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Financial Analysis of Utility Scale Photovoltaic System with Battery Energy Storage System in Nepal

by

Narayan Shrestha

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A thesis submitted in partial fulfilment of the requirements for the degree of Master of Science in Power System Engineering

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CERTIFICATE OF APPROVAL

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ABSTRACT

Renewable energy technologies (RETs) are essential for mitigating greenhouse gas emissions and transitioning to clean energy sources. Among various RETs, solar photovoltaic (PV) systems have gained attention as efficient and effective solutions. However, PV generation is intermittent and variable due to the diurnal cycle of solar geometry and weather conditions. Battery energy storage systems (BESS) integrated into PV systems can address these challenges by storing energy for later use.

Nepal’s energy sector mainly depends on hydropower, which can be affected by natural and seasonal variations. To improve energy security and diversify its energy sources, the government has set goals to increase the use of solar and other renewable energy technologies in power generation. Nepal's favourable geography and abundant solar radiation make it suitable for deploying solar PV systems. Nepal receives an average of 3.6 to 6.2 kWh/m^2/day of solar radiation and around 300 days of sunshine annually.

This thesis evaluates the financial feasibility of implementing a utility-scale PV system coupled with a BESS in Nepal, specifically focusing on a 10 MW PV system and a 5 MW/20 MWh BESS. The study utilizes PVsyst software to simulate the PV system’s performance and an Excel model to assess its financial viability. The results indicated that the PV system without BESS exhibited a higher net present value (NPV) of NRs.209 million and an internal rate of return (IRR) of 21%. However, integrating BESS resulted in a decreased NPV of NRs: 12.70 million and a lowered IRR of 10.4%. Furthermore, the levelized cost of electricity (LCOE) increased from NRs. 4.7/kWh to NRs. 8.17/kWh, while the payback period increased from 5 to 10 years. A sensitivity analysis was conducted to evaluate the effect of various input variables, such as capital cost, battery energy storage system cost, specific yield, interest rate, and power purchase agreement rate, on the financial outcome of the project. The analysis showed that these variables significantly influence the net present value of the investment.

These results emphasise the trade-offs associated with integrating a BESS into a utility-scale PV system in Nepal. While adding a BESS enhances energy storage capabilities and offers supplementary benefits, it also introduces higher costs and potentially reduces financial performance. However, the PV system with BESS could become more competitive and financially viable in the long run if the cost of batteries decreases.

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Narayan Shrestha

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LIST OF ACRONYMS AND ABBREVIATIONS

AEPC	Alternate Energy Promotion Center
BESS	Battery Energy Storage System
CUF	Capacity Utilization Factor
DER-CAM	Distributed Energy Resources Customer Adoption Model
GHI	Global Horizontal Irradiation
GoN	Government of Nepal
GWh	Gigawatt-hour
HOMER	Hybrid Optimization Model for Electric Renewables
HPPs	Hydropower Projects
IPPs	Independent Power Producers
IRR	Internal Rate of Return
kW	Kilowatt
kWh	Kilowatt-hour
kWp	Kilowatt-peak
LCOE	Levelized Cost of Electricity
Li-ion	Lithium-ion
METU NCC	Middle East Technical University Northern Cyprus Campus
MW	Megawatt
MWh	Megawatt-hour
NaS	Sodium Sulphur
NEA	Nepal Electricity Authority
NiCd	Nickel Cadmium
NiMH	Nickel Metal Hydride

NPV	Net Present Value
O&M	Operation and Maintenance
PbA	Lead Acid
PV	Photovoltaic
RE	Renewable Energy
RETs	Renewable Energy Technologies
RoI	Return on Investment
RoR	Run-of-River
SAM	System Advisor Model
STC	Standard Test Conditions
VRFB	Vanadium Redox Flow Battery
Wh/kg	Watt-hour per kilogram
W/kg	Watt per kilogram

CHAPTER ONE: INTRODUCTION

1.1 Background

Any nation's economic and social progress depends on electricity. However, many nations struggle to keep up with the rising demand for power, particularly in isolated and rural areas where grid extension is expensive and challenging. Additionally, traditional methods of producing electricity, including burning fossil fuels and using huge hydroelectric dams, have detrimental effects on the environment and public health, including the release of greenhouse gases, air pollution, a lack of fresh water, and the eviction of local populations. As a result, there is a need for sustainable, alternative energy sources that can give people access to dependable, inexpensive, and clean energy. to the people [1].

Nepal is a country with abundant hydropower potential, but its electricity generation is highly seasonal and dependent on the monsoon rains. During the dry winter months, Nepal faces an energy shortfall and has to rely on power imports from India. To enhance its energy security and meet its climate change commitments, Nepal has been looking into adding other renewable energy sources, especially solar power, to its grid. The Government of Nepal has launched various plans and programs to encourage renewable energy development and aims to achieve 5-10% of generation from other renewable sources in the generation mix by 2026.

Nepal has abundant solar potential. The country has an average insolation of 4.7 kWh/m2/day and an average of 6.8 hours of sunshine per day, indicating a moderately high potential for solar energy [2]. Solar PV systems are thus promising for the development of solar energy technology in Nepal. The commercial potential of grid-connected solar PV is estimated at 2,100 MW in urban areas [3]. However, the country is unable to fully utilize these resources.

As grid-connected solar PV systems become more readily available, Nepal will be able to establish a reliable, varied energy system capable of producing power even if one source fails. Supply diversification is another advantage. Relying solely on hydropower can be risky, particularly in the Himalayan region where the impacts of climate change are becoming increasingly apparent. Solar PV is a good supplement to hydropower, especially in the winter when the rivers are dry. Solar PV has many advantages over conventional sources of electricity generation, such as low operation and maintenance costs, modularity, scalability, flexibility, and environmental friendliness. However, solar PV also has some limitations, such as intermittency, variability, and unpredictability of solar radiation, which affect the stability and quality of power supply.

To overcome these challenges, solar PV can be integrated with BESS, which can store energy for later use. BESS can also provide ancillary services to the grid, such as regulating frequency, controlling voltage, providing spinning reserves, and enabling black start capabilities. BESS can be categorised based on their chemical composition, with common types including lithium-ion, sodium-sulphur, and lead-acid batteries. Each type of battery has its own unique characteristics, such as cost, performance, lifespan, and safety. Among these types, Li-ion batteries are often the preferred choice for integration with solar PV systems. This is due to their high energy density, long lifespan, rapid charge and discharge rates, low maintenance requirements, and environmental advantages. Li-ion batteries are also becoming more affordable due to the increasing demand and production that use them.

In addition to addressing the issue of variability, BESS also provide additional benefits such as peak shaving. Peak shaving allows customers to reduce their peak electricity demand, which can result in lower demand charges. BESS also enable participation in demand response programs, which allows customers to reduce their electricity usage in response to market prices or grid conditions[4]. This can help to enhance the stability and dependability of the electric grid. The major factor affecting the acceptance of the solar PV system is the size and cost of BESS.

Therefore, the financial analysis is necessary to determine the viability of a solar PV system with an integrated BESS. This analysis should consider factors such as the initial investment required for the PV and BESS components, the system's anticipated energy generation and storage capabilities of the system, and the expected performance and lifespan [5].

1.2 Problem Statement

Nepal's energy sector has long been dominated by hydropower, which exploits its abundant water resources. However, hydropower is vulnerable to seasonal variations, climate change impacts, and natural disasters. Nepal faces energy shortages during dry winter months when hydropower output is low. Furthermore, hydropower projects face increasing risks from floods and droughts due to climate change. As the impacts of climate change become more pronounced, the safety and generation capacity of hydropower projects located on rivers may be affected by increased frequency and severity of floods. By 2050, it is estimated that 61% of hydropower around the world will be situated in river basins facing high to extreme risks from water scarcity, flooding, or both [6].

To diversify its energy mix and enhance its energy security, Nepal has been exploring integrating other renewable energy sources, especially solar power, into its grid. Solar power offers a decentralized and distributed power generation option that reduces dependence on centralized grids and imports. It also utilizes Nepal's immense solar potential, especially in hilly and mountain regions, and helps bridge the seasonal gaps in the energy supply. Integrating battery energy storage systems (BESS) enhances solar power by addressing its intermittency. Batteries can store excess energy generated during the day for use during peak demand or when sunlight is limited. This allows for reliable and stable electricity grid that complements hydropower.

Nepal's geographic and climatic conditions make it well-suited for the development of solar energy. However, the financial viability of utility-scale PV with BESS projects in Nepal is not well established. The government of Nepal has formulated various policies and programs to promote renewable energy development and set a target of achieving 10% of power generation from solar PV and other RE technologies in the total electricity mix by 2026. The government has established a goal of installing 500 MWp of solar projects in five years and has issued survey and generation licenses for several solar PV projects.

In the specific context of Nepal, where the financial viability of utility-scale PV with BESS projects remains uncertain, there is a need for a comprehensive financial analysis to evaluate their feasibility and assess whether the initial investment can be recouped. The financial analysis should consider the main factors affecting the PV system deployment, such as the initial capital cost of the system, the power purchase agreement (PPA) rate, and the interest rate. This analysis will help to pinpoint any financial obstacles or difficulties that could impede the attainment of RE targets. It will also help to allocate resources effectively, prioritize investments, and develop supportive policies and incentives.

1.3 Objective, Scope and Limitation

The main objective is:

- To determine the financial feasibility of utility - scale solar PV with battery energy storage systems in Nepal

The specific objectives are:

- To evaluate the technical and financial performance of the system under different assumptions and parameters;
- To compare the system with other alternatives, such as standalone solar PV or grid-connected solar PV without BESS; and
- To provide recommendations for policymakers, project developers, and other stakeholders to promote the deployment of utility-scale PV systems with BESS.

The scope of this study covers the following aspects:

- Focus on utility-scale solar PV with BESS projects in Nepal.
- System design of utility-scale solar PV with BESS using PVsyst and Excel software;
- Financial analysis of the system using key financial aspects such as net present value (NPV), levelized cost of energy (LCOE), payback period (PBP) and internal rate of return (IRR) indicators;
- Sensitivity analysis of the system using tornado diagrams.

The limitations of this study include the following:

- The analysis relies on available data and assumptions, which may have inherent uncertainties.
- The study assumes a certain regulatory framework and policy environment, which may change over time.
- The financial analysis considers specific project scenarios and may not capture all potential variations or market dynamics.

1.4 Thesis Organization

The thesis works contain a total of five chapters, and each chapter contains the following:

Chapter 1 introduces the background and motivation of the study, the research problem and objectives, and the original contributions of the thesis. It also provides an overview of the structure and content of each chapter.

Chapter 2 reviews the relevant literature on utility - scale photovoltaic systems, battery energy storage systems, financial analysis methods, and existing studies on the economic feasibility of photovoltaic-battery systems in Nepal and other countries. It also identifies the research gaps and challenges that this thesis aims to address.

Chapter 3 describes the methodology used to achieve the research objectives. It explains how the technical and financial parameters of the photovoltaic-battery system are determined and how the financial analysis methods are applied to evaluate the system's economic viability. It also describes the data sources and assumptions used in the analysis.

Chapter 4 presents and discusses the results of the financial analysis of the photovoltaic-battery system in different scenarios. It compares the net present value, internal rate of return , payback period , levelized cost of electricity , and sensitivity analysis of the system with and without battery energy storage system. It also evaluates the impact of various factors such as electricity tariff, discount rate, capital cost , operation and maintenance cost , battery degradation , and solar irradiation on the system's financial performance.

Chapter 5 summarizes the main conclusions of the thesis and suggests some directions for future work based on the findings of this study.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Renewable energy technologies (RETs) are essential for mitigating greenhouse gas emissions and transitioning to clean energy sources [7]. Among the various renewable energy technologies, solar photovoltaic (PV) systems have gained attention as efficient and effective solutions. However, solar PV systems face challenges like intermittency, variability, and grid integration issues. To overcome these challenges, battery energy storage systems (BESS) can be used to store energy for later use. This can enhance the reliability, stability, and flexibility of the power system and reduce the need for conventional backup generators [8].

Thee main objective of this thesis is to conduct ae financial analysis of utility-scale PV with BESS systems in Nepal using different methods and scenarios. The specific research questions are:

- What are the technical characteristics and performance of utility-scale PV with BESS systems?
- What are the financial analysis methods and parameters used to evaluate the financial feasibility of utility-scale PV with BESS systems?
- What are the existing studies on the financial feasibility of utility-scale PV with BESS systems in Nepal and other countries?
- What are the results and implications of the financial analysis of utility - scale PV - BESS systems in Nepal under different scenarios?
- What are the research gaps and challenges that need to be addressed in future studies?

To answer these questions, this chapter reviews the relevant literature on utility-scale PV system, BESS, financial analysis methods, and existing studies on the economic feasibility of PV-BESS in Nepal and other countries. It also identifies the research gaps and challenges that this thesis aims to address. The literature reviewed and the findings of the major studies are tabulated in the Table 2.1.

Table 2.1 Literature review and major findings

Authors (Year)	Research Title	Main Findings	Reference
Rudolf et al. (2013)	Financial analysis of utility-scale photovoltaic plants with battery energy storage	Battery energy storage can increase the revenues of utility scale PV plants by providing various grid services under certain market conditions	[9]
Das et al. (2016)	Feasibility analysis of standalone PV/wind/battery hybrid energy system for rural Bangladesh	The paper analyzes the feasibility of a standalone PV/wind/battery hybrid system for rural electrification in Bangladesh, using HOMER simulation software and real data. The paper shows that the hybrid system is the most viable and sustainable option, with low cost of energy, high self-sufficiency, and zero emission.	[10]
Moradi et al. (2018)	Financial Analysis of a Grid-connected Photovoltaic System in South Florida	The paper presents the design, implementation and financial analysis of a grid-tied PV unit for FAU campus. The paper shows that the system has high installation cost but low payback time and electric bill. The paper also shows that the system output varies with seasons and suggests battery storage as a future work.	[11]
Cole et al. (2019)	Cost projections for utility-scale battery storage	The capital cost of LIB storage is expected to decline by 45%–65% from 2020 to 2050.	[12]
Chaurasia et al. (2021)	Technical, economic feasibility and sensitivity analysis of solar	A solar PV/battery energy system can lower the cost, unmet load and emissions of electricity in a low-load area in India. The system	[13]

Authors (Year)	Research Title	Main Findings	Reference
	photovoltaic/battery energy storage off-grid integrated renewable energy system	reduces LCOE by 85.27%, NPC by 85.22%, unmet load by 99.98%, and greenhouse gas emissions by 100% compared to a Diesel Generator only system	
Nkuriyingoma et al. (2022)	Techno-economic analysis of a PV system with a battery energy storage system for small households: A case study in Rwanda	A solar PV system with battery energy storage for Rwandan households is feasible and viable with a payback period of 9.65 years and an IRR of 9.14%. The system can supply a load of 82.34 MWh per year with a high level of self-sufficiency and performance ratio.	[14]
Swathika et al. (2022)	Techno-Economic Analysis on Grid Connected Solar Photovoltaic System with Battery Energy Storage for Domestic and Bulk Customers in Sri Lanka	Grid-connected solar PV systems with battery energy storage are economically viable for both domestic and bulk customers in Sri Lanka. The use of battery energy storage systems can significantly increase the self-consumption of solar energy and reduce the reliance on the grid, resulting in cost savings for customers.	[15]
Chianese et al. (2009)	Feasibility study on Grid connected PV system in Nepal	A grid-connected PV system in Kathmandu is feasible and on-grid photovoltaic installation has the lowest production costs among different technologies.	[16]
Shrestha et al. (2014)	A Techno-Economic Analysis of Utility Scale Photovoltaic Plant	1 MWp Solar PV system in Trishuli is economically and technically viable, with a system yield of 4.81 kWh/kWp-day, LCOE of NRs	[17]

Authors (Year)	Research Title	Main Findings	Reference
	(A Case Study of 1 MWp Plant at Trishuli)	10/kWh, NPV of NRs 23 million and an IRR of 12 percent over 25 years.	
Shakya et al. (2015)	Case Study on Grid Integrated Solar PV for National Dasarath Stadium	The LCOE of a utility-scale hybrid grid-tied stadium PV plant is NRs.18.00 per kWh for 20 years and the LCOE of a purely grid-tied stadium PV plant is 12.5 per kWh for 20 years. The grid-tied PV plant reduces the use of diesel generators and the NEA electricity bill	[18]
Poudyal et al. (2021)	Techno-economic feasibility analysis of a 3-kW PV system installation in Nepal	A 3-kW PV system installation in Kathmandu is feasible and viable with a payback period of 8.6 years and is capable of generating 100% of electricity for a typical residential household.	[19]

These research studies highlight solar PV's positive outcomes and economic viability with BESS systems in different contexts. However, in the specific context of Nepal, where the financial viability of utility-scale solar PV with BESS projects remains uncertain, there is a need for a comprehensive financial analysis to evaluate their feasibility and address the specific challenges and opportunities in the country.

