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Sonam Kunwar

Enhancing Sustainable Energy Management through System Dynamics and Project Management: A Case Study of Butwal Power Company, Nepal

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Author:	Sonam Kunwar
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ABSTRACT:

The study examines how sustainable energy management can be improved through the integration of System Dynamics and project management approaches, using Butwal Power Company as a case study. Sustainable energy management is becoming increasingly important in hydropower organizations due to environmental challenges, financial pressures, and stakeholder expectations. Previous studies have highlighted the importance of sustainable project management and System Dynamics in improving energy management; however, limited research has examined their integration in Nepal's hydropower sector. The study addresses the research question: *How can the integration of System Dynamics and sustainable Project Management practices enhance sustainable energy management at Butwal Power Company (BPC)?*
A qualitative single-case study design was utilized, and data was collected through semi-structured interviews with organizational employees. This approach helped identify sustainability challenges, organizational practices, and the role of System Dynamics in improving project planning and decision-making. The research adds to theory by integrating System Dynamics with sustainability-focused project management in the context of hydropower management in a developing nation, an area that is not fully studied in the existing research.

The findings suggest that sustainability actions within the organization are affected by interrelated environmental, financial, and stakeholder factors. Applying a theoretical framework based on feedback system analysis, the study identifies major feedback connections and delayed effects influencing sustainability outcomes. The study emphasizes the operational value of integrating System Dynamics tools into management decision processes, risk management and long-term sustainability planning. The study provides useful insights for hydropower management, sustainability planning and project planning in Nepal's energy industry. This study contributes both theoretically and practically by demonstrating how the integration of System Dynamics and project management can support sustainable energy management in hydropower organizations, particularly in developing country contexts such as Nepal.

KEYWORDS: *Sustainable Energy Management, System Dynamics, Project Management Practices, Sustainability, Hydropower Sustainability*

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Abbreviations

BPC: Butwal Power Company

SD: System Dynamics

SPM: Sustainable Project Management

SEM: Sustainable Energy Management

PM: Project Management

CLD: Causal Loop Diagram

TBL: Triple Bottom Line

GDP: Gross Domestic Product

IV: Independent Variable

DV: Dependent Variable

GDPR: General Data Protection Regulation

ROI: Return on Investment

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Student Name: SONAM KUNWAR

Student Number: 2402393

Programme: MSc Industrial Engineering and Management

Title of Thesis: Enhancing sustainable energy management through System Dynamics and project management: A case study of Butwal Power Company, Nepal

1 Introduction

The international transformation towards sustainable energy management is significant as the transition toward sustainable energy frameworks is essential for reducing climate-related emissions and achieving energy balance within sustainability targets (Lv, 2023). In the context of developing economic systems, applying sustainable energy approaches and eco-friendly energy methods is crucial due to fast financial growth and rising power usage and the requirement to manage institutional, financial and technological challenges (Falcone, 2023). Hydropower projects are essentially complex systems comprising environmental, technical, financial and societal aspects, these elements are required to be aligned to achieve sustainable results (Liu et al., 2012). System Dynamics has been broadly implemented in energy strategy modelling to analyze the feedback loops, time delays and complicated relationships within energy frameworks (Sterman, 2018). In the same way, sustainable project management highlights the integration of environmental, societal and financial elements throughout power program stages that are progressively recognized and crucial to improve eco-friendly outcomes (Piwowar-Sulej et al., 2023). In this context, BPC plays an important role in Nepal's hydropower sector and sustainable energy development. This study enhances the theoretical knowledge of sustainable management in Nepal’s hydropower sector.

1.1 Background of Study

Butwal Power Company (BPC) is one of the leading privately owned hydropower companies in Nepal. Nepal has extensive hydroelectric capacity because of its flowing water resources; however successful management of hydropower developments continues to be a serious challenge (Sharma & Awal, 2013). Hydropower represents the backbone of Nepal's electricity supply and plays an important role in national economic growth and energy stability (Bhatt & Joshi, 2024). Despite its significant potential, the industry faces sustainability challenges such as ecological impacts, climate-related water flow changes, investment limitations and project execution delays (Singh et al., 2022).

Furthermore, governance and organizational alignment challenges continue to constrain effective long-term hydropower development in Nepal (Ojha, 2025). Sustainable energy management has thus emerged as progressively important in maintaining sustainable operational effectiveness, environmental sustainability and social and economic stability in the hydropower industry (Bhatt, 2017).

Globally sustainable energy management highlights the incorporation of environment related economic and social components into energy strategy formulation along with implementation (Bocken, 2020). This concept is consistent with the triple bottom line approach which encourages organizational responsibility beyond financial results. Triple Bottom Line Framework highlights the integration of ecological conservation, social justice, economic stability and organizational decision-making processes promoting growth impacts aligned with environmental, societal, economic aspects (Elkington, 1998; Slaper & Hall, 2011). In developing countries like Nepal, hydropower projects are required not only to generate energy but further deal with environmental sustainability, stakeholder expectations and their concerns along with long-term sustainability (Dhakal et al., 2022; Sovacool et al., 2020).

Hydropower systems are inherently complex, including interconnected technological, environmental, regulatory, and administrative components that traditional linear management approaches often struggle to address (Sterman, 2018). System Dynamics Theory assists in analyzing response cycles, delays and long-term system patterns, thus enhancing improved policy decisions in such complex settings (Waeselynck & Pfahl, 1994; Sterman, 2000). Similarly, efficient project management practices remain important for assuring that hydropower projects are implemented within a specified scope, schedule, budget and performance standards while gradually including environmental and social concerns into strategic planning and delivery (Agyekum et al., 2021). Modern project management studies highlight the increasing relevance of incorporating sustainability performance indicators and economic goals to promote long-term project success and corporate sustainability (Agyekum et al., 2021; Silvius & Schipper, 2014). Structural systems and energy projects are often exposed to risks such as budget overruns, time delays, stakeholder conflicts and regulatory compliance issues which make sustainable development integration within strategic planning and implementation essential (Agyekum et al., 2021). Integrating sustainable development concepts into project management systems improves sustainable value creation and reduces negative ecological and societal effects.

However, even with the widely accepted relevance of the two approaches, namely System Dynamics and sustainable project management, empirical studies analyzing their combined utilization in the context of Nepalese hydropower organizations in Nepal especially in the case of Butwal Power Company (BPC) is still limited (Martens & Carvalho, 2017; Silvius et al., 2017; Sterman, 2018). Therefore, this study aims to address this gap by examining the way in which the integrated implementation of systems thinking and sustainable project administration methods can improve energy sustainability performance within Butwal Power Company.

1.2 Research Gaps, Question and Objectives

To methodically determine research gap, this study categorizes existing limitations within contextual gap, evidence gap, knowledge gap and theoretical gap (Ridder, 2014).

Contextual Gap

Although eco-friendly energy management and hydropower growth extensively examined international policy frameworks, limited research has examined these issues within the organizational context of hydropower companies in developing countries (Falcone, 2023). Existing studies in hydropower industry primarily concentrate on national energy capacity, regulatory challenges and infrastructure growth rather than company-level strategies (Bhatt & Joshi, 2024). Moreover, evidence-based case analysis examining how particular hydropower firms address long-term sustainability challenges in project design and operational-level strategic decision remains limited (Gyanwali et al., 2020). Therefore, there is lack of context-specific empirical evidence on how sustainability-focused administration strategies can be implemented within private hydropower organizations like Butwal Power Company (BPC) (Pandey & Patodiya, 2023). Examining contextual gap is important in understanding how sustainability models function in real organizational settings within Nepal's hydropower sector.

Evidence Gap

Prior studies on sustainable infrastructure management primarily concentrate on regulatory models, technical efficiency modelling or sustainability impact studies (Piwowar-Sulej, 2023; Lv, 2023). Empirical organizational-level studies examining sustainable operational strategies within hydropower companies within developing countries remain limited (Falcone, 2023).

Within the Nepalese context, studies have mainly focused on hydropower capacity, policy challenges and national-level regulatory frameworks instead of organizational sustainability management (Bhatt & Joshi, 2024). Consequently, many hydropower studies mainly focus on regulatory framework and policy challenges rather than organizational-level sustainability management (Pandey & Patodiya, 2023). This indicates that there are limited case-based studies examining sustainability practices that are implemented within private hydropower companies like Butwal Power Company (BPC).

Knowledge Gap

System Dynamics is commonly used energy systems modelling and projection analysis to understand interactive system responses, delays and functional patterns (Sterman, 2002; Leopold, 2015). Similarly, sustainability-oriented project management studies highlight the demand to incorporate nature-related social and regulatory management principles into project life cycle stages methods to enhance sustainable development outcomes (Silvius & Schipper, 2014; Martens & Carvalho, 2015).

There is limited research that has examined how System Dynamics modelling and sustainable project management practices can be integrated within large-scale hydropower projects.

Theoretical Gap

The literature considers System Dynamics theory, sustainability-oriented project management separate conceptual frameworks with limited theoretical integration, this study therefore aims to resolve theoretical and situational gaps (Sterman, 2002; Silvius & Schipper, 2014). This theoretical segregation limits the development of integrated sustainability governance frameworks capable of managing both system-wide complexity and project management structures simultaneously (Martens & Carvalho, 2015). Particularly in emerging economy, hydropower project environments integrated conceptual frameworks continue to be limited (Falcone, 2023). Therefore, clear theoretical and evidence gaps relating to integrated application of System Dynamics, sustainable project management improve long-term infrastructure management within Nepal-based hydropower companies.

This study aims to examine how System Dynamics and sustainable project management perspectives can be integrated to provide insight into sustainable energy management within a hydropower organization.

Table 1. Summary of Research Gaps.

Gap Type	What Previous Studies Examined	What Is Missing	Relevance to This Study
Contextual Gap	Studies focused on national policy and developed countries	Organizational-level studies in Nepal hydropower sector	Case study of BPC
Evidence Gap	Policy, environmental impact, technical modelling	Organizational-level case evidence in Nepal	Empirical analysis of BPC
Knowledge Gap	SD and PM studied separately	Interaction between SD and Sustainable PM	Integrated framework
Theoretical Gap	Fragmented theoretical perspectives	Unified sustainability governance framework	Conceptual integration

To address this gap, the study is guided by the following research question:

How can the integration of System Dynamics and sustainable Project Management practices enhance sustainable energy management at Butwal Power Company (BPC)?

