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Single Reservoir Pumped Hydro Storage with Seawater:
A Big Battery for Big Problems

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Thesis Report

Single Reservoir Pumped Hydro Storage with Seawater: A Big Battery for Big Problems

by

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Preface

I stand at the culmination of an extraordinary journey – the completion of my thesis – and I write these words with a profound sense of gratitude. Without the unwavering support, encouragement, and understanding of those who have been my pillars of fortitude, this journey would not have been possible.

First and foremost, I would like to express my deepest gratitude to my family, who have always been there for me, believing in me, and encouraging me throughout the various chapters of my academic endeavour. Thank you for your understanding and patience throughout this journey. To my wife, whose love and support have been my constant motivation, and to my daughter, who brings me unbounded pleasure every day. To my parents for their unwavering support, my elder brother for the inspiration, and my younger sister for her steadfast support.

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I would also like to thank my classmates and Indonesian peers, who have provided me with companionship and support throughout this journey.

I am grateful to everyone who has contributed to my academic journey through a deed, a word of encouragement, or a shared experience. Due to these combined efforts and unwavering support, I have reached this educational milestone in my voyage.

With heartfelt gratitude,
Widana Bayu Nugraha
Delft, November 2023

Abstract

Indonesia faces the challenge of attaining renewable energy goals and reducing carbon emissions by 29% by 2030. Despite a renewable energy goal of 23% of the national energy mix by 2025, only 14% of electricity production is projected to be generated from renewable sources by 2023. Accelerated deployment of renewable energy solutions is required to achieve these goals.

Indonesia has abundant renewable energy sources, such as hydropower, solar, and wind. Yet, a challenge arises from the difference between the electricity demand and supply patterns of these sources, which do not match throughout the day. Fluctuating energy supply patterns and variable energy demand necessitate using efficient Energy Storage Systems (ESS) to bridge the gap.

With its extensive coastline, Indonesia can potentially explore single reservoir Seawater Pumped Hydro Storage (SPHS), a variant of Pumped Hydro Energy Storage (PHES), as an alternative to solve these challenges. Similar to an enormous rechargeable battery, the reservoir in an SPHS system functions as an energy storage system. The system works by pumping up the seawater to the reservoir to store surplus energy during periods of ample supply and discharging it to generate electricity through a hydropower plant during periods of high electricity demand. This research aims to identify the ideal locations for SPHS systems in coastal areas of Indonesia. A Python GIS algorithm was developed to automate the selection process. The identified SPHS sites are then evaluated economically to ascertain their viability. The study concludes by comparing the carbon reduction potential of these systems to Indonesia's carbon emission reduction goals.

The research reveals 609 potential SPHS sites across Indonesia, with a total peak power that can be regenerated of technically potential sites of 29 Gigawatt-peak (GWp). Among these, 297 locations are deemed economically feasible, contributing a potential peak power that can be regenerated of 15 GWp. The peak electricity demand in Indonesia is approximately 44 GW, typically occurring at 8 p.m. The technical potential of SPHS promises an 11% reduction in carbon emissions from the energy sector, while the economically feasible sites could achieve a 6% reduction in carbon emissions projected in 2030.

Keywords: Seawater Pumped Hydro Storage (SPHS), renewable energy, Indonesia, QGIS, Energy Storage Systems (ESS).

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Acronyms

AHP Analytic Hierarchy Process 33, 34, 39

BIG Badan Informasi Geospatial 18, 19

CAPEX Capital Expenditure 19, 29, 30, 32, 46, 52, 53, 61

DEM Digital Elevation Model 4, 17, 19, 21, 23, 60
DEMNAS DEM Nasional 18, 60

ESS Energy storage systems 10, 12

GIS Geographic Information System 4, 17–19
GRP Glass Reinforced Plastic 27, 58
GW Gigawatt 6, 9, 10
GWp Gigawatt-peak 38, 49, 51, 52, 59, 60

kWh kilowatt-hours 8, 29, 46, 49, 52, 60

LCOE Levelised Cost of Electricity 46, 49, 50, 60
LCOS Levelised Cost of Storage 19, 29, 30, 33, 36, 46–53, 60, 61

MW Megawatt 9, 15, 19, 28, 37
MWh Megawatt-hours 7, 24
MWp Megawatt-peak 3, 25, 37, 39, 60

OPEX Operational Expenditure 19, 29, 30, 32, 46, 52, 53, 61

PHES Pumped Hydro Energy Storage 1, 2, 4, 11–16, 27, 29, 30, 34, 35, 51
PyQGIS Python QGIS 22, 24, 59

QGIS Quantum Geographic Information System 4, 17–19, 29

SPHS Seawater-Pumped Hydro Storage 2–5, 14, 15, 17–25, 27–30, 32–40, 45–61

TOPSIS Technique for Order of Preference by Similarity to Ideal Solution 33–35, 39, 40
TWh Terawatt-hours 7, 38, 55, 60

Chapter 1

Introduction

1.1. Background

The growing recognition of climate change and the global commitment to reduce greenhouse gas emissions have increased the emphasis on transitioning towards renewable energy sources. As a rapidly developing nation with a significant reliance on fossil fuels for its energy needs, Indonesia faces the challenge of mitigating its carbon footprint while ensuring a sustainable energy supply to meet the demands of its expanding population and growing economy [1]. The motivation behind developing renewable energy solutions in Indonesia lies in saving the planet, addressing environmental concerns, achieving energy security, and fostering economic growth in a socially responsible manner.

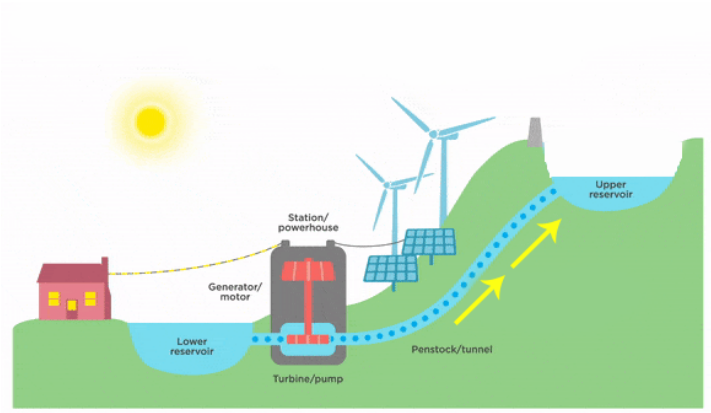
As an effort to answer the climate issue, Indonesia has a renewable energy target of 23% of the national energy mix by 2025. This policy, combined with Indonesia's commitment to reduce carbon emissions by 29% by 2030, is a clear move towards a cleaner energy system and sustainability [1]. However, only 14% of electricity production in Indonesia generated from renewable energy projected in 2023 [2]. So far, Indonesia's energy plan has prioritised the use of domestic coal to satisfy its needs [3], with a longer-term transition away from this resource [4].

Hydropower plants, a grid-connected solution to the need for clean energy sources, have been adopted in Indonesia to generate electricity. However, the system has high seasonal variability due to the supply of water discharge [5]. Hydropower plants need large reservoirs to reduce this limitation, resulting in significant investment costs and lengthy construction times [6]. Solar and wind are two other clean energy alternatives. Yet, solar and wind energy are daily intermittent renewable energy sources, which means their availability varies over a short period [7].

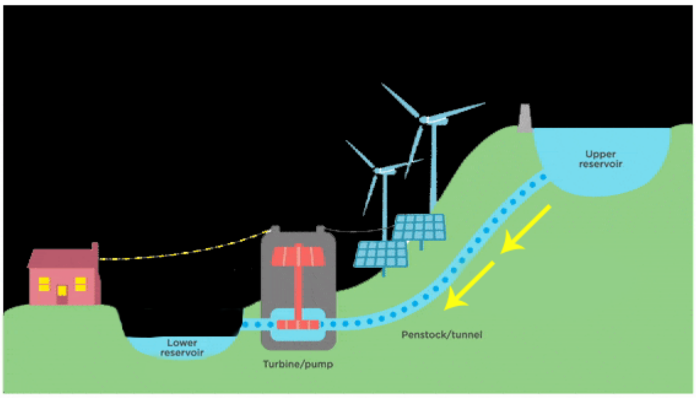
As a result, an energy storage system, such as a battery or a Pumped Hydro Energy Storage (PHES) system, becomes an excellent addition to a system in which variable sources account for a significant source supply energy portion of the energy system. This system facilitates flexibility by keeping operations to an optimum output. When the system's electricity production exceeds the required demand, energy is stored; when demand exceeds production, stored energy is discharged to generate the power. Appropriate storage implementation of wind and solar power allows consistent energy output and increases flexibility.

1.2. Introduction to Pumped Hydro Energy Storage (PHES)

PHES operates on the principle of storing excess energy for later use, similar to other energy storage systems like batteries. It stores surplus energy during periods of low demand and releases it when electricity is required. PHES works by pumping water from a lower reservoir to an upper reservoir when excess electricity is available and releasing it by flowing downhill to generate power when needed for storing energy to maintain stability [8]. PHES is recognised as a technique for storing energy, maintaining the stability of power grids and controlling periods of high energy use [9]. PHES is often combined with intermittent energy sources like solar power to store excess electricity. During periods characterised by an overabundance of energy generation, for instance, occurring during off-peak hours and sunny periods, surplus electricity facilitates water transfer from a lower reservoir to an upper reservoir. This action increases the potential energy of the water, storing the electrical energy in the form of gravitational potential. Figure 1.1 shows the schematic of PHES.



(a) Pumping phase.



(b) Generation phase.

Figure 1.1: Schematic of Pumped Hydro Energy Storage (PHES) [10].

Seawater-Pumped Hydro Storage (SPHS)

Technically, Seawater-Pumped Hydro Storage (SPHS) resembles common PHES, which uses reversible pump turbine units to facilitate energy conversion. The system utilises seawater as the working fluid and eliminates the need for a lower artificial reservoir, using the ocean as the substitute, which is the primary distinction to the common PHES. To minimise head losses and reduce overall investment costs, SPHS facilities must be located close to the coast. Coastal topography, elevation differences, and distance from the coastline are crucial factors in determining the viability of SPHS installations [11]. An example of SPHS implemented in the real world can be found in Okinawa, Japan, as seen in Figure 1.2. This SPHS system was finished in 1999. Built to address Okinawa's energy needs, this facility includes a reservoir that stores 564 thousand m^3 of seawater. The power generation capacity of this SPHS installation is 30 Megawatt-peak (MWp) [12].

Figure 1.2: Okinawa seawater-pumped hydro storage [13].

1.3. Problem Definition

Renewable energy sources, such as solar, wind, and hydroelectric power, offer a cleaner and more sustainable alternative to conventional fossil fuels, such as coals, gas and diesel. However, their intermittent nature poses a challenge to the stability and reliability of the national power grid. Integrating energy storage systems is crucial to effectively harness the potential of renewable energy and ensure a consistent energy supply. Energy storage systems store excess energy during periods of high generation and release it during peak demand or when renewable sources are unavailable. This balancing act enhances grid stability, reduces curtailment of renewable energy generation, and improves the overall efficiency of the energy system.

Indonesia has a long coastline of more than 80,000 km, indicating that many possible SPHS potentials can be developed in the coastal area using seawater. In this context, SPHS emerges as a promising solution to address the energy storage challenges. Indonesia's extensive coastline, abundant seawater resources, and topographical diversity make SPHS a viable option to bridge the gap between intermittent renewable energy generation and fluctuating energy demand. By effectively storing surplus energy during periods of high renewable generation and releasing it during peak demand hours, SPHS can contribute to grid stability, energy security, and the successful integration of renewable energy sources into the national energy mix.

Site selection is an essential step in the life cycle of SPHS plants because it is the first step in project implementation [11]. The process is challenging due to the interplay of topographical, economic, and environmental factors. As these factors vary across different regions, a robust and systematic approach is essential to ensure the accuracy and reliability of site selection.

1.4. Research Objectives

Research objective

The study aims to identify the potential locations for seawater-pumped hydro storage in coastal areas of Indonesia.

Research questions

Based on this objective, the main research question can be formulated as follows: "What is the potential for seawater pumped hydro storage in coastal areas of Indonesia?" To achieve the research objective, the following research questions must be answered:

1. Where are the potential sites for seawater-pumped hydro storage in Indonesia?
2. What is the technical potential of seawater-pumped hydro storage in Indonesia?
3. What is the economical potential of seawater-pumped hydro storage in Indonesia?
4. How much carbon reduction can be achieved by developing seawater-pumped hydro storage in Indonesia?

1.5. Relevance

Numerous studies have identified suitable locations for PHES [14] [15] [16]. Using topographic data, these studies evaluate the viability of various sites for energy storage applications. Mainly, Digital Elevation Model (DEM) data has been instrumental in analysing the topography of potential sites. Geographic Information System (GIS) software, specifically Quantum Geographic Information System (QGIS), has been used to process and visualise topographic data and derive valuable insights. By integrating DEM data with GIS software, researchers identified optimal locations for gravity-driven energy storage, facilitating grid stability and renewable energy integration.

Using GIS, Ghorbani et al. (2019) identified a potential site for PHES in Iran [14]. Jimenez Capilla et al. (2016) determine the optimal potential location for the upper reservoir for pumped-back PHES using DEM data in Spain. Along with that, Pradhan et al. (2021) locate the potential location for SPHS in Curacao using DEM data and automate the process using QGIS features [16].

Meanwhile, there is a lack of research on identifying prospective sites for PHES, especially focusing on seawater pumped hydro storage using DEM data in Indonesia. This research marks a pioneering effort to uncover the PHES potential within Indonesia, exploring uncharted territory. By utilising DEM data to evaluate the topography of potential SPHS sites in Indonesia, this study aims to provide novel insights and substantially contribute to understanding SPHS feasibility in a country rich in coastal areas and ripe for sustainable energy solutions. Consequently, this research provides a perspective separate from previous studies, contributing to the corpus of knowledge in energy storage systems and sustainable development in Indonesia.

1.6. Report Outline

This study is structured into seven chapters. In Chapter 1, the study sets the stage by introducing the background, research problem, objectives, and questions. It provides an overview of the study's scope and purpose, outlining the context for the subsequent chapters. Chapter 2 delves into the literature relevant to the research topic. It reviews prior studies, theories, and practices related to SPHS, renewable energy, and energy demand in Indonesia. This chapter helps establish the theoretical and empirical foundation for the research. Chapter 3 outlines the research methodology employed in the study. It details the data sources, software, tools, and techniques for data collection, analysis, and modelling to identify Indonesia's feasible SPHS site.

Chapter 4 is dedicated to elucidating the methodology employed for ranking and classifying the identified SPHS sites based on pertinent technical parameters. The primary objective of this chapter is to establish an order that reflects the varying degrees of the suitability of these sites, ranging from those exhibiting the most favourable conditions to those facing more challenging circumstances. Chapter 5 presents the research results in the technical and economical potential for SPHS in Indonesia. It highlights key findings, identifies suitable sites based on technical and economic aspects, and discusses the implications of these findings for sustainable energy development.

Chapter 6 focuses on the environmental impact of SPHS development, assessing its implications for carbon reduction efforts and localised environmental concerns, including corrosion and seawater intrusion. The concluding chapter, Chapter 7, draws conclusions based on the research findings. In addition, recommendations for policymakers, stakeholders, and future research directions are provided.

Chapter 2

State of The Art

This chapter explores the relationship between increasing electricity demand, the current energy generation sources, and the untapped potential of renewable resources in a country with vast renewable energy sources. Furthermore, this study aims to analyse the potential transformational capabilities associated with pumped hydro storage technologies, emphasising single reservoir seawater pumped hydro storage.

2.1. Indonesia Energy Demand

Indonesia is characterised by rapid development and demographic growth. The country has significant implications for its electricity demand. With a population of 281 million people and an expected rise to 350 million by 2050 [17], the nation faces a notable surge in energy requirements. Within Indonesia's energy landscape of 2020, the average peak electricity demand approximates 44 Gigawatt (GW), reflecting the integral role of electricity in sustaining diverse sectors and daily activities [18]. Projections for the near future project a significant surge in peak demand, with expectations of reaching approximately 77 GW by 2030. This surge predominantly occurs during evening hours, from 7 to 10 p.m., driven by varied activities requiring electricity consumption [18]. Figure 2.1 shows the average hourly demand pattern in Indonesia. Residential end uses, led by appliances such as air conditioners, lighting, refrigerators, and televisions, significantly contribute to over half of the nation's peak demand [18]. As Indonesia navigates this evolving energy landscape, insights into peak electricity demand and its composition underscore the urgency of energy efficiency measures, sustainable energy integration, and the adoption of intelligent energy storage technologies to ensure a resilient and sustainable energy future.

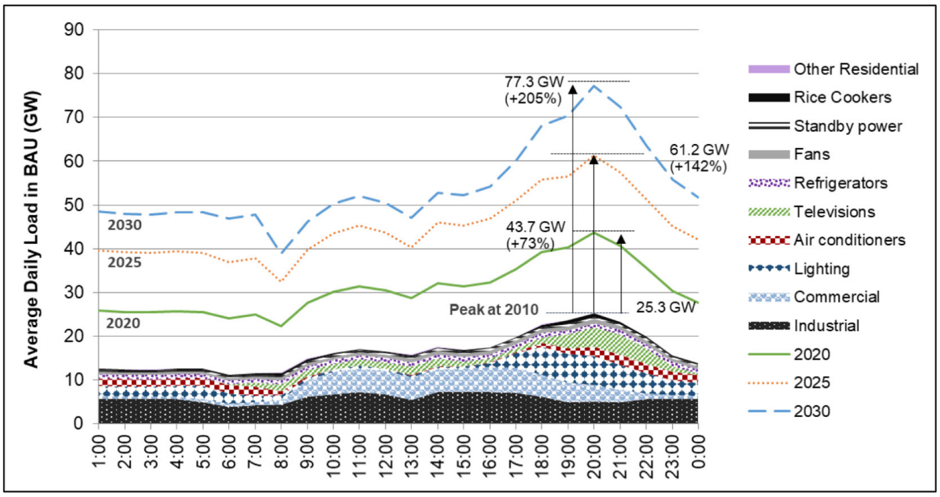


Figure 2.1: Evolution of Indonesian daily load curve between 2010 and 2030 [18].

The growth in energy needs experienced by Indonesia is explained by population expansion and economic development, intensifying the electricity demand. Presently at 1.2 Megawatt-hours (MWh) per capita annually, electricity demand is forecasted to reach 4.5 MWh per capita within the next two decades [19]. The nation's power consumption has a consistent upward momentum due to urbanisation, industrialisation, and societal improvements. Addressing the challenges posed by this escalating electricity demand is pivotal for sustaining reliable energy access [20].

Indonesia's electricity demand currently stands at around 310 Terawatt-hours (TWh) per year, indicative of the growing necessity for energy to facilitate economic progress and population growth [1]. Projections reveal a substantial surge in electricity demand, reaching an estimated 1400 TWh by 2050 [21]. This remarkable escalation underscores the imperative of robust energy policies, sustainable energy integration, and energy efficiency enhancements to secure a dependable and adaptable energy supply [3].

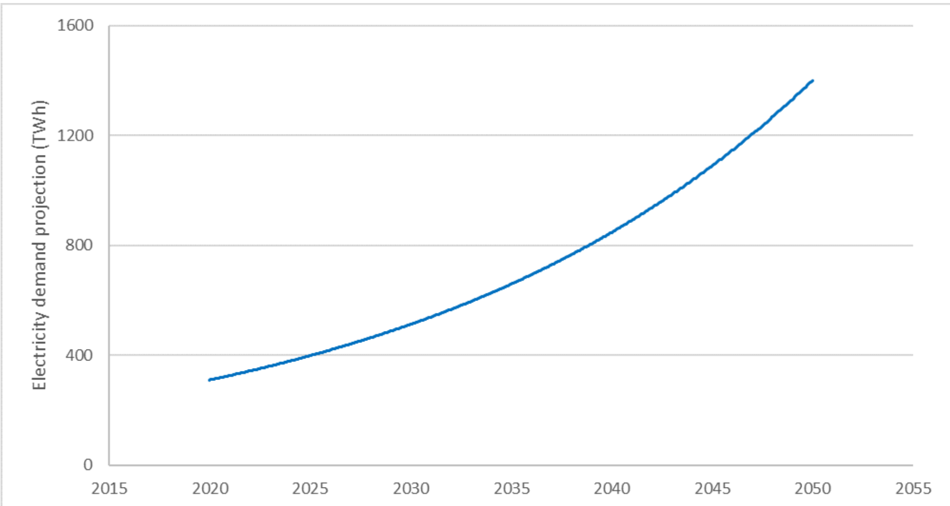


Figure 2.2: Electicity demand projection [21].