2.2 Power Scenario in Nepal

Nepal's power sector is undergoing a significant transformation, as the country aims to improve its energy security, stimulate economic growth, and decrease its reliance on imported fuels. The country has abundant hydropower resources, estimated at 43 gigawatts (GW) of economically viable potential generation capacity, of which only about 5% (~2,190 MW) has been harnessed. Hydropower accounts for 95% of the country's installed capacity. The remaining capacity is from solar PV, and thermal sources.

Nepal Electricity Authority (NEA), the state-owned power utility that operates vertically, is responsible for generation, transmission, distribution, and supply of electricity in the country. The NEA and its subsidiary companies generate about 52% of the country's installed capacity (2.19 GW), while the rest (48%) is produced by the private sector, namely the Independent Power Producers (IPPs). The NEA also manages the national grid and trades electricity with India through cross-border transmission lines.

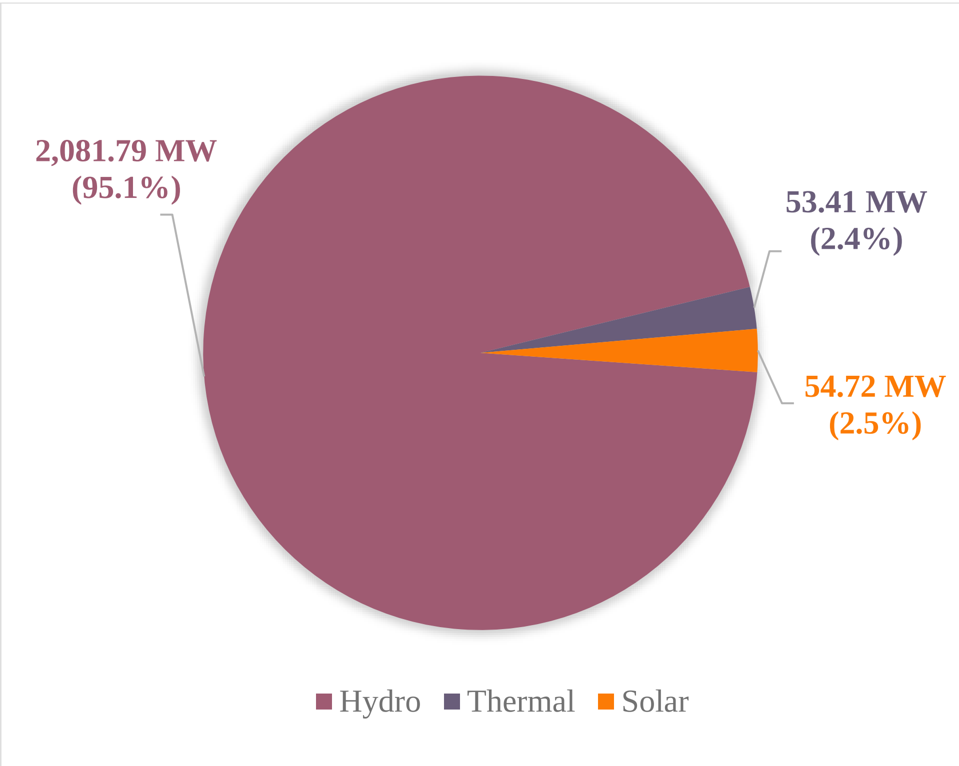

Figure 2.1 Existing Generation Mix of Nepal

Source: NEA Annual Report FY 2021/22

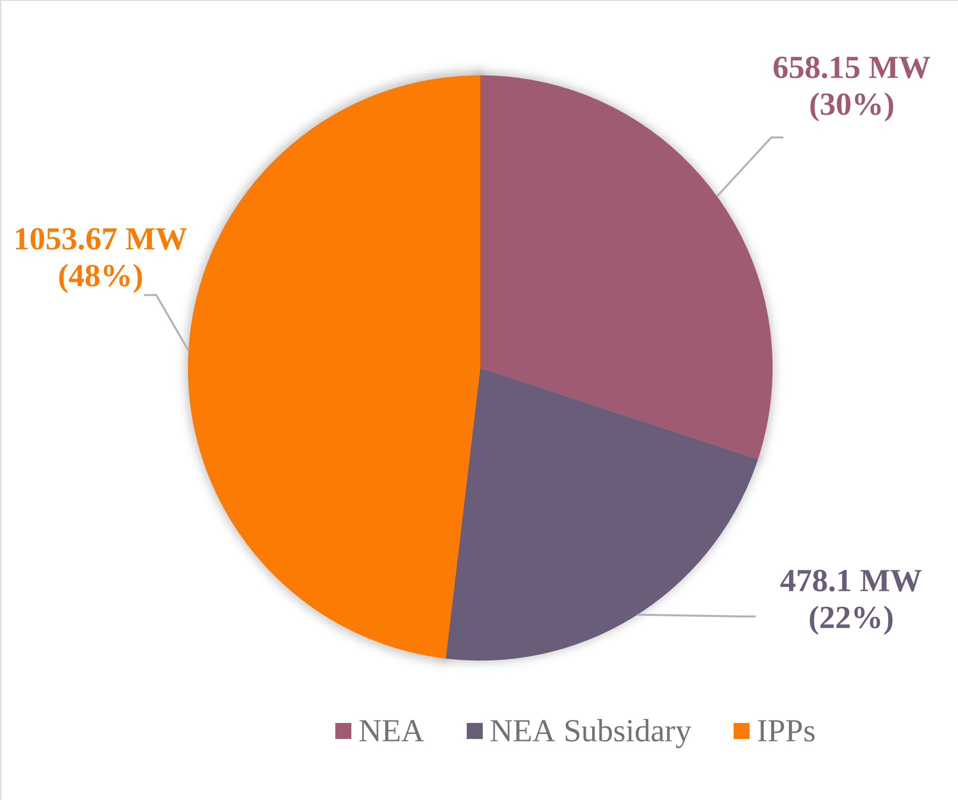

Figure 2.2 Share of NEA and IPP's generation

The electricity generation in Nepal mainly depends on run-of-river (RoR) hydropower projects (HPPs), but its electricity generation is highly seasonal and dependent on the monsoon rains. In the "dry months" of winter, when the water levels are low, Nepal faces an energy shortage and has to import power from India.

In the 2021/22 fiscal year, the amount of energy purchased from Independent Power Producers (IPPs) and subsidiaries of NEA rose to 4,286 GWh and 1,976 GWh respectively, representing an increase of 38.57% and 1,235.14% from the previous year's figures of 3,093 GWh and 148 GWh. In contrast, the total amount of energy imported from India decreased by 45.01%, dropping from 2,806 GWh in 2020/21 to 1,543 GWh in 2021/22. The total energy available in the system increased by 25%, reaching 11,064 GWh in 2021/22 compared to 8,851 GWh in 2020/21. Of the total available energy, NEA and its subsidiaries provided 47.32%, while imports from India and purchases from domestic IPPs accounted for 13.94% and 38.74% respectively. The percentage of total internal generation contributing to the total available energy rose from 68% in 2020/21 to 86% in 2021/22.

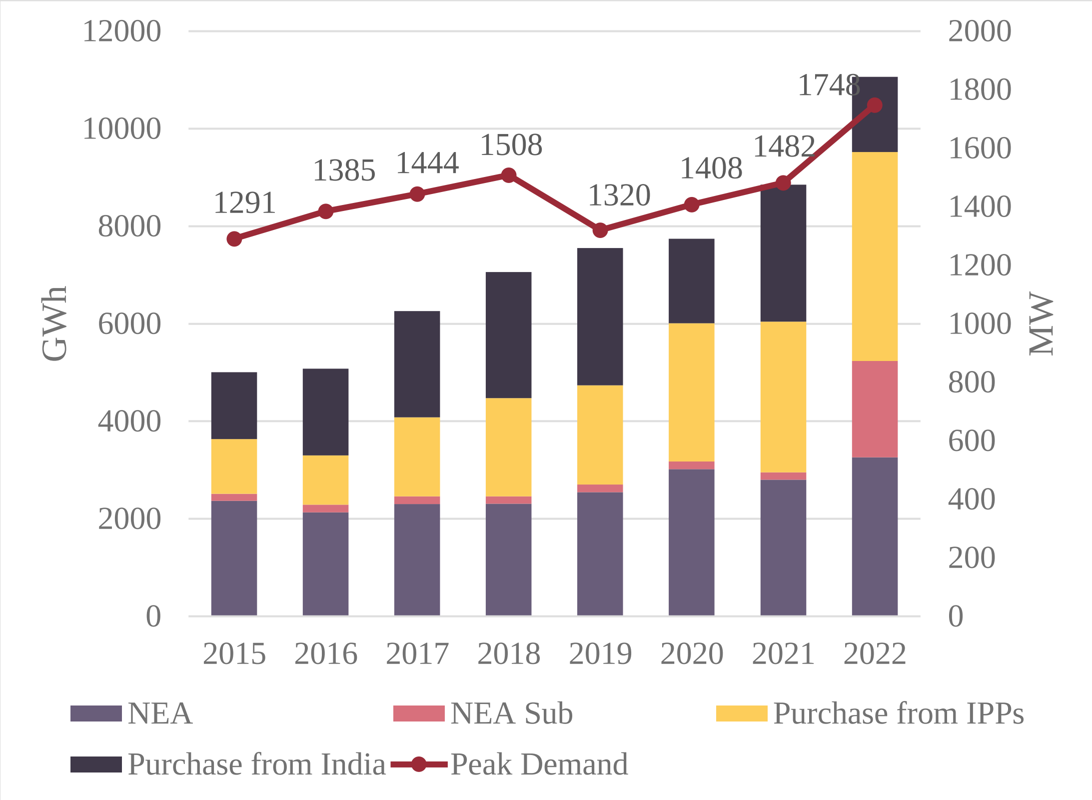

Figure 2.3 Total electricity supply and demand scenario

Source: NEA Annual Report FY 2021/22

2.3 Solar Potential in Nepal

Nepal has great potential for harnessing solar energy, with an average of 300 sunny days per year and 6.8 hours of sunshine per day [20]. Figure 2.4 displays the average daily total specific PV electricity output expressed in kWh/kWp. In Nepal, the average yearly total specific PV power production from a reference system ranges from 1200 kWh/kWp/year to 2200 kWh/kWp/year with higher values in the north-western region of the country [21]. The mountainous region has a higher potential for PV energy yield due to its high elevation and low air temperature. As such, the hills and lower-elevation mountains with good GHI and lower temperatures are the most suitable areas for developing solar PV systems in Nepal. The commercial potential for on-grid solar PV systems in Nepal is estimated to be 2,100MW in urban areas [11].

Despite the availability of good solar resources, Nepal has not yet fully embraced solar installation. Given the high levels of solar radiation received at various locations in Nepal, solar PV installation should be considered as a viable option for increasing generation capacity and meeting electricity demand in a clean and sustainable manner.

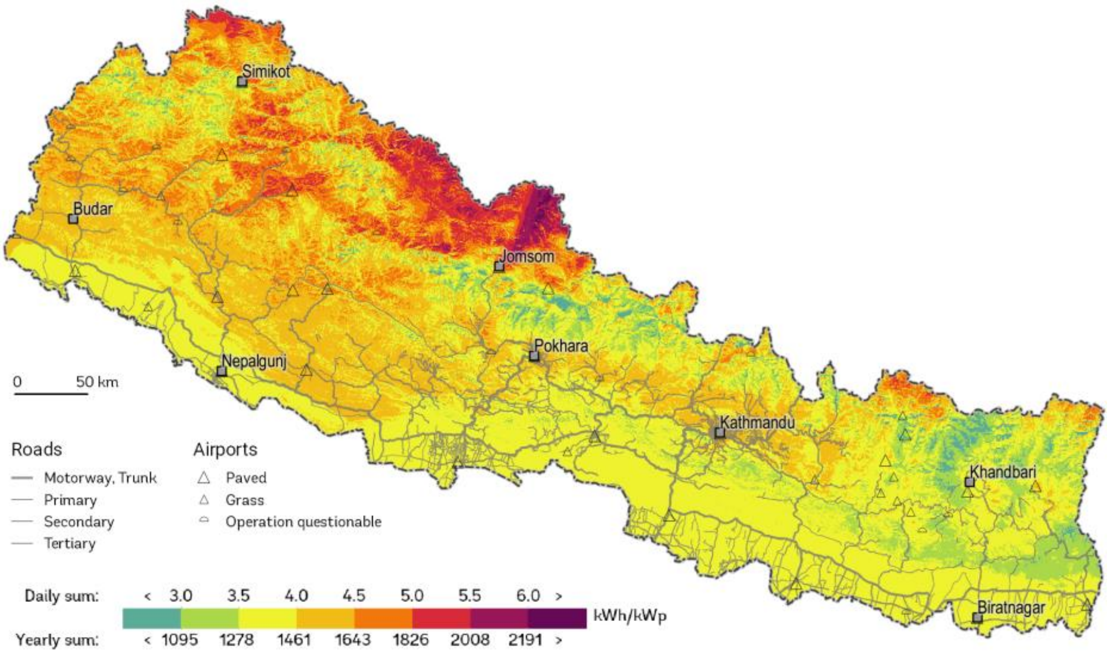

Figure 2.4 Long term average of potential PV production

2.4 Overview of PV and BESS Technology

A utility-scale PV with BESS system consists of three main components: a PV array, a BESS, and a power conversion system (PCS).