This study is based on four main objectives:

1. To analyze the current project management approaches utilized by BPC in achieving sustainable energy goals.
2. To examine how System Dynamics framework can enhance managerial decision-making and strengthen sustainable performance within BPC's hydropower energy projects.
3. To study stakeholder perspectives about major challenges and factors affecting sustainable energy management within BPC.
4. To formulate an integrated framework combining System Dynamics and sustainable project management practices to improve sustainability performance in BPC's operations.

1.3 Definition and Scope of the Study

This section explains the key concepts used in the study and outlines the scope of the research. The study focuses on the relationship between sustainability principles, System Dynamics and project management practices in the context of hydropower energy management. Clarifying these concepts helps define the theoretical framework of the research and identifies the main areas covered in the study and the aspects that are not included.

This study is structured around three core theoretical constructs: Sustainability, System Dynamics and Project Management Practices.

Sustainability: Sustainability refers to the integration of environmental, social and economic factors to ensure long-term sustainability of hydropower development and operations (Agyekum et al., 2021). Under the sustainability dimension, the study explores sustainability-oriented energy management and hydropower sustainability within the organizational setting of BPC. The emphasis is on environmental, social and economic integration within hydropower operations. National-level sustainability policies are not considered.

System Dynamics: System Dynamics is an integrated systems perspectives approach applied to examine the complex model systems marked by interactive system responses, time delays and irregular system relationships (Naugle et al., 2023). System Dynamics is an analytical approach used to study complex systems through feedback loops, delays and interactions (Becerra-Fernandez et al., 2022). Within the System Dynamics dimension, the study employs conceptual systems thinking examine feedback mechanisms, lag effects and dynamic system interactions impacting organizational sustainability results. Numerical System Dynamics modelling and advanced System Dynamics methods are not considered in this study.

Project Management Practices: Project management represents systematic use of knowledge, skills, and tools and techniques to design, implement, monitor and regulate projects established objectives deadline requirements, funding limits and quality constraints (Dedelyuk, 2016). Project management methods include organized scheduling, implementation, supervision and regulation of initiatives to attain defined goals and objectives effectively (Reddy et al., 2024). Within the Project Management Practices framework, this study analyzes integration of sustainability principles that are integrated into hydropower project planning, governance and implementation processes. The study does not consider financial analysis models or national-level investment studies.

Hydropower Sustainability: Hydropower sustainability is defined as environmentally sustainable, socio-culturally inclusive and economically feasible operational management of hydropower projects over time (Moran et al., 2018).

This study adopts a single-organization case study concentrating on Butwal Power Company (BPC) (Hollweck, 2015). A qualitative research method is used, with data collected through semi-structured interviews (Creswell, 1994; Kallio et al., 2016). Causal Loop Diagrams (CLDs) are developed to qualitatively show dynamic interactions and feedback mechanisms (Sterman, 2002). Sustainable energy management practices do not cover numerical System Dynamics modelling, economic modelling and comparative policy study (Forrester, 2012). The study concentrates on qualitative analysis across the organizational setting of Butwal Power Company (BPC).

1.4 Structure of the Study

This thesis is organized into five chapters.

Chapter one introduces the study providing the contextual background of sustainable energy management within Nepal's hydropower sector and the context-specific importance. This chapter outlines the research gap by identifying evidence, knowledge, and theoretical limitations in existing literature. It also presents conceptual clarifications and scope of the study.

Chapter Two provides a conceptual and empirical review. It discusses the theoretical foundations of Sustainability, System Dynamics, and Project Management and evaluates the existing literature related to hydropower sustainability and energy infrastructure management. The chapter concludes by establishing the conceptual framework.

Chapter three presents the research methodology implemented in the study. It explains the qualitative case study approach using BPC as the case study, data collection through semi-structured interviews, and the development of qualitative Causal Loop Diagrams (CLDs). The chapter also addresses methodological validity, reliability and ethical standards.

Chapter four provides the research findings and discussion of the study. The chapter analyzes empirical findings obtained from interviews and examines sustainability challenges, project management practices, and stakeholder perspectives within BPC. The results are interpreted using System Dynamics concepts and sustainable project management theory. The chapter also illustrates key feedback loops and system interactions influencing sustainable energy management and discusses the findings in relation to existing literature.

Chapter five concludes the thesis by summarizing the core insights and significance of the study. This chapter presents methodological or contextual limitations and suggests directions for future research in sustainability practices and governance in hydropower.

2 Literature Review

This chapter studies the historical governmental, financial and technological context regarding Nepal's energy framework. It examines the structure regarding Nepal's electricity production, major energy sources, established potential along with upcoming estimates. Ultimately, the chapter examines Nepal's energy regulations and sustainable energy plans including focus on hydropower growth and commercial sector involvement.

2.1 Sustainable energy management: concepts and scope

Sustainable energy management reflects a company's capability to preserve power efficiency, operational stability, ecological accountability and sustained resource efficiency (Prasad et al., 2024). Sustainable energy management refers to how System Dynamics, project management practices and stakeholder engagement collectively influence energy operations (Dall-Orsoletta et al., 2026). It highlights the efficient power generation, ecological or environmental effect, planned resource utilization serving as an essential indicator of company effectiveness within hydroelectric companies such as Butwal Power Company (BPC) (Blaskovich, 2012).

The concept of sustainable energy management is based on the broader idea of sustainable development (Alemayehu et al., 2025). However, modern energy related research emphasizes the changing complicated characteristics regarding energy frameworks. Sovacool et al. (2015) claim that energy shifts include technical governmental, financial and societal substructures communicating at the same time. Thus, sustainable energy management needs combined or unified evaluative structures that can identify irregular response procedures (Zou et al., 2021).

One important discussion among the academic studies relates to whether Sustainable Energy Management (SEM) is expected to emphasize energy reliability or ecological long-term viability. Within emerging countries, energy reliability guaranteeing dependable provision during economic expense commonly dominates regulation debate or discussion (Gyanwali et al., 2020). On the other hand, weather-related obligations emission reduction routes progressively need equalizing financial development along with ecological accountability (Shrestha et al., 2024). This challenge is particularly evident in hydropower-dependent economies such as Nepal where hydropower is regarded as sustainable but may still create environmental and social impacts (Koirala et al., 2019).

Another important aspect of sustainable energy management is organizational capability. Organizational standards, regulatory transparency and effective project implementation play a key role in achieving sustainable outcomes (Roberts et al., 2024). Therefore, strategic energy planning or management combine long-term planning level forecasting operational-level administration or management practices (Viviroli et al., 2011).

Sustainable energy management can be better understood by using energy change models that consider power systems as dynamic social and technical systems going through long-lasting structural transformation (Morgunova, 2021). The multi-level view describes changes across three stages: small-scale innovations, social and technical systems and external environment pressures (Geels, 2024). This perspective explains sustainable energy management is not just technical problem and affected by organizational systems, economic factors and policy environments (Awan et al., 2014). In this situation, handling energy sustainably needs matching technology-based innovation with management systems and long-lasting transition plans.

Table 2. Conceptual Perspectives on Sustainable Energy Management.

Definition Focus	Key Dimensions	Indicators
Energy efficiency and system optimization	Economic, environmental	Energy intensity, efficiency
Socio-technical transitions	Political, social, technological	Policy support, innovation
Developing country perspective	Energy security, affordability	Access, reliability
Sustainability balance	Environmental, economic, social	Emissions, cost, equity

This comparison shows long-lasting energy management is complex and differs between situations. Whereas some methods focus on effectiveness and technology-based performance, others highlight social organizational aspects. This reflects the need for a combined structure that joins overall system analysis with organizational methods.

2.2 Sustainability theories applied to energy organizations

Energy companies operate within complex socio-technical systems affecting different environmental balance theories.

Triple Bottom Line (TBL)

Triple Bottom Line (TBL) demonstrates sustainable practices using people, planet and profit outcomes (Elkington, 1998). It is commonly used within the hydropower contexts for economic viability along with expense reimbursement, environmental long-term viability concerns waterway, ecosystem health, ecological diversity along with greenhouse gas effects (Martens & Carvalho, 2015). Societal social resilience involves local population, relocation and advantage distribution (Dyllick & Muff, 2013).

However, opponents argue that Triple Bottom Line (TBL) theory frequently continues to be representative instead of functional (Geels et al., 2017). Organizations might present environmental responsibility indicators lacking in integrating such measures within strategic choices procedures (Silvius & Schipper, 2014). In hydro energy initiatives, economic performance frequently controls long-term viability concerns, especially among progressing nations.

Stakeholder Theory

This theory highlights that companies need to address multiple stakeholder expectations, customers, staff, shareholders and local communities along with suppliers (Mahajan et al., 2023). Hydropower initiatives impact community-based populations, regulators, shareholders and ecological organizations (Singh et al., 2020). Within Nepal, stakeholder disagreement has postponed several initiatives because of land purchase, disagreements and ecological issues (Pandey & Patodiya, 2023).

A key limitation of Stakeholder Theory is that it does not have tools intended to address competing priorities (Sovacool et al., 2015). Although the theory recognizes stakeholders, it fails to offer adaptive simulation methods for the purpose of analyzing future-oriented compromises (Geels et al., 2017).

Institutional Theory

Institutional theory highlights the way policy-related structures along with administration standards influence institutional actions. Nepal's hydroelectric power industry remains strongly affected by permitting frameworks, energy procurement contracts and international import-export agreements (MSaleh & IHassan, 2024).
Importantly, institutional theory describes limitations yet fails to provide model-driven methods intended for forecasting network development (Ojha, 2025). This gap highlights the significance regarding combining model-driven analytical structuring.
Generally, environmental responsibility frameworks offer principle-based fundamentals or foundations but need operational or practical methods intended for execution (Jakobsen, 2015).

In this case, hydropower development, these theories clearly affect company-related decision-making. The Triple Bottom Line framework influences how companies assess trade-offs between financial returns, effects on nature and social responsibilities during planning stage (Das et al., 2025). Stakeholder theory becomes important managing conflicts related to land acquisition, environmental problems and public participation which are common in hydropower projects in Nepal (Pandey & Patodiya, 2023). Institutional theory describes official permissions, authorization process and rules and guidelines influence project time schedule money-related decisions (Saikia et al., 2024). Thus, sustainability hydropower organizations are not controlled by single theoretical perspective but come from a combination of economic priorities, stakeholder pressures and organizational restrictions (Hite, 2025).