In response to the increasing demand, Indonesia has primarily relied on common energy sources, such as coal and natural gas, for electricity generation [22]. Nevertheless, renewable energy sources, including solar, wind, hydro, and geothermal, have garnered attention as viable options for diversifying the energy portfolio and addressing the environmental consequences associated with fossil fuel energy sources [19].

2.2. Indonesia Energy Sources

A diverse mix of energy sources characterises Indonesia's energy landscape, each playing a distinct role in meeting the nation's growing energy demand. Historically, the country has heavily relied on fossil fuels, primarily coal, for its energy generation [21]. Coal maintains its position as the prevailing energy source, constituting a significant proportion of Indonesia's energy generation, amounting to 61% [22]. The nation is recognised as a prominent global producer and exporter of coal, hence establishing coal-fired power plants as a substantial source of its energy provision. Nevertheless, the environmental ramifications of coal combustion, such as releasing greenhouse gases and air contamination, where carbon emissions associated with coal-fired power plants are estimated to be around 820 grams of CO_2 per kilowatt-hour (gCO_2/kWh) of electricity produced [23].

Natural gas also holds a significant share in Indonesia's energy mix (21%), providing a cleaner alternative to coal and oil [1]. The country's substantial natural gas reserves make it a valuable resource for electricity generation and industrial processes. Natural gas power plants are relatively efficient and emit fewer pollutants per kilowatt-hours (kWh) than coal-fired plants, with 490 gCO_2/kWh [24]. Figure 2.3 shows Indonesia's share of electricity generation sources projection until 2030.

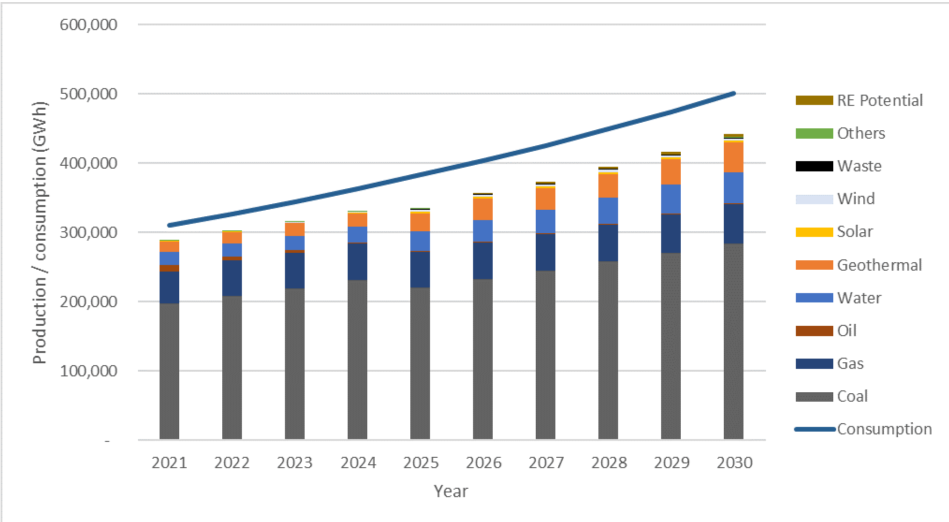


Figure 2.3: Power plant installed capacity and generation projection [1] [2].

Currently, renewable energy sources, including hydropower, geothermal, solar, wind, and biomass, collectively contribute 14% to the country's electricity production [2]. Despite the dominant role of fossil fuel energy sources in Indonesia's current energy supply, there is a strong governmental commitment and determination to diversify the energy mix by promoting and establishing more renewable energy sources [2].

2.3. Potential of Renewable Energy Sources in Indonesia

As a nation rich in natural resources and diverse geographical features, Indonesia holds significant potential for harnessing clean energy sources. Figure 2.4 compares renewable energy potential, current installed capacity and 2050 projection in Indonesia.

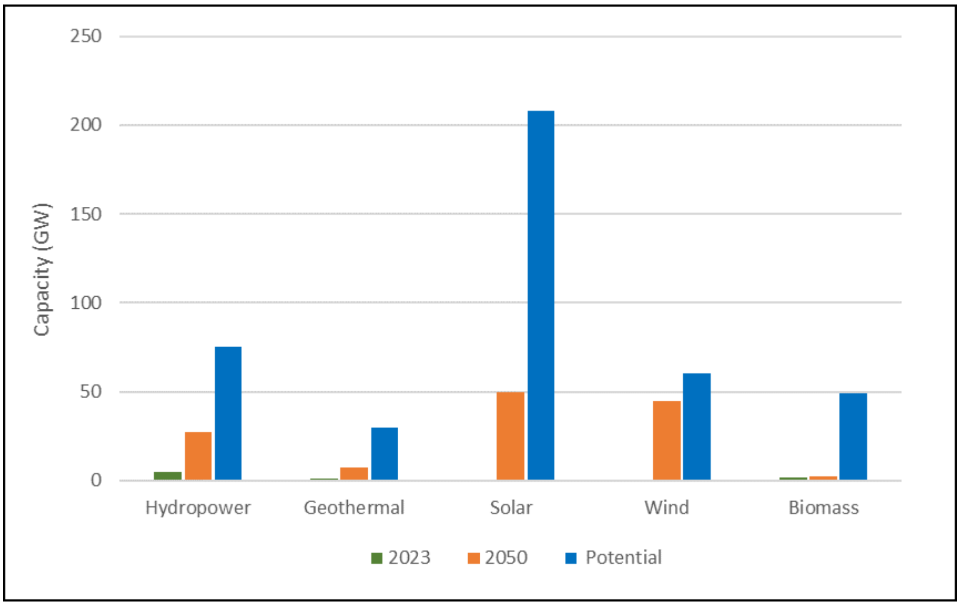


Figure 2.4: Comparison between renewable energy potential and installed capacity.

Hydropower

Endowed with numerous rivers and water bodies, Indonesia possesses considerable hydropower potential. Hydropower presents an opportunity for sustainably meeting the nation's energy needs, with an estimated range between 550 TWh to 700 TWh and an associated capacity of 63 GW to 80 GW [25]. Despite the substantial potential for hydropower in Indonesia, the installed capacity of hydropower plants remains relatively modest, standing at just 5 GW [2].

Geothermal energy

Sitting within the Pacific Ring of Fire, Indonesia boasts abundant geothermal resources, making it one of the world's top geothermal energy producers. The geothermal energy potential in the country is nearly 40% of the global geothermal energy potential, roughly equivalent to 29 GW [26]. However, the current utilisation of this capacity for power generation within the country is a modest 1.4 GW [2].

Solar energy

Indonesia's equatorial location positions it advantageously for harnessing solar energy. With abundant sunlight throughout the year, solar energy presents a viable and sustainable option for electricity generation. Previous studies have constantly emphasised the considerable capacity of Indonesia's land for the utilisation of solar energy [27][28][29]. A range of solar irradiation values, ranging from 4.6 kWh/m^2 to 7.2 kWh/m^2, has been observed, equivalent to a capacity of 207 GW nationwide. However, the current installed capacity of solar panels in Indonesia only provides 78 Megawatt (MW) [2].

Wind energy

Indonesia has ventured into the realm of utility-scale wind power, evident through the establishment two noteworthy wind power plants: Tolo 1, with a capacity of 72 MW, which commenced operations in 2019, and Sidrap, with a capacity of 75 MW, operational since 2018. The projected objective for wind power is to achieve a capacity of 850 MW by 2025, with an additional 597 MW of capacity anticipated to be added by 2030 [2]. At the national level, the country possesses an estimated potential of 61 GW [30].

Bioenergy

Indonesia's agrarian landscape provides ample opportunities for bioenergy production. Biomass, biogas, and biofuels derived from organic materials hold the potential to contribute to the energy mix [31]. The expansive geographical landscape of Indonesia calls for the revitalisation of regions to strategically reposition the potential of biomass resources [32]. The estimated biomass resource potential in Indonesia, which is obtained from plants and garbage, is approximately 49 GW nationwide [32]. Currently, the installed capacity of bioenergy sources in Indonesia is approximately 1.7 GW [2].

2.4. Necessity of Energy Storage Systems (ESS) for Supporting Renewable Energy Sources

Incorporating intermittent renewable energy sources, such as solar and wind energy, into the power grid offers significant potential for advancing sustainable energy generation. Nevertheless, the fluctuating nature of these sources requires a methodical approach to guarantee a consistent and dependable energy provision. Energy storage systems (ESS) becomes an essential element of this strategy, providing a solution to address the disparity between energy production and consumption [33]. Some common examples of ESS include battery storage, pumped hydro storage, and flywheel systems.

Intermittent Energy Sources and their Challenges

Intermittent energy sources are non-consistent or fluctuating energy sources. These sources typically depend on external factors, such as weather or natural conditions, and their power output may not be constant [34]. Solar and wind power are examples of intermittent energy sources.

The fluctuation of solar power generation is influenced by factors such as cloud cover, meteorological conditions, and the onset of night, necessitating the implementation of energy storage technologies to store surplus energy for utilisation during periods of reduced sunshine [35].

Wind energy generation is contingent upon the impact of varying wind velocities and patterns, leading to erratic power generation. The presence of sudden fluctuations in wind velocity introduces an element of uncertainty in the power system, necessitating the implementation of technologies to manage these variations and avert any potential disruptions [34].

Role of Energy Storage Systems

Energy storage technology encompasses diverse solutions, each uniquely designed to cater to specific power needs, efficiency requirements, and the pattern to capture and release energy during peak and off-peak demand periods [36]. Within power system contexts, energy storage serves various purposes, including daily equilibrium operation, peak load reduction, enhancement of power quality, and the exploitation of energy price disparities for consumers [36]. Energy storage methods within power systems are frequently categorised into three primary classifications: electrical, thermal, and mechanical. These distinct categories encapsulate various techniques utilised to store and manage energy resources within power infrastructure effectively [35].

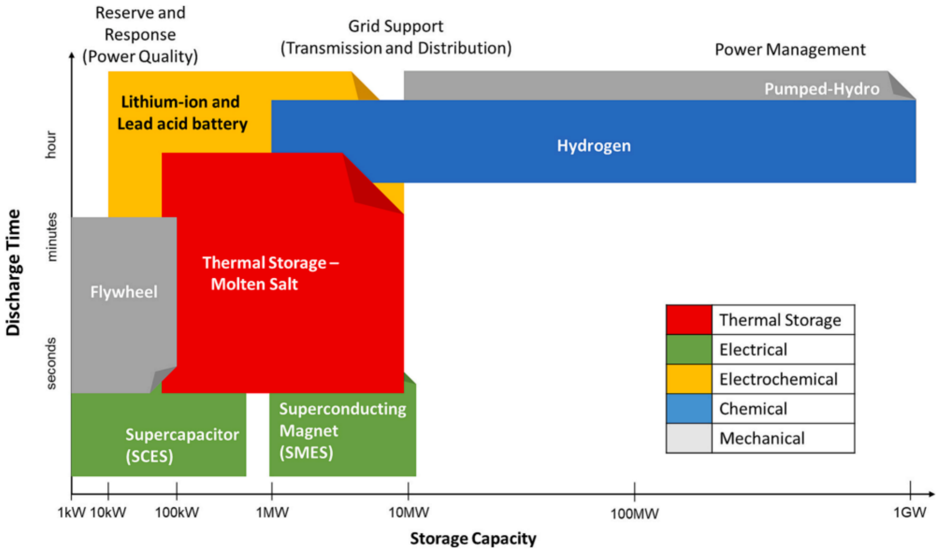


Figure 2.5: Illustration of energy storage systems according to their storage capacity and discharge duration within power system utilisation [36].

Battery technologies, such as lithium-ion and advanced lead-acid batteries, offer minutes to hours duration scale energy storage solutions that rapidly respond to demand fluctuations [33]. They store surplus energy during periods of high generation and discharge it during peak demand, ensuring grid stability [33]. Pumped hydro storage facilitates large-scale energy storage and is sustained for hours or even up to a day, depending on the size and capacity of the system. [37]. This ability makes PHES well-suited for applications requiring longer duration and bigger scale energy storage than batteries [36]. Flywheel systems store energy in rotational motion and release it by converting kinetic energy back into electricity. They offer rapid response times and high cycling efficiency [35]. The duration of the flywheel system's generation phase is relatively shorter than batteries and PHES [35].

2.5. Pumped Hydro Energy Storage

Blakers et al.(2021) explain that PHES transfers the stored water from the higher reservoir to the lower reservoir whenever there is a rise in energy demand or a decline in renewable energy production. When the water travels downward, it passes through turbines now functioning as generators to produce power from the potential energy. The stored energy is converted back into electrical energy through this process, which may then be delivered to the grid to satisfy rising demand [8]. Figure 2.6 shows the components of PHES.

PHES's capacity to react quickly to shifts in energy demand gives it its efficiency. PHES stands out from many other energy storage options due to its long-duration storage capability. PHES facilities are beneficial for meeting energy demands for extended periods since they can store energy for long periods, ranging from hours to even days.

PHES projects need appropriate topography considering the storage capacity and the elevation differential between the higher and lower reservoirs [11]. Typically, the building process entails the engineering of dams, tunnels, and penstocks and the setting up of turbines and generators [11]. Despite the original investment in infrastructure, PHES is renowned for having very cheap operational and maintenance costs over its prolonged working lifespan [36].

PHES has been successfully implemented in several nations worldwide as a mature technology, making a substantial contribution to grid stability, renewable energy integration, and energy storage capacity [38]. PHES stands apart from other energy storage systems thanks to several compelling characteristics, including:

1. High Efficiency: PHES has one of the greatest energy conversion efficiencies among energy storage devices. It is a very efficient way to store and release energy, with round-trip efficiencies topping 70% to 87% [39].
2. Long Duration Storage: Depending on reservoir capacities, PHES can store energy for long periods, extending from hours to days. This capacity addresses short-term fluctuations and long-term energy management requirements [40].
3. Large-Scale Capacity: PHES facilities have a large amount of storage space that allows them to store gigawatt-hours of energy and deliver steady power for a long time [38].
4. Low Environmental Impact: Because PHES systems use water as the energy storage medium, their environmental impact is negligible. Compared to other storage options, they have a modest operational footprint [41].

Compared to other ESS, PHES exhibits definite advantages, including:

1. Battery Energy Storage Systems (BESS): PHES offers improved long-duration storage capabilities and longer lifespans, making it suitable for handling prolonged energy demand periods. BESS systems deliver high power output and quick response times [42].
2. Flywheel systems: PHES frequently have greater storage capacity, enabling them to hold and release more energy for extended periods. Compared to flywheel systems, PHES is typically more cost-effective regarding initial investment and ongoing operating costs [43].
3. Thermal Energy Storage (TES): Because TES systems store energy as heat, their flexibility for producing electricity is constrained. PHES offers a more versatile means of converting potential energy into kinetic energy [43].

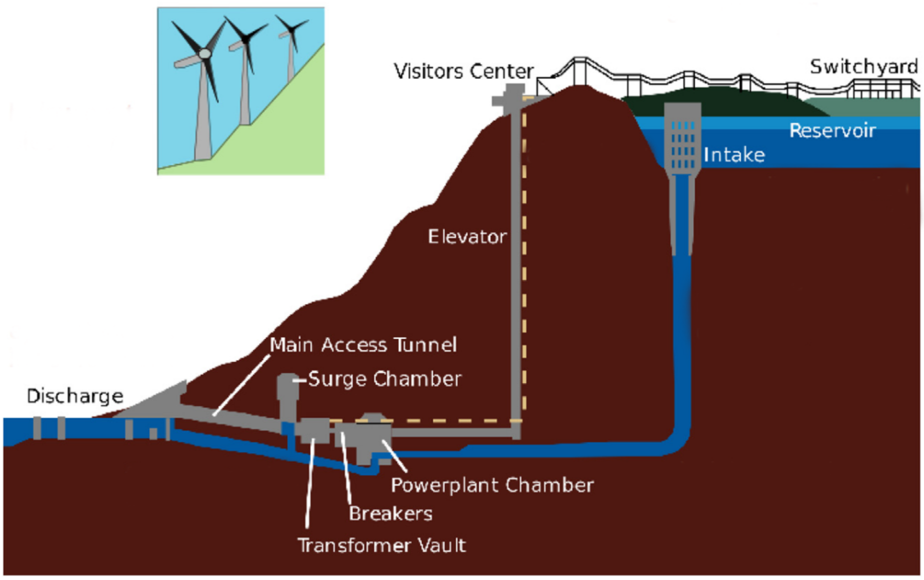


Figure 2.6: Components of pumped hydro energy storage [15].

PHES encompasses several distinct types based on the characteristics of the reservoirs' location, including pumped-back, open-loop, and closed-loop systems. When selecting the type of PHES, several factors must be considered. These factors include technical, environmental, regulatory, and economic considerations to ensure that the chosen system fulfils the requirements and objectives of the project [9]. The site's physical characteristics, such as elevation differences, natural water bodies, and available land, are crucial in determining which PHES type is feasible [11]. The availability and sustainability of water sources have a significant bearing on the choice of PHES. Open-loop and pumped-back PHES systems rely on natural water bodies, whereas closed-loop PHES systems require artificial reservoirs.

Pumped-back Pumped Hydro Storage (PBPHS)

The same river acts as both the upper and lower reservoirs. However, when energy storage is required, this PHES form acts as a pumped storage system backed by potential energy in the higher reservoir. In normal circumstances, it functions as a traditional hydropower plant [9].

Figure 2.7: Pumped-back pumped hydro energy storage [44].

Open Loop Pumped Hydro Storage

The primary distinction between open-loop PHES and other types of PHES resides in the water sources used and the characteristics of those water sources. In an open-loop PHES system, the reservoirs are connected to a natural water body, typically a river or lake, providing continuous water discharge. The water used for energy storage and conversion is replenished naturally and is part of the extant water cycle [9]. Open-loop pumped hydro storage systems necessitate cautious water management to ensure a consistent and sustainable water supply.

Figure 2.8: Open loop pumped hydro energy storage [45].

Closed Loop Pumped Hydro Storage

The distinction between closed-loop pumped hydro storage and other types of PHES resides in their methods of utilising water sources and the properties of those sources. In a typical closed-loop PHES system, the water source consists of reservoirs that have been artificially created and are located at various elevations. These reservoirs contain water dedicated solely to the energy storage process and not a component of the natural water cycle [9]. Figure 2.9 illustrates a closed-loop PHES system. In this configuration, both reservoirs are isolated and not connected to a natural water body, such as a river or lake.

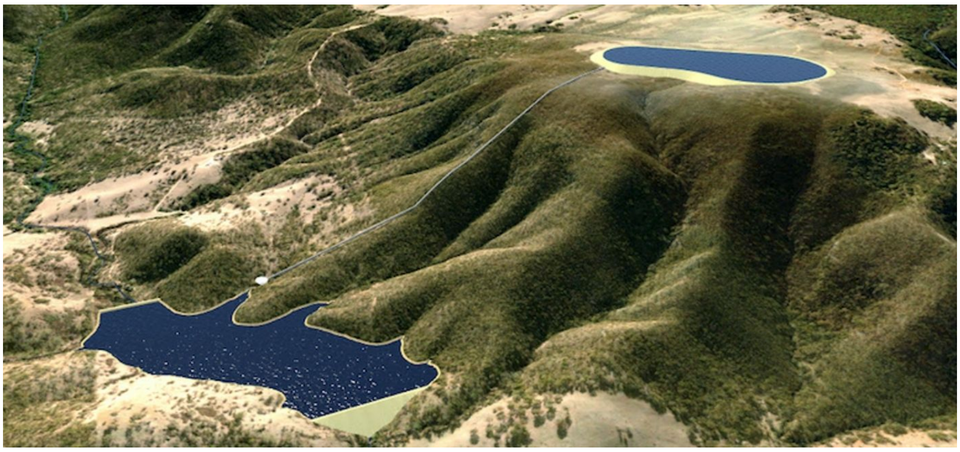


Figure 2.9: Closed loop pumped hydro energy storage [46].

2.6. Seawater PHES

Both Seawater Pumped Hydro Storage (SPHS) and Pumped Hydro Energy Storage (PHES) are types of hydropower-based energy storage, but there are differences between them. SPHS is a variant of PHES whose working fluid is seawater. Instead of constructing two reservoirs, SPHS systems are typically constructed near the coast, with the sea as the lower reservoir [47]. During periods of excess energy, seawater is pumped to a reservoir at a higher altitude or further inland. When electricity is needed, seawater is released from the reservoir and flows through turbines back into the ocean to generate electricity. One advantage of SPHS is that it doesn't compete with freshwater resources used for drinking, irrigation, tourism, and other purposes.

Due to the enormous quantity of available seawater, the SPHS possesses the potential for large-scale energy storage. The seawater serves as one of the reservoirs, thereby reducing the infrastructure requirements and environmental considerations associated with reservoir construction [48]. Figure 2.10 shows an example of an upper reservoir for a SPHS system in Ludington, Michigan, located next to the coastline.