PV array comprises multiple PV modules that convert sunlight into direct current (DC) electricity. The amount of power produced by a PV array is influenced by various factors, including solar irradiance, ambient temperature, shading, tilt angle, and orientation. A MPPT algorithm is employed to optimize the output power by adjusting the operating voltage or current of the PV array.

BESS consists of multiple battery cells that store or release electrical energy through chemical reactions. The main characteristics of a BESS are its capacity, power, state of charge (SOC), depth of discharge (DOD), efficiency, lifetime, etc. Different types of batteries have different characteristics and suitability for different applications. Some common types of batteries used for utility-scale applications are lead - acid, lithium - ion, sodium - sulphur, flow batteries, etc.

PCS comprises multiple power electronic converters that convert the DC electricity from the PV array and the BESS to alternating current (AC) electricity that can be synchronized with the grid or the load. The PCS also provides functions such as voltage regulation, frequency regulation, power factor correction, harmonic filtering, etc. The PCS can be configured in different ways depending on the connection and control of the PV array and the BESS. Some common configurations are:

i) **DC-coupled:** The PV array and the BESS are connected to a common DC bus, and a single inverter converts the DC electricity to AC electricity. This configuration has the advantage of reducing the number of converters and losses, but it also requires a bidirectional converter for the BESS and a complex control strategy to balance the power flows. Figure 2.5 shows a simple single-line diagram of an DC-coupled PV with BESS configuration.

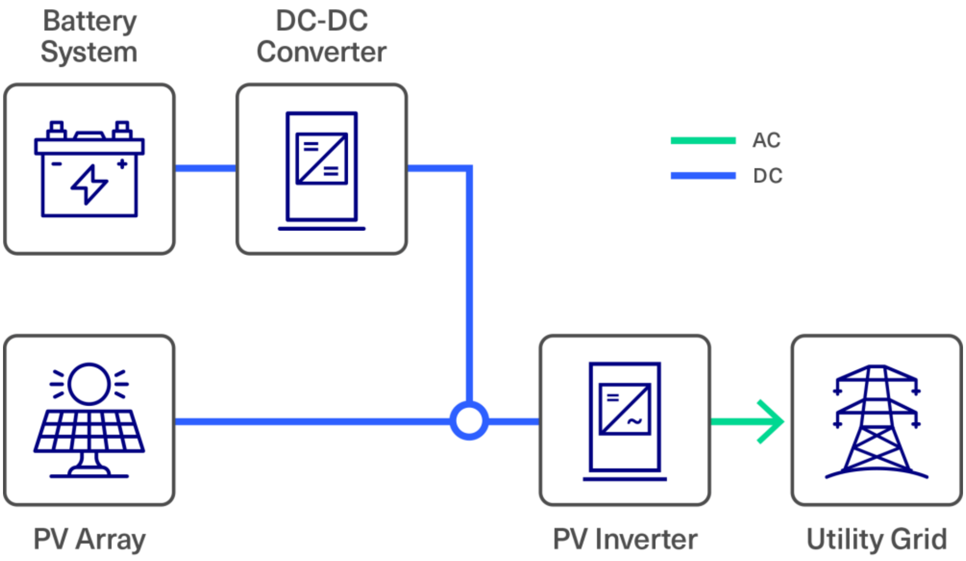

Figure 2.5 DC-Coupled PV-BESS Configuration

ii) **AC-coupled:** The PV array and the BESS are connected to separate inverters, and a common AC bus connects them to the grid or the load. This configuration has the advantage of simplifying the control strategy and allowing independent operation of the PV array and the BESS, but it also increases the number of converters and losses. Figure 2.6 shows a simple single-line diagram of an AC-coupled PV with BESS configuration.

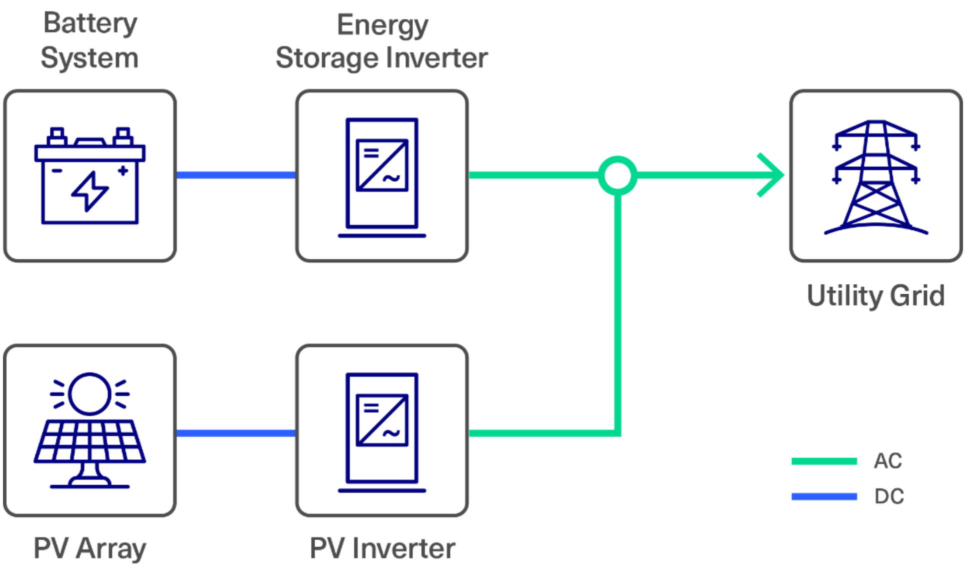

Figure 2.6 AC-Coupled PV-BESS Configuration

2.4.1 PV Cell Technology

here are different types of PV cell technologies that can convert sunlight into electricity. The main categories are:

Crystalline silicon (c-Si): This is the most common and mature technology, accounting for about 95% of the global PV market in 2022. Crystalline silicon cells are made from thin wafers of silicon that are either monocrystalline (mono-Si) or multicrystalline (multi-Si). Mono - Si cells have higher efficiency and more uniform appearance, but they are also more expensive and require more energy to produce. Multi-Si cells have lower efficiency and a more varied appearance, but they are cheaper and use less energy to produce. The typical efficiency range of c-Si modules is 15–22%.

Thin-film: This newer and less dominant technology accounted for about 5% of the global PV market in 2021. Thin-film cells are made from materials, such as amorphous silicon (a-Si), cadmium telluride (CdTe), copper indium gallium selenide (CIGS), or perovskite. Thin-film cells have a lower efficiency and a shorter lifespan than c-Si cells, but they are also cheaper, lighter, and more flexible. They can also perform better in low-light and high-temperature conditions. The typical efficiency range of thin-film modules is 10–16%.

Concentrator PV (CPV): This niche and emerging technology accounted for less than 1% of the global PV market in 2022. Concentrator PV cells employ lenses/mirrors to focus sunlight onto high-efficiency cells, such as multi-junction (MJ) cells. MJ cells are made from multiple layers of semiconductor materials, each capturing a different wavelength of light. CPV systems require direct and intense sunlight and active cooling and tracking systems. They have the highest efficiency and the highest cost of all PV technologies. The typical efficiency range of CPV modules is 25–40%.

2.4.2 Battery Chemistry and Technology

There are different types of battery technologies that is being used in the solar PV system. The most common battery technologies used are as under:

- lead- acid,
- lithium- ion,
- nickel- cadmium,
- nickel- metal hydride,
- sodium- sulphur,
- vanadium-redox flow

The comparison of different battery technologies available are presented in the table 2.2.

Table 2.2 Comparison of different battery technologies [8]

Characteristics	Pb-acid	Li-ion	NiCd	NiMH	NaS	VRFB
Specific energy [Wh/kg]	25 - 50	80 - 250	30 - 80	40 - 110	150 -240	10 - 130
Specific power [W/kg]	150 -400	200 - 2000	80 -300	200- 300	90-230	50-150
Energy density [kWh/m3]	25-90	95-500	15-150	40-300	150-350	10-33
Power density [kW/m3]	10-400	50-800	40-140	10-600	1.2-50	2.5-33
Lifetime [years]	2-15	5 - 15	10 - 20	2 - 15	10 - 15	5 - 15

Characteristics	Pb-acid	Li-ion	NiCd	NiMH	NaS	VRFB
Lifetime cycles [cycles]	250-2000	100-10000	1000-5000	300-1800	2500-40000	10000-16000
Cell voltage [V]	2-2.1	2.5-5	1.2-1.3	1.2-1.35	1.8-2.71	1.2-1.4
Efficiency [%]	63-90	75-97	60-90	50-80	75-90	75-90

2.4.3 Application of PV and BESS

PV and BESS systems can provide various services to the power system, depending on their size, location, configuration, and control strategy. Some of the main applications are:

- **Arbitrage and Load Shifting:** This involves storing electricity when its value is low and discharging it when its economic value is higher, which can occur at various levels of the grid and typically involves time frames of several hours or more each day. It is increasingly being used to reduce curtailment and offer firmer energy contracts, with a typical application involving one charging and one discharging cycle per day.
- **Output Smoothing and Ramping Support:** These use the same principle as load shifting, but smoothing occurs over much shorter time intervals due to variations in PV output. A BESS may undergo hundreds of partial cycles per day for this application, requiring different battery performance. Ramping services, on the other hand, may have multi-hour time horizons similar to traditional peak load shifting.
- **Peaking or Firm Capacity Provision:** A BESS can be installed specifically to avoid the use of conventional thermal peaking capacity that is only used for a few hours of system peak each day. More broadly, a BESS can provide significant capacity when used for peak load shifting on its own or as part of a PV with BESS project.

- **Network Congestion Management and Investment Deferral:** PV with BESS can help manage the loading of transmission lines by storing energy that cannot be transferred due to inadequate transfer capability and releasing it later. Batteries located near load centres can also reduce peak demand on transmission or distribution lines and help defer network upgrades.
- **Ancillary Services Provision**: These include frequency control and the provision of operating reserves

CHAPTER THREE: METHODOLOGY

3.1 Methodology Approach

A research methodology is a comprehensive, conceptual assessment of the procedures used in a field of study. The research methodology employed in the thesis is designed to investigate and analyse the financial aspects of utility-scale photovoltaic systems with and without battery energy storage in Nepal.

The methodology adopted in this study is shown in Figure 3.1.

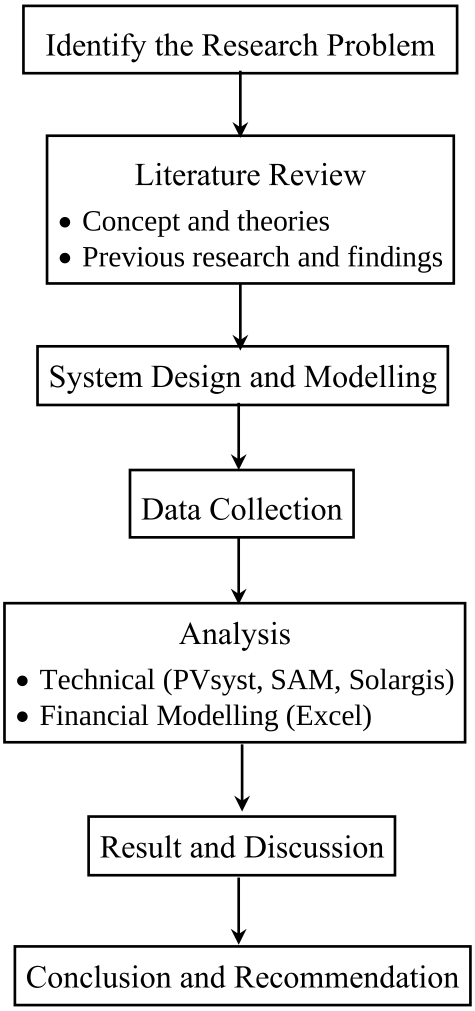

Figure 3.1 Research Methodology Approach

The thesis aims to provide valuable insights into the financial analysis of utility - scale photovoltaic systems with battery energy storage in Nepal by following this research methodology.

3.2 Mathematical Modelling

The output of PV system mostly depends on environmental factors such as solar irradiance and temperature and this can be calculated as

$$P_{pv\_dc}(t) = d_{pv} \times P_{pv\_rated} \frac{I(t)}{I(t)_{STC}} \left[1 + \alpha\left(T_c - T_{c,STC}\right)\right] \tag{3.1}$$

where, d_{PV} denotes the derating factor (%), $P_{PV,\ rated}$ is the PV rated capacity under standard test conditions (kW), $I(t)$ is the irradiance on the PV array (kW/m^2), $I(t)_{STC}$ is the irradiance at standard test conditions (kW/m^2), α is the temperature coefficient of PV cell (% ^{o}C), T_c is the PV cell temperature and $T_{c,\ STC}$ is PV celli temperature under standard test conditions.

The actual ac power of the PV system is computed as

$$P_{ac} = P_{dc}\eta \tag{3.2}$$

where, P_{dc} is dc output power of the PV system (kW) and η is inverter efficiency (%).

The annual ac energy generated from the PV system is expressed mathematically as

$$E_{ac} = \int_{t=1}^{8760} P_{ac}(t)dt \tag{3.3}$$

where t denotes the time.

The annual ac energy generated by the PV system can be also calculated from

$$E_{PV} = Y_s.P_{PV,rated} \tag{3.4}$$

where Y_s is the specific yield or output (kWh/kW/year) and $P_{PV,\ rated}$ is the PV-rated capacity (kW).

The energy required to charge the battery is computed by

$$E_{ch} = \frac{E_{b,rated} \times \text{cycle/day} \times DOD\%}{\eta_{ch}} \tag{3.5}$$

where is rated battery capacity (kWh/kW/year), DOD is the depth of discharge, and η_{ch} is charging efficiency.

The battery discharging energy is computed by

$$E_{dis} = E_{b,rated} \times \text{cycle/day} \times DOD\% \times \eta_{dis} \tag{3.6}$$

Where is rated battery capacity (kWh/kW/year), *DOD* is the depth of discharge and η_{dis} is discharging efficiency.

The net energy to the grid is calculated as

$$E_g = E_{PV} - E_{ch} + E_{dis} \tag{3.7}$$

The revenue generated by selling electricity in year *n* can be calculated as

$$\text{Revenues}_n = E_g.\text{PPA Rate} \tag{3.8}$$

The expenses include operation and maintenance (O&M), insurance, and battery replacement costs. It is calculated in yearn *n* as

$$\text{Expenses}_n = C_{O\&M,n} + C_{insurance,i} + C_{battery\ \text{replacement},n} \tag{3.9}$$

The earnings before interest, taxes, depreciation, and amortization (EBITDA) are computed as

$$EBITDA_n = \text{Revenues}_n - \text{Expenses}_n \tag{3.10}$$

The annual payment (*AP*) due to the lender is given by

$$AP = DA.\frac{i(1+i)^r}{(1+i)^r - 1} \tag{3.11}$$

where *DA* denotes debt amount, *i* is interest rate p.a. (%) and *r* is repayment period.

