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Virtual Power Purchase Agreement (VPPA) in Renewable Energy and its Relevance to developing countries like Nepal

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Abstract

The study discusses virtual power purchase agreements in the renewable energy sector in Nepal. Nepal is rich in renewable energy resources like hydropower as there are more than 6000 rivers with slopes and steep topography. Currently, Nepal is in a position to export power to the cross-boarders (India and Bangladesh). However, there are many obstacles and hurdles in the development of Hydropower in the country. Developing a hydropower plant involves significant financial risks due to its capital-intensive nature, long gestation period, and reliance on external factors like hydrology and regulatory frameworks. In this scenario, if there were a competitive market with the Virtual Power Purchase Agreement, it could reduce the financial risk. It could incentivize national and international investors for financing to produce more renewable energy. Further, VPAA allows it to meet its renewable energy targets easily.

Keywords: Finance, Power Purchase Agreement, Virtual, Green House Gas, Trading

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Introduction

Nepal beautiful country located between China and India is well known for renewable energy resources that are a clean form of energy. Fortunately, Nepal is rich in renewable resources including biomass, solar energy, biogas, and hydropower. The drawbacks of conventional energy that threaten the global climate and the enormous renewable energy potential in developing countries provide opportunities to invest in renewable energies. Nepal needs more renewable energy and power for economic development. This will in the end lead to overall sustainable development of the country. According to the NEA Annual Report (2024), 94.5% of energy comes from hydropower.

Nepal has a large amount of hydropower potential due to its sharp terrain with more than 6000 rivers (ADB, 2020). The study shows that the country has approximately 43,000 MW of economically feasible hydropower potential. The Hydropower Policy is determined to harness the potential of hydropower sources, expand the electrification within the country, and export the power to neighboring countries (MoEWI, 2024) like India, China, and Bangladesh. In addition, the policy makes it possible for the private sector to invest in the development of hydropower. Government policy permits private investors to construct and run hydropower projects in Nepal using the Build, Operate, Own, and Transfer (BOOT) model. At the same time, realizing a strong demand for power in domestic as well as in neighboring countries, private sectors are also invited to develop run-off-river hydropower projects. The government has provided licenses to more than 200 private companies in Nepal (DOED, 2025).

Energy as the backbone of any country's development, is a major source of energy is electricity in Nepal. The electricity demand has increased due to the expansion of industrialization and urbanization over 3 decades in Nepal(Chaudhary, 2024). Furthermore, connecting energy as a crucial element in the process of development to give people social and economic advantages. According to a power generation roadmap released by the Nepal Government, 28500 MW of electricity will be produced by 2035, of which 13500 MW will be used for domestic consumption and 15000 MW for cross-border trade. (MoEWRI, 2025). One of the

government's top priorities for a prosperous and contented Nepal is the quick expansion of the power sector. Additionally, long-term power agreements have been signed by the Nepali government and India to provide India with 10,000 MW of electricity. (Sharma, 2024). Similarly, electricity usage has been steadily increasing over the years in the country. At present, total Energy generation is around 3401 MW, and out of that, 65 % is the run-off-river type of hydropower plants(NEA, 2025). In recent years Integrated Nepal Power System (INPS) has surplus during the wet season (June- November) and a shortage during the dry season (December to May). There is a high potential for expert hydropower energy in India and Bangladesh (MOF, 2021).

Likewise, NEA imports electric power from the competitive Indian Exchange market and buys power through bilateral power purchase agreements and the Indian Exchange Real and DAM Market. Currently, there are 12 numbers of interconnections to exchange power between Nepal and India through 33 kV to 400 kV transmission voltage levels. However, there is a great challenge to exploring investors to produce more hydropower energy; they wish to secure their investments. To get financial support from the banks, the banks ask for a Power Purchase Agreement (PPA) to secure their income. The financial constraints and risks encourage the concept of a Virtual Power Purchase Agreement (VPPA), though there should be a competitive market.