Indonesia's extensive shoreline offers ample access to seawater, which can be utilised for energy storage. This abundant coastal resource is a reason for research to examine the potential of SPHS in Indonesia.

Figure 2.10: SPHS system in Ludington, Michigan [49].

2.7. Pumped Hydro Storage in Indonesia

In Indonesia, PHES seems to have great potential for facilitating the integration of intermittent renewable energy sources. Its advantages and difficulties are integral to pursuing a sustainable energy future. With PHES, Indonesia's extensive solar, wind, and hydroelectric power potential can be utilised more efficiently, which allows for storing excess renewable energy, mitigating the intermittent nature of sources such as solar and wind. PHES enables efficient energy balancing by storing extra energy during low-demand hours and delivering it when required, thereby reducing reliance on fossil fuels and enhancing energy security. By maximising the utilisation of renewable energy sources, PHES can contribute to Indonesia's climate goals by substantially reducing greenhouse gas emissions.

The first PHES project in Indonesia is the Upper Cisokan pumped storage hydropower plant, set to be located in West Java, which is planned to commence in 2022. With an expected capacity of 1,040 MW, this project aims to address the growing electricity demand during peak periods and provide substantial energy storage capabilities to facilitate the integration of renewable energy sources. As a result, it will contribute to a more environmentally sustainable and dependable electricity supply, benefiting consumers in the densely populated regions of Java and Bali [50].

To navigate the development of PHES in Indonesia, it is crucial to consider its prospective benefits and significant implementation obstacles. The construction of PHES facilities may have environmental repercussions, such as habitat destruction, water consumption, and alterations to the natural river flow. Identifying sites with the necessary topography and water resources, particularly in densely populated areas, can take time and effort. Furthermore, It is essential to balance land use and environmental concerns. The initial investment required for PHES development can be sizable, where financing and investment models must be established to attract private and public funding. Moreover, successful PHES projects must involve local communities and resolve their concerns regarding land use, environmental impacts, and potential disruptions.

Chapter 3

Methodology

Chapter 3 provides a detailed insight into the methodology employed to identify potential SPHS sites in Indonesia. This chapter outlines the data sources, software tools, and systematic procedures utilised to assess the technical and economic feasibility of SPHS across the nation. Furthermore, it explains the method for collecting technical site attributes.

3.1. Data and Software

Identifying potential sites for SPHS is contingent upon the availability and utilisation of data sources, specialised software, and analytical tools. In the analysis and decision-making processes, DEM, software platforms, and geospatial tools are indispensable.

Geographic Information System (GIS) is a technology used to capture, store, analyse, and present spatial and geographical data [14]. In this study, GIS is utilised to process the DEM data. GIS platforms, such as QGIS and ArcGIS, enable the integration, visualisation, and analysis of numerous geospatial datasets stored in DEM data. These software packages enable researchers and engineers to generate topographic maps, contour lines, and 3D visualisations, which facilitates identifying and evaluating suitable SPHS locations.

In addition, specialised geospatial tools, such as SAGA and PCRaster, frequently incorporated into GIS software, enable professionals to conduct comprehensive analyses. These instruments facilitate the calculation of slope angles, drainage patterns, and flow direction, thereby facilitating the selection of upper and lower reservoir sites. Incorporating hydrological data to evaluate water availability and flow dynamics ensures a comprehensive evaluation of site viability.

3.1.1. Digital Elevation Model (DEM)

Analysing the topography is crucial in locating sites suitable for SPHS. DEM data has emerged as an indispensable resource for this endeavour, providing a complete depiction of a region's terrain. DEM data, typically derived from satellite or airborne surveys, provides a detailed elevation profile of the land surface, including altitude and slope variations.

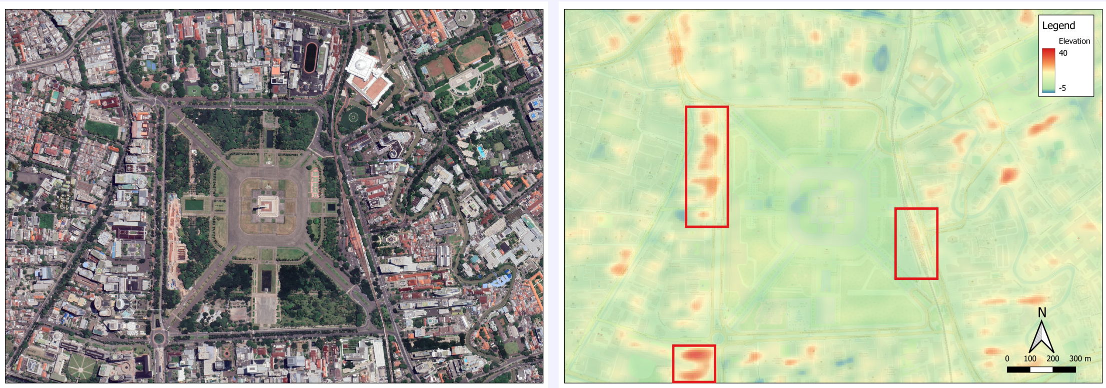
DEM data facilitates the construction of topographic maps, contour lines, and three-dimensional visualisations, thereby facilitating the visualisation of potential SPHS sites. These maps and models provide a comprehensive view of elevation changes, allowing for the identification of prospective upper reservoir locations and the evaluation of their hydraulic viability.

To identify potential sites for SPHS in Indonesia, selecting the optimal DEM data source is crucial.

DEM Nasional (DEMNAS), a comprehensive dataset provided by Badan Informasi Geospatial (BIG) of Indonesia, was utilised for this research. DEMNAS has a spatial resolution of 8.25 meters (0.27-arcsecond), a notable feature. This level of detail enables us to depict Indonesia's diverse terrain's intricate nuances precisely. The higher resolution of DEMNAS relative to other alternatives, such as the Shuttle Radar Topography Mission (SRTM) data, enables us to discern elevation variations and subtle topographical features that may be essential for determining SPHS suitability.

DEMNAS gathering method

DEMNAS was constructed from multiple Digital Terrain Models (DTM) and Digital Surface Model (DSM) data sources, such as IFSAR data (5m resolution), TERRASAR-X (5m resampling resolution from the original 5-10 m resolution), and ALOS PALSAR (11.25 m resolution) [51]. Due to the use of DSM, the provided data may be canopy elevation rather than terrain elevation.



(a) Satellite view **(b)** DEMNAS

Figure 3.1: Satellite view vs. DEMNAS.

Figure 3.1 (highlighted in red) illustrates that the data obtained from DEMNAS pertains to land cover elevation rather than terrain elevation.

While it is possible that DEMNAS provides data related to the elevation of land cover, it can still be effectively utilised in this study. This is primarily because the study area predominantly encompasses rural regions with extensive vegetation cover. In these areas, the specific elevation of natural features and terrain details may not be as critical as obtaining a general understanding of the terrain's broader characteristics.

3.1.2. GIS Software

QGIS has been selected as the GIS software for this study. QGIS is an open-source program, which makes it readily available to researchers and professionals. This accessibility aligns with the dedication to accessibility and transparency in the research endeavours. In contrast to proprietary GIS software such as ArcGIS, QGIS eliminates licensing fees and restrictions, ensuring the analysis is not constrained by financial constraints. This accessibility democratises geospatial analysis, enabling a larger audience to interact with and benefit from our research findings.

One of the most notable features of GIS to support this study is its robust support for Python scripting for customisation and automation. Python, a versatile and widely used programming language, enables the automation of complex geospatial duties. Creating Python programs that facilitate the analysis of

DEM data makes the workflow significantly more streamlined and repeatable. The compatibility of QGIS with Python demonstrates its adaptability and versatility in meeting our research's specific needs.

3.1.3. Tools and Features

In the research, the QGIS plugin known as PCRaster played a role in the geospatial analysis, which included streamflow identification to identify the valleys, catchment delineation, and inundation calculation. With an emphasis on objective and reproducible analysis, these key functionalities were utilised to evaluate potential sites for SPHS in Indonesia.

Stream identification using the PCRaster plugin identifies and delineates the geographical features associated with valleys where SPHS systems might be potentially constructed. Catchment delineation utilised DEM data and PCRaster's capabilities to identify watershed boundaries and define catchment areas associated with particular valleys. The third feature, inundation calculation, enabled estimating areas impacted by submersion or inundation during reservoir construction.

3.2. Identification of Potential SPHS Sites

The study evaluates power generation potential, head loss, investment requirements, and penstock line topography. It was initiated by collecting data, including DEM data from BIG. Using GIS tools, streamflows were identified within the DEM data, aiding in the recognition of locations with valleys suitable for SPHS. The primary objective of this study is to identify potential SPHS locations in Indonesia that possess significant energy potential, surpassing the qualifications for medium-scale hydropower generation, which is typically defined as having an energy capacity exceeding 15 MW. By emphasising this threshold, the objective is to distinguish sites with the ability to generate a considerable amount of power, thereby maximising the investment efficiency. This approach helps ensure that the identified locations are not only numerous but also possess the necessary power generation capabilities to make them economically viable and environmentally beneficial for the development of SPHS systems.

The economic assessment carried out in this study aims to calculate the Levelised Cost of Storage (LCOS) for each identified site. This calculation considers various factors, including Capital Expenditure (CAPEX), Operational Expenditure (OPEX), and other relevant parameters. Once the LCOS for each site is determined, it is compared with the ceiling price of electricity in the respective region. This comparison is essential to assess the economic viability of each site, as it determines whether the potential SPHS system can generate electricity at a cost lower than the prevailing electricity price ceiling in its designated area. The detailed information about LCOS calculation is explained in Subsection 3.2.5.

Environmental impact assessment focuses predominantly on carbon reduction. The transition from fossil energy generation to renewable energy sources represents a fundamental shift toward sustainable and environmentally responsible energy practices, making this evaluation essential. This study highlights the environmental benefits associated with developing SPHS in Indonesia by quantifying the reduction in carbon emissions resulting from this transition.

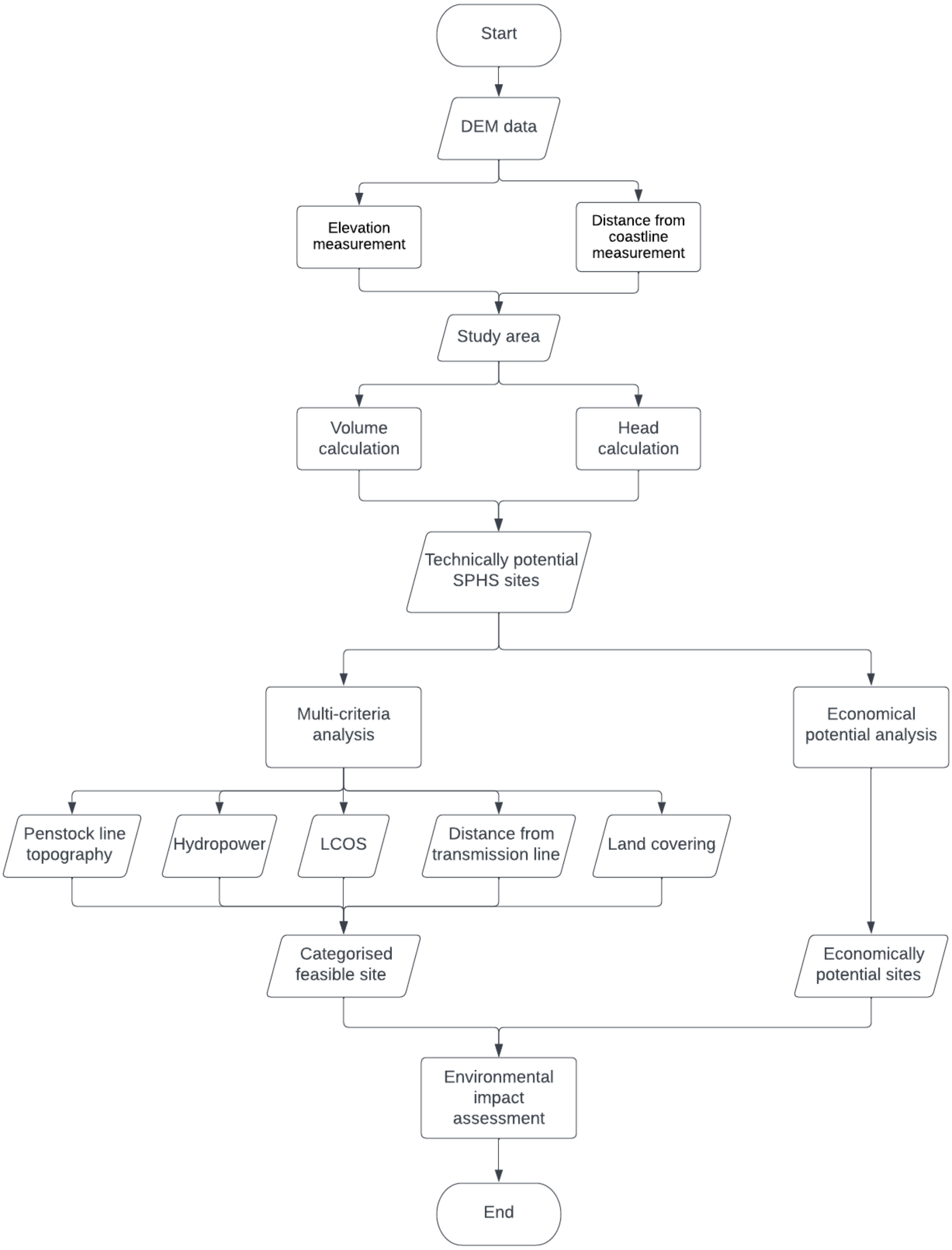


Figure 3.2: The methodology flow chart of the research.

3.2.1. GIS-based Model (DEM Analysis)

The primary focus of this study is the development of a Python script to automate the process of identifying potential SPHS locations. Automating the processes with a Python script is crucial in streamlining the SPHS site selection process.

Identifying valleys and inundation areas is a feature of the script. These characteristics are necessary for evaluating the topographical suitability of potential SPHS sites. By outsourcing the extraction and delineation of these geographical elements, the Python script ensures consistency and efficiency while reducing the time and effort required for analysis.

The development of the Python script represents a significant development in the research, as it enables the study to expand its analysis to encompass a broader range of potential SPHS sites. In addition, the automation of the script ensures the reproducibility and transparency of the research methodology, allowing others in the field to replicate and validate the findings.

Preprocessing

This study's initial analysis phase involves merging the acquired DEM files. This process is necessary due to the limited size of the downloaded DEM datasets, which typically cover an area of approximately 770 square kilometres for each file. Due to Indonesia's immense and diverse geography, which spans numerous islands and coastal regions, it is necessary to combine these individual datasets to represent the nation's topography. With 38 provinces in Indonesia, 37 of which have coastlines, the study is designed to strategically conduct analyses on a provincial level.

In the following analysis stage, a buffer zone is established 8 kilometres inland from the coast. This buffer zone is set at an 8-kilometre distance from the shoreline because SPHS site suitability is typically enhanced by proximity to the coast. To ensure that the selected locations within the buffer zone are suitable for SPHS, the analysis also imposes an elevation criterion, requiring that the land within this area be at least 200 meters above sea level. This elevation threshold is set to fulfil specific requirements related to the water storage volume and the inundation area necessary to store a minimum amount of energy efficiently.

After defining the buffer zone with the specified elevation threshold, the analysis focuses on this particular study area. This concentrated study area is selected because it is more likely to contain suitable topographical characteristics for SPHS development, such as the necessary elevation differentials and proximity to marine sources.

After defining the focus area, the next stage is clipping the DEM data to this focus area. This process isolates and extracts the topographical data within the focus area from the broader DEM dataset. By isolating this specific region, the study can evaluate the terrain's suitability for potential SPHS sites, considering elevation, storage volume, and other topographical parameters essential for determining SPHS feasibility.

The next step is creating a dataset of local drain directions using the PCRaster plugin, followed by the delineation of streamflows to identify the valleys, constituting the subsequent phase in the analysis. local drain directions dataset contains vital information regarding water flow direction across the study area's terrain. It depicts how water naturally travels and drains across the landscape by identifying its paths. This directional information is indispensable for the subsequent analysis processes.

After generating a dataset of local drain directions, the study defines streamflows. Streamflows represent various levels or magnitudes of river flow, each illustrating a distinct flow scenario. These streamflows aid in evaluating the hydrological characteristics of the terrain, enabling the evaluation of how water travels through the landscape under different conditions. By delineating streamflows at multiple levels, the study ensures a thorough examination of the topographical suitability of the study area. This approach identifies optimal SPHS locations that align with specific valleys represented by streamflows. This study categorises the streamflows used for analysis based on their stream order, focusing mainly on streams with a Strahler order of 5. The selection of Strahler Order 5 in this study is based on a thorough evaluation of various Strahler orders. Strahler Order 5 is deemed the most suitable for identifying valleys and river networks that align with the requirements of SPHS systems. This choice was made after a series of trial-and-error processes.

The preprocessing phase has been meticulously described and encapsulated in the Python QGIS (PyQGIS) script, which is available for reference in Appendix C or as "01.preprocessing.py" within the supplementary files. This script encapsulates the precise sequence of operations carried out during the preparatory phase, such as data merging, buffer area creation, local drain direction generation, and streamflow delineation.

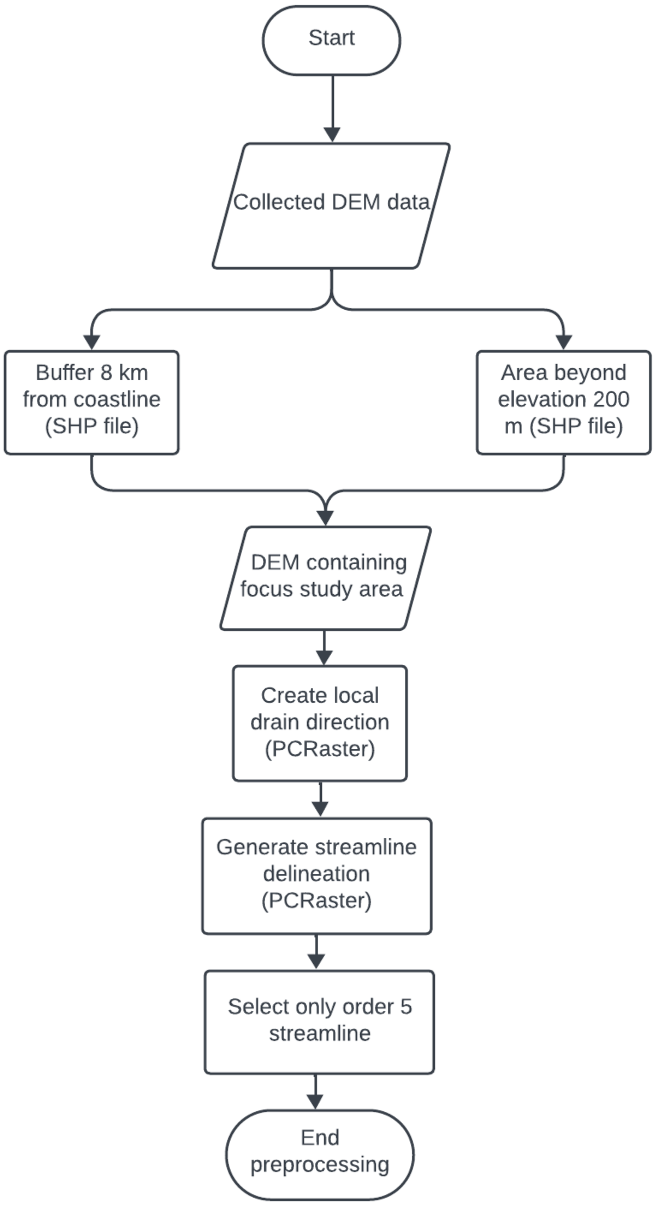


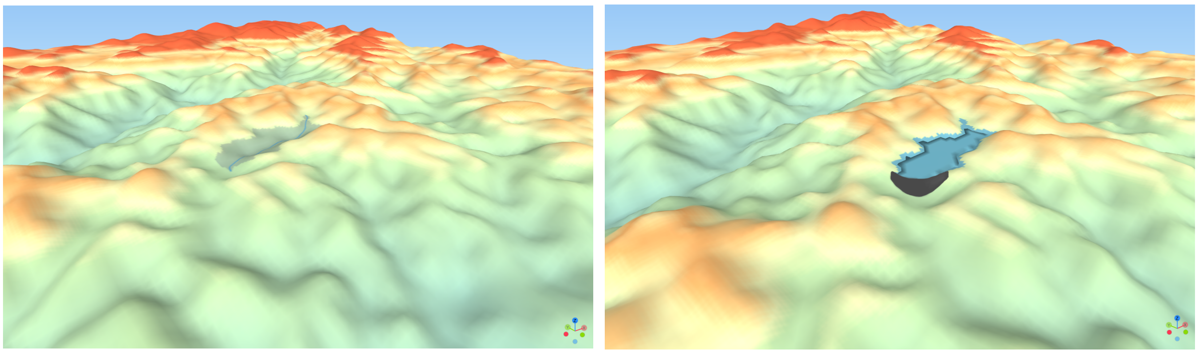
Figure 3.3: Preprocessing flowchart.