The interest (*I*) in year *m* is computed as

$$I_m = i.DB_{m-1},\ m \geq 1 \text{ and } DB_0 = DA \tag{3.12}$$

where *i* is interest rate, *DA* is debt amount and *DB* is debt balance.

The debt principal repayment (*DR*) in year *m* is given by

$$DR_m = AP - I_m \tag{3.13}$$

The debt balance (*DB*) for year *m* is computed as

$$DR_m = DB_{m-1} - DR,\ m \geq 1 \text{ and } DB_0 = DA \tag{3.14}$$

The depreciation in year *n* is given by

$$D_n = D\%.C_0 \tag{15}$$

where *D*% is the depreciation rate and C_o is the total installed cost of the system.

The taxable income for year *n* is given by

$$TI_n = EBITDA_n - I_n - D_n \tag{3.16}$$

The tax amount for year *n* is calculated as

$$Tax_n = Tax\ Rate_n \times TI_n \tag{3.17}$$

The net cashflow in year *n* is given by

$$CF_n = EBITDA_n - I_n - D_n - Tax_n \tag{3.18}$$

To analyse the economic viability of the power plants, the levelized cost of electricity (LCOE) and the net present value (NPV) metrics are used.

The net present value (*NPV*) is calculated as

$$NPV = \sum_{n=0}^{N} \frac{CF_n}{(1+d)^n} \text{ and } CF_0 = -C_0 \tag{3.19}$$

where *d* is the discount rate (%)

The internal rate of return (*IRR*) is given by

$$NPV = \sum_{n=0}^{N} \frac{CF_n}{(1+IRR)^n} = 0 \tag{3.20}$$

The LCOE can be calculated as

$$LCOE = \frac{C_0 + \sum_{n=1}^{N} \frac{F_n}{(1+d)^n}}{\sum_{n=1}^{N} \frac{E_n}{(1+d)^n}} \tag{3.19}$$

The payback period is the number of years required to recover the original investment in the project. It is given by following formula

$$\text{Simple Payback Period} = \frac{\text{Initial Investment}}{\text{Annual Cash Inflow}}$$

3.3 Data Collections

The data used in this study is collected from various sources, including primary and secondary data sources. Primary data is collected through surveys, interviews, and site visits. The primary data is collected from project developers, investors, and other stakeholders involved in the development of utility-scale solar PV with BESS projects in Nepal. This data is important because it provides firsthand information on the costs, revenues, and other financial metrics associated with these projects.

Secondary data is collected from published reports, academic papers, and other publicly available sources. The battery cost and performance data are derived from the literature and market surveys. The economic parameters, such as discount rate, inflation rate, project lifetime, etc., are assumed based on the prevailing conditions in Nepal.

3.4 System under Consideration

This study evaluates the feasibility of a utility scale solar photovoltaic (PV) plant with battery energy storage system (BESS) in Nepal. The system consists of a 10 MW PV array and a 5 MW/20 MWh BESS, using an AC-coupled configuration as shown in Figure 3.2. The system is designed to operate as a peaking storage plant, providing power during peak demand periods. For base case scenario, dang district is selected for the study.

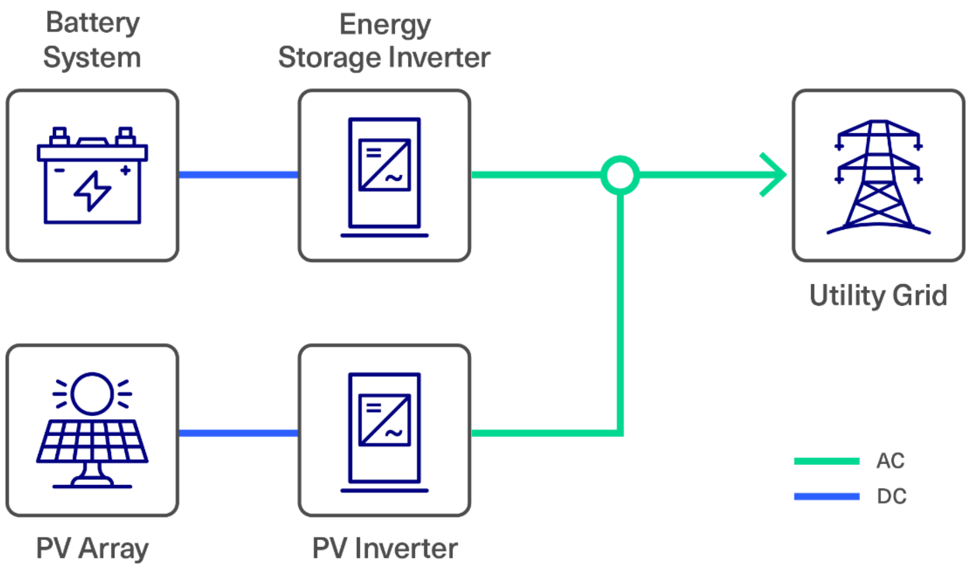

Figure 3.2 System under consideration and model

Figure 3.2 shows the analytical framework for financial modelling.

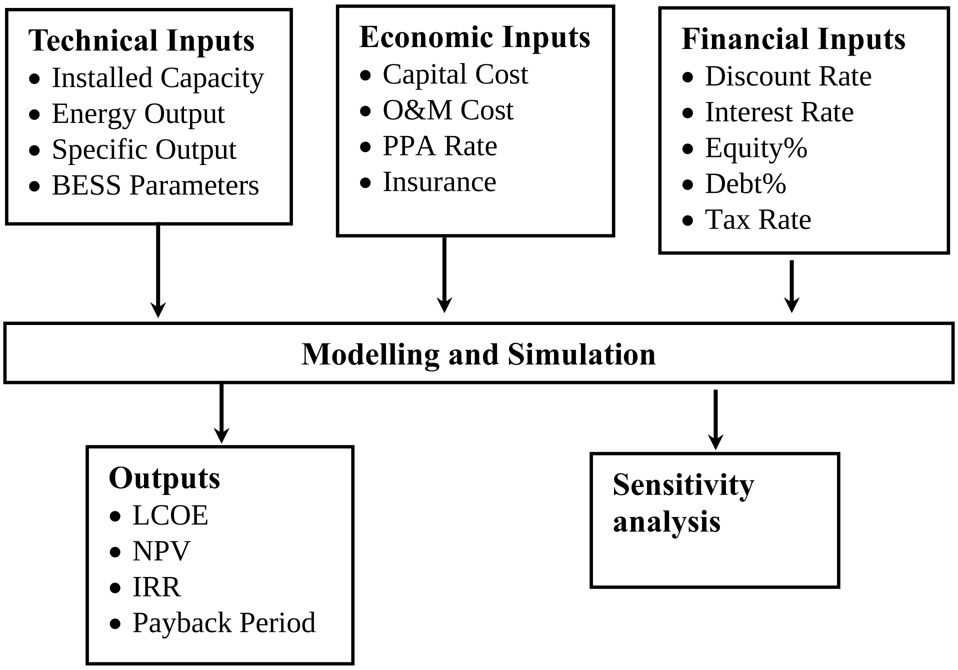

Figure 3.3 Framework of Financial Modelling

The financial analysis is performed using Excel, under certain financial and economic assumptions as inputs for financial modelling. Table 3.1-3.6 summarizes the system and technical parameters, installation costs, operation and maintenance costs, financial parameters, tax rates, and PPA rates used in this study.

Table 3.1 System and Technical Parameters

Parameters	Values	Reference
PV System		
PV System Capacity (MW)	10	
BESS		
BESS Power (MW)	5	
BESS Capacity (MWh)	20	
BESS Duration (h)	4	
Depth of Discharge (%)	90%	[22]
Cycles per day	1.00	

Parameters	Values	Reference
Round-trip efficiency (%)	95%	[22]
Annual PV Energy Degradation	0.5%	[23]
Annual Battery Energy Degradation	2%	[24]

Table 3.2 Installation Costs

Parameters	Values	Reference
PV System		
PV Capex (Million NRs. /MW)	65	[25]
Total PV System Capex (NRs.)	650,000,000	
BESS		
Capex (NRs. /kWh)	20000	[26]
Replacement Cost (NRs. /kWh)	10000	
BESS Capex (NRs.)	400,000,000	
Total system installed cost (NRs.)	1,050,000,000	

Table 3.3 Operation and Maintenance

Parameters	Values	Reference
Fixed annual cost (%/year)	1.5%	[27]
Fixed annual cost (NRs. /year)	15,750,000	

Table 3.4 Financial Parameters

Parameters	Values	Reference
Analysis period (years)	25	[28]
Discount rate (%/year)	10%	[28]
Interest rate (%/year)	10%	[28]
Debt percent (%)	70%	[28]

Parameters	Values	Reference
Equity percent (%)	30%	[28]
Salvage Value	10%	[29]
Depreciation (%)	4%	[30]
Repayment period (years)	15	

Table 3.5 Tax Rates

Parameters	Values	Reference
Tax up to 10 years	0%	[31]
Tax from 10-15 years	10%	[31]
Tax after 15 years	20%	[31]

Table 3.6 PPA Rates

Parameters	Values	Reference
Peak PPA Rate	12.40	[32]
Off Peak PPA Rate	5.94	[33]

3.5 Software and Tools

To conduct the financial analysis of solar PV with BESS, several softwares and tools can be utilized. These include:

- **Financial Modelling Software:** This software, such as Microsoft Excel or other spreadsheet applications, helps create detailed financial models that account for project costs, revenue projections, operational expenses, discount rates, and tax incentives. The software also enables scenario analysis and sensitivity testing to examine the financial feasibility of the system under different conditions.

- **Energy Production Modelling Software:** This software, such as PVsyst, SAM (System Advisor Model), or Solargis, simulates and analyses the energy generation of the solar PV systems. The software takes into account factors like solar irradiation, panel orientation, shading, and weather patterns to estimate the system's electricity generation potential. The energy production data from this software is essential for estimating the revenue generation capacity of the system.
- **Battery Performance and Optimisation Tools:** These tools, such as HOMER or DER-CAM analyse the performance and optimisation of battery energy storage systems. The tools consider parameters like battery capacity, discharge rates, charge and discharge cycles, and electricity demand profiles to optimise the sizing of the battery energy storage system.
- **Financial Analysis Tools:** These tools, such as NPV (net present value) calculators, IRR (internal rate of return) calculators, and LCOE (levelized cost of electricity) calculators, evaluate the financial performance of the solar PV system with BESS. These tools measure the profitability, payback period, and financial viability of the system by considering factors like initial investment, operational costs, electricity tariffs, and financial incentives.

This study uses PVsyst and Microsoft Excel as the main software and tools for conducting a comprehensive financial analysis of a solar PV system with battery energy storage. PVsyst is reliable and suitable software for simulating and analysing the technical performance of PV systems. It has a large database of PV modules, inverters, and meteorological data, and it allows for detailed modelling of system losses and degradation. It also provides output data on the energy production, performance ratio, and yield of the PV system, which are essential inputs for the financial modelling. Microsoft Excel is versatile and user-friendly software for creating financial models. It enables the incorporation of various financial parameters, such as project costs, revenue projections, operational expenses, discount rates, and tax incentives. It also allows for scenario analysis and sensitivity testing to examine the financial feasibility of the system under different conditions.

CHAPTER FOUR: RESULT AND DISCUSSION

4.1 PVsyst Simulation

This study uses PVsyst, a software for modelling and simulating solar photovoltaic systems, to evaluate the technical performance of a 10 MW grid-connected PV system. The PV system consists of 39,220 modules with a nominal power of 10 MWp and 9 inverters with a nominal power of 9 MWac. The nominal power ratio, which is the ratio of the PV array power to the inverter power, is 1.11. This indicates that the system is slightly oversized to compensate for losses and increase the energy yield. The PV system is designed with a tilt angle of 30 degrees to optimise the capture of solar radiation. The simulation considers various factors that affect the energy production and efficiency of the system, such as solar irradiation, temperature, module quality, losses, and environmental conditions. The summary of PVsyst's simulation results is shown in Figure 4.1.

Project: Utility Scale Solar Photovoltaic (PV) System

Variant: New simulation variant

PVsyst V7.1.1
Simulation date:
11/06/23 08:20
with v7.1.1

Project summary

Geographical Site		**Situation**		**Project settings**	
Dāng		Latitude	28.12 °N	Albedo	0.20
Nepal		Longitude	82.30 °E		
		Altitude	620 m		
		Time zone	UTC+5.8		

Meteo data
Dāng
Meteonorm 7.3 (1981-2010), Sat=100% - Synthetic

System summary

Grid-Connected System		**No 3D scene defined, no shadings**			
PV Field Orientation		**Near Shadings**		**User's needs**	
Fixed plane		No Shadings		Unlimited load (grid)	
Tilt/Azimuth	30 / 0 °				

System information

PV Array		**Inverters**	
Nb. of modules	39220 units	Nb. of units	9 units
Pnom total	10.00 MWp	Pnom total	9000 kWac
		Pnom ratio	1.111

Results summary

Produced Energy	18686 MWh/year	Specific production	1868 kWh/kWp/year	Perf. Ratio PR	81.68 %

Figure 4.1 PVsyst Simulation Result

The PVsyst software simulation yields the following key results:

Total Annual Energy Production: The simulation predicts a total annual energy production of 18,686 MWh for the grid-connected solar PV system. This metric serves as a crucial indicator of the system's electricity generation potential, which directly influences its financial viability and contribution to the grid. The energy balance is presented in the Table 4.1.

Table 4.1 Energy Balances

Month	**GlobHor kWh/m²**	**DiffHor kWh/m²**	**T_Amb °C**	**GlobInc kWh/m²**	**GlobEff kWh/m²**	**EArray MWh**	**E_Grid MWh**	**PR ratio**
January	142.7	22.66	11.95	215.5	211.8	1899.0	1858.1	0.862
February	148.4	32.32	16.33	198.4	194.9	1706.4	1671.4	0.842
March	200.9	35.90	22.03	235.1	230.4	1851.9	1815.3	0.772
April	202.9	64.35	27.33	207.4	202.4	1600.3	1568.9	0.757
May	218.5	85.70	29.12	203.0	197.3	1618.8	1587.8	0.782
June	172.2	93.30	28.35	154.0	149.2	1292.3	1268.4	0.823
July	149.4	84.96	27.28	135.2	130.9	1150.8	1128.2	0.834
August	164.0	81.55	26.94	159.3	154.7	1335.9	1309.9	0.822
September	150.1	66.33	25.89	162.6	158.6	1342.9	1316.8	0.810
October	163.3	45.78	23.81	205.4	201.7	1696.5	1663.2	0.810
November	141.8	25.98	18.55	207.4	203.5	1775.4	1740.8	0.839
December	130.6	26.41	13.88	204.0	200.2	1793.4	1756.8	0.861
Year	**1984.7**	**665.24**	**22.65**	**2287.3**	**2235.5**	**19063.5**	**18685.6**	**0.817**

Legends

GlobHor	Global horizontal irradiation
DiffHor	Horizontal diffuse irradiation
T_Amb	Ambient Temperature
GlobInc	Global incident
GlobEff	Effective Global
EArray	Effective energy at the output of the array
E_Grid	Energy injected into grid
PR	Performance Ratio

The simulation predicts the total annual energy production of a grid-connected solar PV system considering factors such as irradiance level, temperature losses, module quality, ohmic wire losses, and inverter losses. The losses are shown in Figure 4.2.