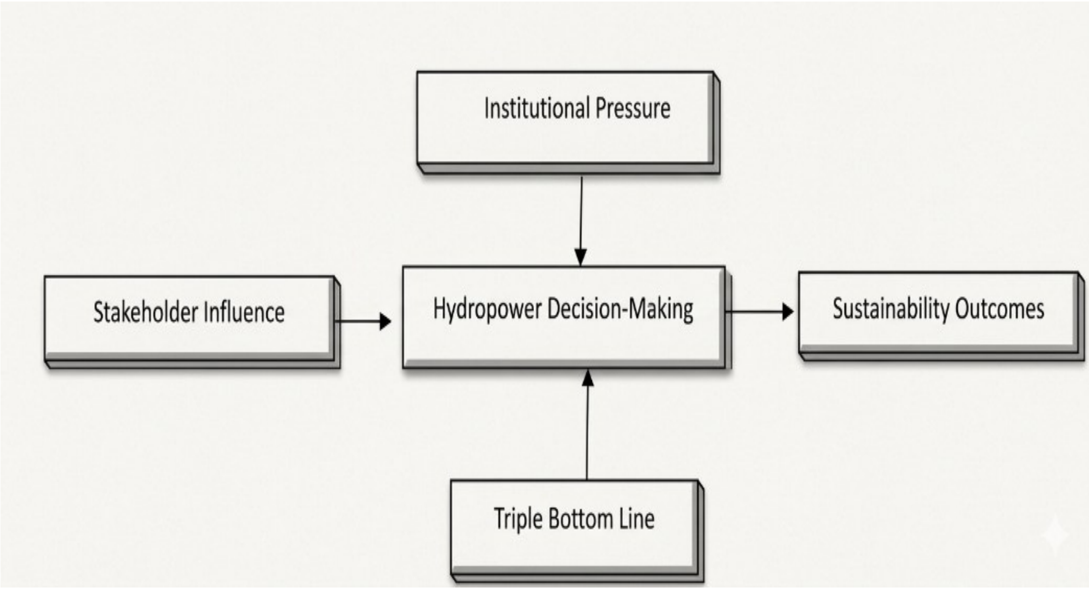

Figure 1. Integrated Theoretical Framework

The diagram shows that hydropower decision-making is influenced by three linked factors: economic, environmental, and social considerations (TBL), people's demand and organizational pressures. These elements work together in changing ways affecting project results and lasting environmental and social outcomes. This perspective provides stronger study base compared to examining each theory separately.

Table 3. Comparison of Sustainability Theories.

Theory	Core Idea	Strength	Limitation	Relevance to Hydropower
Triple Bottom Line (TBL)	Balance economic, environmental, social goals	Holistic sustainability view	Often not practically implemented	Helps evaluate project feasibility and impacts
Stakeholder Theory	Value for all stakeholders	Improve engagement and legitimacy	Lacks conflict resolution mechanism	Important for managing local community and regulators
Institutional Theory	Influence of rules and governance	Explains regulatory impact	Limited predictive capability	Explains licensing, approvals, and policy delays

The comparison highlights that although each theory provides useful understanding, none is enough by itself. Sustainable energy management in hydropower requires combining these views to deal with social and organizational difficulties.

2.3 Hydropower sustainability in Nepal: key challenges and drivers

Nepal is a landlocked country characterized by diverse geographical features. The country shifted towards union-based representative state during 2008 and implemented recent legal framework during 2015 reorganizing administration as central state-level and community-level stages. This reorganization substantially affected facilities, growth and energy administration (Shrestha, 2025).

Nepal is classified as a developing nation having money transfers, agriculture and service sector adding significantly toward GDP (Karki & Pradhan, 2024). However, energy reliability continues to be an essential factor regarding manufacturing, growth and financial change (Kafle, 2025). Traditionally, Nepal encountered long-term electricity scarcities and periodic power cuts because of insufficient production, potential and distribution limitations (Shrestha, 1970). Even though substantial advancements have been realized from 2017, the systemic issues continue (Bhatt, 2017).

The studied challenges suggest that hydropower sustainability in Nepal is not caused by separate factors but linked overall System Dynamics (Samjhana & Manan, 2025). Environmental risks like weather changes affect water supply that clearly impact power generation and financial performance (Kim et al., 2022). Similarly, social problems related to land acquisition can slow down project schedule, increase costs and lower investor belief (Smyth & Vanclay, 2024). Based on theory, interactions align with system-based thinking, which highlight response relationships and non-linear patterns in complex systems (Matta, 2025). Therefore, understanding hydropower sustainability needs to move beyond simple explanation analysis towards combined system-focused method (Habersack & Bradley, 2022).

Hydropower Sustainability Driver–Challenge

Table 4. Hydropower Sustainability Drivers and Challenges.

Dimension	Key Drivers	Key Challenges	Sustainability Impact
Environmental	Renewable energy potential, low emissions	River ecosystem disruption, climate variability	Affects long-term resource availability
Economic	Export potential, energy demand growth	High capital cost, financing risk	Influences project feasibility
Social	Employment, rural development	Community conflict, resettlement issues	Causes delays and resistance
Institutional	Government policies, energy strategies	Bureaucratic delays, regulatory complexity	Impacts project implementation

Hydropower serves as the backbone of Nepal's energy strategy. Although it provides or offers minimal functional discharges, the system's long-term viability is debated.

1. **Environmental Challenges:** River-based hydropower initiatives modify or change river ecosystems and impact ecological diversity (Shrestha, 2015). Weather patterns change additionally raise water-related unpredictability complicating or threatening sustained potential projecting (Sharma & Awal, 2013).
2. **Financial and Governance Risks:** Infrastructure large-scale projects worldwide experience expenses, overspending and timeline setbacks (Flyvbjerg, 2014). Within Nepal, power transfer obstacles and funding or capital limitations increase uncertainty liability (Bardhan, 2002).
3. **Social Risks:** Local population along with remuneration conflicts frequently hinder initiative time frames (Singh et al., 2020). These community-related aspects immediately influence initiative long-term viability effectiveness.

Drivers of Sustainability

Despite challenges hydroelectric power expansion remains motivated or driven by international sales, potential area-specific energy trade and country-level environmental obligations (Aryal et al., 2024).

The crucial challenge represents that hydroelectric power, and sustainability relies not only on technological production potential but also interactive interconnections between environmental conditions, monetary resources and consumption expansion (Geels et al., 2017). This complication supports implementing system-based modeling methods.

2.4 System Dynamics: core concepts (feedback loops, delays, leverage points)

System Dynamics is an analytical approach used to study complex systems through feedback loops, delays, and interactions (Becerra-Fernandez et al., 2022). Within energy coordination, System Dynamics enables managers or supervisors to understand and analyze the relationships among materials creation and utilization facilitating hypothetical analysis along with knowledge-based decision making (Naeem et al., 2023). Through modeling or simulating utility systems adaptively firms or organizations can predict outcomes arising from managerial choices and enhance long-term sustainable results (Alemayehu et al., 2025). System Dynamics is especially beneficial within hydropower projects for recognizing constraints, evaluating regulatory measures and analyzing systemic consequences regarding power efficiency and environmental performance or outcomes (Laimon et al., 2022).

2.4.1 Feedback Loops

Energy investment or allocation of fund enhances production capability that affects power charges along with consumption expansion (Sterman, 2002). Strengthening cycles or loops might speed up expansion whereas regulating loops maintain equilibrium frameworks.

2.4.2 Time Delays

Hydropower initiatives or projects include extended development durations (Sterman, 2002). Setbacks or delays between capital allocation or investment choices and functional production might create supply demand imbalances (Famiyeh et al., 2017).

2.4.3 Leverage Points

Leverage points or zones indicate planned involvement domains in which small regulatory changes produce substantial framework outcomes (Leventon et al., 2021).

System Dynamics is based on feedback rules and unpredictable system actions in which system setup decides long-term changes (Carreno, 2024). Unlike linear study methods, internal actions coming from feedback loops, time lags and collections (J. S. Li et al., 2023). Reinforcing loops (positive feedback) cause growth or decline whereas negative cycles (negative feedback) control systems (Wellmanns & Schmiemann, 2020). Time delays between choices usually create ups and downs and policy resistance which often happen in large-scale infrastructure systems like hydropower (Pomerening, 2009).

2.5 System Dynamics applications in energy management and policy

Latest studies use System Dynamics (SD) regarding sustainable energy transformations along with physical systems development planning (Wang et al., 2021; Laimon et al., 2022). SD frameworks have been applied to

- Estimate electricity demand
- Examine sustainable Policy benefits (incentives)
- Model power network reliability during weather patterns fluctuations,

System Dynamics is especially beneficial within hydropower projects for recognizing constraints, evaluating regulatory measures and analyzing systemic consequences regarding power efficiency and environmental performance or outcomes (Irianto & Wasesa, 2026). However, mainly System Dynamics operate or exist as country-level along with regulation-focused (Sterman, 2002). Organizational-level implementations within non-governmental hydropower firms continue to be insufficiently studied especially within South Asian region (Gulagi et al., 2021). This indicates there is major study opportunity.

While System Dynamics is commonly used in energy planning rules and designing, its advantages lie in including long-term system behavior, feedback interactions and scenario analysis (Mutingi et al., 2017). However, System Dynamics models are strongly affected by initial ideas, data availability and model limits which may reduce forecasting accuracy (Kanellos et al., 2025). Most of the applications concentrate on country-level and policy-level analysis, with little focus on company-level decision-making (Wijnberg et al., 2002).

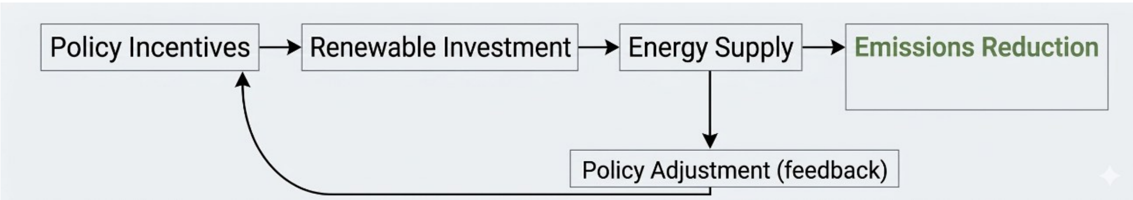

Figure 2. System Dynamics Policy Model in Energy Systems

Table 5. Applications of System Dynamics in Energy Sector.