Main Process

Identifying prospective SPHS sites requires evaluating each candidate location via a series of steps. First, for each valley represented by a branch of streamflow with a Strahler order of 5, the analysis identifies the lowest elevation along that branch to determine the outflow point. This essential stage pinpoints the ideal location within the stream network for potential SPHS development.

Subsequently, the calculation of catchment areas is carried out using the "catchment" algorithm available in the PCRaster software. This algorithm aids in delineating the catchment boundaries associated with each selected streamflow branch. These catchment areas serve as the foundation for further analysis.

After defining the catchment areas, the analysis simulates the installation of a 15-meter-tall dam at the outflow of each catchment. In this study, Indonesian regulatory considerations primarily influenced limiting the dam's height to 15 meters. Dams exceeding 15 meters in height are considered "large dams" under Indonesian regulations. This classification necessitates more intricate and stringent design and safety procedures, which can significantly impact the planning and implementation of a hydropower project. Figure 3.4 illustrates the 3D visualisation of the simulation result.



(a) Before inundation

(b) After inundation

Figure 3.4: 3D Visualization of identified SPHS site: algorithm-generated potential location for SPHS

The dam replicates the structure used in an SPHS system and enables the identification of inundation zones within the catchment. The study obtains insight into the available energy potential by calculating the water-impounding volume resulting from this flooding. This analysis uses a cell-by-cell approach to estimate the inundation volume. This indicates that the analysis quantifies the volume of water for each DEM cell or pixel. To achieve this, the following formula is applied to each cell.

$$V = \sum_{i=1}^{n} h_i * gridsize^2 \tag{3.1}$$

The volume calculation formula considers several variables, including the DEM elevation data and the area represented by each cell. It calculates the volume of water that would occupy the space defined by the difference elevation between the water level in the reservoir with the related ground level (h_i) and the area of the cell. The analysis systematically evaluates the entire dam-formed reservoir by executing this calculation for every DEM cell.

The resolution of the DEM data is an essential factor to consider in this procedure. The resolution of a dataset refers to the measurement of each cell or pixel. A DEM dataset with a higher resolution contains smaller, more numerous cells that provide precise topographic detail. In contrast, a DEM dataset with a lower resolution incorporates larger cells and provides coarser topographical information.

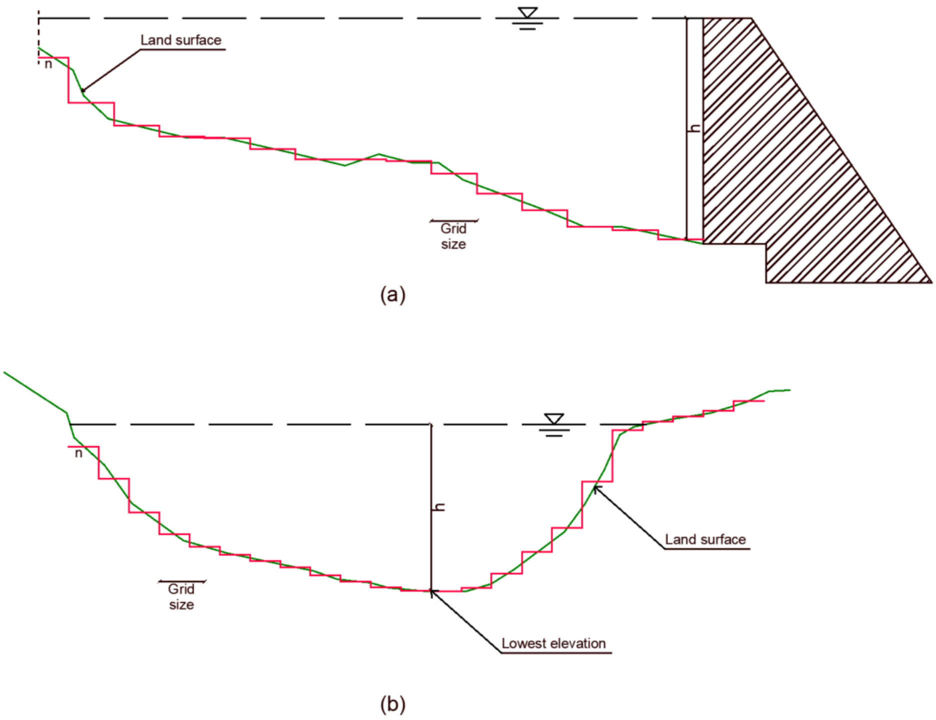


Figure 3.5: Longitudinal (a) and cross-sectional (b) profile of the reservoir.

The calculation of potential energy considers the dam-created reservoir's inundation volume and elevation. This calculation helps estimate the energy production capacity of each identified location. If the calculated potential energy exceeds a predetermined threshold value, in this study 120 MWh, the analysis continues to generate additional vital data. The following formula calculates the potential energy stored in the reservoir.

$$E = \frac{\eta * \rho * g * V * H}{3600} \tag{3.2}$$

Where E is potential energy stored in the reservoir in watt-hour (Wh), η is the efficiency of the system, in this study, the efficiency is determined to be 80%, V is the volume of the reservoir in m^3, and H is the head in meters.

For locations that meet the energy threshold, the analysis further characterises the site by determining its exact distance from the nearest coastline. In addition, the calculation evaluates the penstock slope, which is essential for effectively transferring water between the upper and lower reservoirs during the generation phase of SPHS operation. The study also quantifies the potential power that can be generated during this generation phase.

By following these steps, the analysis systematically evaluates potential SPHS sites, considering multiple factors and criteria to identify locations that offer the most promising prospects for efficient and sustainable energy storage in the coastal regions of Indonesia.

As shown in Figure 3.6, the outlined stages have been incorporated into a PyQGIS script, automating each streamflow branch's evaluation. This report's Appendix D for the detailed script entitled "02. main-process.py" can be used as a reference for the process. This scripted method streamlines the analysis, allowing for an accurate and reproducible evaluation of prospective SPHS sites across Indonesia's coastal regions.

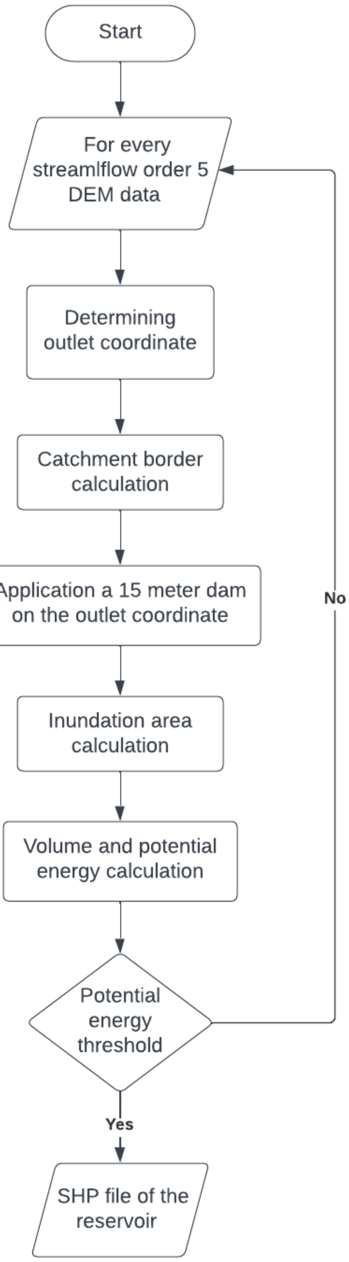


Figure 3.6: Main processing flowchart.

3.2.2. Hydropower Calculation

In this study, the hydropower calculation aligns with the typical daily energy consumption pattern, reflecting the gradual increase in electricity demand. This pattern is observable from 4 p.m. onwards, with the peak power demand occurring at 8 p.m., as illustrated in Figure 3.7. Consequently, the SPHS system design considers this energy consumption curve and aims to provide power over an 8-hour duration, commencing at 4 p.m. and concluding at 12 a.m., where the hourly power generation distribution can be seen in Figure 3.8. The power production potential of SPHS is determined by evaluating the peak power generation capacity, measured in MWp, representing the maximum power produced in one generation phase.

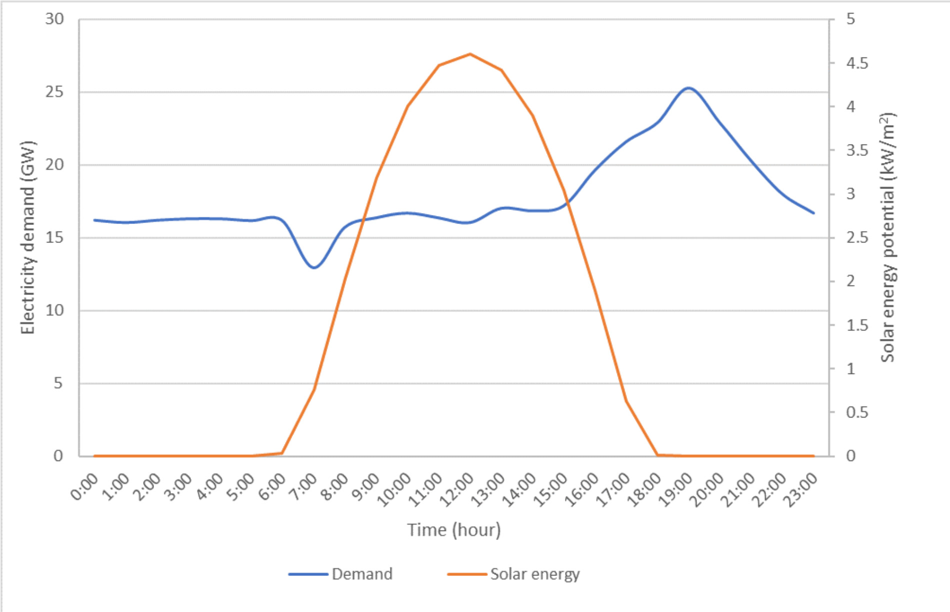


Figure 3.7: Daily electricity demand pattern vs solar energy availability [18] [52]

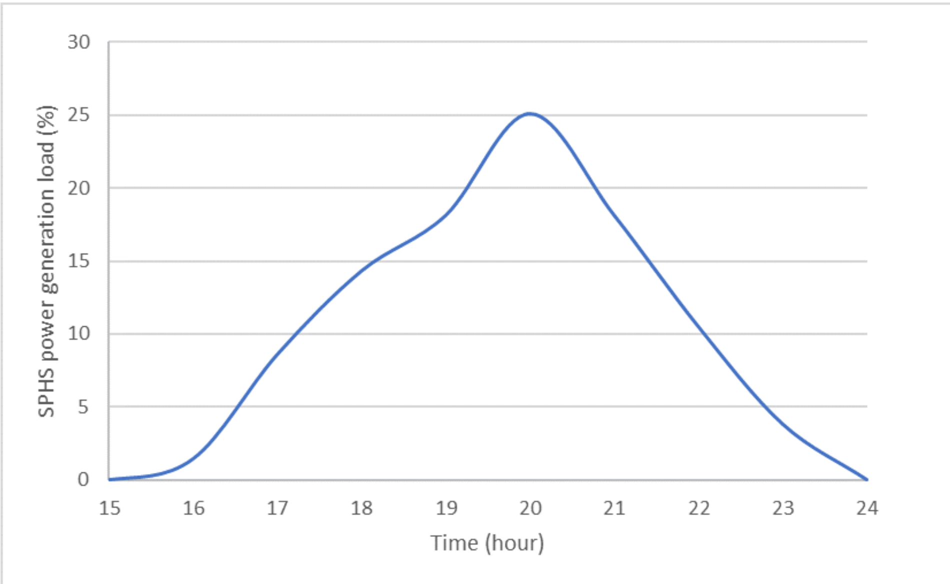


Figure 3.8: Daily SPHS generation phase pattern.

As water flows through various components of the hydropower system, such as penstocks, frictional losses occur. Mainly, roughness-induced losses and localised losses due to changes in the cross-section of the direction of the flow are influenced by variables such as flow velocity, penstock dimension, roughness, and fluid viscosity. Frictional losses directly impact the system's efficiency and, consequently, the amount of energy that can be harnessed.

On the other hand, local losses occur at specific points in the system where the flow is interrupted or redirected. Abrupt changes in the geometry of the conduit, such as bends, junctions, or sudden expansions or contractions, frequently cause these losses. Local losses can significantly impact the overall system efficiency and must be accounted for in hydropower potential calculation.

Head Loss Calculation

Calculating head loss for PHES necessitates careful consideration of several factors to ensure accurate and reliable results. The system's hydraulic characteristics must be specified first, including the penstock's length and dimensions. In addition, the choice of materials and surface texture of the hydraulic components significantly impact head loss calculations. Flow rates, fluid characteristics, and environmental conditions such as temperature and pressure also play crucial roles. In addition, the system must account for the effects of friction, turbulence, and any connectors or valves. Lastly, it is imperative to account for any losses caused by the pump turbine. To accurately estimate head loss and maximise the efficiency of PHES systems, it is necessary to conduct a comprehensive analysis of these factors. The following formula can describe the total head losses (ΔH_{ea}).

$$\Delta H_{ea} = \Delta H_f + \Sigma \Delta H_s \tag{3.3}$$

Where ΔH_f is friction loss in penstock and ΔH_s is local losses produced by valve, pipe bend, trash rack and other parts of the hydropower.

1. **Friction Loss in Penstock:** The calculation of friction loss (ΔH_f) within the Seawater Pumped Hydro Storage (SPHS) system involves a systematic series of steps to ensure efficiency and accuracy. To begin, the peak discharge is determined based on the system's operational requirements. This discharge value is crucial for further calculations. Subsequently, an initial velocity of 4 m/s is set as a starting point, serving as a reference for the dimension of the penstock required. The discharge is then divided by this initial velocity to establish the penstock's preliminary dimensions.

   To align with practical market availability, these dimensions are rounded up to match readily accessible sizes. However, this is not the final step, as the velocity must be evaluated to fall within the optimal range of 2-5 m/s. The friction loss itself is determined using the Hazen-Williams formula, considering the hydraulic slope (S). The hydraulic slope is calculated using a specific formula, as can be seen in Equation 3.4.

$$S = \frac{Q^{1.85}}{0.08905 * C^{1.85} * D^{4.87}} \tag{3.4}$$

   The parameter "C" represents the roughness coefficient, which describes the inner surface of the pipe used for the SPHS penstock. This coefficient measures the resistance to water flow within the penstock and is affected by the pipe's surface roughness.

   Glass Reinforced Plastic (GRP) pipe has been selected for the penstock. The selection of GRP pipes is based on their specific properties, which make them suitable for this application. Corrosion resistance is one of the primary advantages of using GRP pipes in the SPHS system. Given that the system operates with seawater, which can be extremely corrosive to many materials, it is crucial to choose a corrosion-resistant material such as GRP. This decision helps ensure the penstock's long-term durability, avoiding potential problems associated with corrosion-induced damage. The roughness coefficient (C) for GRP is 150. Q and D are discharge in m^3/s and penstock diameter in meters respectively.

   The study considers the operational pressure within the penstock, which is the pipeline or channel used to transport water in a pumped hydro storage system. This operational pressure must meet certain standards of the American Society for Testing and Materials) (ASTM) and the manufacturer's specifications [53].

Finally, the friction loss is subsequently computed by multiplying this hydraulic slope by the length of the penstock, as can be seen in Equation 3.5. Moreover, the penstock length (L) is determined by the vertical distance between the lowest elevation of the reservoir and sea level (h) and the distance between the reservoir outlet and the coastline (l). The shortest horizontal distance between the reservoir outlet and the coastline (l) must be multiplied by a factor to consider the topography condition between the reservoir and the coastline and the delta condition requiring a longer distance. The multiplying factor was assumed to be 1.5 in this study.

$$\begin{aligned} \Delta H_f &= S * L \\ L &= \sqrt{l^2 + h^2} \end{aligned} \tag{3.5}$$

2. **Local losses:** Local losses (ΔH_s) in head loss calculations encompass a variety of hydraulic factors that can influence the system's overall effectiveness. These elements include bends in the penstock, the design and configuration of trash racks, the characteristics of intake and outlet structures, and other components. These local losses (ΔH_s) must be considered because they impact the hydropower system's overall performance. This study uses the simplified estimation of local losses by attributing them to approximately 50% of the estimated friction losses experienced along the penstock. This simplification permits a reasonable approximation of local losses while maintaining a practical and computationally manageable approach to the head loss calculation, particularly when dealing with complex systems such as SPHS.

Pump-Turbine

The selection of an appropriate pump-turbine for a hydropower system is contingent on several crucial factors, including head, discharge, and generated power. The head, the vertical distance between the water source and the turbine, is the most critical factor. It directly impacts the available energy for conversion and dictates the type of pump-turbine required. The volume of water passing through the turbine per unit of time is determined by the discharge or water flow rate. This, along with the head, defines the system's hydraulic conditions and power potential. The ultimate objective is to generate power, which is contingent upon the combination of head and discharge, as well as the efficacy of the chosen pump turbine.

In this study, the selection of Francis turbines for the hydropower system is influenced by specific factors, such as the desire to generate more than 15 MW of electricity. The Francis turbine is renowned for its adaptability to various hydraulic conditions, making it an ideal choice for situations involving variable flow rates and head levels.

The efficiency of a Francis turbine can vary based on several variables but typically falls between 80% and 95% [54]. In this particular study, an 85% pump turbine efficiency ($\eta_{turbine}$) has been assumed. This assumption allows a conservative estimate of the system's performance based on a reasonable assumption to be made. Although actual efficiency may vary depending on the design, operation, and environmental conditions of the turbine, a 85% efficiency assumption provides a practical and widely accepted baseline for the calculations.

Finally, the power generated by the system (P) can be estimated using Equation 3.6.

$$P = \eta_{turbine} * \rho * g * Q * (H - \Delta H_{ea}) \tag{3.6}$$

Where ρ is the density of the seawater in kg/m^3, Q is the flow discharge, calculated by dividing the reservoir volume (m^3) by the operational phase duration (hours converted to seconds), and H is the elevation different between the reservoir and the sea level in meters.

3.2.3. Distance from The Electricity Grid

The distance between each SPHS system and the closest electric grid must be computed to evaluate the system's integration into the electrical infrastructure. This calculation is based on estimating the distance between the SPHS installations and the nearest 500 kV or 150 kV transmission line. To accomplish this, the Indonesian Ministry of Energy and Mineral Resources provides a specific map from which the transmission lines are extracted. This map is a trustworthy and authoritative source of information regarding the locations of transmission lines, enabling accurate distance calculations.

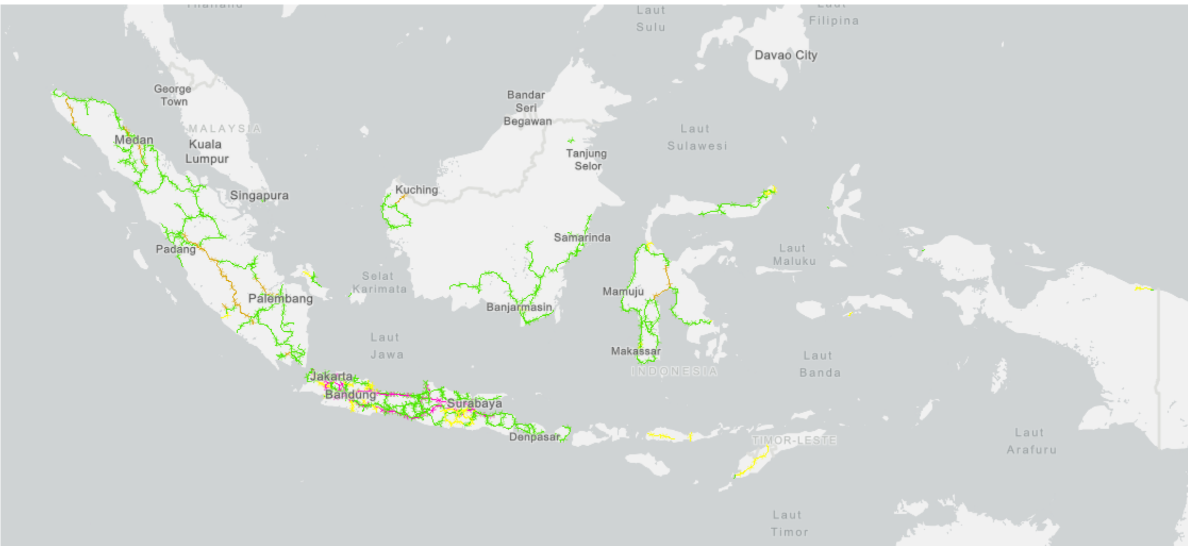


Figure 3.9: Indonesia's electric transmission lines map [55]

In addition to optimising electrical infrastructure planning, this distance measurement will be a crucial factor in the multi-criteria analysis of the potential sites. Considering the proximity distance of each PHES system to the grid and the associated electrical infrastructure, the costs associated with connecting these systems to the grid and transmitting the generated energy can be estimated.