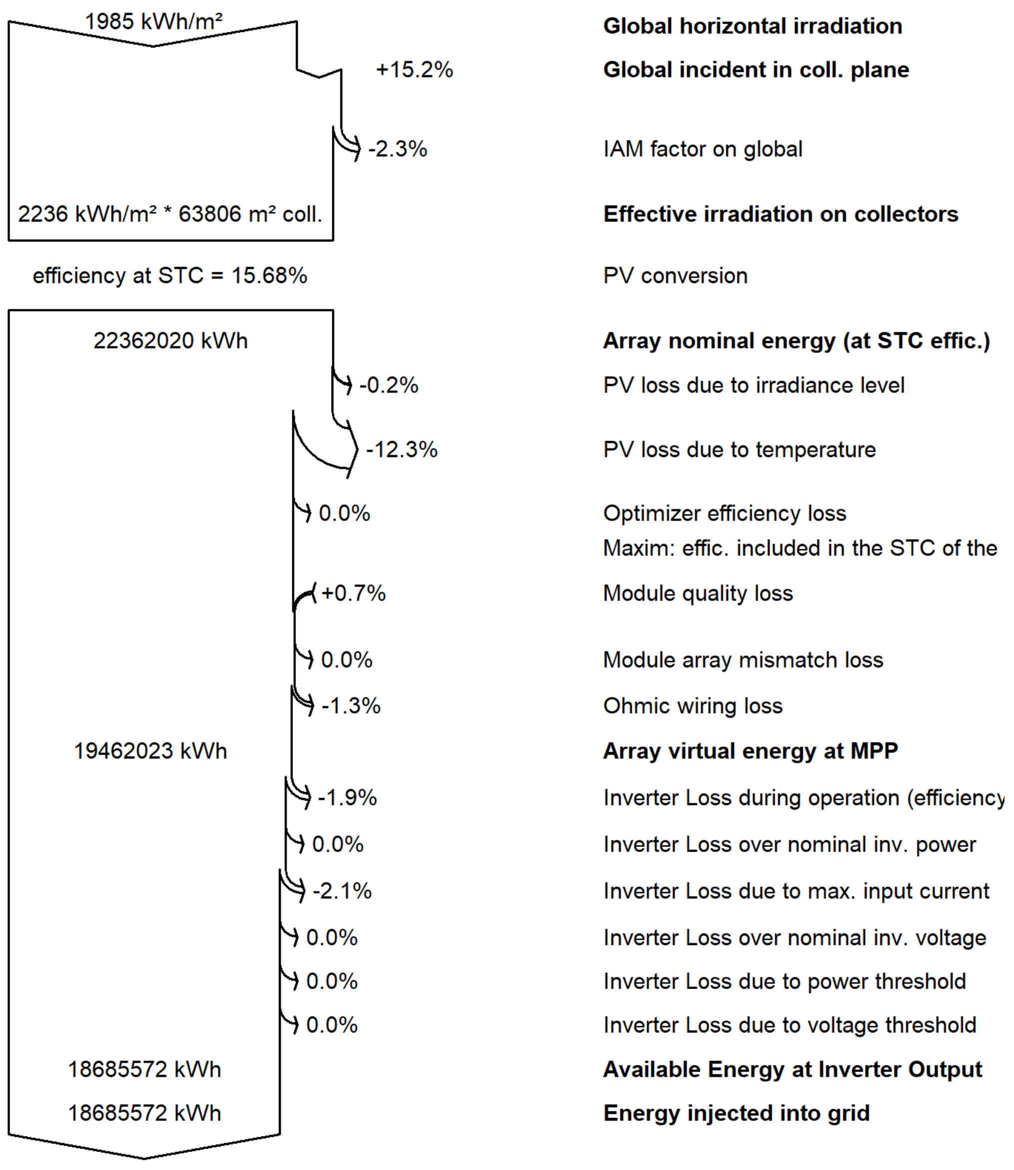

Figure 4.2 Loss Diagram

Specific Production: The specific production value of 1,868 kWh/kWp/year signifies the average energy output per installed kilowatt-peak (kWp) of the PV system. A higher specific production indicates efficient energy conversion and utilization, enhancing the project's overall financial attractiveness.

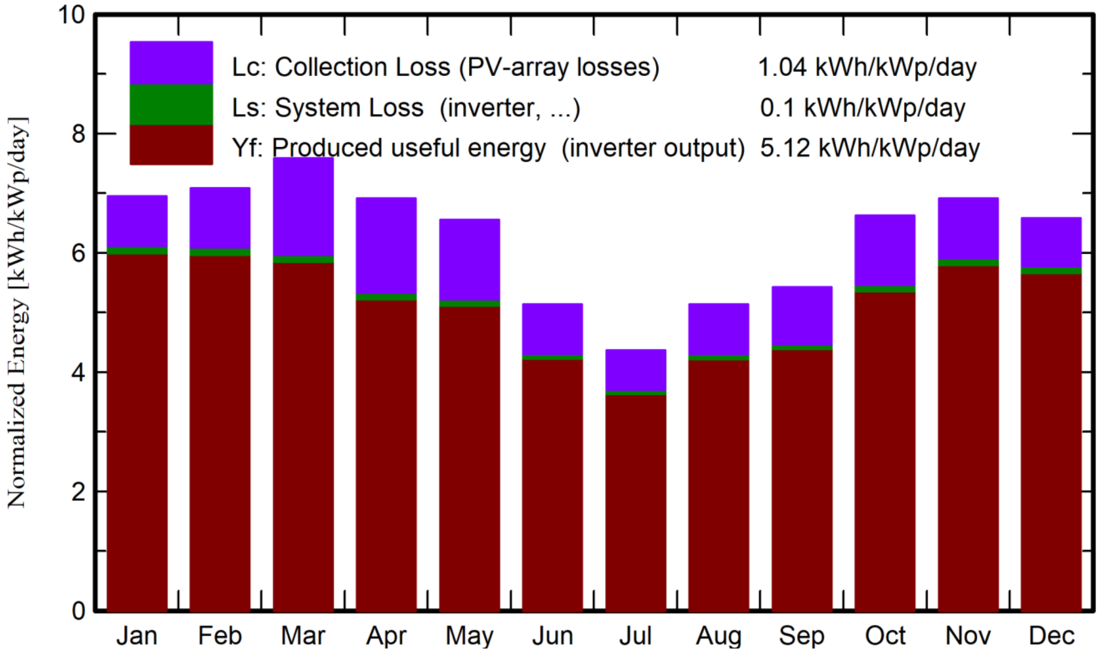

Figure 4.3 Normalized productions

Performance Ratio: The simulation predicts a performance ratio (PR) of 81.68% for the grid-connected solar PV system with BES. The PR reflects the system's efficiency in converting available solar irradiation into usable electricity, considering factors like losses, shading, soiling, and environmental conditions. A higher PR denotes optimized energy generation and improved.

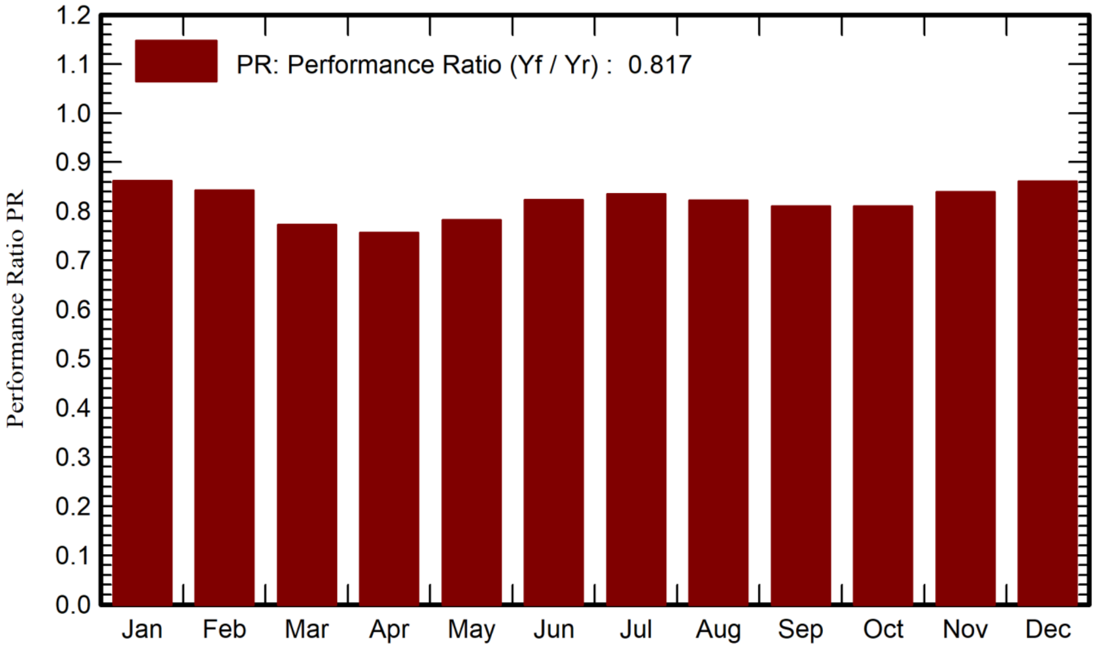

Figure 4.4 Performance Ratio

4.2 Financial Analysis Results

The financial analysis of utility - scale solar photovoltaic system with battery energy storage system in Nepal is performed after technical analysis. The key results are shown in Table 4.2.

Table 4.2 Key Results

Financial Metrics	**PV**	**PV with BESS**
NPV [Million NRs]	209	12.70
IRR [%]	21%	10.4%
LCOE NRs/kWh]	4.7	8.17
Payback Period [Years]	5	10

The results in Table 4.8 compare the financial metrics of a utility-scale photovoltaic (PV) system both with and without a Battery Energy Storage System (BESS). Here is an explanation of each metric:

NPV (Net Present Value): The NPV measures the overall profitability of an investment by calculating the difference between the present value of cash inflows and outflows. In this case, the PV system has an NPV of NRs. 209 million, indicating a positive net value. However, when the BESS is added, the NPV decreases to NRs. 12.70 million suggesting a lower financial return.

IRR (Internal Rate of Return): The IRR represents the rate of return at which the net present value of cash flows becomes zero. A higher IRR indicates a more attractive investment. The PV system has an IRR of 21%, demonstrating a relatively favourable return. On the other hand, the PV system with BESS has a lower IRR of 10.4%, suggesting a reduced profitability compared to the standalone PV system.

LCOE (Levelized Cost of Electricity): LCOE calculates the average cost of generating electricity over the system's lifetime per unit of energy produced. The PV system has a lower LCOE of NRs. 4.7/kWh, indicating a lower cost of electricity generation. However, when the BESS is integrated, the LCOE increases to NRs. 8.17/kWh, suggesting higher costs associated with the addition of energy storage.

Payback Period: The payback period refers to the amount of time it takes to recoup the investment. The PV system has a relatively short payback period of 5 years, indicating a quicker return on investment. In contrast, the PV system with BESS has a longer payback period of 10 years, suggesting a longer time required to recoup the initial investment due to the added costs of the energy storage system.

Overall, these results highlight the financial implications of integrating a BESS into a utility-scale PV system in Nepal. While the BESS may enhance energy storage capabilities and provide additional benefits, it also introduces higher costs and potentially reduces the overall financial performance of the system, as evident from the lower NPV, IRR, and higher LCOE and payback period compared to PV system.

The cash flow in Figure 4.5 shows the status of the project during its life period

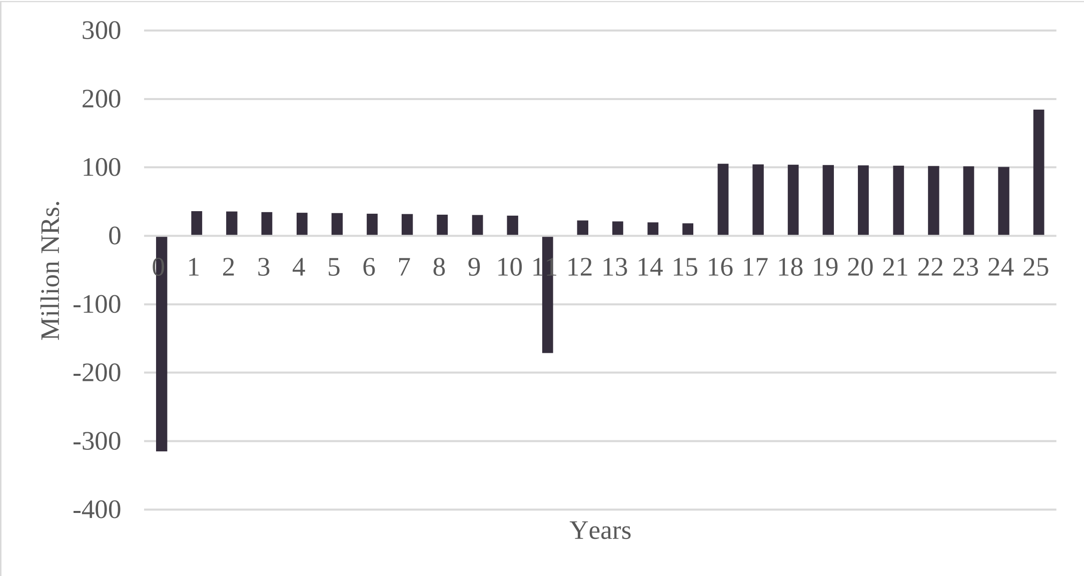

Figure 4.5 Cash flow diagram

4.3 Sensitivity Analysis

Sensitivity analysis is a technique that examines how the output of a financial model changes when the input variables are varied. It is useful for evaluating the uncertainty and risk associated with different scenarios and assumptions. In this thesis, sensitivity analysis is applied to the financial analysis of utility-scale photovoltaic systems with battery energy storage systems in Nepal. The main objective of the sensitivity analysis is to identify the key factors that affect the net present value (NPV) of the project and to measure their impact on the profitability and feasibility of the project. The input variables, such as capital cost, BESS cost, specific yield, interest rate, and PPA rate are considered for the sensitivity analysis.