Study Context	Application Area	Key Insight	Limitation
National energy policy	Demand forecasting	Long-term planning support	Data sensitivity
Renewable transition	Policy simulation	Scenario analysis	High complexity
Energy markets	Price dynamics	Market feedback understanding	Limited firm-level use

2.6 Project Management in hydropower: lifecycle, governance, and controls

Hydropower projects involve multiple phases, from feasibility studies to operation. Project management highlight objectives or project boundaries schedule, cost, uncertainty and reliability or quality regulation (Sharma & Awal, 2013). In relation to sustainable energy or power initiatives, effective project management provides timely delivery, efficient resource use, risk mitigation and stakeholder collaboration (Change, 2023). Effective project management methods minimize delays, improve operational effectiveness and coordinate project results in accordance with sustainable development goals (Martens & Carvalho, 2015).

Nevertheless, traditional project management methods remain challenges because of emphasizing upon immediate or temporary indicators while overlooking system-wide relationships (Martens & Carvalho, 2016). Infrastructure initiatives often encounter overconfidence bias and underassessing risk vulnerability (Flyvbjerg, 2014).

Within Nepal's weak hydroelectric initiatives is associated with financial overruns, sustainability issues, however, strong effective enhances renewable energy governance (Pokharel & Rijal, 2021). Enhancing project administration and monitoring systems remains necessary.

Traditional project management concentrates on time, cost and scope control, whereas eco-friendly ways go beyond including nature-related community concerns (Kehinde, 2025). In hydropower projects, this difference is particularly important because of strong effect on nature, long project lifecycles and importance of stakeholder concerns (Ghimire et al., 2021). While traditional methods focus on efficiency, eco-friendly project planning prioritizes future benefits and reducing risks (Elseknidy et al., 2025).

Figure 3. Hydropower Project Lifecycle

Table 6. Risk Classification in Hydropower Projects.

Risk Type	Example	Impact
Environmental	River disruption	Sustainability risk
Financial	Cost overrun	Profitability
Social	Community conflict	Project delay
Institutional	Regulatory approval	Implementation delay

2.7 Sustainable Project Management: integrating sustainability into delivery

Sustainable project management expands beyond traditional project management by integrating ecological and societal standards within project administration (Silvius & Schipper, 2014).

Sustainable Project Management focuses on:

- Project phases ecological influence evaluation
- Stakeholder involvement models
- Climate-resilient facilities or infrastructure planning
- Sustainable outcomes generation.

Latest study suggests that long-term viability needs to remain integrated during the long-term preparation phase instead of included in the process of execution (Martens & Carvalho, 2016).

Still sustainable project management independently fails to represent large-scale response loops and relationships affecting initiative sustainability (Martens & Carvalho, 2015). This approach emphasizes operationalization instead of system-based modeling.

Sustainability integration occurs through adding environmental and social factors through project stages (Stanitsas et al., 2020). While planning, studies related to the effects on nature help in decision-making. In the implementation stage, reducing waste and stakeholder engagement are prioritized. In the stage of operation, long-term performance is monitored by using indicators like emissions, cost-effectiveness and social impact (Ezeh et al., 2024)

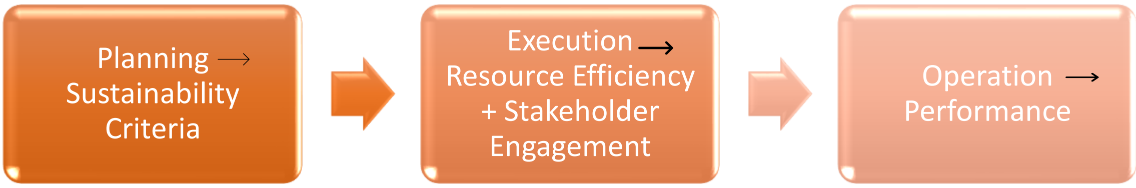

Figure 4. Integration of Sustainability in Project Lifecycle

Table 7. Sustainability Performance Indicators in Hydropower Projects.

Dimension	Indicator
Environmental	Emissions, water impact
Economic	Cost efficiency
Social	Community satisfaction

2.8 Integrating System Dynamics and Sustainable Project Management

A key limitation in existing research is the lack of integration between System Dynamics (SD) and Sustainable Project Management (SPM). System Dynamics supports strategic analysis of complex systems, while sustainable project management focuses on practical implementation of sustainability principles within projects (Rodrigues & Bowers, 1996). Combining both allows:

- Predicting regulation along with economic environment response loops impacts.
- Enhancing vulnerability or uncertainty prediction.
- Coordination or matching project execution in accordance with sustainable energy framework.

Rodrigues and Williams (1998) suggest that integrating System Dynamics (SD) along with project management improves timeline and uncertainty forecasting. Regarding hydropower firms, this combination may improve or enhance both planning and project performance.

Overall existing studies show that although sustainable development frameworks provide regulatory principles for energy management, operational execution remains limited. System Dynamics provides analytical modelling tools while sustainable project management provides structured processes for project execution (Calderon-Tellez et al., 2023). However, insufficient studies combine these methods within hydropower organizations. Based on the reviewed literature, several limitations can be identified, which form the basis of this study.

The integration of System Dynamics and Sustainable Project Management occurs through connecting strategic simulation with project implementation (Calderon-Téllez et al., 2025). System Dynamics models provide long-term forecasting find response loops while Sustainable Project Management converts understanding into project-based decisions (Leon et al., 2017). This interaction enables organizations to prepare for problems, improve use of resources and align project completion with long-term sustainability goals (Adukpo et al., 2025).

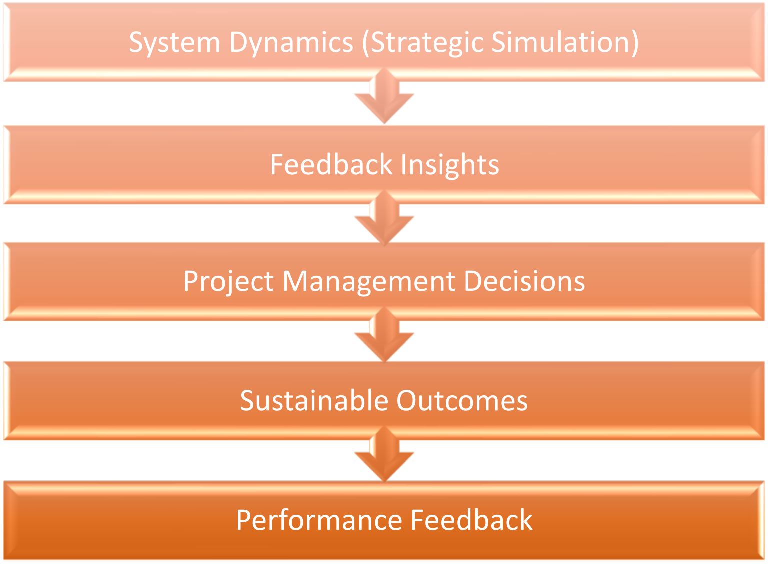

Figure 5. Integrated System Dynamics and Project Management Framework

2.9 Research gap and proposed conceptual framework

The literature review highlights three major gaps that form the basis of this study:

- Insufficient integration of System Dynamics (SD) along with Sustainable Project Management within long-term energy study.
- Inadequate organizational-level case studies within Nepal.
- Lack of systematic models integrating long-term modeling in conjunction with initiative operationalization.

Existing literature has examined sustainable energy management, System Dynamics and Project management independently (Apostolou, 2025). However, few studies combining these areas at an organizational level especially in the case of hydropower developing countries (Yuksel, 2007). Furthermore, company-level applications of System Dynamics are not studied much, creating a gap in understanding strategic planning to support project-level decision-making.

Conceptual Framework

This study suggests one combined conceptual framework which investigates the way the combination of System Dynamics (SD) and Project Management (PM) improves long-term energy management within Butwal Power Company, Nepal.

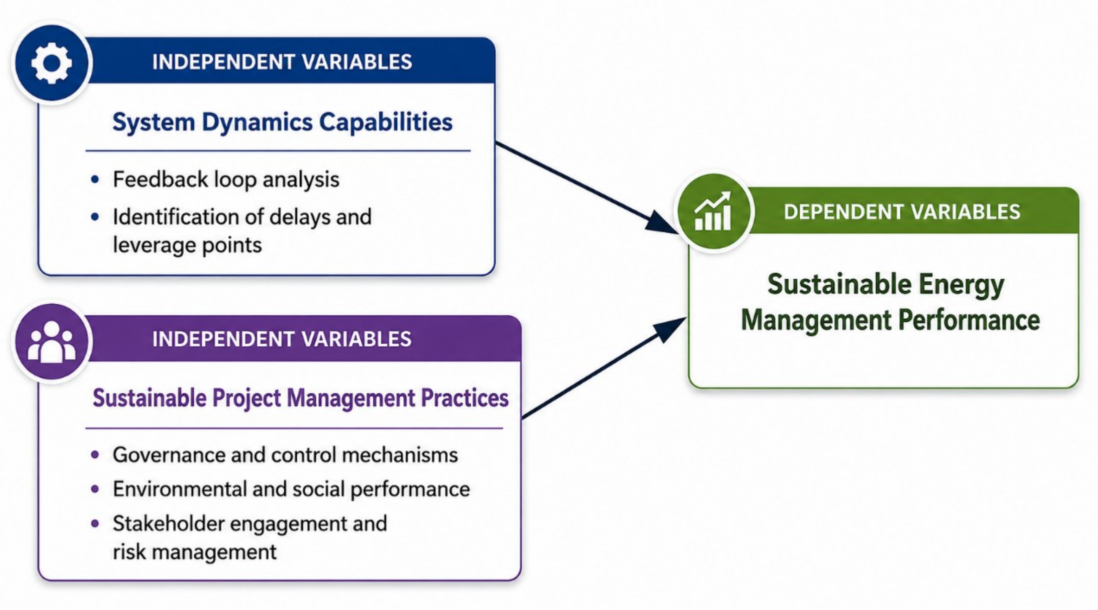

Figure 6. Conceptual framework (Becerra-Fernandez et al., 2022; Agyekum et al., 2021; Shahi 2025; Pandey and Patodiya 2023)

Independent Variables (IV):

- System Dynamics (SD)
- Sustainable Project Management (SPM)

Dependent Variable (DV):

- Sustainable Energy Management (SEM)

The conceptual framework suggests that sustainable energy management is strongly influenced by System Dynamics and Sustainable Project Management. System Dynamics helps by allowing strategic-level understanding by using studying circular responses predicting system modelling. This helps with better long-term planning and decision making (Martinez-Moyano, 2023).