3.2.4. Penstock Line Topography

The topography of the penstock line is evaluated by calculating the standard deviation of the slope for each cell that the penstock traverses. This assessment uses the "terrain profile" plugin in QGIS. When the standard deviation of the slope in each cell is lower, it indicates that the topography of that area is more favourable for supporting SPHS project. In other words, a lower standard deviation of the penstock line slope suggests a more even and suitable terrain for developing the SPHS system.

3.2.5. Levelised Cost of Storage (LCOS)

LCOS calculation formula comprises several key components, each contributing to the overall assessment of the cost of energy storage over its operational lifetime. These components include CAPEX, representing the installation and construction costs associated with the energy storage system. It comprises equipment, infrastructure, land, permits, and installation expenditures. Typically, CAPEX is expressed as a cost per unit, such as euros per kWh of storage capacity. Secondly, OPEX consists of the ongoing expenses associated with operating and maintaining the energy storage system over its lifetime. This includes routine maintenance, labour, monitoring, insurance, and any other recurring operational expenses. Typically, OPEX is expressed as an annual cost. LCOS is also dependent on the revenue produced by the energy storage system (E_{out}). It represents the revenue earned from selling stored energy to the grid or participating in energy markets. Typically, the revenue is determined by the system's energy output and the prevailing electricity market prices.

In LCOS calculations, both the discount rate (i) and the system's operational lifetime (t) are considered. The discount rate is an essential parameter to adjust future costs and benefits to their present value. It considers that the value of money declines over time due to inflation and the opportunity cost of committing capital to the project. A 6% discount rate has been selected for this study. This means that future costs and benefits are converted to their equivalent value in today's currency, considering the expected inflation rate. The operational lifetime of the energy storage system is the number of years the system is expected to function efficiently and effectively before requiring significant maintenance or replacement. In this study, the system lifetime is set to 50 years, indicating that the analysis considers the costs and benefits of the energy storage system over 50 years.

$$\text{LCOS} = \frac{\text{CAPEX} + \Sigma_{t=1}^{n} \frac{\text{OPEX}}{1i^t}}{\Sigma_{t=1}^{n} \frac{E_{out}}{1i^t}} \tag{3.7}$$

In this study, the LCOS is calculated using a method developed by Al Zohbi in 2022, as documented in the Encyclopedia of Energy Storage [56]. The work of Al Zohbi (2022) is an important contribution to the field of energy storage economics. His approach simplifies the LCOS estimation procedure, making it more accessible and applicable to PHES project stakeholders.

Al Zohbi's method is intended to provide a simple and user-friendly method for evaluating the economic viability of PHES systems. Using his methodology, project developers, investors, and policymakers can gain valuable insight into the financial aspects of PHES projects. This method simplifies the LCOS calculation, making it easier to make well-informed decisions regarding the implementation and funding of PHES technology.

Capital Expenditure (CAPEX)

In this study, the calculation of CAPEX for SPHS system considers several investment factors. These components include the electro-mechanical equipment, which includes the cost of required machinery, electrical components, and associated technologies for the storage system to function. In addition, CAPEX accounts for civil works, which include the costs associated with the construction of infrastructure, such as the reservoir, penstock, and other structures essential to the system's operation. In addition, indirect costs such as permitting, engineering, project management, and other associated overheads necessary to successfully implement the energy storage project are included in CAPEX. This study aims to provide a comprehensive assessment of the capital expenditure required to establish the energy storage system, thereby contributing to a more accurate evaluation of its economic viability and long-term cost-effectiveness.

1. **Cost of electro-mechanical equipment:** In the context of hydropower plants, the cost of electro-mechanical equipment typically comprises between 30% and 40% of the total project cost. This cost allocation is affected by several factors, including the head, the discharge, and the power generated by the hydro-power system. To accurately estimate the cost of electro-mechanical equipment, it is necessary to have a thorough understanding of these factors. In a recent study published in 2022 by Al Zohbi [56], an attempt was made to consolidate the calculation method by drawing on the work developed by Cavazzini et al. in 2016 [57] and Al Zohbi in 2018 [58]. Equation 3.8 shows

a simplified formula for estimating the cost of electro-mechanical equipment for hydropower systems (C_{EM}) employing Francis Turbines.

$$C_{EM} = 190.37H_m^{1.27963} + 1441610.56 * Q_{ls}^{0.03064} + 9.62402P_{kW}^{1.28487} - 162157.28 \tag{3.8}$$

2. **Cost of civil works:** Due to the dependence on the site's particular layout, estimating civil works costs is complex. Civil construction cost is estimated using unit prices and parameters such as excavation volume in cubic meters. Expenses associated with excavating the reservoir and piping, backfilling, lining, constructing waterways, the powerhouse, and installing electrical lines and piping fall under this category.

   The expense associated with constructing a reservoir (C_{res}) varies depending on the type of reservoir and several key parameters. These factors encompass excavation costs, land acquisition expenses (C_{land}), coating expenditures (C_{coat}), and spillway outlays ($C_{spillway}$). Notably, in the case of valley dam types, the excavation cost is typically disregarded. To estimate these costs, the following expressions can be employed:

$$\begin{aligned} C_{land} &= \alpha * S_{tank} \\ C_{coating} &= \delta * S_{coat} \\ C_{spillway} &= \sigma * C_{land} + C_{coating} \\ C_{res} &= C_{land} + C_{coating} + C_{spillway} \end{aligned} \tag{3.9}$$

   where S_{tank} is the surface of the reservoir (m^2), S_{coat} is the surface needed to be coated (m^2), α is the cost of 1 m^2 of land (€/m^2), and δ is the cost of coating of 1 m^2 (€/m^2).

   The cost associated with the penstock (C_{pens}) is calculated by combining several components, including the thickness of the penstock (t_{pens}) [59], excavation expenses ($C_{pens,exc}$), penstock material costs ($C_{pens,mat}$), and the cost of concrete work ($C_{pens,conc}$) [60]. Equation 3.10 shows the estimation for the penstock expenditure formula.

$$\begin{aligned} t_{pens} &= \frac{0.1 * H * D_{opt}}{2\sigma} \\ C_{pens,exc} &= 1.39 * D_{opt}^2 * C_e * L_{pens} \\ C_{pens,mat} &= t_{pens} * \rho * L_{pens} * C_m \\ C_{pens,conc} &= 0.6 * D_{opt}^2 * L_{pens} * C_c \\ C_{pens} &= C_{pens,exc} + C_{pens,mat} + C_{pens,conc} \end{aligned} \tag{3.10}$$

   where σ is the allowable stress for the material of the penstock.

   The powerhouse refers to the building that houses the majority of the electrical and mechanical equipment required for power generation. This power plant can be underground or on the ground's surface. Using a formula developed by Signal et al. (2008) [61], the construction cost of the powerhouse (C_{PH}) is determined by factors such as the head (H) and the power output (P) of the hydroelectric system.

$$C_{PH} = 30421.22P^{-0.238}H^{-0.0602} \tag{3.11}$$

   The cost associated with the investment in transmission line infrastructure is derived from Midcontinent Independent System Operator (MISO) guidelines [62]. These guidelines consider the costs associated with land acquisition and securing the right-of-way for transmission lines, construction structures and their foundations, professional services and overhead, and the conductor (the wire that carries the electricity) and shield wire (used for safety and grounding purposes). These factors estimate the total investment required for power line transmission (C_{trans}).

3. **Indirect cost:** In this context, indirect costs include a variety of engineering-related expenses, such as project management, taxes, costs associated with potential risks and unforeseen events, and project monitoring expenses. By the methodology proposed by Zhang et al. (2012), these indirect costs are equal to 50% of the direct costs, which include the combined costs of electromechanical equipment and civil work [59]. Indirect costs are supplementary expenditures necessary for the successful planning, execution, and oversight of the hydroelectric project but not directly related to the physical construction of equipment or infrastructure.

Operational Expenditure (OPEX)

The OPEX costs are the expenses associated with the ongoing operation and maintenance of the hydroelectric system's various components. These elements include the electrical infrastructure, hydro-mechanical components (such as turbines and generators), and the civil engineering framework (including dams and other structures). Numerous studies have evaluated OPEX costs, and the method of calculation can vary [63] [64]. It is typically expressed as a percentage of the initial CAPEX or as an annual cost per kilowatt (cost/kW) of installed capacity.

In this study, the approach used for estimating OPEX costs aligns with research conducted by De Jager et al. (2011). Their research suggests that, for large hydropower installations, the average OPEX cost is approximately $42 per kilowatt per year [63]. This figure provides a valuable benchmark for assessing the ongoing expenses associated with operating and maintaining a hydropower plant, in this case, SPHS, helping to ensure the project's economic feasibility and sustainability over time.

3.3. Carbon Emission Reduction Calculation

The study uses the technical and economic potential of SPHS to calculate the carbon emission reduction. This strategy entails scenarios predicated on these potentials, in which SPHS systems are presumed to generate substantial electricity. This electricity generation is a direct replacement for Indonesia's primary source of carbon emissions, coal-fired power production. The method necessitates determining the difference in CO_2 emissions between electricity generated by coal-fired power plants and SPHS systems. The calculated difference represents the quantifiable reduction in carbon emissions that can be realised by implementing SPHS technology.

Chapter 4

Site Rank and Classification Criteria

This chapter delves into the methodology used to rank and classify the identified SPHS sites based on their priority and feasibility. This chapter explains the criteria and parameters for assessing and differentiating these sites.

4.1. Selection Criteria

This study uses a hybrid method known as Analytic Hierarchy Process-Technique for Order of Preference by Similarity to Ideal Solution (AHP-TOPSIS) to classify potential SPHS sites based on multiple criteria [65]. Using the Analytic Hierarchy Process (AHP) method, weights are assigned to various evaluation criteria based on their relative importance [66]. Once the criteria are weighted, the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method is applied to classify and rank the potential SPHS sites based on their overall performance against the established criteria, using the weights assigned to each criterion [15]. This combined approach offers a robust and systematic way to assess and classify potential SPHS locations, ensuring that the most suitable sites are identified for development.

These analysis parameters included the topography of the penstock line, the potential power that could be harnessed at each site, the site's distance from the electrical grid, the type of land covering the area, the site's proximity to the coastline, the LCOS, and the site's total inundation area. The achieved consistency ratio (CR) from AHP analysis is 0.058, which is comfortably below the required threshold of 0.1, validating the consistency of the AHP results. These weighting factors were subsequently used in the TOPSIS analysis, allowing for a comprehensive and systematic classification of the potential SPHS sites based on their weighted criteria, as detailed in Table 4.1.

Table 4.1: Weights of selected criteria for the TOPSIS analysis

Criterion	Weight
Topography of penstock line	0.55
Potential power	0.16
Type of land covering	0.09
Distance from the grid	0.06
LCOS	0.06
Area of the site	0.05
Distance from the coastline	0.03

4.2. Ranking The Feasible Sites

Following determining parameter weights through the AHP, the analysis advances to the TOPSIS analysis, which is the next crucial step. This comprehensive approach involves several distinct steps, each contributing to the systematic classification and ranking of the potential SPHS sites. The TOPSIS method includes the following steps:

1. **Creating the Decision Matrix (D):** The decision matrix is formed by organising the gathered data into a structured format. Each row in the matrix corresponds to a potential PHES site, while each column corresponds to a specific criterion. The data values in the matrix represent the performance or characteristics of each site about each criterion. Consequently, the size of the matrix depends on the number of sites and evaluation criteria.

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} w_1 & w_1 & \cdots & w_n \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \end{array} \tag{4.1}$$

2. **Normalisation of Criteria (R):** The next step is to normalise the evaluation criteria (R). Normalisation guarantees that all decision-making criteria are on the same scale and have equal weight. This step aids in the elimination of potential biases caused by differences in measurement units or scales.

$$\begin{aligned} R &= r_{ijmn} \\ r_{ij} &= \frac{x_{ij}}{{}_{i=1}^{m} {x_{ij}}^2} \end{aligned} \tag{4.2}$$

3. **Weight Assignment (V):** In this phase, weights are assigned to each criterion to reflect their relative importance in decision-making. Those criteria deemed more important are assigned greater weights, while those considered less critical are assigned smaller weights.

$$\begin{aligned} V &= v_{ijmxn} \\ v_{ij} &= w_j * r_{ij} \end{aligned} \tag{4.3}$$

4. **Determination of Positive Ideal Solutions (PIS) and Negative Ideal Solutions (NIS):** The ideal solution represents the most desirable values for each criterion, whereas the negative ideal solution represents the most undesirable values. These solutions are determined based on the specified criteria and their respective weights. For each criterion, the ideal solution is denoted by the maximum value, whereas the minimum value denotes the negative ideal solution.

$$\begin{aligned} PIS: A: v_1, \cdots, v_j, \cdots, v_n, \qquad & v_j = maxv_{ij} \\ NIS: A^-: v_1^-, \cdots, v_j^-, \cdots, v_n^-, \qquad & v_j^- = minv_{ij} \end{aligned} \tag{4.4}$$

5. **Calculation of Similarity Scores (S):** Similarity scores, referred to as proximity measures, are computed to determine the similarity between each alternative and the optimal solution. These

scores are calculated based on the weighted normalised values of the criteria for both the positive and negative ideal solutions.

$$S_i = \sqrt{{}_{j=1}^{n} v_{ij} - v_j{}^2}$$
$$S_i^- = \sqrt{{}_{j=1}^{n} v_{ij} - v_j^-{}^2} \tag{4.5}$$

6. **Calculating Relative Closeness to Ideal Solution (CP):** Each alternative's proximity to the optimal solution is determined by comparing its similarity scores to optimal and negative ideal solutions. Potential PHESes with greater relative proximity values are deemed preferable and ranked higher.

$$CP_i = \frac{S_i^-}{S_i \; S_i^-} \tag{4.6}$$

7. **Ranking:** The potential PHESes are arranged in descending order based on relative closeness values. The alternative with the highest relative closeness value is deemed the most appropriate or preferred option.

Using TOPSIS to rank feasible sites for PHES installations enables a systematic evaluation of potential locations based on various criteria shown in Table 4.1. Considering these criteria and their respective weights, the method identifies the most suitable sites that align with the project's objectives and constraints, facilitating informed decisions in planning renewable energy projects.

4.3. Classification

In this study, the classification of identified potential SPHS locations employs a Relative Closeness to the Ideal Solution (CP) distribution from the TOPSIS analysis result. This classification is based on calculating average values (μ) and standard deviations (σ). The identified potential SPHS sites are categorised into ten classes, with the Relative Closeness to the Ideal Solution (CP) of each potential site serving as the criterion for classification, as outlined in Table 4.2.

Table 4.2: Classification criteria

Class	Closseness Index (CP_i)	
	Min	Max
1	$>\mu + 0.8\sigma$	
2	$>\mu + 0.6\sigma$	$\leq \mu + 0.8\sigma$
3	$>\mu + 0.4\sigma$	$\leq \mu + 0.6\sigma$
4	$>\mu + 0.2\sigma$	$\leq \mu + 0.4\sigma$
5	$>\mu$	$\leq \mu + 0.2\sigma$
6	$>\mu - 0.2\sigma$	$\leq \mu$
7	$>\mu - 0.4\sigma$	$\leq \mu - 0.2\sigma$
8	$>\mu - 0.6\sigma$	$\leq \mu - 0.4\sigma$
9	$>\mu - 0.8\sigma$	$\leq \mu - 0.6\sigma$
10		$\leq \mu - 0.8\sigma$

Chapter 5

Technical and Economical Potential of Seawater Pumped Hydro Storage

This chapter examines the technical and economic potential of SPHS in Indonesia. In terms of the technical aspect, it examines the system's capacity for power regeneration and energy supply and potential sites categorised for their suitability. On the economic front, the chapter examines several aspects, including the LCOS, initial investment requirements, and a comparative analysis concerning other energy storage systems.

5.1. Technical Potential

Following the execution of the PyQGIS model explained in Chapter 3, a thorough evaluation revealed 682 potential SPHS sites dispersed across nearly all of Indonesia's major islands except Kalimantan Island. However, 73 of these potential SPHS sites were located within protected natural areas. Given the conservation objectives and environmental sensitivity of these regions, the construction of large-scale infrastructure, such as SPHS, is strictly prohibited. Finally, 609 feasible sites of SPHS have been found. Figure 5.1 visually depicts these potential SPHS sites and their geographical distribution, indicated by red dots.

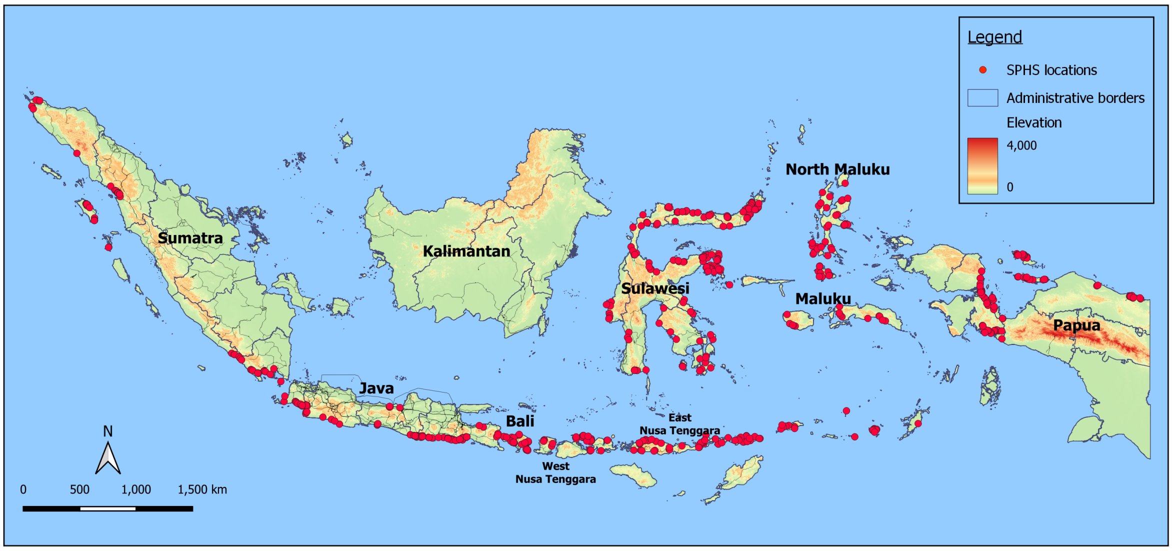


Figure 5.1: Distribution of 609 identified SPHS sites in Indonesia.

The absence of identified SPHS sites in Kalimantan and the eastern coast of Sumatra can be attributed to the geographical characteristics of these regions. In Kalimantan, such a head differential is not prominent, making it unsuitable for SPHS development. Similarly, the eastern coast of Sumatra faces a similar limitation due to a lack of significant head differences in the terrain. As for the western coast of Sumatra, the topography consists of extremely steep hills and narrow valleys, which presents challenges in constructing ideal reservoirs for SPHS systems. These geographical factors play a pivotal role in determining the feasibility and suitability of SPHS development in different regions of Indonesia.

5.1.1. SPHS Potential on National and Grid System Level

Leaving aside the potential locations in the nature reserve areas, 609 noteworthy sites were identified as prime possible sites for constructing SPHS facilities following an evaluation utilising the developed model. This evaluation included many factors and considerations, such as minimum power that can be regenerated, maximum distance from coastline, and minimum elevation, to ensure that these locations met the criteria, ensuring their viability and potential for successful SPHS implementation. These selected sites exhibit a wide range of geographical and topographical characteristics, demonstrating the adaptability of SPHS as an energy storage system to various terrains and landscapes. The peak power generation capability, as explained in Subsection 3.2.2, across these 609 locations varies widely, spanning from 15 to 316 MWp for each site.

Figure 5.2 represents the distribution among the identified SPHS sites, categorised by the power they can provide. This data provides insights into the prevalence of SPHS sites across different power ranges. Notably, a substantial portion of the identified sites falls within the 15 to 45 MW range, with 420 locations falling into this category. On the other hand, SPHS sites that can deliver more than 200 MW represent a smaller population in comparison.