The sensitivity analysis is performed by varying each input variable by ±20% from its base value while keeping the other variables constant. The resulting changes in the NPV are then plotted in a tornado diagram in Figure 4.6, which shows the relative importance and direction of each input variable on the NPV. The tornado diagram also helps to identify the most sensitive and insensitive variables for the project. From the tornado diagram shown in Figure 4.6, specific yield is the most sensitive parameter for NPV.

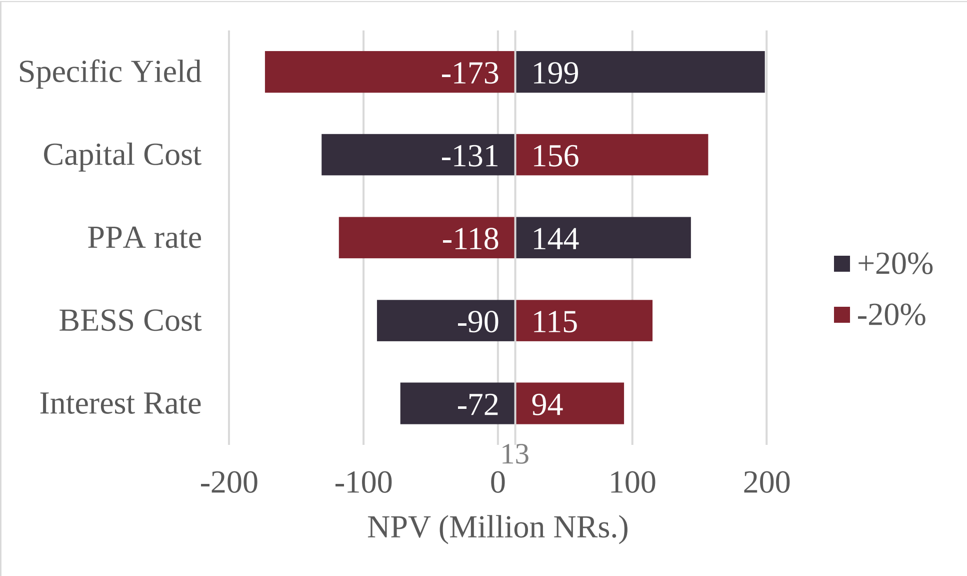

Figure 4.6 Tornado Diagram

The sensitivity analysis from the above tornado diagram in Figure 4.6 can be interpreted as follows:

- **Specific yield:** This is the amount of electricity generated per unit of installed capacity of the project. When the specific yield is reduced by 20%, the NPV becomes – NRs. 173 million, which means that the project becomes less profitable and feasible. When the specific yield is increased by 20%, the NPV increases to NRs. 199 million, which means that the project becomes more profitable and feasible. This indicates that the NPV is positively correlated with the specific yield and that the specific yield is a sensitive variable for the project.
- **Capital cost:** This is the initial investment required for the project. When the capital cost is reduced by 20%, the NPV increases to NRs. 156 million, which

means that the project becomes more profitable and feasible. When the capital cost is increased by 20%, the NPV decreases to - NRs. 131 million, which means that the project becomes less profitable and feasible. This indicates that the NPV is negatively correlated with installed capital cost.

- **PPA rate:** This is the price at which the energy produced by the project is sold to the grid or a third party. When the PPA rate is reduced by 20%, the NPV decreases to – NRs. 118 million, which means that the project becomes less profitable and feasible. When the PPA rate is increased by 20%, the NPV increases to NRs 144 million, which means that the project becomes more profitable and feasible. This indicates that the NPV is positively correlated with the PPA rate and that the PPA rate is a sensitive variable for the project.
- **BESS cost:** This is the cost of installing and operating a battery energy storage system for storing excess electricity generated by the project. When the BESS cost is reduced by 20%, the NPV increases to NRs. 115 million, which means that the project becomes more profitable and feasible. When the BESS cost is increased by 20%, the NPV decreases to - NRs. 90 million, which means that the project becomes less profitable and feasible. This indicates that the NPV is negatively correlated with the BESS cost and that the BESS cost is a sensitive variable for the project.
- **Interest rate:** This is the rate at which the project borrows money to finance its capital cost. When the interest rate is reduced by 20%, the NPV increases to NRs. 94 million, which means that the project becomes more profitable and feasible. When the interest rate is increased by 20%, the NPV decreases to – NRs. 72 million, which means that the project becomes less profitable and feasible. This indicates that the NPV is negatively correlated with the interest rate and that interest rate is a sensitive variable for the project.

4.3.1 Sensitivity Analysis on Capital Cost

The sensitivity analysis conducted on the capital cost examines the impact of varying the initial investment required for the project. The results indicate that as Capital Cost increases from NRs. 40 million/MW to NRs. 80 million/MW, there are significant changes in the financial performance indicators as shown in Table 4.9 and Figure 4.7. The Payback Period (PB) lengthens from 4 to 18 years, indicating a longer time required to recover the investment. The Internal Rate of Return (IRR) declines from 24% to 6%, suggesting reduced profitability as the Capital Cost increases. The Net Present Value (NPV) decreases from NRs. 289 million to NRs. -153 million, indicating a less favourable financial outcome with higher initial investment costs. Additionally, the Levelized Cost of Electricity (LCOE) increases from NRs. 6.41/kWh to NRs. 9.22/kWh, implying higher costs of electricity generation. Overall, the sensitivity analysis highlights that higher Capital Costs lead to longer payback periods, lower profitability, less favourable NPV, and higher electricity generation costs.

Table 4.3 Sensitivity analysis on capital cost

Results	**Capital Cost (Million NRs. /MW)**				
	40	**50**	**60**	**70**	**80**
NPV (Million NRs.)	289	179	68	-43	-153
LCOE (NRs. /kWh)	6.41	7.11	7.82	8.52	9.22

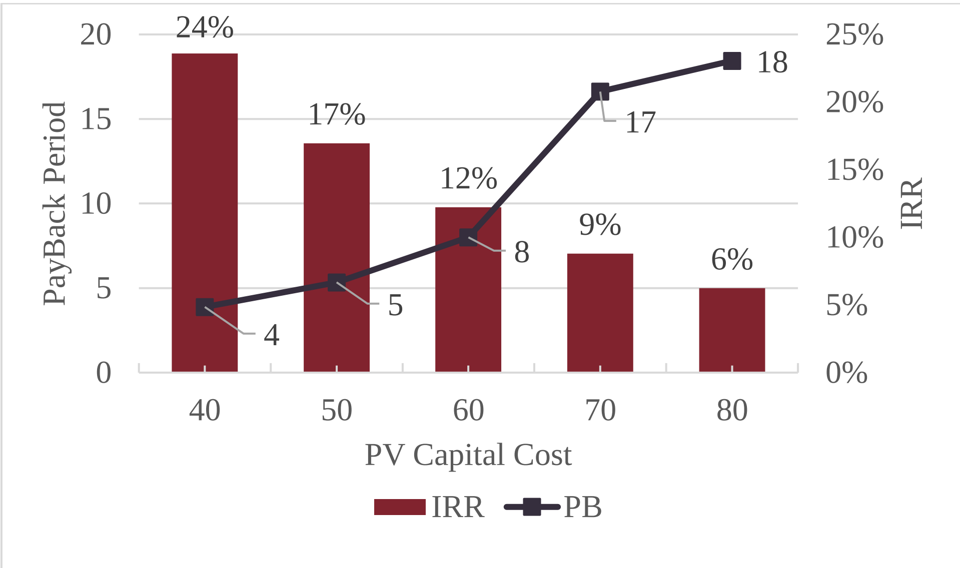

Figure 4.7 Sensitivity analysis on capital cost

4.3.2 Sensitivity Analysis on BESS Cost

The sensitivity analysis conducted on the BESS cost reveals the impact of varying BESS costs on key financial indicators. As the BESS cost increases from NRs. 10,000/kWh to NRs. 30,000/kWh, there are noticeable changes in the financial performance metrics as shown in Table 4.10 and Figure 4.8. The payback period (PB) lengthens from 5 to 20 years, indicating a longer time required to recover the investment. The Internal Rate of Return (IRR) declines from 21% to 4%, suggesting a reduced profitability as the BESS cost increases. The Net Present Value (NPV) decreases from NRs. 269 million to NRs. -244 million, indicating a less favourable financial outcome as the BESS cost rises. The Levelized Cost of Electricity (LCOE) increases from NRs. 6.54/kWh to NRs. 9.79/kWh, signalling higher costs of electricity generation. Overall, the sensitivity analysis highlights the sensitivity of the financial analysis to changes in BESS cost, with higher costs leading to longer payback periods, lower profitability, less favourable NPV, and higher electricity generation costs.

Table 4.4 Sensitivity analysis on BESS cost

Results	**BESS Cost (NRs. /kWh)**				
	10000	**15000**	**20000**	**25000**	**30000**
NPV (Million NRs.)	269	141	13	-115	-244
LCOE (NRs. /kWh)	6.54	7.35	8.17	8.98	9.79

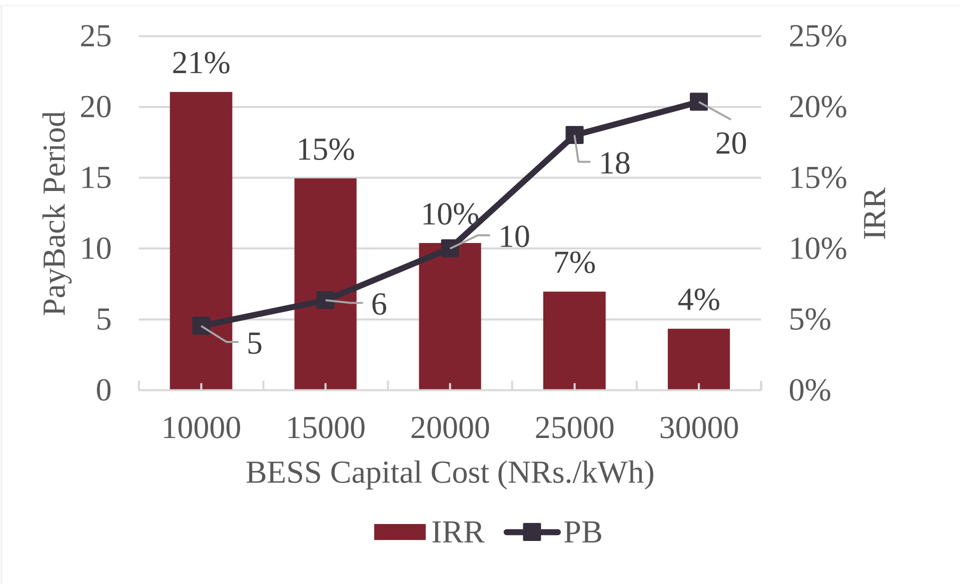

Figure 4.8 Sensitivity analysis on BESS cost

4.3.3 Sensitivity Analysis on Specific Yield

The sensitivity analysisperformed on the specific yield examines the impact of varying the energy production efficiency of the photovoltaic system. The results show that as the specific yield increases from 1200 kWh/kW to 2000 kWh/kW, there are noticeable changes in the financial performance indicators. The Payback Period (PB) decreases from 24 to 8 years, indicating a shorter time required to recoup the investment. The Internal Rate of Return (IRR) increases from 2% to 12%, suggesting improved profitability with higher energy production efficiency. The Net Present Value (NPV) improves from NRs. -320 million to NRs. 78 million, indicating a more favourable financial outcome with higher specific yield. Additionally, the Levelized Cost of Electricity (LCOE) decreases from NRs. 12.78/kWh to NRs. 7.63/kWh, implying lower costs of electricity generation. Overall, the sensitivity analysis highlights that higher specific yield leads to shorter payback periods, increased profitability, improved NPV, and lower electricity generation costs.

Table 4.5 Sensitivity analysis on specific yield

Results	**Specific Yield (kWh/kW)**				
	1200	**1400**	**1600**	**1800**	**2000**
NPV (Million NRs.)	-320	-220	-121	-21	78
LCOE (NRs. /kWh)	12.78	10.92	9.54	8.47	7.63

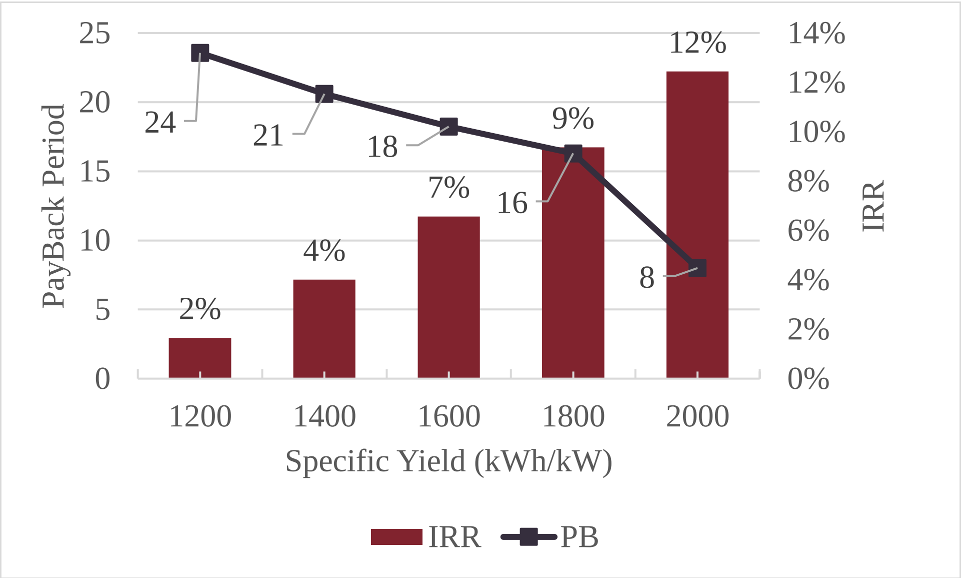

Figure 4.9 Sensitivity analysis on specific yield

4.3.4 Sensitivity Analysis on PPA Rate

The sensitivity analysis conducted on the Power Purchase Agreement (PPA) rate examines the impact of varying the rate at which electricity is sold to the grid. The results shown in Table 4.12 and Figure 4.10 demonstrate that as the peak PPA rate increases from NRs. 8/kWh to NRs. 16/kWh, there are noticeable changes in the financial performance indicators. The Payback Period (PB) decreases from 21 to 6 years, indicating a shorter time required to regain the investment. The Internal Rate of Return (IRR) increases from 4% to 17%, suggesting improved profitability with higher PPA rates. The Net Present Value (NPV) improves from NRs. -220 million to NRs. 203 million, indicating a more favourable financial outcome with higher PPA rates. Additionally, the Levelized Cost of Electricity (LCOE) shows a slight increase from NRs.8.10/kWh to NRs. 8.22/kWh, implying a marginal increase in the cost of electricity generation. Overall, the sensitivity analysis highlights that higher PPA rates lead to shorter payback periods, increased profitability, improved NPV, and a relatively stable LCOE.

