehicles on Nepali roads: DoTM, Published by myrepublic on July 4, 2018. Available at: <https://myrepublica.nagariknetwork.com/news/3-1-million-motor-vehicles-on-nepali-roads-dotm/>
- Poudel, D.D., 2008. Management of Eight ‘Ja’ for Economic Development in Nepal. *Journal of Comparative International Management*, 11(1): 15–27.
- Poudel, D.D., 2009. The Asta-Ja Environmental and Natural Resources Policy Framework (Asta-Ja ENRPF) for Sustainable Development in Nepal. *Journal of Comparative International Management*, 12(2): 49–71.
- Poudel, D.D., 2011. A strategic framework for environmental and sustainable development in Nepal. *International Journal of Environment and Sustainable Development*, 10(1): 48–61.
- Poudel, D.D., 2012. The Asta-Ja Management Capacity-building Framework for Sustainable Development in Nepal, *International Journal of Sustainable Development*, Vol. 15, No. 4, pp. 334–352.
- Poudel, D.D., 2016. Management of Asta-Ja System, *Journal of Comparative International Management*, 19(2): 19–40.
- Poudel, D.D., 2018a. Management of Cooperatives Focusing on Asta-Ja and Globalization, *Journal of Comparative International Management*, 21(1): 77–84.



- Poudel, D.D., 2018b. Restructuring National Planning Commission Focusing on Asta-Ja and Nepal Vision 2040, *Asian Profile*, 46(2): 151–167.
- Poudel, D.D., 2021. Asta-Ja Framework: A Peaceful Approach to Food, Water, Climate, and Environmental Security Coupled with Sustainable Economic Development and Social Inclusion in Nepal, *Strategic Planning for Energy and the Environment*, Vol. 39, 1–4, 243–318. doi: 10.13052/spee1048-4236.391412
- Poudel, D.D., and Duex, T.W., 2017. Vanishing Springs in Nepalese Mountains: An Assessment of Water Sources, Farmer’s Perceptions, and Climate Change Adaptation, *Mountain Research and Development*, 37(1):35–46. DOI: <http://dx.doi.org/10.1659/MRD-JOURNAL-D-16-00039.1> <http://telegraphnepal.com/asta-ja-crusade-for-a-fast-paced-agro-jadibuti-industrialization-of-nepal/>
- Rai, K.R., 2020. Micro hydro plants destined for oblivion in rural Nepal, Published in the Kathmandu Post on September 2, 2020, Available at: <https://kathmandupost.com/money/2020/09/02/micro-hydro-plants-which-lighted-up-rural-nepal-destined-for-oblivion>
- Rogelj, J., Shindell, D., Jiang, K., Fifita, S., Forster, P., Ginzburg, V., Handa, C., Kheshgi, H., Kobayashi, S., Kriegler, E., Mundaca, L., Séférian, R., and Vilariño, M.V., 2018. Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development. In: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J.B.R., Chen, Y., Zhou, X., Gomis, M.I., Lonnoy, E., Maycock, T., Tignor, M., and Waterfield, T. (eds.)]. In Press. Available at: [https://www.ipcc.ch/site/assets/uploads/sites/2/2019/02/SR15\\_Chapter2\\_Low\\_Res.pdf](https://www.ipcc.ch/site/assets/uploads/sites/2/2019/02/SR15_Chapter2_Low_Res.pdf)
- The Kathmandu Post., 2018. Fuel import bill balloons to all-time high of Rs. 131.93b, Published on June 12, 2018. Available at: <https://kathmandupost.com/money/2018/06/12/fuel-import-bill-balloons-to-all-time-high-of-rs13193b>
- UNCC (United Nations Climate Change). The Paris Agreement, Available at: <https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement>

- Upreti, B. N., 1999. An overview of the stratigraphy and tectonics of the Nepal Himalaya. *Journal of Asian Earth Sciences*, 17(5–6), 577–606.
- Wikipedia., 2021. List of power stations in Nepal. Available at: [https://en.wikipedia.org/wiki/List\\_of\\_power\\_stations\\_in\\_Nepal](https://en.wikipedia.org/wiki/List_of_power_stations_in_Nepal)
- Wildavsky, A., 1972. Why Planning Fails in Nepal, *Administrative Science Quarterly*, Dec., 1972, Vol. 17, No. 4 (Dec., 1972), pp. 508–528 Published by: Sage Publications, Inc. on behalf of the Johnson Graduate School of Management, Cornell University Stable URL: <https://www.jstor.org/stable/2393830>

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