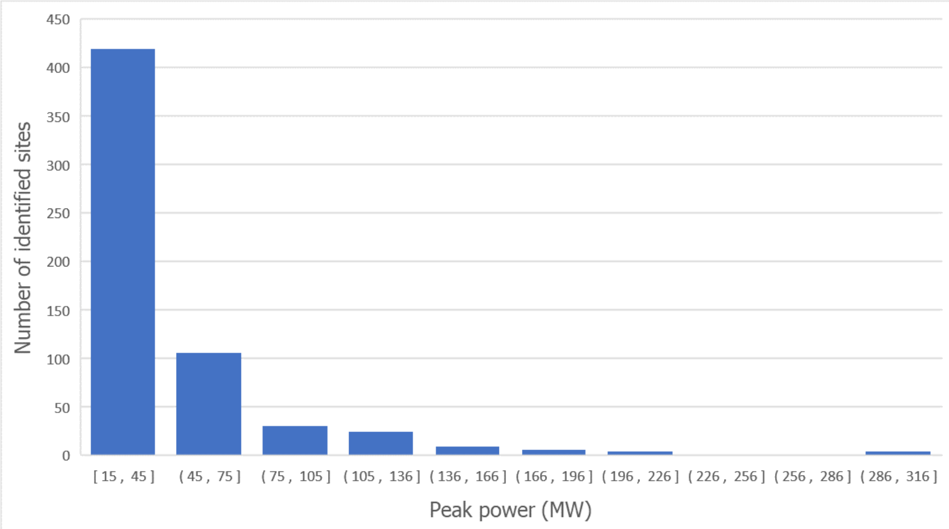


Figure 5.2: Distribution of SPHS sites per peak power classification.

The cumulative peak power potential that can be regenerated across all 609 sites is 29 Gigawatt-peak (GWp), 37% of projected peak power demand in 2030 on a national scale (77 GWp [18]). This substantial power regeneration seems to potentially contribute to Indonesia's energy needs, supporting the nation's growing demand for dependable and sustainable power sources. These SPHS sites could collectively store and regenerate approximately 48 TWh of electricity annually, almost 10% of annual energy demand nationwide (500 TWh). Furthermore, these SPHS systems are poised to support the effective integration of intermittent energy sources into the nation's energy grid. Their ability to store excess energy during periods of surplus and discharge it during high-demand periods ensures a consistent and reliable energy supply, contributing to Indonesia's energy ecosystem's overall resilience and sustainability. The comparison at the national level between the potential energy storage and power generation of SPHS and the predicted energy consumption in 2030, serving as a benchmark year, is presented in Table 5.1.

Table 5.1: Comparison of annual energy and daily peak power between demand and SPHS

	Seawater-pumped hydro storage	Projected consumption 2030
Annual energy production/consumption (TWh)	48	500
Daily peak power generation/consumption (GWp)	29	77

At the national level, the potential energy harnessed from SPHS presents a notable percentage compared to the overall energy demand. Based on its technical potential, SPHS is expected to play a role in stabilising the energy production landscape, particularly with the increasing integration of intermittent renewable energy sources into the grid. The detailed information regarding SPHS sites properties can be found in Appendix A. However, a deeper dive into the grid system level reveals a more nuanced picture.

Take, for instance, the highly populated islands of Sumatra and Java, where energy demand is notably higher than the energy that SPHS systems could provide. These regions represent significant energy hubs, and while SPHS contributes to the energy mix, it may only partially cover the energy needs. This highlights the need for a diversified energy portfolio and enhanced infrastructure to ensure a stable and uninterrupted power supply to these populated areas.

In contrast, there is a remarkable surplus of energy supplied by SPHS compared to local demand on other islands. This disparity between energy supply and demand highlights the need for a strategic and well-integrated approach to energy planning and infrastructure development, taking into account the unique energy landscapes of the different regions of the archipelago. Figure 5.3 presents the detailed findings of SPHS potential in every electrical grid.

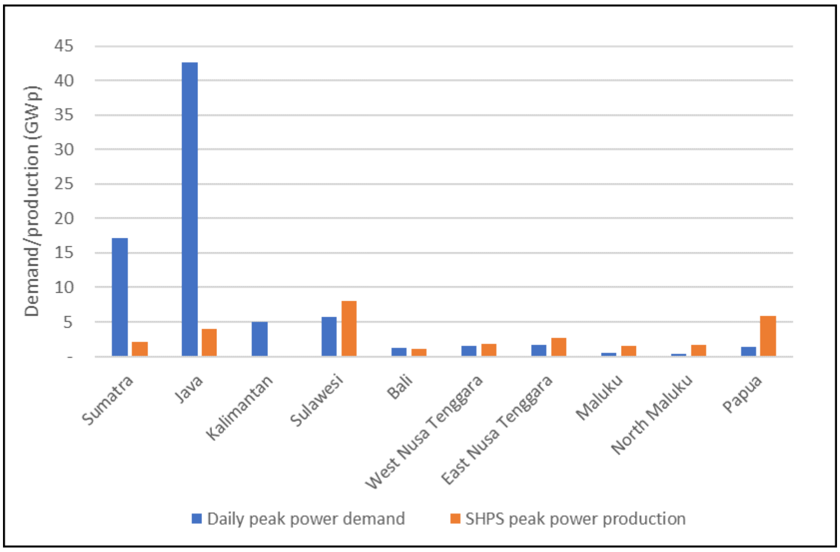


Figure 5.3: Electricity demand and SPHS power production per electrical grid.

5.1.2. Classification of The Potential SPHS Sites

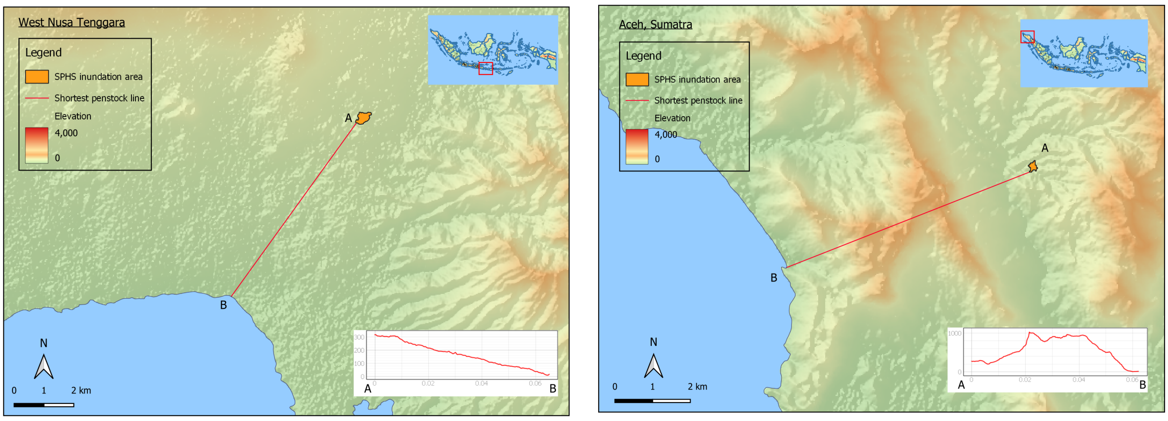
Given the economic constraint regarding investment in the infrastructure and energy dynamics across Indonesia's electrical grids, it becomes essential to prioritise the potential sites for SPHS. This prioritisation is a factor to be considered for effective energy planning and resource allocation. Building upon the conditions and criteria outlined in Chapter 4, as well as the corresponding weightings assigned to these criteria through AHP analysis, the study employs the TOPSIS method to carry out this classification.

Each of the 609 potential sites identified through the study was assigned a unique rank ranging from 1 to 609. Once all sites were ranked, they were classified into ten distinct classes based on their relative closeness values calculated through the TOPSIS analysis, as explained in Subsection 4.3. Each class represents a cluster of sites that exhibit similar characteristics and meet specific criteria for suitability and feasibility in hosting SPHS installations. For instance, Class 1 represents the highest priority potential sites for SPHS, while Class 10 includes the least favourable sites regarding suitability and feasibility.

Figure 5.4 illustrates two distinct examples of identified sites with varying characteristics. The first example, as seen in Figure 5.4a, represents Class 1 of the classification, situated in West Nusa Tenggara province. This site boasts a substantial peak power capacity of 116 MWp. Notably, the topography of the shortest penstock line exhibits a favourable attribute with a uniform slope, enhancing its suitability. Furthermore, the predominant land cover in this area consists of shrubland.

In contrast, the second example, as seen in Figure 5.4b, in Aceh province, represents Class 10. This site has a relatively lower peak power capacity of 27 MWp. Moreover, it is important to note that the topography of the shortest penstock line in this location is less ideal due to a significant difference in elevation between the site and the coastline, which presents engineering challenges for implementation.

While there is potential for constructing the penstock underneath the ground using a tunnel, this study considers penstock lines built above ground level. The decision to exclude underground penstock options is a deliberate choice, and as a result, the topography of the penstock line becomes an essential aspect of consideration.



(a) Site West Nusa Tenggara 3225

(b) Site Aceh 235

Figure 5.4: Example of the SPHS sites

From the TOPSIS analysis explained in Chapter 4, it becomes evident that Class 1 sites, representing the most promising locations under the multicriteria analysis (TOPSIS analysis), exhibit the highest peak power production among all classes. It is noteworthy that even though Class 1 sites provide substantial peak power, they still fall short of meeting the energy demand within most grid systems, except for the Papua grid system. This observation underscores the need for strategic site selection and the potential for SPHS to play a role in specific regional energy solutions. Table 5.2 presented below shows SPHS peak power production across different electrical grid systems, categorised by their respective classes.

Table 5.2: SPHS peak power production on each electrical grid system per class

Grid system	Demand (GWp)	SPHS (GWp)	SPHS power per class (GWp)										Number of sites
			1	2	3	4	5	6	7	8	9	10	
Sumatra	17	2	0.2	-	-	-	-	-	-	-	0.6	1.4	56
Java	42	4	0.3	0.4	1.4	0.8	0.6	0.1	0.1	0.2	0.1	-	109
Kalimantan	5	-	-	-	-	-	-	-	-	-	-	-	-
Sulawesi	6	8	2.2	0.5	0.5	0.5	1.4	0.7	0.6	0.3	0.3	1.0	152
Bali	1	1	0.2	0.4	0.2	0.1	-	0.1	0.0	0.0	0.0	0.4	28
West NT	2	2	0.7	0.4	0.1	0.1	0.2	0.2	0.0	-	-	-	36
East NT	2	3	0.5	0.2	0.3	0.2	0.7	0.2	0.1	0.1	0.1	0.2	54
Maluku	0.5	1	0.5	0.2	0.2	0.2	0.0	0.1	0.0	-	0.0	0.3	33
N. Maluku	0.5	2	0.3	0.2	0.3	0.4	0.2	0.1	0.1	-	0.1	0.1	43
Papua	1	6	2.1	0.2	0.4	0.8	0.3	0.5	0.2	0.0	0.2	1.0	98
Total	**77**	**29**	**6.9**	**2.6**	**3.4**	**3.1**	**3.4**	**2.0**	**1.2**	**0.7**	**1.4**	**4.1**	**609**

Figure 5.5 through Figure 5.14 provide visual representations of these sites, organised according to their respective classes. These figures offer insights into the geographic diversity of SPHS potential in Indonesia, shedding light on how these sites are dispersed across different regions and their classification within the ten distinct classes.

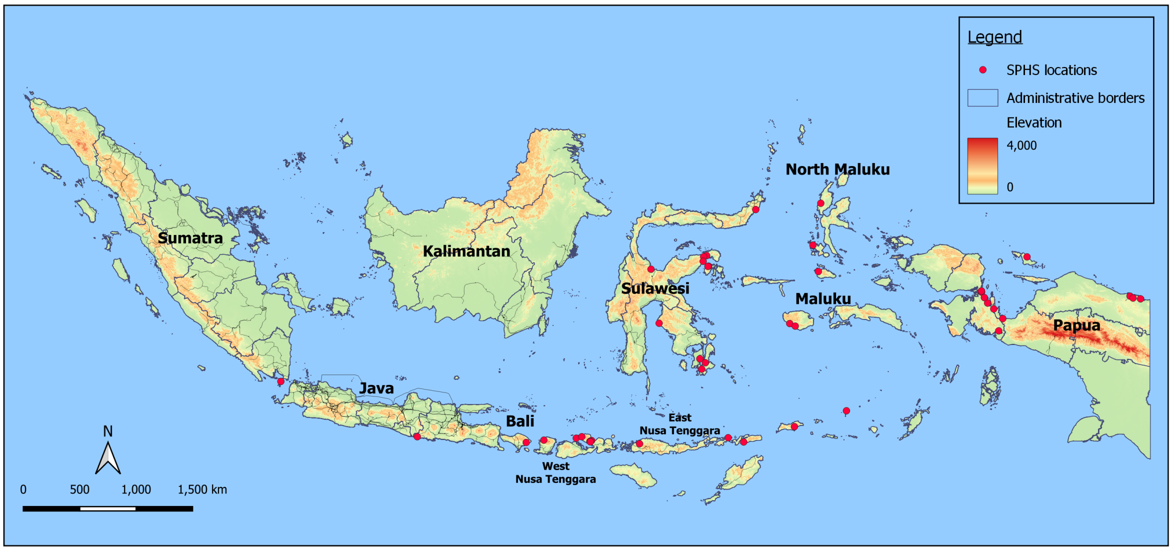


Figure 5.5: Distribution of class 1 SPHS sites.

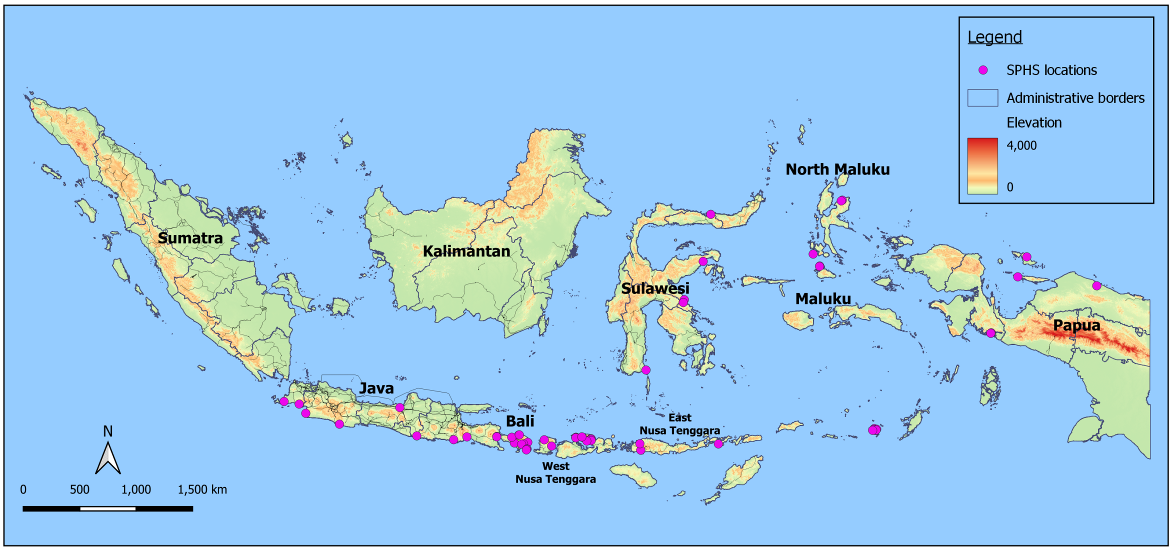


Figure 5.6: Distribution of class 2 SPHS sites.

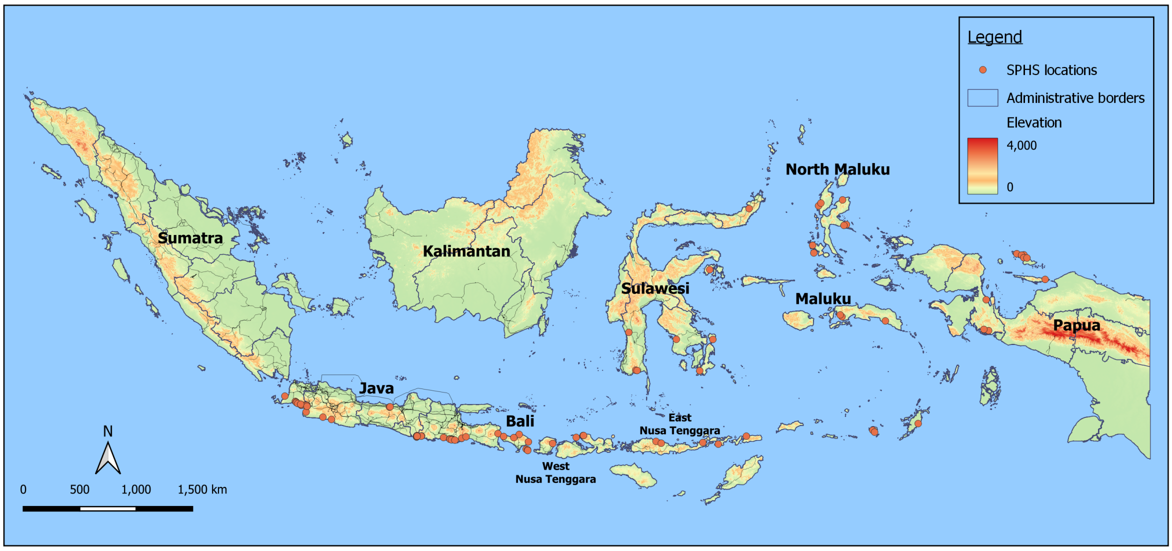


Figure 5.7: Distribution of class 3 SPHS sites.

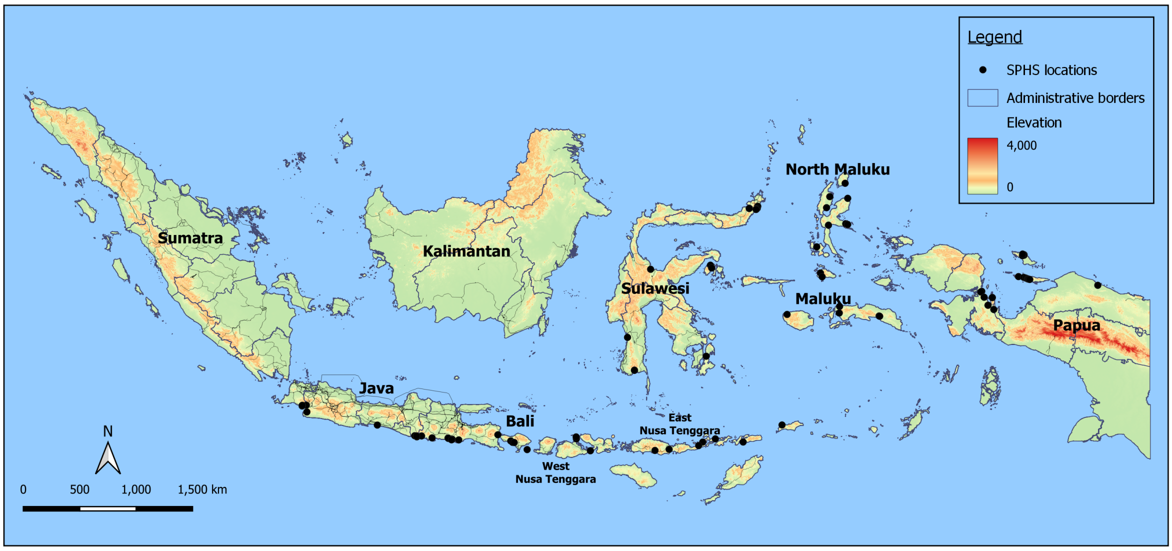


Figure 5.8: Distribution of class 4 SPHS sites.

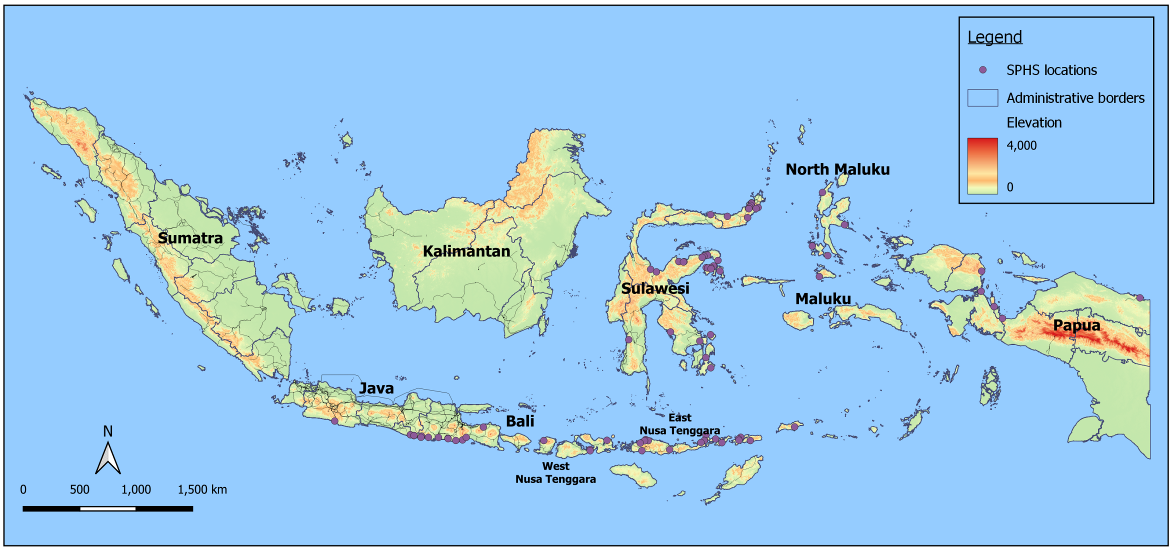


Figure 5.9: Distribution of class 5 SPHS sites.