According to Jahnel, Hundt & Sprungk (2024), when a VPPA deal is announced, there are notable positive abnormal returns; VPPA functions as a financial hedge, allowing the industrial buyer to achieve a decarbonization effect and a risk-minimizing hedge. VPPA could incentivize national and international financiers. Virtual Power Purchase Agreement may be a game changer in Nepal's renewable energy development by fostering investment, enabling sustainability goals, and enhancing the country’s reputation as a clean energy hub in South Asia. However, this VPPA concept is new for Nepal, and hence, this study shall fill the gap by exploring VPPA's relevancy in Nepal's renewable energy development. For the study, the systematic literature review is reviewed rigorously.

Present Power Status of Nepal

Electricity usage has been steadily increasing over the years. There has been significant progress in expanding the electricity infrastructure and improving access to power. Table 1 shows the total installed capacity generator capacity. However, a total capacity of around 95% of generators is hydropower and 65% of the total capacity is Run-off-River plants. As a result in the present context, Nepal faces challenges in meeting the growing demand for electricity during the dry season especially from December to May months, when river discharge is reduced to around 1/3rd of its capacity, as most of the hydropower plants are Run of the River (Chaudhary, 2024), and hence there is a shortage during the dry season when the discharge in the river is minimal. Therefore, trade is crucial in the area to alleviate the excess generation during the rainy season and the power shortage during the dry season. In this circumstance, regional trading can play a vital role in balancing the demand and supply of the country (Pandey, 2024).

Table 1: Generation Capacity of Power Energy

S.N	No of Projects	Installed Capacity(MW
NEA	19	662
NEA Subsidiary	5	646
IPPS	185	2094
Total	209	3402

Source: NEA, 2025

The practice of Power Purchase Agreement (PPA) in Nepal

Nepal practices physical power purchase agreement (PPA) to make import-export electricity. For Nepal, a Power Purchase Agreement (PPA) is a legal contract between an Electricity Generator (e.g., renewable energy developers, power plants) and a Purchaser (e.g., utilities, businesses, or government agencies)(WB, 2024). Under the PPA, the generator agrees to produce and sell electricity to the purchaser at a pre-determined price for a specified period. PPAs are commonly used in renewable energy projects, such as solar and wind farms, and serve as the financial backbone of such

projects**.** Typically PPA ranges from 10 to 25 years. The term is often chosen to match the financial modeling of the project. Energy Pricing can be fixed, variable, or indexed to market rates. Some PPAs include escalation clauses too. Specifying the amount of energy the generator is expected to deliver is also mentioned in PPA. Risk allocation is done that determine who bears risks such as resource availability, grid issues, and regulatory changes. It defines conditions under which the agreement can be terminated by either party. This too addresses the 'Force majeure'. This 'Force majeure' addresses unforeseeable events like natural disasters, which could disrupt energy production or delivery. Ownership of Renewable Energy Credits (RECs) is clearly mentioned if applicable. The PPA outlines who owns the environmental benefits of renewable energy production (COMMERCE, 2023).

Types of PPAs:

- Physical PPA: The energy is physically delivered to the purchaser.
- Virtual PPA (vPPA): A financial agreement where no physical energy is delivered. Instead, the parties settle on the difference between the market rate and the contract price.
- On-Site PPA: Often used for rooftop solar or small wind installations, where energy is consumed at the point of generation.
- Sleeved PPA: A third party (often a utility) facilitates the physical delivery of power from the generator to the purchaser (WB, 2024).

Advantages of PPAs:

- For Developers: It ensures a stable revenue stream to secure project financing.
- For Purchasers: It locks in energy prices, often providing cost savings and a hedge against price volatility.
- For Both Parties: It supports renewable energy deployment and sustainability goals (Montel, 2024)

Challenges in PPAs:

- Negotiating terms can be complex, particularly for grid integration.
- Long durations may lead to risks associated with market or regulatory changes.
- Alignment of energy production with consumption needs

In Nepal, the Nepal Electricity Authority (NEA) has been signing a Power Purchase Agreement (PPA) directly with the private sector on behalf of the government. NEA either transacts power energy directly with State distribution companies of the states of India like Bihar, UP, and Uttarakhand under the Indo-Nepal PEC mechanism or through PPA with government-appointed nodal power trading agency NTPC Vidyut Vyapar Nigam (NVVN), India and Power Trading Company India Limited (PTC). Since May 1, 2021, NEA has been importing and exporting electricity from the Indian Exchange Market. The NEA has already signed a PPA for an installed capacity of 3,600 MW of such power projects, and preparing to sign for more than 15000 MW in the future.

