Sustainable Energy Generation in the Lower Mekong Region: Feasibility and Potentials of the Implementation of Green Hydrogen Production

Masterarbeit

zur Erlangung des akademischen Grades „Master of Science (M.Sc.)“ im Studiengang Wirtschaftsingenieurwesen der Fakultät für Elektrotechnik und Informatik, Fakultät für Maschinenbau und der Wirtschaftswissenschaftlichen Fakultät der Leibniz Universität Hannover

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Hannover, 28. April 2025

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1 Introduction

Southeast Asia is currently one of the most dynamic regions worldwide, undergoing rapid economic and social transformation. In recent decades, the member states of the Association of Southeast Asian Nations (ASEAN) have been experiencing sustained economic growth, as well as population growth, which has been accompanied by accelerated urbanization. Metropolitan areas such as Bangkok, Jakarta and Ho Chi Minh City nowadays already rank among the world's largest, and projections indicate that this trend will persist (Fennell, 2021).

These developments are associated with a substantial increase in energy demand. Projections indicate that the total energy demand of ASEAN countries will rise by approximately 60% by the year 2040, while electricity consumption is expected to nearly double (IEA, 2024). The German Agency for International Cooperation (GIZ) has even predicted an increase of 70% compared to the current level (GIZ, 2023).

To address this energy demand, the ASEAN region currently relies predominantly on fossil fuels, a course of action that would result in substantial future greenhouse-gas emissions (ASEAN Centre for Energy, 2024; IEA, 2024). Paradoxically, these same nations are particularly vulnerable to the adverse impacts of climate change. This phenomenon is evidenced by the recent extreme flooding and heatwaves observed in countries such as Thailand, Myanmar, and Vietnam (Fennell, 2021; Kliem and Anton, 2024).

Consequently, the ASEAN members have committed to the decarbonization of their energy systems, adopting national net-zero strategies and collaborative roadmaps that prioritize a rapid expansion of renewable energy sources (ASEAN Centre for Energy, 2025, 2024). In this context, the potential of hydropower is of particular significance, given the substantial untapped resources in Southeast Asia (Xu et al., 2023). Specifically, the Mekong River, which is among the world's largest rivers, is regarded as a pivotal element in the future supply of power due to its substantial discharge rates. Consequently, the expansion of hydropower plants in the Mekong Basin is already underway. Laos, in particular, has expressed its aspiration to become the "Battery of Southeast Asia" and is undertaking an extensive dam-building program, exemplified by the Xayaburi Hydropower Plant, which was commissioned in 2019 (Ang et al., 2024; Hecht et al., 2019).

Nevertheless, the expansion of hydropower development along the Mekong River has faced considerable criticism. The construction of large-scale dams represents a profound intervention into the Mekong River system, impacting ecosystems and jeopardizing the livelihoods of millions of individuals who depend on the river for sustenance and economic opportunities (Li et al., 2017). However, research on the economic benefits of such projects has yielded conflicting conclusions. While certain studies have identified substantial economic benefits (MRC, 2011), others have raised concerns regarding potential ecological and social costs (Intralawan et al., 2018). The observed discrepancies are attributable to methodological differences and a lack of reliable data. For the majority of dams, there is an absence of verified long-term discharge records and publicly accessible energy generation profiles, which hinders the execution of robust cash flow analyses and thus complicating financial assessments.

In addition to renewable energy sources, green hydrogen is regarded as a fundamental component of the energy transition. As a zero-emission energy carrier, it possesses the potential to decarbonize critical sectors, including transport, energy, and industry (Capurso et al., 2022). Although the strategic relevance of green hydrogen has already been recognized in net-zero scenarios across ASEAN nations, including Laos, there is still a gap in the implementation of concrete strategies (ASEAN Centre for Energy, 2025). The plans for production, transport infrastructure, and market development remain undefined. Furthermore, the financial viability of hydrogen production in Southeast Asia under current conditions is not yet apparent. In this instance, reliable financial assessments are also largely absent.

In light of recent developments in Southeast Asia, particularly in Laos, it has become evident that several theoretical and practical challenges remain unresolved. The present study has been designed to address these challenges by deriving two main research objectives:

1) The analysis of the financial feasibility of large-scale hydropower projects along the Mekong River based on realistic hydrological and economic data, in order to assess the potential economic value of such investments.
2) The identification of opportunities for the integration of localized green hydrogen production and the assessment of its financial viability.

Both objectives are addressed using the Xayaburi Hydropower Plant as an exemplary case study. The findings of this analysis contribute to a roadmap for sustainable development in the Mekong River Basin.

To achieve the objectives outlined above, this study follows a multi-step methodological approach based on a clear and structured framework.

The first step is to establish the theoretical foundations. This includes the definition of the research area as well as the basics of hydropower and hydrogen production. These serve as a conceptual basis to which reference is made throughout the study.

The next chapter presents the methodological framework for the financial analysis of the investments, which forms the basis for all subsequent financial feasibility calculations.