At the same time, Sustainable Project Management affects sustainable energy outcomes through successful project execution, stakeholder management and combining sustainability guidelines throughout the project (Magano et al., 2021).

The framework considers a direct relationship between strategic-level modelling (System Dynamics) and operational-level practices (Project Management) independently and together support sustainable energy management. This approach makes the analysis process easier while maintaining strong theoretical relevance.

3 Research Methodology

This chapter explains the research methods adopted to examine sustainable energy management in the hydropower industry. It presents research philosophy, research design, case selection, data collection methods, sampling approach and analytical methods applied in the study. The chapter additionally explains the System Dynamics conceptual modelling method used in the study followed by explanations regarding robustness and ethical considerations and explains how System Dynamics that is combined with qualitative analysis, provides deeper insight into Butwal Power Company.

The methodological framework of this study is based on Mark Saunders et al. research onion which provides a systematic approach to research design. The study adopts an interpretivist approach, a qualitative approach and a single case study method to examine the multidimensional nature of sustainable practices and decision-making processes. This approach ensures consistency among the research objectives, framework and data analysis methods, thus, improving research clarity and transparency.

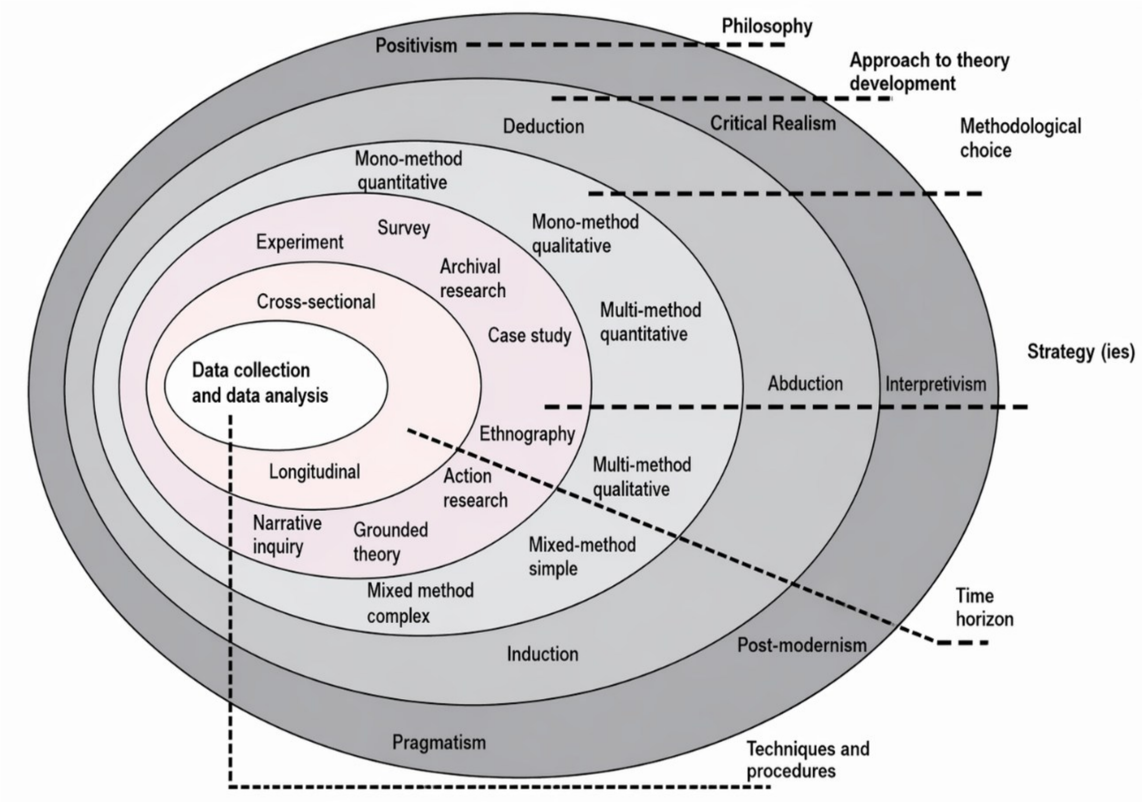

Figure 7. Research Onion Framework (adapted from Saunders et al., 1996)

The research onion framework helps to logically explain each research method choice and ensures consistency between research objectives and conceptual framework.

3.1 Research philosophy and approach

The philosophical foundation refers to the collection of beliefs, knowledge and nature of reality that informs research procedure (Saunders et al., 1996). This study was based on an interpretivist approach. The interpretivist approach assumes that social reality is socially constructed and is best understood through interpretations, concepts and contextual influences instead of positivist numerical assessment exclusively (Djamba & Neuman, 2002). This approach is especially suitable for this study because sustainable energy management depends on human decisions, organizational behavior and contextual factors which cannot be fully understood using numerical data alone.

This study uses a qualitative research approach, which enables understanding of how sustainable energy practices are applied in a hydropower company. Compared to quantitative methods, it provides deeper insights into processes, challenges, and decision-making (Bhandari et al., 2018). This is important for understanding the complexity of energy management and project work in Nepal's hydropower sector.

Even though positivism emphasizes factual measurement and quantitative analysis, it is less appropriate for this study, as this study aims to understand complex organizational operations and stakeholder perspectives. This study uses an interpretivist approach considering that the reality is shaped by society, and knowledge (epistemology) is developed through understanding participants' experiences. This approach is relevant for understanding the system complexity and environmental elements in sustainable energy management.

This philosophical approach clearly impacts data interpretation and analysis. Instead of aiming for broadly applicable laws, this study emphasizes understanding the trends, relationships and perceptions arising from qualitative data. Thematic analysis was used to explain participant's opinions whereas, System Dynamics modelling supported in understanding overall system interactions. This integration ensures that both human experiences and system complexity are successfully represented.

3.2 Research design: qualitative single-case study

This study adopts a single-case study design focusing on Butwal Power Company. This approach is suitable when the research aims to study a real-life situation in depth within its natural setting (Coombs, 2022). This design is particularly suitable as it enables in-FY

The selection of single-case study is supported as it enables the detailed context-based analysis of organizational practices. A single case is suitable when the case is unique or provides detailed understandings into modern day problems such as sustainable energy management in hydropower organizations (Annamalah et al., 2025). In this study, Butwal Power Company provides a relevant information-rich context for studying the combination of System Dynamics and Project Management activities. While the findings might not be numerically generalizable, the study aims for theory-based generalization linking empirical insights to existing theories and frameworks.

This design helps to better understand how sustainable energy management is practiced within Butwal Power Company in a real-world setting.

3.3 Case selection and study context: Butwal Power Company

Butwal Power Company was selected for this study as the case because of its important role in Nepal's hydropower sector. The company has many years of experience in developing and managing hydropower projects, making it a suitable case for examining sustainable energy management practices.

Nepal depends heavily on hydropower for electricity generation. Companies like Butwal Power Company operate under environmental limits, regulatory policies and infrastructure challenges. These factors make this case useful for examining how sustainability is managed in real situations.

The selection of Butwal Power Company is determined by three main criteria: strategic relevance, representativeness, and accessibility. The firm has a significant role in Nepal's hydropower industry and is involved in various project planning and management activities, which makes it suitable for analyzing sustainable energy management practices. It represents a common hydropower company functioning under legal and environmental context of Nepal enabling the findings to show wider sector-related situations. Additionally, practical availability to organizational understandings and participants enables in-depth qualitative analysis. The organization's participation in project implementation and operational management provides appropriate context for analyzing the relationship between System Dynamics and project management in achieving sustainability results.

3.4 Data sources and data collection methods

Primary data were collected through semi-structured interviews with selected employees from Butwal Power Company who are involved in project management and sustainability practices. Semi-structured interviews are appropriate for this qualitative research as they are flexible while maintaining the focus on key research objectives (Jamshed, 2014). This method allows participants to share detailed ideas about organizational processes, challenges and decision-making related to sustainable energy management.

The interview guide was developed based on study objectives, with main themes comprising sustainable energy management practices, project management processes, and system-level decision-making. This approach ensures alignment between data collection and the study's conceptual framework.

Along with primary data, secondary data were collected by reviewing company documents like project reports, sustainability reports and policy documents. This helps to provide contextual understanding and supports the findings from the interviews (Ajayi, 2025). In energy sector studies, using company and policy documents is important for understanding how organizations function and how systems are structured (Drago & Gatto, 2022).

Documents were chosen based on the relevance, credibility and timeliness including project documents, sustainability reports and organizational guidelines that specifically relate to energy management and project implementation.

The use of both primary and secondary data helps to compare information from various sources, which improves the research and makes it more reliable and trustworthy (Meydan & Akkaş, 2024). This approach supports data triangulation, improves reliability of information, and provides a comprehensive understanding of sustainable energy management practices.

All the interviews were recorded with participants' permission and later transcribed to ensure accuracy. To minimize bias in self-reported data, responses were validated with organizational documents where appropriate. This helps enhance the reliability and validity of the findings.

This method made it possible to gather practical insights from the participants about how sustainability is handled in everyday organizational work.

To provide a clear overview of the interview process, Table 8 presents participant information including roles, interview duration and participant IDs.

Table 8. Interview Participant Details

Position/Role	**Participant ID**	**Interview Duration**
Project Manager	BPC1	45 min
Senior Engineer	BPC2	45 min
Hydropower Engineer	BPC3	60 min
Sustainability Officer	BPC4	45 min

Project Coordinator	BPC5	30 min
Technical Officer	BPC6	45 min

The table illustrates the variety of participants and enhances the transparency and credibility of the data collection process which is essential for ensuring the reliability of qualitative findings.