Nepal Government has published a white paper with a mix of generation resources as mentioned in Table 2. Nepal Government is providing peaking RoR and storage types of hydropower generation. Similarly, alternative sources of power energy are also given priority. However, Nepal's power generation varies seasonally, despite its heavy reliance on hydropower. In order to bridge the gap between supply and demand, particularly during the dry season, Nepal has been importing electricity from India.

Table 2: Various types of plants and percentages allocated

Scheme of Energy	Allocated percentage
Run off the river, RoR	40-45%
Peaking RoR	25-30%
Storage	20-25%
Alternative Sources	5-10%

Source: NEA, 2025 Note. RoR means Run-off-River

Nepal's Regional trading and its achievements

The cross-border power trading between Nepal and India dates back to 1971 through Government-to-Government and bilateral arrangements. Nepal joined the Indian Energy Exchange (IEX) on April 17, 2021, becoming the first SAARC country. Trade mainly focused on exports to India during the wet season and imports during the dry season with imports/exports on the Day-Ahead market of IEX and Real-Time

market and bilateral agreement. As indicated in Table 3, twelve regional trading connections between Nepal and India allow power to be exchanged via different lines running at voltages ranging from 33 kV to 400. Through these lines, NEA purchases power from the Indian Exchange Real and DAM Market, as well as through bilateral agreements, and imports power from the competitive Indian Exchange market.

Table 3: Existing Cross-Border Interconnection Power(MW)

S.N	Existing Nepal -India Interconnection	Voltage	Power
1	Dhalkebar- Mujaffarpur	400	1000
2	Kataiya- Kusaha	132	140
3	Kataiya- Kusaha II	132	100
4	Raxaul- Parwanipur	132	100
5	Tanakpur- Mahendranagar	132	70
6	Ramnagar- Gandak	132	40
7	Mainahiya- New Nautanwa(UP	132	100
8	Jaynagar- Siraha	33	12
9	Nanpara- Nepalgunj	33	12
10	Raxaul-Birgunj	33	12
11	Kataiya- Rajbiraj	33	12
12	Sursand- Jalwshwor	33	12
	Total Existing Capacity (MW)		1610

Source: NEA, 2025

Table 4 shows the total Power Purchase Agreement conducted projects out of 472 projects, 190 numbers of projects are in operation, 141 are under construction and 141 projects are in different stages. There are many obstacles and hurdles in the development of Hydropower in Nepal. One of the major hurdles in the construction phase is financial risk. Because of the financial problem, the projects are delayed and result in an overrun of cost and time. Nepal's hydropower potential is promising, and addressing financial hurdles is crucial for the successful development of the projects(Nepal et al., 2021). In the present case, the country had an

ambitious plan of 28500 MW by 2023 (MoEWRI, 2025). Many projects are in the process of PPA. Furthermore, to have financial support from banks, the banks are asking for the Power Purchase Agreement so that they can secure their income. Hence, developing a hydropower plant involves significant financial risks due to its capital-intensive nature, long gestation period, and reliance on external factors like hydrology and regulatory frameworks. Therefore, in this type of situation if we had a competitive market with the Virtual Power Purchase Agreement then reduce the financial risk (WB, 2024).