Subsequently, a hydrological model is presented and applied to derive the daily river discharge at specific locations. The resulting values are essential inputs for the calculation of a realistic energy output of the hydropower plant.

In the following chapter, the daily electricity generation of the Xayaburi Hydropower Plant is calculated. To this end, a model is developed that estimates daily energy output based on realistic parameters. Utilizing the input data from the preceding hydrological simulation, the model is employed to calculate the plant's daily electricity generation.

In accordance with the preceding data, the subsequent section aims to calculate the net present value of the plant, thereby determining the essential financial indicators necessary for the ensuing investment evaluation. Furthermore, the financial viability of a potential capacity expansion is evaluated.

The subsequent chapter examines the prospective implementation of hydrogen production at the hydropower site. To this end, realistic application scenarios are first defined and introduced from a techno-economic perspective. The financial analysis of these use cases subsequently provides insights into their financial viability.

Finally, the results and findings of the study are discussed, leading to the formulation of a final strategic recommendation for the future development of the Mekong Basin.

The findings of this study are intended to provide a foundation for effective decision-making that will inform the continued development of the Mekong Basin. Additionally, the study offers specific, implementable insights to address the strategic challenges faced by the region.

9 Conclusion

The objective of this thesis was to evaluate the financial feasibility of large-scale hydropower projects in the Mekong Basin, using realistic hydrological and economic data, as well as exploring the potential for integrating local production of green hydrogen and assessing its financial viability. The Xayaburi Hydropower Plant was selected as a representative case study.

Initially, a methodological framework was developed to facilitate the financial assessment of investments. This was followed by hydrological simulations to determine realistic discharge values at the Xayaburi site. Daily power generation was subsequently calculated using linear optimization. The financial analysis of the existing hydropower plant and a potential capacity expansion was carried out using NPV analysis and sensitivity analyses. Finally, the techno-economic potential for green H_2 production was assessed under various scenarios.

The intermediate results obtained from these individual steps, including the simulation outcomes and the daily hydropower capacity model, provided realistic data and represent valuable foundations for further research.

The hydropower analysis revealed that, under median discharge conditions, the XHP generates approximately 6.7 TWh annually, with significant seasonal variation observable from daily energy data. Utilizing a discount rate of 8%, the plant attained an NPV of approximately 525 million USD and an IRR of 9.46%. Although this indicates positive overall investment return, it remains below the 12% threshold set by multilateral development banks. The additional examination of a capacity expansion of 125 MW in the spillway led to an approximate 200 GWh increase in annual production. The utilization of existing infrastructure in this expansion resulted in an NPV of approximately 53 million USD and an IRR of 14.4%.

These findings suggest that large-scale hydropower projects in the Mekong region currently possess limited standalone attractiveness. However, targeted capacity expansions significantly enhance their financial potential. It should be noted that the present study intentionally concentrated on financial indicators. Ecological impacts and social distributional effects were not extensively analyzed, but should be integrated into future economic research. Nevertheless, the model developed here offers robust frameworks for investors, operators, and policymakers to better assess project risks, adjust tariff structures, and develop regional infrastructure strategies.

The financial analysis for H_2 production demonstrated that to achieve an IRR of 12%, the five evaluated H_2 pathway combinations currently necessitate selling prices ranging from 5.1 to 11.5 USD/kg. Projections indicate that technological learning curves will reduce this range to between 4.4 and 9.3 USD/kg by 2030, with the scenario S1.Truck (liquefaction and road transport) achieving the lowest breakeven price.

A comparison of the anticipated market prices for green H_2 and the implementation evaluated herein indicates that the implementation offers only limited economic attractiveness. The profitability of on-site H_2 production strongly depends on the utilization of electrolyzer capacity, the transport pathways utilized, and future developments in H_2 price. However, given the single-site analysis conducted for the XHP, the potential scale effects from integrating multiple hydropower facilities into an H_2 network remain unexplored. A collaborative approach that combines surplus electricity from multiple plants could increase utilization rates, lower opportunity costs, and share infrastructure investments. This, in turn, could significantly reduce marginal costs, highlighting a key area for further research.

In conclusion, under current electricity pricing conditions, the Xayaburi Hydropower Plant achieves moderate profitability, which could be notably improved through relatively straightforward retrofits of existing plants or adjusted planning of new facilities. While the financial viability of standalone H_2 production remains contingent on price, the projected expansion of hydropower plants, coupled with the anticipated cost reductions in H_2 technology, could substantially enhance its financial attractiveness. The establishment of a comprehensive H_2 network, comprising multiple energy suppliers and a multifaceted transport infrastructure, has the potential to transform the region into a significant contributor of green H_2.

In consideration of the impending developments in the Mekong Basin, the present study offers a substantial contribution in the form of a practical and actionable framework for future decision-making. Furthermore, it provides a comprehensive dataset and a thorough identification of research requirements, thereby establishing a solid foundation for subsequent theoretical investigations.