3.5 Sampling strategy and participant recruitment

Purposive sampling was used in this study as it allows the selection of participants with relevant expertise in hydropower project management and sustainability practices. In qualitative research, purposive sampling is commonly used to identify participants who can provide useful and meaningful information (Meydan & Akkaş, 2024).

Participants were selected according to their active participation in project management, sustainability activities or decision-making processes. Employees who do not have relevant roles or sufficient experience in these areas were excluded to ensure quality and relevance of the data.

Staff members of Butwal Power Company who are involved in project planning, implementation and sustainability activities are considered as the target population for this study. For sample size, approximately 5-10 participants are considered sufficient to achieve in-depth understanding in a single-case qualitative study (Wutich et al., 2024).

The sample size (5-10 participants) is regarded as sufficient to achieve depth of understanding and theme-based saturation, which is the main objective of qualitative case study research instead of numerical generalization.

Through formal communication with the organization and professional contacts, participants were selected. Before participating, participants were informed about the purpose of the study and that their participation is voluntary.

Potential sampling bias may occur because of purposive selection and organizational structure. Power dynamics within Butwal Power Company may affect how participants respond, especially in hierarchical relationships. To minimize this, confidentiality and voluntary participation were ensured to promote open and truthful responses.

3.6 Data analysis procedures (thematic analysis and coding)

The data collected for this study were analyzed using thematic analysis which is suitable for identifying and interpreting patterns in qualitative data. The data collected through semi-structured interviews were analyzed manually using thematic analysis, following the six-phase framework by (Braun & Clarke, 2006; Ahmed et al., 2025).

A hybrid coding method was used by integrating deductive codes based on conceptual framework (e.g., System Dynamics, project management, sustainability) along with inductive codes that arise from the dataset.

The data analysis followed several steps. First, interview data were transcribed and reviewed to understand it clearly. Second, initial codes were created from meaningful parts of the data. Third, these codes were grouped into main themes related to sustainable energy management, project management, and System Dynamics.

Themes were formed through repetitive coding and continuous comparison across interview records. They were improved by examining consistency, relevance to research objectives and alignment with the conceptual framework to ensure analytical validity (Ahmed et al., 2025).

The coding process was guided by the study's framework to ensure alignment between theory and findings (Naeem et al., 2023). Thematic analysis is suitable for this study as it maintains analytical rigor and flexibility. This approach ensures systematic and rigorous interpretation of qualitative data.

According to the study's ethical and institutional guidelines, the data were analyzed manually. The manual thematic analysis allowed the study to achieve an in-depth, context-sensitive understanding of participants' experiences, which is important for qualitative research that focuses on depth over numbers (Naeem et al., 2023). Manual coding is adopted to enable more in-depth involvement with data and improved understanding of contextual meanings. Although software tools can assist analysis, manual coding improves flexibility and self-reflection which are essential in qualitative case study research (Basit, 2003).

This analysis helped identify common patterns in how sustainability practices and decisions are understood and applied within the organization.

3.7 System Dynamics conceptual modelling procedure (CLD development)

This study applies System Dynamics (SD) to develop a conceptual model using Causal Loop Diagram (CLD). System Dynamics is useful for studying complex systems that have feedback effects, time delays, and non-linear relationships (Azar, 2012). The CLD development followed these steps:

1. Identification of important variables derived from qualitative data and previous studies.
2. Developing cause-and-effect relationships between variables.
3. Development of feedback loops (amplifying and balancing).
4. Development of the framework structure

Additionally, the CLD development process involves identifying key factors related to energy management, project implementation and organizational performance (Andrei et al., 2022). The relationships between these factors are used to explain the increasing and balancing feedback loops.

System Dynamics has been used commonly in energy policy and studies on sustainability to understand the long-term system patterns and support decision making (Ahmad et al., 2015). In this study, SD supports qualitative results by providing an organized representation of system interactions. Qualitative data from interviews were used to determine system factors, relationships and feedback loops ensuring that the framework represents the real organizational activities and decision-making processes (Dahal, 2025).

To improve reliability, the CLD was verified through repeated evaluation and comparison with existing previous studies. Where possible, feedback from knowledgeable respondents was incorporated to ensure that the system model accurately reflects System Dynamics (Kunc, 2016).

This modelling approach provides insight into how different factors are connected and how they influence sustainable energy management over time.

3.8 Trustworthiness and Ethical Considerations

To maintain the quality and credibility of this qualitative study, trustworthiness and rigor were ensured. In qualitative research, trustworthiness was evaluated using the criteria of credibility, dependability, confirmability and transferability (Ahmed, 2024). These criteria are closely related to ethical research practices as maintaining rigor requires responsible and transparent handling of data.

Credibility was ensured by collecting data from people who have experience working in hydropower project management and sustainability practices within Butwal Power Company. This ensured that the findings reflect real company practices. In addition, triangulation was applied by comparing interview responses and organizational documents which strengthened the validity and consistency of the data (Carter et al., 2014).

Dependability was ensured by documenting the study process such as data collection and analysis process. This allowed the study to be reviewed and understood by others (Sutton & Austin, 2015). An audit trail was kept by recording coding choices, theme development and data analysis steps, enabling transparency in the research process (McLeod, 2024).

Confirmability was ensured by checking that the findings are supported by interview answers and additional data rather than researcher's opinion. Written notes and files about how data was studied were saved to make the process transparent (Kocaman, 2024). It was also ensured by maintaining impartiality in data analysis and connecting findings directly to participant responses (Ahmed, 2024). The researcher recognizes the potential for personal bias in data analysis and ensures self-reflection by carefully examining assumptions across study process. This ensures that the findings are based on data rather than research assumptions (Pannucci & Wilkins, 2010).

Transferability was ensured by providing detailed background information about the Butwal Power Company and other hydropower sectors. This enables the readers to evaluate the applicability of the findings to similar contexts (Drisko, 2024).

Ethical considerations were integrated throughout the research process to ensure participants' safety, data protection, and responsible research conduct.

Informed Consent was obtained from all participants prior to data collection. The document clearly described the objectives of the study, data collection methods, planned use of data, and measures established to ensure privacy and data security. The details were communicated in plain and user-friendly language to support informed consent.

Confidentiality and Anonymity In all cases, verbal agreement was obtained at the start of each interview session, specifically when recordings were being captured. Participants were aware of their participation in the study and their right to discontinue whenever they wished without any explanation. It is clearly stated that all the data from the interviews would be rendered anonymous. Furthermore, the participants were informed that the information they provided would be only used for academic purposes and their data would be securely protected.

Data Protection The data were securely stored and backed up in the cloud which was only accessible to the researcher and the supervisor. All the interview recordings were converted into texts manually. And all the identifying information was removed to ensure confidentiality. Data was stored safely in compliance with institutional ethics guidelines and appropriate data protection regulations like GDPR ensuring that respondent information is protected and used only for academic purposes.

Ethical considerations also influenced the study design especially in ensuring voluntary participation, careful selection of participants and anonymized information usage throughout analysis and reporting.

4 Findings and Discussion

This chapter provides the results of the study and explains those with respect to study aims and existing studies. The analysis is developed upon qualitative data collected via interview sessions and concentrates on interpreting environmentally sustainable energy management within BPC. This chapter is organized into key themes including organizational context project management approaches, sustainability related challenges, stakeholder opinions and understandings related to System Dynamics. Every part provides interpretation or explanation and presents the results along with relevant theoretical concepts ensuring direct relationship between empirical data and study's framework

4.1 Organizational context and sustainability priorities at BPC

The results indicate that BPC functions within a complicated hydropower field where ecological sustainability is identified but not consistently incorporated as a major long-term priority. The organization mainly concentrates on power generation and practical performance, whereas sustainability is frequently perceived in the context of sustained project, environmental compliance and efficient utilization of resources.

One respondent mentioned, "The company's priority is upon project execution and effectiveness. Sustainability is moderately considered, commonly in the terms of fulfilling climate-related rules instead of long-term planning.” (BPC2)

However, environmental sustainability is not implemented through a particular system or policy. Sustainability is integrated within regular functional and project management methods. Majority of respondents mentioned that economic priorities such as expense control and timely project delivery are prioritized more than environmental and societal elements. This shows that environmentally sustainable methods are available but are not completely integrated within the organizational planning.

Such outcomes indicate that environmental sustainability objectives are influenced by external factors including government-related regulations, environmental requirements and customer demand. This demonstrates that the organization responds to ecological challenges rather than directly supporting environmental sustainability initiatives.

The Sustainability approach may be more effectively interpreted via Stakeholder Theory and Triple Bottom Line (TBL) that highlights maintaining balance among financial, ecological and societal goals (Nogueira et al., 2023). Even though BPC demonstrates an authorized dedication regarding environmentally sustainable development. The company's strategic policies and project goals are heavily affected by external demands, regulatory conditions, public requirements and environmental policies. This indicates the organizational reaction in which organizations implement environmentally sustainable approaches to maintain reputation rather than being completely motivated through authentic environmental awareness.

One evident gap is present among the expressed environmental sustainability regulations and the organization's implemented methods in BPC. From strategic dimensions, the organization prioritizes ecological conservation, community participation and long-term environmental sustainability aims. However, implementation is generally restricted or limited by economic limitations, implementation delays and technological challenges.

Although ecological assessments are methodically implemented, those recommendations are not fully implemented because of economic limitations and deadlines (Joshi, 2024). This gap demonstrates the lack of coordination between sustainability goals and real implementation.

This indicates that sustainable methods are insufficiently incorporated within important management-related planning process but remain partially implemented in program compatibility and material accessibility. This approach indicates that economic key concerns continue to influence decision making process with environmental sustainability operating as lower priority instead of completely integrated priority.

4.2 Current Project Management practices supporting sustainability

Project management plays an important role in encouraging environmental sustainability at BPC. This organization adopts structured project management processes including strategy development, time allocation, financial planning and uncertainty handling. Such approaches result in efficient resource utilization and help reduce inefficiency across project implementation.

However, there is a lack of a clear integration of sustainable practices as a core principle in project management. The approach to the handling of environmental and social matters is mostly to comply with the law as opposed to form part of proactive sustainable planning. Environmental evaluations are conducted but often are viewed as regulatory work rather than strategic tools.

One participant commented: “Environmental assessments are needed, but often not used as a planning tool but as a formality” (BPC3). This shows that sustainability is predominantly for compliance, not proactively planned.