Table 4. Total Power Purchase Agreement conducted

S.N	Stages of Projects	No of Projects	PPA in MW
1	Operation	190	2741
2	Under Construction	141	4064
3	Different Stages	141	4363
	Total	472	11168

Source: NEA, 2025 *Note.* MW-Megawatt

Concept of Virtual Power Purchase Agreement

A Virtual Power Purchase Agreement (VPPA) is a financial arrangement between a renewable energy generator and a buyer (such as a corporation or organization) that allows the buyer to maintain renewable energy and offset their carbon emissions without physically contracting the energy. The VPPA is nothing but a financial transaction in which renewable energy certificates (RECs) and a variable-priced payment flow are exchanged for a fixed-priced cash flow (Kansal, 2019). It functions as a price hedge for the underlying electricity amount and is the opposite of the physical PPA. The industrial buyer can attain a decarbonization effect and a risk-minimization hedge by using VPPA as a financial hedge (Jahnel et al., 2024). A fixed price for the future energy output of the renewable energy asset is linked to a variable market price through a Contract for Difference (CoD) structure. For instance, if the price at the time of the agreement was Rs 4 per kWh, but it was signed at Rs 3 per kWh, the generator must reimburse the customer Rs 1 per kWh (outside the market

transaction) for the difference. Similarly, if the power was traded at Rs 2 per kWh, then the consumer would pay Rs 1 per kWh to the generator. This kind of settlement is called a contract for difference or "fixed-for-floating swap".

Key Characteristics of a VPPA:

A virtual Power Purchase Agreement is a Financial Contract for Difference: The strike price is the set price that is agreed upon by the energy generator and the buyer for the electricity produced. On the other hand, the generator sells electricity at the market price to the wholesale market. If the market price is higher than the strike price, the generator pays the difference to the buyer. If it's lower, the buyer compensates the generator (WB, 2024).

Renewable Energy Certificates (RECs): The buyer typically receives RECs associated with the renewable energy generated. These certificates are used to claim the environmental benefits of energy production and contribute to the buyer's sustainability goals (Chen, 2024)

No Physical Delivery of Energy: The VPPA buyer does not directly receive electricity. Instead, Although the energy is sold into the local grid, the buyer still gets their electricity from their usual supplier or utility (Chen, 2024).

Benefits of a VPPA:

A VPPA allows a company to meet its renewable energy targets more easily because it does not need to be physically connected to the energy developer. It helps to reduce carbon footprint and achieve its sustainability targets. It contributes to the development of renewable energy in a cost-effective manner.

Environmental Impact: VPPA assists the purchaser in achieving sustainability and carbon-reduction objectives while promoting the growth of renewable energy projects.

Price Hedging: Provides a hedge against future energy price volatility. It hedges the price difference between market prices and PPA prices.

No On-Site Infrastructure: This does not require the buyer to install renewable energy infrastructure at their location.

Corporate Responsibility: Enhances a company's reputation for taking climate action through financing renewable energy projects.

The difference between a VPPA and a Physical PPA

The energy industry frequently uses two types of contractual agreements: virtual power purchase agreements (VPPAs) and physical power purchase agreements (PPAs), but they differ in structure and purpose. A PPA is a long-term agreement between an electricity generator (typically a renewable energy developer) and a buyer (such as a utility, corporate, or government entity). The buyer purchases the physical electricity generated by a specific project at a predetermined price for a fixed duration. Furthermore, the buyer receives the actual electricity generated by the project. Buyers also often receive Renewable Energy Certificates (RECs) associated with electricity. However, the fixed price protects against market price fluctuations. PPAs can be used for on-site energy generation (e.g., rooftop solar) or off-site projects (e.g., utility-scale wind farms) (WB, 2024).

VPPA is a financial contract rather than a physical electricity purchase agreement. The buyer agrees to purchase the renewable energy attributes (e.g., RECs) and settle the financial difference between a fixed price and the market price of electricity. There is no physical delivery as electricity generated by the project is sold into the local grid, and the buyer does not take physical delivery. This only acts as a hedge against market price volatility. The buyer pays or receives the difference between the fixed price in the contract and the actual market price. Buyers still claim the environmental benefits by owning the RECs.