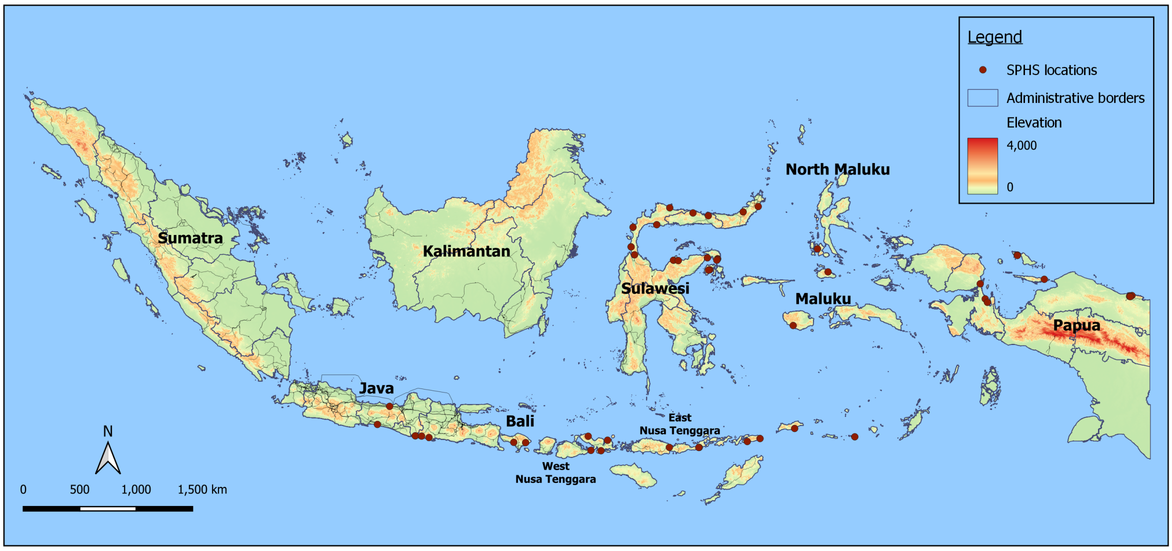


Figure 5.10: Distribution of class 6 SPHS sites.

Figure 5.11: Distribution of class 7 SPHS sites.

Figure 5.12: Distribution of class 8 SPHS sites.

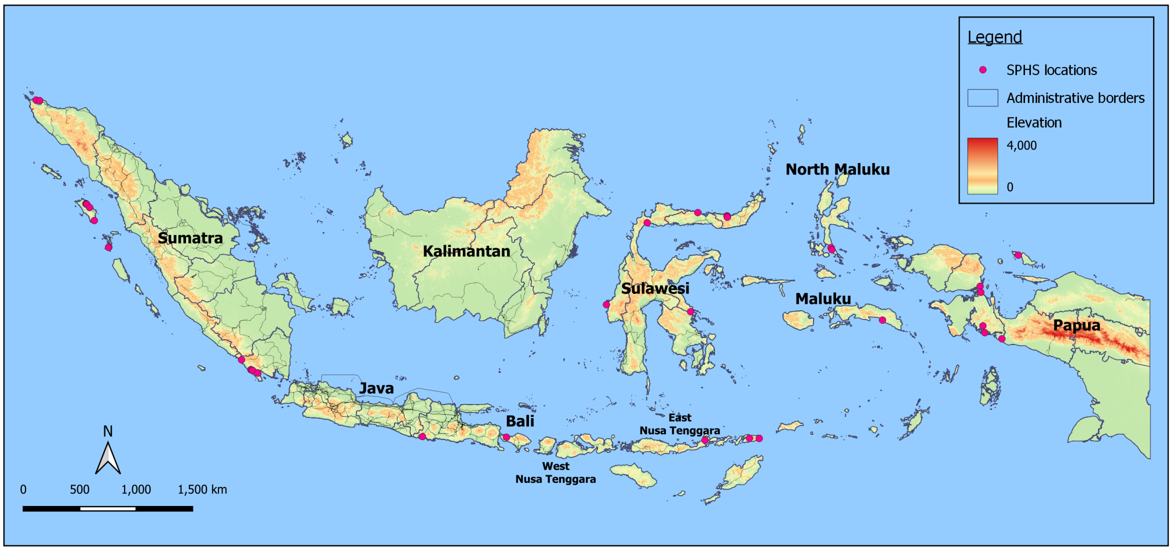


Figure 5.13: Distribution of class 9 SPHS sites.

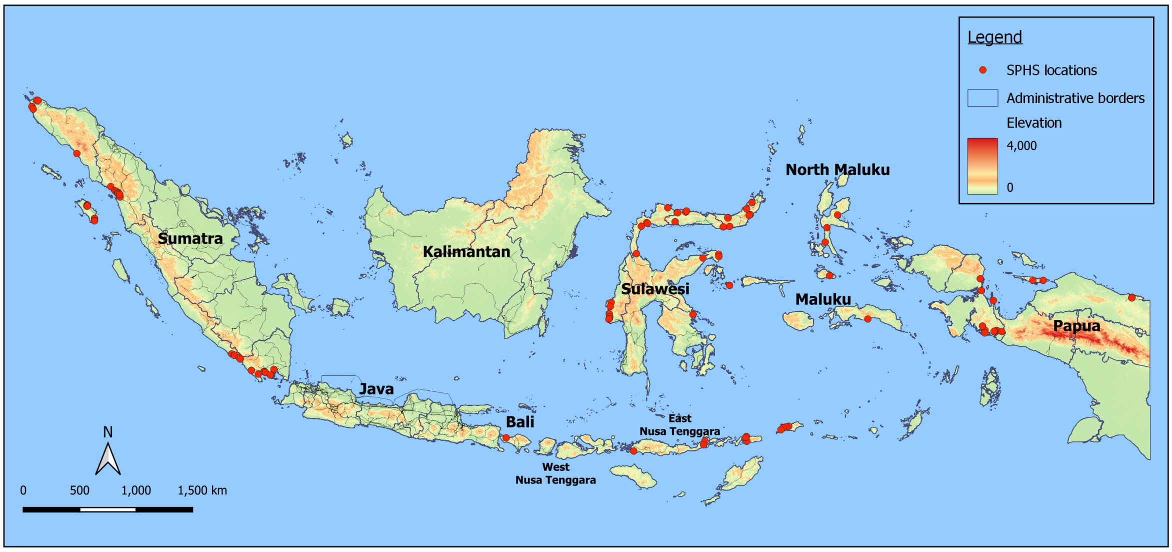


Figure 5.14: Distribution of class 10 SPHS sites.

Figure 5.5 shows that the Class 1 priority classification consists of 44 SPHS sites, primarily concentrated in eastern Indonesia. This distribution is influenced mainly by ideal heads and suitable topographical conditions in these areas. In contrast, the SPHS sites identified in Java Island are classified as lower priority, falling mainly within Class 2 to 5. This categorisation is primarily because power produced by SPHS systems identified in Java is lower than Class 1.

The SPHS sites identified in Sumatra are predominantly classified as Class 9 and 10. This classification is attributed to the challenging topography observed along the penstock lines in Sumatra, which is more demanding than other islands. The rugged terrain and geographical characteristics in this region make it less suitable for SPHS development, resulting in a lower priority classification. The SPHS sites identified in Sulawesi, Maluku, Nusa Tenggara, and Papua display a broader distribution across various priority classes, ranging from Class 1 to Class 10. Unlike some other regions where the classification tended to be concentrated in a few specific classes, these areas in eastern Indonesia exhibit a more balanced distribution of SPHS sites across different priority levels. This suggests that these regions' topography and geographical conditions allow for a wider range of SPHS development possibilities. The detailed classification of identified SPHS sites can be seen in Appendix B.

Table 5.3 below summarises the peak power and annual energy production potential for the identified SPHS sites. This information underscores the contribution that SPHS can make to the nation's energy landscape. However, it's important to remember that harnessing this potential effectively will require careful planning and consideration of various factors, including grid integration.

Table 5.3: Power and energy provided by identified SPHS systems

Class	Number of sites	Power		Annual energy	
		Average per site (MW)	Total (GW)	Average per site (GWh)	Total (TWh)
1	44	157	7	243	11
2	57	46	3	77	4
3	89	39	3	66	6
4	87	35	3	60	5
5	81	42	4	70	6
6	50	41	2	69	3
7	40	31	1	54	2
8	20	34	1	59	1
9	37	37	1	63	2
10	104	40	4	66	7
Total	**609**		**29**		**48**

5.2. Economical Potential

The assessment of the economic potential of SPHS in Indonesia involves an analysis of the comparison of electricity prices in Indonesia with the total LCOS associated with SPHS and the average Levelised Cost of Electricity (LCOE) related to renewable energy sources in Indonesia, as calculated by existing studies. LCOS represents the cost of storing energy over the system's lifetime, considering factors such as initial capital expenditure, operation and maintenance costs, and the discount rate.

The goal is to assess whether SPHS can offer competitive pricing for energy storage while supporting the integration of intermittent renewable energy sources. By comparing electricity prices and the total LCOS and LCOE values, this analysis aids in understanding the cost-effectiveness and economic feasibility of implementing SPHS in the Indonesian energy landscape.

5.2.1. Levelised Cost of Storage (LCOS)

The LCOS for SPHS in Indonesia exhibit a range from approximately 3 cents €/kWh to 10.14 cents €/kWh, with an average value of approximately 6.25 cents €/kWh, consider 6% discount rate and 50 years lifetime of the project. The average CAPEX per site is 56.8 million euros, while the average OPEX is 1 million euros per site per year. Interestingly, as can be seen in Figure 5.15, the LCOS trend shows that as the power capacity of the SPHS system increases, the LCOS tends to decrease, indicating a potential economy of scale. However, a notable exception exists for SPHS systems with a power range of 195-255 MW, where the LCOS appears to increase. This phenomenon suggests that while power significantly determines LCOS, other factors such as distance to the coastline, land acquisition costs, material expenses, and other site-specific variables influence the final LCOS figure.

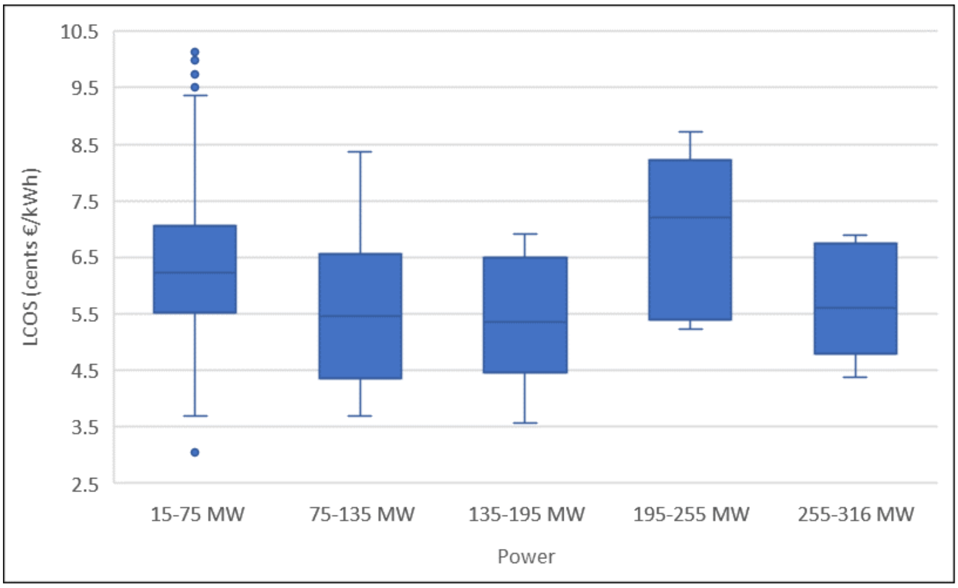


Figure 5.15: LCOS statistics.

In addition to analysing LCOS based on power production, exploring LCOS variations across different regions is equally intriguing to gain insights into localised economic and geographical factors that may influence the cost dynamics of SPHS deployment. By considering regional variations in factors like land acquisition costs, construction expenses, and other economic variables, stakeholders can make more informed decisions regarding the feasibility and prioritisation of SPHS development in specific areas of Indonesia. Figure 5.16 shows the LCOS's statistics in each region.

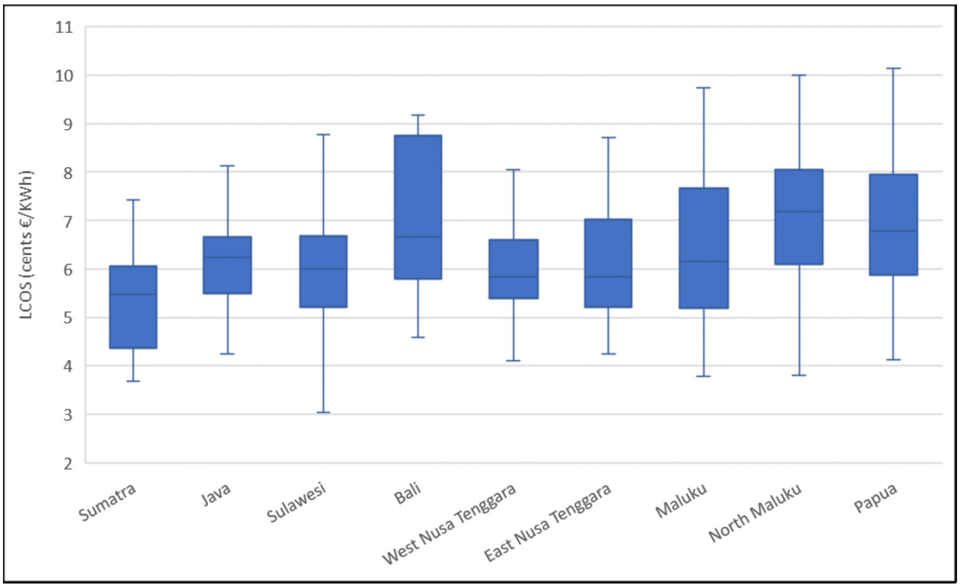


Figure 5.16: Distribution of LCOS per region.

Analysing the LCOS on a regional or grid system basis provides valuable insights into the economic feasibility of SPHS across different parts of Indonesia. One notable observation is that LCOS slight differences from region to region exist. Even though there are slight variations, these distinctions are instrumental in understanding the localised economic dynamics that can impact the viability of SPHS projects.

For instance, LCOS in Bali, an island known for its tourism and relatively high land prices, emerges as the highest among the regions studied. This higher LCOS in Bali can be attributed, at least partially, to the relatively elevated land acquisition costs in this tourist destination. The need to secure suitable land for constructing SPHS infrastructure contributes to the overall project expenses, impacting this region's LCOS.

Conversely, regions like Java and Sumatra present relatively lower LCOS figures compared to the other areas in Indonesia. Several factors may contribute to this cost advantage, including more favourable land acquisition conditions, proximity to suitable coastal areas for reservoirs, and other site-specific attributes that positively impact the overall cost-effectiveness of SPHS development. In contrast, in Papua, the relatively higher cost of civil works can be attributed to potentially elevated material prices in the region, which may impact the overall expenses associated with SPHS infrastructure development. Figure 5.17 below shows each region's average investment cost composition for a SPHS project.

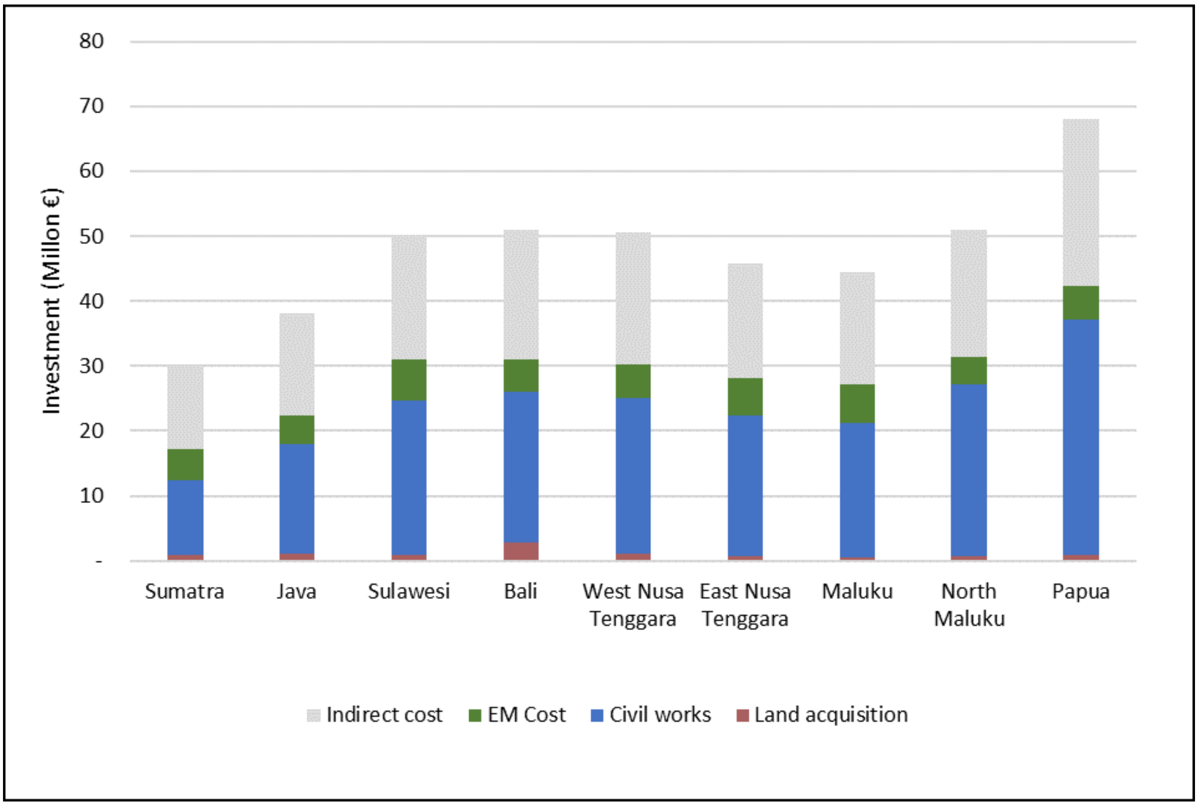


Figure 5.17: Average investment per site.

To summarise the distribution of LCOS, Figure 5.18 below illustrates the disparity in LCOS between various regions of Indonesia. The data demonstrates a similarity and consistency in the range of LCOS across these diverse regions. While the overall range of LCOS remains comparable, this observation emphasises the significance of contemplating regional nuances within a national context. Although LCOS may not vary substantially from region to region, other crucial factors, such as energy demand, available resources, and grid integration capabilities, may vary significantly and must be carefully considered during the SPHS deployment decision-making process.

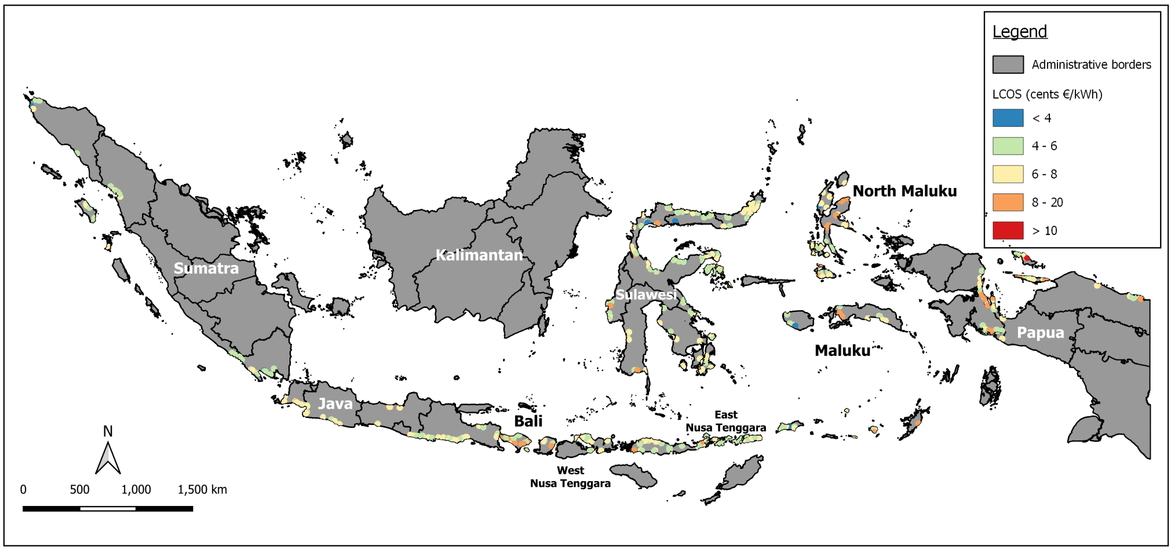


Figure 5.18: Map of SHPS' LCOS.