Moreover, project management emphasizes the achievement of short-term performance measures (cost, time and quality). Sustainability outcomes are not always considered in decision making for long-term sustainability. This creates a disconnect between project implementation and sustainability objectives. Although BPC has incorporated other project management concepts into the management of projects such as environmental assessments, stakeholder discussions and regulatory monitoring, effectiveness has not been consistent.

These measures are often carried out as formal measures rather than as instruments for integrating sustainability. This means that they have a restricted impact on actual project results. Traditional project management methods mainly focus on budget, time and project scope while sustainable project management expands this focus to include environmental factors and societal factors (Balouch et al., 2024). In the context of BPC, even though aspects of sustainable project management are present, the overall approach continues to remain similar to traditional models. Sustainability aspects are frequently considered at the initial stages but are not regularly tracked across project lifecycles.

This finding emphasizes that environmentally sustainable methods are considered as one supplementary element instead of integrated part of the project management structure. The sustained effectiveness and sustainability related programs are reduced due to lack of regular monitoring and assessment. This limits their contribution to overall project effectiveness.

4.3 Key challenges affecting sustainable energy management at BPC

Various challenges impacting sustainable energy management at BPC are highlighted in this study. Such challenges are interdependent and affect both project results and long-term environmental sustainability.

Environmental challenges are critical because of uncertainty in water resources. Instability or variations in water flow immediately impact energy generation and makes sustained planning difficult. Also, climate risks increase the uncertainty in project outputs.

One respondent stated, "Water supply is uncertain, and it significantly impacts the way in which we prepare and manage projects." (BPC1) This statement indicates how environmental uncertainty immediately affects functional choices and restricts the organizations' capacity to implement consistent environmental sustainability related plans.

Economic issues were also highlighted as one of the major challenges. Hydropower projects require significant initial funding along with financial planning, and budget overruns are common because of postponements and unexpected challenges. These fiscal pressures weaken the capacity to allocate funds in environmental sustainability.

Similarly, social challenges include local population, land purchasing complications and stakeholder disagreements. These issues commonly delay project plans and increase costs.

4.4 Stakeholder perspectives on sustainability performance and constraints

The findings indicate that different stakeholders in the organization have different opinions related to environmental sustainability. Most participants agreed that environmental sustainability is important, however, there are differences in how it is understood and given importance.

One top-level manager stated, "We consider sustainability in terms of extended feasibility and financial return", whereas, field-level workers mentioned," we experience practical problems such as lack of materials, limited time and application issues." (BPC4, BPC5).

Some respondents also mentioned that stakeholder demands, especially from regulatory bodies and the expectations of local community impact sustainable practices. However, managing these expectations is commonly complex because of limited resources and multiple priorities.

The issues highlighted are environmental, economic and societal. Such factors are not independent but are highly interrelated. A System Dynamics method shows that such issues impact one another in complex ways generating feedback loops and limiting environmentally sustainable energy management (Laimon et al., 2022).

Such as economic constraints limit investment in modern technologies that lead to reduced effectiveness along with increased environmental influence. This increases legal burdens, project delays and increases costs.

In the same way, delays in project implementation caused stakeholder dissatisfaction, increased resistance and slowed down the progress.

As a result, a pattern arises where economic constraints lead to inefficiencies and lower productivity results in delays and additional increase in economic burdens. This feedback loop emphasizes the challenges of managing sustainable development within power projects (Antoniades, 2025).

Such mutually dependent nature of challenges indicates that addressing individual issues separately may not be effective. In contrast, a holistic and systems-based approach is essential in disrupting such loops and improving environmentally sustainable progress (Head, 2022).

This reflects a disconnection between strategic and operational perspectives; this may result in inconsistent implementation of sustainability practices across the company.

4.5 System Dynamics insights: major feedback loops and time-delay effects

The findings show several structural interactions that impact environmental sustainability outcomes at BPC.

A significant positive feedback loop was identified where increased investment hydropower projects leads to increased power generation that enhances income and enables more reinvestment. Such process leads to a loop of progress or extension.

Simultaneously, regulating cycles were recognized. Project delays lead to budget overruns that weaken the economic capacity and limit future financing. This leads to a limitation on system expansion.

Time delays are also crucial; there remains a significant gap between financial decisions and project completion that leads to uncertainty in forecasting or planning processes. Such time delays might cause disruptions between energy supply and requirement.

The study reveals both strengthening and balancing feedback loops in project contexts. One important growth-enhancing loop can be identified in which higher investment results in increased power generation that produces higher earnings, thus, allowing extra funding. On the other hand, a balancing loop takes place where project delays lead to higher expenses that restrict more capital and delay project development.

Time lags or delays play an important role in influencing system performance. Such as, delays in regulatory approval, fund disbursement and project implementation create one time delay in decision-making along with actual results (Khalid et al., 2022). These delays commonly result in mismatch between planned effectiveness and actual performance, decreasing the overall efficiency (Diana & Amin, 2025).

The identified feedback loops and time delay patterns were observed based on theme-based analysis of qualitative data and understanding using a System Dynamics approach. Even though a quantitative model was not developed, the conceptual framework gives important insights regarding System Dynamics.

These findings indicate that the sustainable methods cannot completely be understandable through one-to-one relationships. Rather it requires a systems thinking approach that incorporates feedback loops and time lags.

4.6 Integration points: how SD strengthens PM decision-making in BPC

This study indicates that System Dynamics can strengthen project management operations at BPC by improving decision-making processes. Through recognizing feedback loops and time delays, project managers can make increasingly informed decisions throughout strategy development phases and implementation phases.

Such as analyzing the delay between investment and project results may support managers to prepare for more realistic schedules and minimize overestimation of immediate results (Khahro et al., 2023). Similarly, identifying the feedback loops can strengthen long-term decisions regarding allocation of resources and uncertainty management (Carreno, 2024).

Yet, the incorporation of System Dynamics into project management at BPC remains primarily conceptual. There is insufficient evidence regarding systematic implementation in decision making processes indicating a gap between conceptual capacity and practical implementation (Javidroozi et al., 2019).

Project management focuses on execution or implementation whereas, System Dynamics provides a broader understanding of how different components impact one another in the long-term. Through merging both methods, the company can more efficiently forecast risks, handle uncertainties and improve strategy development.

Analyzing system feedback cycles can help in recognizing how time lags or budget overruns affect future projects. Similarly, identifying time lags may improve strategy development, timelines and resource allocation.

The incorporation of System Dynamics and project implementation management can generate a more coordinated approach that includes both short-term results and sustainability.

4.7 Discussion of findings against literature and sustainability theories

The results of this study are aligned with prior research regarding sustainable energy management which demonstrates the complexity of managing financial, environmental and social goals. Like previous studies, the results suggest that financial considerations such as expense management and project delivery usually are prioritized over wider sustainability objectives (Handoyo, 2026; Bhatt & Joshi, 2024). This finding supports the argument that in the context of developing country settings, sustainability is often influenced by operational and financial limitations instead of strategic incorporation.

The study also aligns sustainability frameworks especially Triple Bottom Line Framework (TBL) which highlights the need to maintain the balance between economic, environmental and social performance. Moreover, stakeholder theory is represented in the findings where different organizational levels show different views on sustainability priorities emphasizing the impact of stakeholder concerns regarding decision making (Freeman et al., 2018).

From a systems viewpoint, the findings support System Dynamics which highlights the importance of system feedback cycles and time lags in influencing system behavior patterns (Sterman, 2000). The recognition of positive feedback loops and negative feedback loops within project investment and performance supports the importance of systems thinking in analyzing sustainable energy management. However, this study expands existing literature by showing the way in which these system behaviors work in the organizational level within Butwal Power Company highlighting the importance of combining System Dynamics with project management practices for better environmental outcomes.

Thun et al. (2024) demonstrate that extensive integration of environmental sustainability into organizational practices, this study shows that sustainability at BPC is only incompletely integrated and is generally less important to economic factors. This finding indicates a difference between theory and application particularly, within the setting of developing nations.

This study provides a theoretical body of knowledge by explaining how System Dynamics can be used to analyze environmental sustainability challenges in hydropower initiatives within Nepal. This extends theories by highlighting the importance of cause-and-effect loops and time delays in affecting project outcomes.

This indicates that even though existing theories provide a valuable base, their applied implementation remains limited in actual organizational settings such as BPC, indicating the need for integrated approaches. This also implied that integrating System Dynamics with project management, can support managers move beyond short-term results and more clearly understand long-term consequences while making decisions.

4.8 Summary of findings aligned to research objectives

This study aimed to examine the way in which sustainable energy management can be enhanced through the integration of System Dynamics methods and project management processes in BPC. The results are discussed in the next part with respect to the study objectives.

Objective 1: To examine the existing project management methods used by BPC in achieving sustainable energy goals.

The results indicate that sustainable methods are observed within BOC mainly regarding environmental compliance. effective use of resources and sustainability. However, environmentally sustainable methods are not structurally integrated into a planned system and are largely integrated in regular operational activities.

Objective 2: To examine how System Dynamics framework can enhance managerial decision-making and strengthen sustainable performance within BPC's hydropower energy projects.

The study showed that System Dynamics provides important understanding regarding system feedback cycles, time lags and interactions in hydropower projects. Such findings strengthen future strategy development, risk recognition and decision-making emphasizing the approach's capability to improve environmental sustainability results.

Objective 3: To study stakeholder perspectives about major challenges and factors affecting sustainable energy management

The findings demonstrate that stakeholders recognize the importance of environmentally sustainable methods but face various issues like environmental uncertainty, budget limitations and societal issues related to local population resistance. Differences in perspectives among organizational levels additionally impact how sustainability is emphasized and implemented.

Objective 4: To formulate an integrated framework combining System Dynamics and sustainable project management practices

The study indicates that integrating System Dynamics along with project management can improve long-term strategy development and operational implementation. While project management ensures effective implementation, System Dynamics supports the understanding of system behavior allowing more informed and responsible decision-making.

The findings suggest that while BPC demonstrates a formal commitment to sustainable practices, practical implementation is limited by financial factors, technical factors and organizational factors. Sustainability practices are present but not fully incorporated into project management practices.