Relevancy of Virtual Power Purchase Agreement in Nepal

Nepal has immense potential for renewable energy, particularly hydropower and solar energy. A VPPA could attract international or domestic corporate buyers to invest in Nepal's renewable energy projects, helping to finance the expansion of clean energy infrastructure. Companies that are aiming to meet sustainability or carbon-neutrality goals can enter into VPPAs with renewable energy developers in Nepal. These agreements could enable such companies to claim Renewable Energy Certificates (RECs) or equivalent credits, even if they don't directly use the electricity.

Likewise, Nepal has been exporting surplus electricity to neighboring countries like India through cross-border electricity trade agreements. A VPPA could align with such trade, where renewable electricity generated in Nepal is sold in India, and the environmental attributes are purchased by international buyers. Facilitating the registration of VPPA projects under the International Renewable Energy Certificate (I-REC) system in Asia, Africa, and Latin America helped to reduce greenhouse gas emissions; it would not only allow multinational corporations to benefit from cross-border certificate utilization but also position India to capitalize on the burgeoning international market demand(Singh, 2024). Similarly, a VPPA is a long-term contract with utilities or other organizations that build renewable energy-generating facilities (Keyshon & Yeo, 2023).

Hence, ultimately a VPPA structure could incentivize private and international investors to finance renewable projects in Nepal without worrying about physical delivery constraints. This could be particularly appealing for solar, wind, or hybrid energy projects, which are still underdeveloped in the country. Similarly, the Nepal Electricity Authority (NEA) is working on integrating variable renewable energy (VRE) sources into the national grid. Revenue from VPPAs could fund grid improvements, including better voltage control, reactive power compensation, and smart grid technologies. Since, like all the countries, the countries in South Asia have also committed to the target of zero emissions. Similarly, various industries are mandatory for reducing emissions. Therefore in this context, country IPPs of Nepal can have agreement with the industries in India and have a virtual Power Purchase agreement. This will give IPPs opportunities to build hydropower in Nepal and the Industries in India to have the REC without physical delivery of power. As IPPs have to sell power to the Competitive market. This leads to a win-win situation for both the power producers and the industries. However, there should be both well-developed competitive power markets and financial markets for the implementation of the VPPA concept.

Conclusion and Implication

IPPS of Nepal could ultimately partner with international organizations that use VPPAs to meet global sustainability goals. And it

would result in significant investment flow in the renewable energy project development. In the long run, this will diversify the sources of income and lower the risks related to the volatility of electricity prices in the wholesale competitive market. By utilizing VPPAs for renewable energy projects, Nepal could increase its position as a clean energy exporter to India and other neighboring countries and draw in international climate finance. Global and international corporations and organizations are increasingly adopting VPPs to achieve the organization's carbon neutrality targets. Nepal can benefit as a key supplier of renewable credits and clean energy supplier in South Asia. Therefore, for envisioning the VPPA in Nepal there should be the policy robust legal and regulatory frameworks for the enforcement of the contracts. Similarly, to have a regional market strong grid infrastructure is essential to strengthen the national grid to handle increased renewable energy generation, especially from solar and wind, which are intermittent sources. Last but not least educating local developers and corporations about the benefits and mechanics of VPPAs is essential too.

Virtual PPAs shall be beneficiary to obtain sustainability goals. It also helps to maintain price stability as the energy market is volatile and can be influenced by geopolitical events or natural disasters. However, virtual PPA provides a hedge against this uncertainty. A virtual PPA isn't just about financial benefits but also support for renewable energy development providing renewable energy to developers with the financial assurance needed to build new projects. In a nutshell VPPA framework, if implemented effectively, could be a game-changer for Nepal's renewable energy sector mainly for the hydropower development in the country, fostering investment, enabling sustainability goals, and enhancing the country's reputation as a clean energy hub in South Asia. A VPPA allows a company to meet its renewable energy targets more easily because it does not need to be physically connected to the energy developer. It helps to reduce carbon footprint and achieve its sustainability targets. It contributes to the development of renewable energy in a cost-effective manner. However, the market should be stable and competitive. The policy should address it through a legal aspect. Future research may contribute to further discussion on its application and mechanism in Nepal.

Conflict of Interest: The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declares the absence of conflicting interests with the funders.

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