Table 4.6 Sensitivity analysis on PPA rate

Results	**PPA rate (NRs. /kWh)**				
	8	**10**	**12**	**14**	**16**
NPV (Million NRs.)	-220	-114	-8	97	203
LCOE (NRs. /kWh)	8.10	8.13	8.16	8.19	8.22

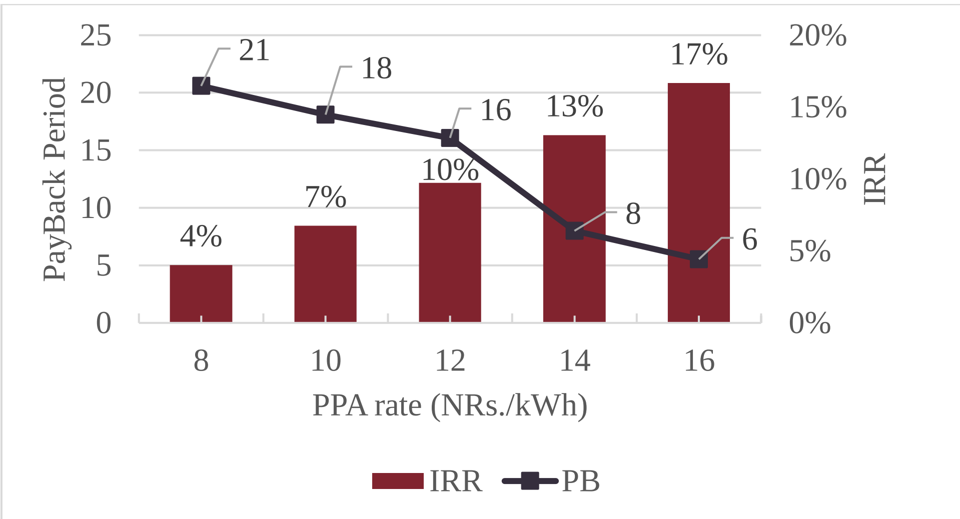

Figure 4.10 Sensitivity analysis on PPA rate

4.3.5 Sensitivity Analysis on Interest Rate

The sensitivity analysis showed on the Interest rate the impact of varying the cost of financing the project. The results indicate that as the Interest Rate increases from 6% to 14%, there are noticeable changes in the financial performance indicators. The Payback Period (PB) increases from 6 to 19 years, indicating a longer time required to recoup the initial investment. The Internal Rate of Return (IRR) declines from 16% to 6%, suggesting reduced profitability as the interest rate rises. The Net Present Value (NPV) decreases from NRs. 171 million to NRs. -161 million, indicating a less favourable financial outcome with higher interest rates. Additionally, the Levelized Cost of Electricity (LCOE) increases from NRs. 7.17/kWh to NRs.9.26/kWh, implying higher costs of electricity generation. Overall, the sensitivity analysis highlights the sensitivity of the financial analysis to changes in the interest rate, with higher interest rates leading to longer payback periods, lower profitability, less favourable NPV, and higher electricity generation costs.

Table 4.7 Sensitivity analysis on interest rate

Results	Interest rate				
	6%	8%	10%	12%	14%
NPV (Million NRs.)	171	94	13	-72	-161
LCOE (NRs. /kWh)	7.17	7.65	8.17	8.70	9.26

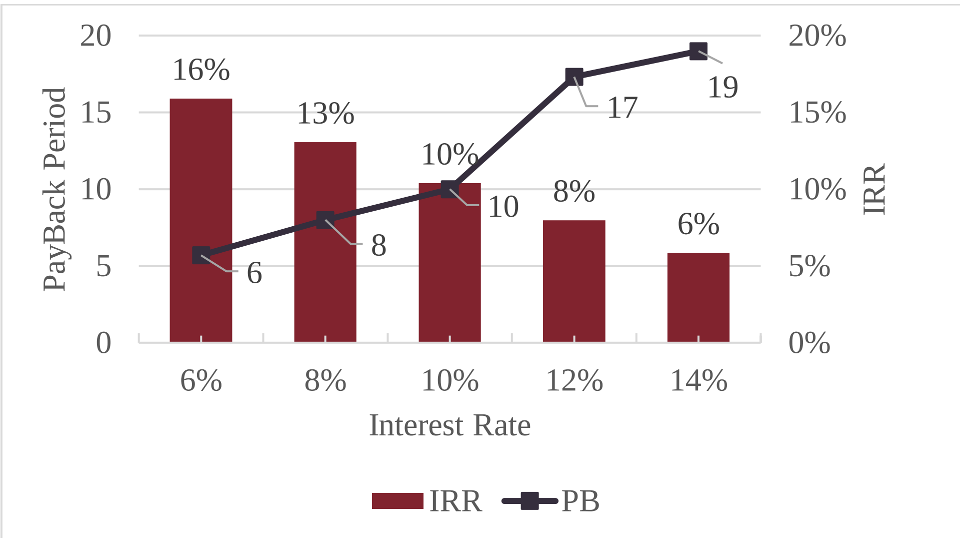

Figure 4.11 Sensitivity analysis on interest rate

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In conclusion, the financial analysis of utility - scale solar PV with a battery energy storage system (BESS) in Nepal has shed light on its feasibility and financial viability. The results demonstrate that these projects can offer positive returns on investment and be financially viable.

The PVsyst software simulation provided key results that serve as crucial indicators of the system's performance and financial viability. The total annual energy production was estimated at 18,686 MWh, with a specific production value of 1,868 kWh/kWp/year, indicating efficient energy conversion and utilisation. The performance ratio (PR) was predicted to be 81.68%, reflecting optimised energy generation and improved system efficiency.

The financial analysis was performed using an Excel model, considering a 10 MW utility-scale PV system and a 5 MW/20 MWh BESS. The analysis period of 25 years, in line with the generation license and solar module warranty, was considered. The results showed that the PV system without BESS had a higher net present value (NPV) of NRs. 209 million and an internal rate of return (IRR) of 21%. However, when the BESS was integrated, the NPV decreased to NRs. 12.70 million, and the IRR dropped to 10.4%. The levelized cost of electricity (LCOE) also increased from NRs. 4.7/kWh to NRs. 8.17/kWh, and the payback period extended from 5 to 10 years.

These financial metrics indicate that while the integration of BESS enhances energy storage capabilities, it introduces higher costs and potentially reduces the overall financial performance compared to the standalone PV system. The sensitivity analysis conducted on various input variables, including capital cost, BESS cost, specific yield, interest rate, and power purchase agreement (PPA) rate, further highlighted their impact on the net present value (NPV). The specific yield was found to be the most sensitive parameter, followed by capital cost, PPA rate, BESS cost, and interest rate.

Overall, the results demonstrate that the financial feasibility of a utility-scale PV system with BESS in Nepal is influenced by various factors. The choice of input variables and their values significantly affect the project's profitability, payback period, and overall financial performance. Therefore, careful consideration and optimization of these variables are crucial when making investment decisions in such projects.

5.2 Recommendations

Based on the findings of this thesis, it is recommended that policymakers, investors, and developers take the following actions to promote utility-scale photovoltaic with the integration of battery energy storage systems in Nepal and enhance their financial viability:

1. **Policy Support:** The government should provide stable and attractive policies to incentivize investment in utility-scale solar PV with BESS projects. This includes offering competitive power purchase agreement (PPA) rates and tax breaks to make the projects financially appealing for investors.
2. **Financial Incentives:** To lower the upfront capital costs associated with BESS integration, targeted financial incentives should be implemented. These incentives can take the form of grants, low-interest loans, or other mechanisms that reduce the financial burden on project developers.
3. **Risk Assessment:** Comprehensive risk assessments should be conducted to evaluate the financial viability and bankability of utility-scale solar PV with BESS projects. These assessments should consider technical, market, and policy risks, and identify potential challenges that may arise. Mitigation strategies should be developed to address these risks and enhance the overall project feasibility.
4. **Knowledge Sharing and Capacity Building:** To promote sustainable growth in the sector, initiatives should be undertaken to share knowledge and build capacity among stakeholders. This can include organizing training programs, workshops, and information-sharing platforms focused on the financial aspects of utility-scale solar PV with BESS projects. Building local expertise and understanding will enable better decision-making and project implementation.

By implementing these recommendations, stakeholders can create an enabling environment for utility-scale solar PV with BESS projects in Nepal. This will attract investment, reduce financial barriers, mitigate risks, and foster the development of renewable energy in the country, ensuring a sustainable and reliable electricity supply.

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APPENDICES

Appendix A: Installed Capacity

A1. Total Installed Capacity (kW)

Power Plants	NEA	NEA Subsidiary	IPP	Total
Hydropower	583,160	478,100	1,020,528	**2,081,788**
Solar	21,580	-	33,140	**54,720**
Thermal	53,410	-	-	**53,410**
Total	**658,150**	**478,100**	**1,053,668**	**2,189,918**

A2. NEA Power Plants

S.N.	Power Plants	Location	Capacity (kW)
Major Hydropower			
1	Kaligandaki A	Syangja	144,000
2	Middle Marsyandi	Lamjung	70,000
3	Marsyandi	Tanahun	69,000
4	Kulekhani I	Makwanpur	60,000
5	Upper Trishuli 3A HEP	Nuwakot	60,000
6	Kulekhani II	Makwanpur	32,000
7	Chameliya	Darchula	30,000
8	Trishuli	Nuwakot	24,000
9	Gandak	Parasi	15,000
10	Devighat	Nuwakot	15,000
11	Modi Khola	Parbat	14,800
12	Kulekhani III HEP	Makwanpur	14,000
13	Sunkoshi	Sindhupalchok	10,050
14	Puwa Khola	Illam	6,200
	Sub Total		**564,050**
Small Hydropower			
1	Chatara	Sunsari	3,200
2	Panauti	Kabrepalanchowk	2,400
3	Tatopani	Myagdi	2,000
4	Seti	Kaski	1,500
5	Tinau	Butwal	1,024
6	Fewa	Kaski	1,000
7	Sundarijal	Kathmandu	970
8	Pharping***	Kathmandu	500
9	Gamgad	Mugu	400
10	Khandbari**	Sankhuwasabha	250
11	Jomsom**	Mustang	240
12	Phidim**	Taplejung	240
13	Baglung***	Baglung	200

S.N.	Power Plants	Location	Capacity (kW)
14	Surnaiyagad	Baitadi	200
15	Doti***	Doti	200
16	Ramechhap	Ramecchap	150
17	Terhathum**	Terhathum	100
	Sub Total		**14,574**
Small Hydropower-Isolated			
1	Kalikot	Kalikot	500
2	Heldung	Humla	500
3	Achham	Accham	400
4	Jhupra***	Surkhet	345
5	Darchula**	Darchula	300
6	Bhojpur**	Bhojpur	250
7	Dhankuta***	Dhankuta	240
8	Jumla**	Jumla	200
9	Syaprudaha**	Rukum	200
10	Bajura**	Bajura	200
11	Bajhang**	Bajhang	200
12	Dolpa	Dolpa	200
13	Chaurjhari**	Rukum	150
14	Arughat	Gorkha	150
15	Taplejung**	Taplejung	125
16	Okhaldhunga	Okhaldhunga	125
17	Rupalgad	Dadeldhura	100
18	Syangja***	Syangja	80
19	Manag**	Manag	80
20	Gorkhe***	Ilam	64
21	Helambu	Sindhupalchowk	50
22	Chame**	Manang	45
23	Dhanding***	Dhanding	32
	Sub Total		**4,536**
		Total Hydropower	**583,160**
Solar			
1	Simikot	Humla	50
2	Gamgadhi	Mugu	50
3	Battar	Nuwakot	21,480
		Total Solar	**21,580**
Thermal			
1	Duhabi Multifuel	Morang	39,000
2	Hetauda Diesel	Makwanpur	14,410
		Total Thermal	**53,410**

** Leased to Private Sector
*** Not in Normal Operation

A3. NEA Subsidiary Power Plants

S.N.	Developer	Projects	Location	Capacity (kW)
1	Chilime Hydro Power Company Ltd.	Chilime	Rasuwa	22,100
2	Upper Tamakoshi Hydropower Ltd.	Upper Tamakoshi	Dolakha	456,000
			Total	**478,100**

A4. IPP Power Plants

S.N.	Developer	Projects	Location	Capacity (kW)
		IPP Hydropower Projects		
1	Himal Power Ltd.	Khimti	Dolakha	60000
2	Bhotekoshi Power Company Ltd.	Upper Bhotekoshi	Sindhupalchowk	45000
3	Syange Electricity Company Limited	Syange Khola	Lamjung	183
4	National Hydro Power Company Ltd.	Indrawati - III	Sindhupalchowk	7500
5	Butwal Power Company Ltd.	Jhimruk Khola	Pyuthan	12000
6	Butwal Power Company Ltd.	Andhi Khola	Syangza	9400
7	Arun Valley Hydropower Dev. Co. (P.) Ltd.	Piluwa Khola Small	Sankhuwasabha	3000
8	Rairang Hydro Power Development Co. (P) Ltd.	Rairang Khola	Dhading	500
9	Sanima Hydropower (Pvt.) Ltd.	Sunkoshi Small	Sindhupalchowk	2500
10	Alliance Power Nepal Pvt. Ltd.	Chaku Khola	Sindhupalchowk	3000
11	Khudi Hydropower Ltd.	Khudi Khola	Lamjung	4000
12	Unique Hydel Co. Pvt.Ltd.	Baramchi Khola	Sindhupalchowk	4200
13	Thoppal Khola Hydro Power Co. Pvt. Ltd.	Thoppal Khola	Dhading	1650
14	Gautam Buddha Hydropower (Pvt.) Ltd.	Sisne Khola Small	Palpa	750
15	Kathmandu Small Hydropower Systems Pvt. Ltd.	Sali Nadi	Kathmandu	250

S.N.	Developer	Projects	Location	Capacity (kW)
16	Khoranga Khola Hydropower Dev. Co. Pvt. Ltd.	Pheme Khola	Panchthar	995
17	Unified Hydropower (P.) Ltd.	Pati Khola Small	Parbat	996
18	Task Hydropower Company (P.) Ltd.	Seti-II	Kaski	979
19	Ridi Hydropower Development Co. (P.) Ltd.	Ridi Khola	Gulmi	2400
20	Centre for Power Dev. And Services (P.) Ltd.	Upper Hadi Khola	Sindhupalchowk	991
21	Gandaki Hydro Power Co. Pvt. Ltd.	Mardi Khola	Kaski	4800
22	Himal Dolkha Hydropower Company Ltd.	Mai Khola	Ilam	4500
23	Baneswor Hydropower Pvt. Ltd.	Lower Piluwa Small	Sankhuwasabha	990
24	Barun Hydropower Development Co. (P.) Ltd.	Hewa Khola	Sankhuwasabha	4455
25	Bhagawati Hydropower Development Co. (P.) Ltd.	Bijayapur-1	Kaski	4410
26	Nyadi Group (P.) Ltd.	Siuri Khola	Lamjung	4950
27	United Modi Hydropwer Pvt. Ltd.	Lower Modi 1	Parbat	10000
28	Synergy Power Development (P.) Ltd.	Sipring Khola	Dolakha	9658
29	Laughing Buddha Power Nepal (P.) Ltd.	Middle Chaku	Sindhupalchowk	1800
30	Aadishakti Power Dev. Company (P.) Ltd.	Tadi Khola (Thaprek)	Nuwakot	5000
31	Ankhu Khola Jal Bidhyut Co. (P.) Ltd.	Ankhu Khola - 1	Dhading	8400
32	Nepal Hydro Developer Pvt. Ltd.	Charanawati Khola	Dolakha	3520
33	Laughing Buddha Power Nepal Pvt. Ltd.	Lower Chaku Khola	Sindhupalchowk	1800
34	Bhairabkunda Hydropower Pvt. Ltd.	Bhairab Kunda	Sindhupalchowk	3000
35	Radhi Bidyut Company Ltd.	Radhi Khola	Lamjung	4400
36	Pashupati Environmental Eng. Power Co. Pvt. Ltd.	Chhote Khola	Gorkha	993
37	Mailung Khola Hydro Power Company (P.) Ltd.	Mailung Khola	Rasuwa	5000