This study contributes to theoretical development integrating System Dynamics with sustainability-oriented project management within the context of hydropower sector in Nepal. From a practical perspective, the findings provide insights for improving decision-making by implementing a comprehensive and system-based approach.

Overall, the study highlights the need for improved alignment between sustainability goals and operational practices to achieve long-term sustainable energy management.

5 Conclusion and Recommendations

This chapter outlines the conclusion and recommendations regarding the study based on the findings that are discussed in the previous chapter. This chapter summarizes the main understandings and provides a definite answer to research questions related to sustainable energy management within Butwal Power Company. The chapter additionally presents practical recommendations for enhancing sustainability performance and emphasizes aspects related to future research. Overall, this chapter integrates the study's findings with the study's objectives and presents the theoretical along with practical inputs from the study.

5.1 Conclusion and answer to the research question

This study aimed to analyze how sustainable energy management can be strengthened through the combination of System Dynamics and project management practices within Butwal Power Company. The findings suggest that although the organization demonstrates awareness of environmental sustainability principles, such principles are not fully integrated in a structured long-term framework. Rather, sustainability is managed through functional activities mainly influenced by legal compliance and project effectiveness.

The study reveals that project management plays an important role in promoting sustainable development by ensuring effective scheduling, resource allocation and uncertainty mitigation. However, such methods concentrate mainly on short-term performance indicators such as cost, time and quality along with limited focus on long-term sustainability results. This leads to a gap between operational execution and wider sustainable development goals.

Furthermore, the study emphasizes the significance of System Dynamics for examining complex System Dynamics, particularly loops and time-related delays that affect project effectiveness and long-term development. The findings indicate that combining System

Dynamics together with project execution can improve decision making, enhance long-term planning and promote further environmentally sustainable results.

This study contributes to the discussion on sustainable hydropower management in developing nations by showing that sustainability issues are not independent management problems but interrelated system-wide concerns. In contrast to previous studies that primarily concentrate on operational or economic performance, this study highlights the importance of incorporating System Dynamics with sustainable project management to clearly analyze feedback connections, delays and stakeholder engagement. The study thus provides an innovative input by connecting systems thinking with managerial decision processes in the hydropower industry of Nepal by providing a comprehensive perspective on sustainable energy management.

Overall, the study concludes that environmentally sustainable energy management at Butwal Power Company can be greatly enhanced through a more coordinated strategy that integrates system-level analysis with effective project implementation process.

5.2 Summary of key findings

The study revealed multiple significant results regarding sustainable energy management within Butwal Power Company.

First, sustainability is identified within the organization but is not officially included in the long-term decision-making process. It is primarily demonstrated through environmental protection, compliance and effective project implementation instead of preventive sustainable development practices.

Second, project management methods support environmental sustainability by enabling effective resource utilization and project implementation. However, sustainability is not directly emphasized within such methods reducing their overall impact.

Third, several system constraints influence environmental sustainability performance such as ecological unpredictability, economic limitations and societal issues including stakeholder disputes.

System Dynamics provides important insights regarding feedback loops and delayed responses indicating the approach's capacity to enhance decision-making and promote sustainable energy management.

The findings further show that sustainable energy management functions as an evolving system influenced by feedback connections, interconnectedness, and delayed effects, strengthening the importance of system thinking in hydropower project settings.

The findings also demonstrate that long-term energy management within BPC operates as a dynamic and interconnected system influenced by response, relationships, shared reliance and delayed consequences. Environmental unpredictability, interest group relationships, implementation delays and economic limitations were recognized as producing, enhancing and balancing the outcomes that shape sustainability results. This indicates the importance of implementing a systems approach viewpoint where sustainability challenges are analyzed not only as a separate concern but as combined elements in a broader organizational and project context.

5.3 Practical recommendations for Butwal Power Company

Based on the findings, the following recommendations are suggested to improve sustainability performance:

1. **Strengthen strategic integration of sustainability:** The organization is recommended to develop a well-defined sustainability strategy that coordinates environmental, social and financial goals with organizational objectives. This can be achieved by integrating sustainability measures within project planning and performance evaluation processes. Senior management is expected to be responsible for integrating sustainability into long-term decision making.

2. **Integrate System Dynamics into project planning:** System Dynamics tools are recommended to be used to support decision-making through analyzing feedback loops and time lags, and possible risks. This can support enhancing prediction, reduce uncertainty and improve strategic planning. Training initiatives are necessary to develop internal capacity for implementing system-based methods.
3. **Improve stakeholder engagement methods:** The organization is recommended to improve its communication and involvement among key stakeholders such as local communities and legal authorities. Early participation of stakeholders may reduce conflicts, enhance project approval and facilitate more efficient project implementation.
4. **Improve risk management and planning processes:** Project management approaches must be expanded to incorporate long-term sustainability related uncertainties such as ecological unpredictability and community-based impacts. This will help in reducing delays, managing costs and enhancing overall project efficiency.
5. **Promote organizational learning process and capacity building**: The organization is recommended to allocate resources in skill development and knowledge sharing programs to enhance understanding regarding environmental sustainability and systems thinking approach among employees. This can support improved alignment between strategic planning and project implementation.

Table 9. Practical Recommendations for Butwal Power Company

Recommendation	Priority Level	Implementation Timeline	Responsible Unit	Sustainability Indicator
Integrate sustainability indicators into project planning and evaluation	High	Short-term	Senior Management & Project Team	Reduced project delays and improved compliance
Apply System Dynamics tools for forecasting and risk analysis	High	Medium-term	Planning and Technical Department	Improved long-term decision-making accuracy
Strengthening stakeholder engagement and communication mechanisms	Medium	Short-term	Community Relations Unit	Reduced stakeholder conflicts and complaints
Develop climate-risk monitoring and adaptive planning systems	Medium	Long-term	Sustainability and Technical Teams	Improved resilience to hydrological variability
Conduct sustainability and systems-thinking training programs	Low	Medium-term	Human Resource Department	Increased employee awareness and coordination

The above-mentioned recommendations must be implemented through a staged process to improve organizational applicability and long-term effectiveness. Short-term priorities must emphasize enhancing management systems, participants coordination and environmental sustainability coordination in current project management structures. Middle-phase strategies must emphasize the implementation of System Dynamics for estimating risk and scenario assessment. Similarly, long-term approaches must emphasize environmental adjustment preparation, organizational learning process and continuous supervision related to sustainability results. This phased implementation process can allow continuous organizational transformation and improve long-term sustainable management within the organization

5.4 Future research directions

This study provides several essential findings related to long-term energy management, although it additionally highlights the aspects for further studies.

Future studies are recommended to analyze various hydropower companies for providing cross-comparative evaluation and improving applicability. This process may support understanding how different organizational contexts influence sustainability approaches.

Quantitative study may also be conducted to identify the influence of System Dynamics incorporation on project effectiveness along with sustainability results. This method would provide more reliable evidence-based data to strengthen the findings.

Furthermore, further studies might examine the specific role of policy-related systems and legal settings while affecting sustainable energy management. This would provide a more extensive viewpoint apart from organizational level evaluation.

Ultimately, further analysis might develop and confirm the improved systems simulation approach structured for the purpose of replicating long-term energy-related scenarios and strengthen managerial decision-making within the hydropower sector.

Further studies might also analyze the environmental conditions and adjustments modelling in hydropower initiatives, particularly the impact of fluctuating water flows and uncertain weather-related situations upon continuous environmental sustainability effectiveness. Extra research might also examine stakeholder conflict modelling applying modern System Dynamics methods to obtain more profound understanding regarding the overall relationship between regulatory management, community engagement and project implementation.

Cross-national research throughout hydropower organizations across South Asia might support to more effectively understand the way in which environmental sustainability management is implemented within distinct country-level and organizational settings.

Furthermore, future studies might emphasize developing practical environmental sustainability effectiveness measures together with model-based strategy development methods that are able to help policymakers in energy sector.

5.5 Limitations of the Study

This study has several limitations that must be examined while analyzing the results. First, the study is built upon a single case analysis that restricts the overall applicability of the results for other companies. Although the case provides detailed understanding, the results may not fully represent the broader hydropower industry.

Secondly, the study depends mainly on qualitative data collected through interviews. As a result, findings of the study are based on respondent's views and experiences, that may be impacted by individual bias or partial implementation. Although efforts were made to ensure credibility, some degree of subjectivity cannot be completely avoided in qualitative research.

Thirdly, the sample size is comparatively small, focusing on limited number of participants within the organization. This may limit the variety of viewpoints recorded in the study.

The study focuses on conceptual System Dynamics understanding instead of developing completely quantitative simulation framework. Consequently, the findings provide analytical insights instead of forecasting results.

Additionally, the qualitative nature of the study indicates that results are affected by respondents' perspectives and researcher interpretation. Although reflexivity and theme-based analysis methods were implemented to decrease subjectivity, some analytical bias may continue. Limitations in organizational accessibility also reduced participant availability for interviews which might have affected the variety of viewpoints collected. Moreover, the lack of quantitative System Dynamics simulation analysis limits the research capability to develop predictive findings indicating that the results should be understood as initial findings rather than universally applicable.

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Appendices

Appendix: Semi-Structured Interview Questions

Section A: Background Information

1. What is your current role at Butwal Power Company?
2. How long have you been working in the organization?
3. Are you involved in project management, sustainability, or decision-making processes?

Section B: Sustainability Practices (Objective 1)

1. How do you understand "sustainable energy management" in your organization?
2. What sustainability practices are currently followed in your projects?
3. To what extent are environmental and social factors considered during project planning?
4. Is sustainability integrated into strategic decision-making, or mainly addressed during project execution?

Section C: Challenges in Sustainable Energy Management

1. What are the main challenges affecting sustainability in your projects (environmental, financial, or social)?

Section D: System Dynamics and Decision-Making (Objective 2)

1. Are you familiar with system thinking or System Dynamics concepts?
2. How are long-term risks, delays, and uncertainties considered in decision-making?
3. How do changes in one area (e.g., cost, delays, environment) affect other project outcomes?
4. In your opinion, how could System Dynamics improve planning and decision-making?

Section E: System Dynamics & Decision-Making

1. How are long-term effects such as delays, risks, and interdependencies considered in decision-making?
2. In your opinion, how could a system-based approach (e.g., System Dynamics) improve planning and sustainability?

Section F: Integration & Improvement

1. What improvements would you suggest to better integrate sustainability into project management practices?