S.N.	Developer	Projects	Location	Capacity (kW)
38	Joshi Hydropower Dev. Co. Ltd.	Upper Puwa -1	Ilam	3000
39	Sanima Mai Hydropower Limited	Mai Khola	Ilam	22000
40	Bojini Company Private Limited	Jiri Khola Small	Dolakha	2200
41	Ruru Hydropower Project (P) Ltd.	Upper Hugdi Khola	Gulmi	5000
42	Prime Hydropower Co. Pvt. Ltd.	Belkhu	Dhading	518
43	Api Power Company Pvt. Ltd.	Naugadh gad Khola	Darchula	8500
44	Kutheli Bukhari Small Hydropower (P).Ltd	Suspa Bukhari	Dolakha	998
45	Sanima Mai Hydropower Ltd.	Mai Cascade	Ilam	7000
46	Chhyangdi Hydropower Limited	Chhandi	Lamjung	2000
47	Panchakanya Mai Hydropower Ltd	Upper Mai Khola	Ilam	9980
48	Sayapatri Hydropower Private Limited	Daram Khola A	Baglung	2500
49	Electro-com and Research Centre Pvt. Ltd.	Jhyadi Khola	Sindhupalchowk	2000
50	Khani Khola Hydropower Company Pvt. Ltd.	Tungun-Thosne	Lalitpur	4360
51	Daraudi Kalika Hydro Pvt. Ltd.	Daraudi Khola A	Gorkha	6000
52	Khani Khola Hydropower Company Pvt. Ltd.	Khani Khola	Lalitpur	2000
53	Sapsu Kalika Hydropower Co. Pvt. Ltd.	Miya Khola	Khotang	996
54	Sinohydro-Sagarmatha Power Company (P) Ltd.	Upper Marsyangdi “A”	Lamjung	50000
55	Madi Power Pvt. Ltd.	Upper Madi	Kaski	25000
56	Panchthar Power Company Pvt. Ltd.	Hewa Khola A	Panchthar	14900
57	Sanvi Energy pvt. Ltd.	Jogmai	Ilam	7600
58	Bhugol Energy Dev Compay (P). Ltd	Dwari Khola	Dailekh	3750
59	Mai Valley Hydropower Private Limited	Upper Mai C	Ilam	5100
60	Dronanchal Hydropower Co.Pvt.Ltd	Dhunge-Jiri	Dolakha	600

S.N.	Developer	Projects	Location	Capacity (kW)
61	Dibyaswari Hydropower Limited	Sabha Khola	Sankhuwasabha	4000
62	Puwa Khola-1 Hydropower P. Ltd.	Puwa Khola -1	Ilam	4000
63	Shibani Hydropower Co. Pvt. Ltd.	Phawa Khola	Taplejung	4950
64	Mount Kailash Energy Pvt. Ltd.	Thapa Khola	Myagdi	13600
65	Mandakini Hydropower Limited	Sardi Khola	Kaski	4000
66	Garjang Upatyaka Hydropower (P.) Ltd.	Chake Khola	Ramechhap	2830
67	Union Hydropower Pvt Ltd.	Midim Karapu	Lamjung	3000
68	Syauri Bhumey Microhydro Project	Syauri Bhumey	Nuwakot	23
69	Molung Hydropower Company Pvt. Ltd.	Molung Khola	Okhaldhunga	7000
70	Sikles Hydropower Pvt. Ltd.	Madkyu Khola	Kaski	13000
71	Himal Dolkha Hydropower Company Ltd.	Mai sana Cascade	Ilam	8000
72	Barahi Hydropower Pvt. ltd	Theule Khola	Baglung	1500
73	Leguwa Khola Laghu Jalbidhyut Sahakari Sastha Ltd.	Leguwa Khola	Dhankuta	40
74	Super Mai Hydropower Pvt. Ltd.	Super Mai	Ilam	7800
75	Chimal Gramin Bidhyut Sahakari Sanstha Ltd.	Sobuwa Khola-2 MHP	Taplejung	90
76	Deurali Bahuudesiya Sahakari Sanstha Ltd.	Midim Khola	Lamjung	100
77	Bindhyabasini Hydropower Dev. Co. (P.) Ltd.	Rudi Khola A	Lamjung & Kaski	8800
78	Mandu Hydropower Ltd.	Bagmati Khola Small	Makawanpur/ Lalitpur	22000
79	Salmanidevi Hydropower (P). Ltd	Kapadi Gad	Doti	3330
80	Eastern Hydropower Pvt. Ltd.	Pikhuwa Khola	Bhojpur	5000

S.N.	Developer	Projects	Location	Capacity (kW)
81	Mountain Hydro Nepal Pvt. Ltd.	Tallo Hewa Khola	Panchthar	22100
82	Pashupati Environmental Power Co. Pvt. Ltd.	Lower Chhote Khola	Gorkha	997
83	United Idi Mardi and R.B. Hydropower Pvt. Ltd.	Upper Mardi	Kaski	7000
84	Rairang Hydropower Development Company Ltd.	Iwa Khola	Taplejung	9900
85	Api Power Company Pvt. Ltd.	Upper Naugad Gad	Darchula	8000
86	Arun Kabeli Power Ltd.	Kabeli B-1	Taplejung, Panchthar	25000
87	Rangoon Khola Hydropower Pvt. Ltd.	Jeuligad	Bajhang	996
88	Dolti Power Company Pvt. Ltd.	Padam Khola	Dailekh	4800
89	Bindhyabasini Hydropower Dev. Co. (P.) Ltd.	Rudi Khola B	Lamjung & Kaski	6600
90	Ghalemdi Hydro Limited (Previously, Cemat Power Dev Company (P). Ltd.)	Ghalemdi Khola	Myagdi	5000
91	Terhathum Power Company Pvt. Ltd.	Upper Khorunga	Terhathum	7500
92	Upper Solu Hydroelectric Company Pvt. Ltd	Solu Khola	Solukhumbu	23500
93	Sagarmatha Jalabidhyut Company Pvt. Ltd.	Super Mai 'A'	Ilam	9600
94	Mai Khola Hydropower Pvt. Ltd.	Super Mai Cascade	Ilam	3800
95	Century Energy Pvt. Ltd.	Hadi Khola Sunkoshi A	Sindhupalchowk	997
96	Rawa Energy Development Pvt. Ltd.	Upper Rawa	Khotang	3000
97	Himalayan Hydropower Pvt. Ltd.	Namarjun Madi	Kaski	11880
98	Manakamana Engineering Hydropower Pvt. Ltd.	Ghatte Khola	Dolakha	5000
99	Everest Sugar and Chemical Industries Ltd.	Everest Sugar and Chemical Industries Ltd.	Mahottari	3000
100	Civil Hydropower Pvt. Ltd.	Bijayapur 2 Khola	Kaski	4500

S.N.	Developer	Projects	Location	Capacity (kW)
101	Taksar-Pikhuwa Hydropower Pvt. Ltd.	Taksar Pikhuwa	Bhojpur	8000
102	Shiva Shree Hydropower (P.) Ltd.	Upper Chaku A	Sindhupalchowk	22200
103	Robust Energy Ltd.	Mistri Khola	Myagdi	42000
104	Singati Hydro Energy Pvt. Ltd.	Singati Khola		25000
105	Richet Jalbidhyut Company Pvt. Ltd.	Richet Khola	Gorkha	4980
106	Samling Power Company Pvt. Ltd.	Mai Beni	Ilam	9510
107	Manang Trade Link Pvt. Ltd.	Lower Modi	Parbat	20000
108	Asian Hydropower Pvt. Ltd.	Lower Jogmai	Ilam	6200
109	Green Ventures Pvt. Ltd.	Likhu-IV	Ramechhap	52400
110	Chhyangdi Hydropower Limited	Upper Chhyangdi Khola	Lamjung	4000
111	Universal Power Company Ltd.	Lower Khare	Dolakha	11000
112	Three Star Hydropower Company Ltd.	Sapsup Khola	Khotang	6600
113	Numbur Himalaya Hydropower Pvt. Ltd.	Likhu Khola A	Solukhumbu & Ramechap	24200
114	Indushankar Chini Udhyog Ltd.	Indushankar Chini	Sarlahi	3000
115	Upper Syange Hydropower P. Ltd.	Upper Syange Khola	Lamjung	2400
116	Buddha Bhumi Nepal Hydro Power Co. Pvt. Ltd.	Lower Tadi	Nuwakot	4993
117	Arun Valley Hydropower Dev. Co. Ltd.	Kabeli B-1 Cascade	Panchthar	9940
118	Upper Hewa Khola Hydropower Co. Pvt. Ltd.	Upper Hewa Khola Small	Sankhuwasabha	8500
119	Suri Khola Hydropower Pvt. Ltd.	Suri Khola	Dolakha	6400
120	Nyadi Hydropower Limited	Nyadi	Lamjung	30000
121	Himalaya Urja Bikas Co. Pvt. Ltd.	Upper Khimti	Ramechhap	12000
122	Himalaya Urja Bikas Co. Ltd.	Upper Khimti II	Ramechhap	7000
			IPP Hydro Total	**1020528**

S.N.	Developer	Projects	Location	Capacity (kW)
		IPP Solar		
1	Kathmandu Upatyaka Khanepani Bewasthapan Board	Solar	Lalitpur	680.4
2	Surya Power Company Pvt. Ltd.	Bishnu Priya Solar Farm Project	Nawalparasi	960
3	Ridi Hydropower Development Co. Ltd.	Butwal Solar Project	Rupandehi	8500
4	Eco Power Development Company Pvt. Ltd	Mithila Solar PV	Dhanusha	10000
5	Api Power Company Ltd.	Chandranigahpur Solar Project	Rautahat	4000
6	Solar Farm Pvt. Ltd.	Belchautara Solar Project	Tanahun	5000
7	Api Power Company Ltd.	Dhalkebar Solar Project	Dhanusha	1000
8	Sagarmatha Energy and Construction Pvt. Ltd.	Dhalkebar Solar Project	Dhanusha	3000
			IPP Solar Total	**33140.4**

Appendix B: Financial Analysis

Operating Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
Energy (AC GWh)																										
PV System		19	19	18	18	18	18	18	18	18	18	18	18	18	18	17	17	17	17	17	17	17	17	17	17	17
BESS Charging		-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6
BESS Discharging		6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Electricity to Grid		18	18	18	18	18	18	18	18	17	17	17	17	17	17	17	17	17	17	17	16	16	16	16	16	16
Revenue (In Million NRs.)																										
Revenue		149	148	147	146	146	145	144	143	143	142	141	141	140	139	138	138	137	136	136	135	134	134	133	132	132
Salvage Value																										105
Total Revenue		149	148	147	146	146	145	144	143	143	142	141	141	140	139	138	138	137	136	136	135	134	134	133	132	237
Expenses (In Million NRs.)																										
O&M		16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Battery Replacement Cost												200														
Total Expense		16	16	16	16	16	16	16	16	16	16	216	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Gross Operating Profit (EBITDA)		133	132	131	131	130	129	128	128	127	126	-74	125	124	123	123	122	121	121	120	119	119	118	117	117	221
Cash Flow:(In Million NRs																										
Cash Flows from Operating Activities																										
EBITDA		133	132	131	131	130	129	128	128	127	126	-74	125	124	123	123	122	121	121	120	119	119	118	117	117	221
Interest Payment		-74	-71	-69	-66	-63	-59	-56	-52	-47	-42	-37	-31	-24	-17	-9	0	0	0	0	0	0	0	0	0	0
Total		59	61	63	65	67	70	73	76	80	84	-111	94	100	107	114	122	121	121	120	119	119	118	117	117	221

Cash Flows from Investing Activities																										
Installed Cost	1050																									
Total Capital Cost	1050																									
Cash Flows from Financing Activities																										
Debt	735																									
Equity	315																									
Debt Principal Repayment	0	-23	-25	-28	-31	-34	-37	-41	-45	-50	-55	-60	-66	-73	-80	-88	0	0	0	0	0	0	0	0	0	0
Total	1050	-23	-25	-28	-31	-34	-37	-41	-45	-50	-55	-60	-66	-73	-80	-88	0	0	0	0	0	0	0	0	0	0
Project Returns (In Million NRs.)																										
Project Returns: Pre-Tax																										
Issuance of equity	-315	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pre-tax cash flow	0	36	35	35	34	33	32	32	31	30	30	-171	28	27	27	26	122	121	121	120	119	119	118	117	117	221
Total	-315	36	35	35	34	33	32	32	31	30	30	-171	28	27	27	26	122	121	121	120	119	119	118	117	117	221
Project Returns: After-Tax																										
Federal Income Taxes																										
EBITDA		133	132	131	131	130	129	128	128	127	126	-74	125	124	123	123	122	121	121	120	119	119	118	117	117	221
Interest Payment		-74	-71	-69	-66	-63	-59	-56	-52	-47	-42	-37	-31	-24	-17	-9	0	0	0	0	0	0	0	0	0	0
Tax Depreciation		-38	-38	-38	-38	-38	-38	-38	-38	-38	-38	-38	-38	-38	-38	-38	-38	-38	-38	-38	-38	-38	-38	-38	-38	-38
Taxable Income		21	23	25	27	29	32	35	38	42	46	-149	56	62	69	76	84	84	83	82	81	81	80	79	79	183
Tax Rate (%/year)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tax		0	0	0	0	0	0	0	0	0	0	0	-6	-6	-7	-8	-17	-17	-17	-16	-16	-16	-16	-16	-16	-37
Total	-315	36	35	35	34	33	32	32	31	30	30	-171	23	21	20	18	105	105	104	104	103	102	102	101	101	184
Cumulative Cashflow	-315	-279	-243	-209	-175	-142	-109	-78	-47	-16	13	-158	-135	-114	-94	-76	30	134	238	342	445	547	649	750	851	1036

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By Narayan Shrestha

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