5.2.2. Economical Feasibility

The economic potential of SPHS in Indonesia is assessed through a comparative analysis that takes into account the LCOS and the LCOE associated with intermittent energy sources, specifically wind and solar energy. A combination of 50% wind and 50% solar energy generation is considered to derive these costs. According to research by the Institute for Essential Services Reform (IESR), the LCOE for wind energy is projected to be approximately 5.8 cents €/kWh, while for solar energy, it is estimated to be around 5.7 cents €/kWh in 2030 [67]. These costs are then compared to the projected electricity ceiling prices in 2030. The baseline for these future ceiling prices is set based on the current ceiling prices established in the Ministry of Energy and Mineral Resources Decree number 169/2021, which vary by region [68], with an added consideration of a 6% interest rate. Consequently, the economic potential of SPHS varies across different regions in Indonesia due to variations in electricity pricing and resource availability.

Out of the 609 analysed SPHS sites, it's important to note that only 297 of them exhibit both total LCOS and LCOE values that fall below the existing ceiling price for electricity. These 297 SPHS sites can collectively regenerate the power of 15 GWp. This finding underscores an economic consideration. While numerous SPHS sites have been identified in this study, not all of them are economically viable within the electricity pricing framework. Therefore, the economic feasibility of these SPHS projects is contingent upon potential adjustments to the ceiling price or other economic factors that could enhance their viability in the future. Figure 5.19 below illustrates the locations of SPHS sites, distinguishing between economically feasible and not.

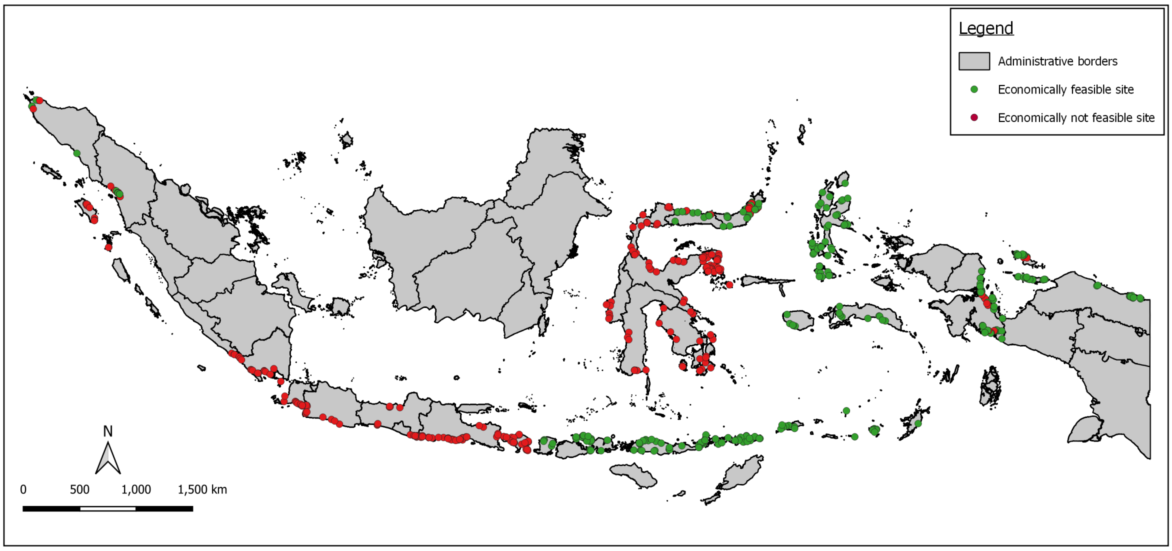


Figure 5.19: Economically feasible location of SPHS in Indonesia.

Many of the SPHS sites in the eastern part of Indonesia are economically feasible, while potential locations in Java and Bali do not meet the economic criteria. This discrepancy can be attributed to the ceiling electricity price regulations, where the more densely populated islands like Java and Bali tend to have lower electricity prices than other regions.

Table 5.4: Comparison between electricity ceiling price and total LCOE/LCOS per region

Region	Estimated ceiling price 2030 (cents €/kWh)	LCOS + LCOE (cents €/kWh)		
		Minimum	Maximum	Average
Sumatra	11.0	9.4	13.2	11.1
Java	7.4	10.0	14.6	11.9
Sulawesi	12.6	8.8	14.7	11.7
Bali	7.4	10.3	14.9	12.7
West Nusa Tenggara	14.0	9.8	13.8	11.7
East Nusa Tenggara	15.1	10.0	14.5	11.8
Maluku	19.7	9.5	15.5	12.1
North Maluku	17.9	9.5	15.7	12.9
Papua	14.7	9.9	15.9	12.6

The analysis results presented in Table 5.4 reveal some subtle variations in the average values of total LCOE and LCOS across different regions in Indonesia. However, the most critical factor determining project feasibility within each region is undeniably the ceiling price. Notably, the ceiling prices in Java and Bali are significantly lower compared to other regions. This discrepancy renders SPHS projects economically unfeasible in these areas. Therefore, there is a compelling need to reevaluate and adjust the ceiling prices in Java and Bali to ensure that SPHS projects become economically viable and contribute to Indonesia's sustainable energy future. The discrepancy between the technical and economic potential of SPHS becomes apparent when examining the results for each region, as illustrated in 5.20 below.

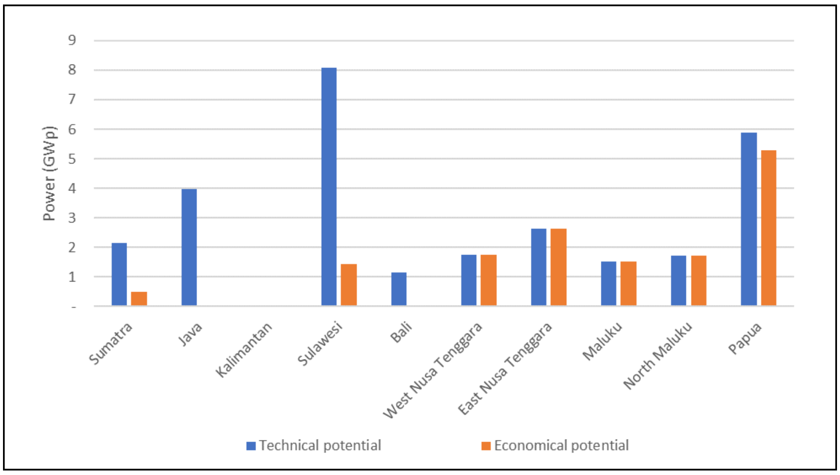


Figure 5.20: Comparison between technical and economical potential

The transition from the technical potential of 29 GWp power to the economical potential of 15 GWp highlights a significant reduction in feasible SPHS sites. Intriguingly, all the identified sites in the highly populated regions of Java and Bali do not align with economic feasibility criteria. Meanwhile, only a quarter of the identified locations in Sumatra and Sulawesi meet the economic viability.

5.2.3. Comparison with Other Energy Storage System

To put the result of the LCOS analysis conducted in this study into context, comparisons were made with LCOS values from previous studies on various energy storage systems. For instance, Mugyema et al. (2023) investigated battery and flywheel energy storage for a small-scale energy storage system (ESS) with a capacity of 10 MW [69]. Their research revealed significantly higher LCOS values of 28.8 cents $/kWh for batteries and 11.5 cents $/kWh for flywheels, underscoring the favourable LCOS of SPHS found in this study.

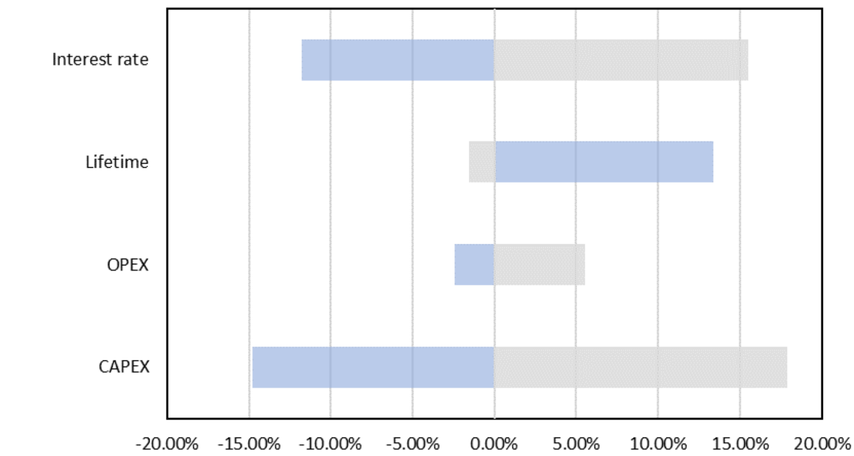
Cristea et al. (2022) assessed battery LCOS in Romania [70], while Martinez de Leon et al. (2023) focused on LCOS for hydrogen storage systems [71]. The LCOS values from these studies were generally higher than the LCOS of SPHS presented in this research. Moreover, a 2023 report from the Institute for Essential Services Reform (IESR) in Indonesia examined the LCOS of both PHES and batteries with a capacity of 100 MW. This report also indicated that the LCOS for these systems was higher than that of SPHS, reinforcing the economic competitiveness of SPHS as an energy storage solution in Indonesia. Table 5.5 presents the comparison of LCOS values obtained from this study and previous research.

Table 5.5: Comparison of LCOS Values - This Study vs. Previous Studies

ESS	This study	Mugyema, et.al (2023)	Cristea et.al (2022)	Martinez de Leon, et.al (2023)	IESR (2023)
SPHS/PHES	3 - 10.14 cents €/kWh				7.7 cents $/kWh
Battery		28.8 cents $/kWh	28 - 36.9 cents €/kWh		21.8 cents $/kWh
Hydrogen				13.8 cents €/kWh	
Flywheel		11.5 cents $/kWh			

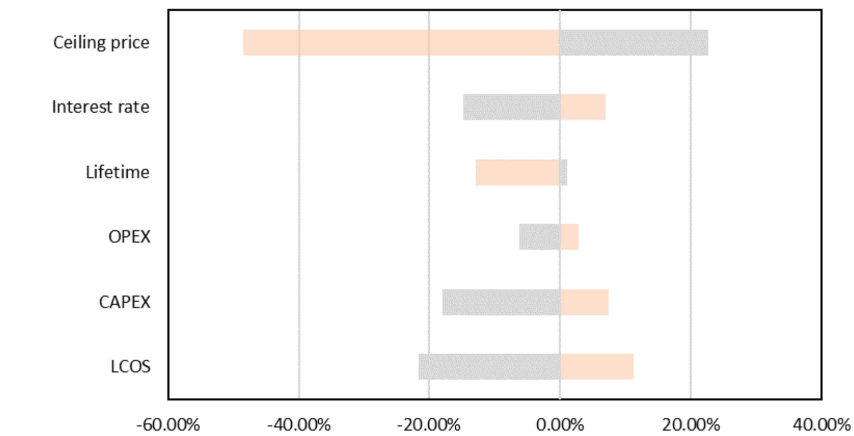
5.2.4. Sensitivity Analysis

Sensitivity analysis is a tool for assessing the economic potential of SPHS in Indonesia. It involves the evaluation of variables such as CAPEX, OPEX, interest rates, infrastructure lifespan, and ceiling prices to understand their impact on the LCOS and, consequently, the economic feasibility of SPHS projects. This analysis helps identify which variables significantly enhance the economic potential of SPHS in Indonesia. Additionally, it aids in pinpointing support schemes or policy adjustments that can improve the economic viability of SPHS initiatives in the country. The LCOS and economic potential were assessed by varying each parameter within a ±20% range relative to the base LCOS value, which stands at 6.25 cents €/kWh, determined based on the average LCOS result. Similarly, the base value is 15 GWp for the economic potential. Figure 5.21 and Figure 5.22 show the sensitivity analysis results.



	CAPEX	OPEX	Lifetime	Interest rate
Decrease by 20%	-14.80%	-2.44%	13.38%	-11.79%
Increase by 20%	17.87%	5.51%	-1.57%	15.50%

Figure 5.21: Sensitivity analysis of LCOS



	LCOS	CAPEX	OPEX	Lifetime	Interest rate	Ceiling price
Decrease by 20%	11.31%	7.47%	2.89%	-12.88%	7.06%	-48.54%
Increase by 20%	-21.65%	-18.06%	-6.24%	1.10%	-14.84%	22.65%

Figure 5.22: Sensitivity analysis of potential sites

The sensitivity analysis revealed that CAPEX has the most substantial impact on LCOS, followed by interest rate, infrastructure lifespan, and OPEX in descending order of significance. When CAPEX is reduced by 20%, LCOS can be decreased by around 15%. Conversely, a 20% increase in CAPEX leads to an LCOS increase of more than 17%.

The sensitivity analysis result also indicates that while changes in LCOS, CAPEX, OPEX, interest rate, and infrastructure lifespan have a limited impact on the economic feasibility of SPHS, increasing the ceiling price by 20% has a more pronounced effect. Specifically, raising the ceiling price by 20% can enhance the economic feasibility of SPHS by 23%. In contrast, a 20% reduction in the ceiling price leads to a substantial decrease in economic feasibility, amounting to a 48% reduction. This underscores the pivotal role of ceiling price adjustments in determining the economic viability of SPHS projects in Indonesia.

Chapter 6

Environmental Impact

Chapter 6 delves into an examination of the environmental impact of SPHS development in Indonesia. As we continue our exploration of this energy storage solution, it is necessary to assess its environmental effects. This chapter offers a balanced perspective, discussing the positive contributions of SPHS in mitigating carbon emissions and the potential challenges and negative impacts.

6.1. Carbon Emission Reduction

In Indonesia, electricity generation still heavily relies on fossil fuels, particularly coal. Coal-fired power plants are a prominent part of the energy mix, contributing 61% to the nation's electricity generation capacity [2]. Meanwhile, coal is one of the most carbon-intensive energy sources, emitting a substantial amount of carbon dioxide (CO_2) per unit of electricity generated. As shown in Figure 6.1, the carbon emissions associated with coal-fired power plants are estimated to be around 820 grams of CO_2 per kilowatt-hour (gCO_2/kWh) of electricity produced [23]. However, Indonesia aims to cut carbon emissions by 29% by 2030, with a focus on reducing coal-based electricity generation. By combining renewable energy sources, such as wind and solar, with SPHS, carbon emissions can be significantly reduced to meet the climate goals and maintain reliable energy production.

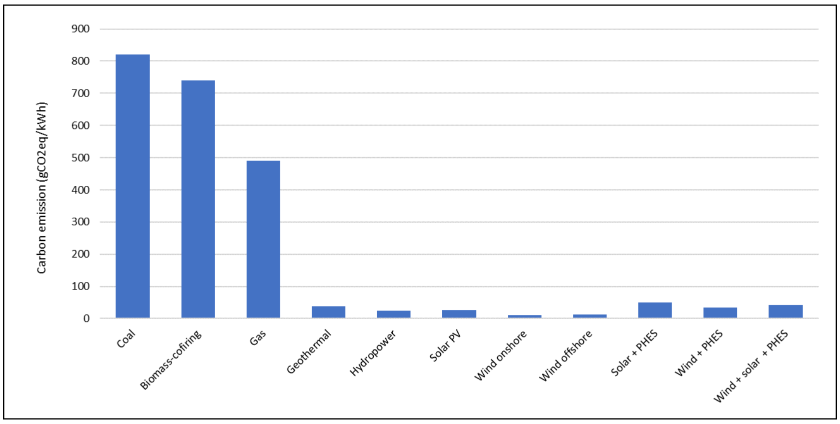


Figure 6.1: Carbon emission of various electricity generation

The technical and economical potential of SPHS become the foundation for calculating carbon emission reductions. In the scenario based on these potentials, SPHS generates a substantial amount of electricity, replacing coal-fired production. Specifically, the 47 TWh of electricity produced by coal-fired power plants produce 39 million tons of CO_2 emissions. In contrast, the combination of wind, solar, and SPHS, which generates 47 TWh of energy in the technical potential scenario, emits only 2 million tons of CO_2. Similarly, the production of 24 TWh of electricity through coal-fired means contributes 20 million tons of CO_2, while the same amount generated through the combined renewable and SPHS system in the economical potential scenario results in just 1 million ton of CO_2 emissions. Table 6.1 below compares carbon emission produced by coal-fired power generation and SPHS system for every scenario.

According to the Electricity Supply Business Plan for 2021-2030, the carbon emissions from Indonesia's electricity sector are projected to reach 335 million tons in 2030 [2]. To meet the target of reducing carbon emissions by 29% in 2030, a substantial reduction of 97 million tons of CO_2 is required. The technical potential of SPHS offers a promising solution, as it has the potential to reduce carbon emissions by 37 million tons of CO_2, equivalent to 11% of the total carbon emissions, or around 38% of the target, aligning with Indonesia's emissions reduction objectives. Moreover, the economical potential of SPHS presents a reduction of 19 million tons of CO_2, which accounts for 6% of the total carbon emissions in 2030, or around 20% of the carbon reduction target.

Table 6.1: Carbon reduction per year

Scenario	Energy production per year (TWh)	Carbon emission per year (million ton CO2)		Carbon reduction per year (million ton CO2)
		Coal-fired	SPHS systems	
Technical potential	48	39	2	37
Class 1	11	9	1	8
Class 2	4	4	1	3
Class 3	6	5	1	4
Class 4	6	5	1	4
Class 5	6	5	1	4
Class 6	3	3	0.1	3
Class 7	2	2	0.1	2
Class 8	1	1	0.1	1
Class 9	2	2	0.1	2
Class 10	7	6	0.3	6
Economical potential	24	19.9	0.9	19

The distribution of SPHS sites and their energy potential, both in terms of technical and economic feasibility, leads to varying levels of carbon emission reduction across different grid systems within the nation. To visualise this discrepancy, Figures 6.2 and Figure 6.3 present the distribution of carbon emission reduction under the technical potential and economic potential scenarios, respectively. These figures provide valuable insights into how SPHS implementation can contribute to carbon emission reduction on a regional scale.

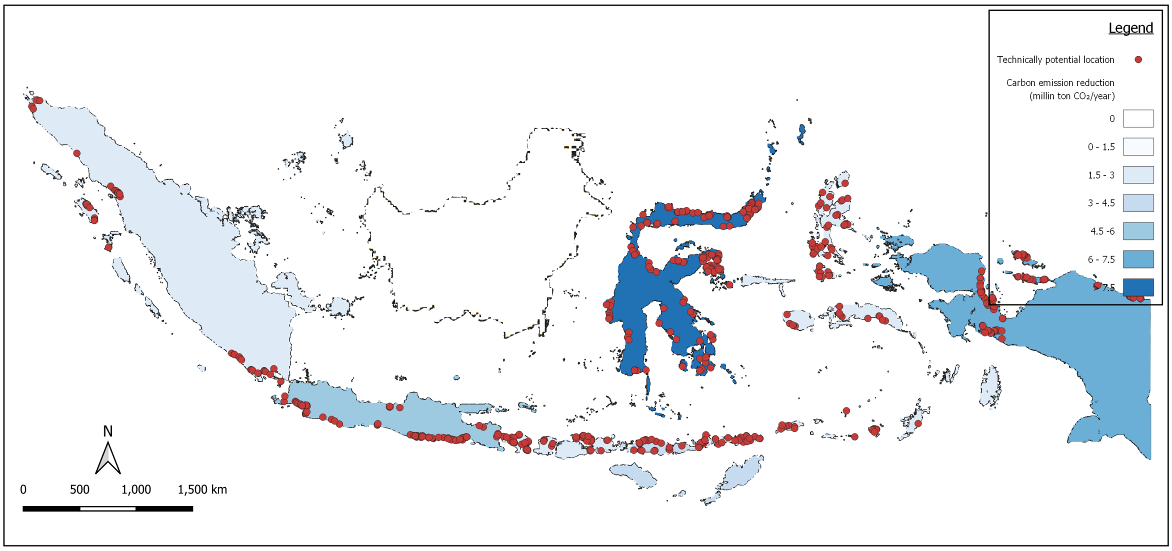


Figure 6.2: The reduction of carbon emission production per year based on the SHPS technical potential in every electrical grid.

Sulawesi emerges as the region with the most substantial technical potential for SPHS, capable of reducing 10 million tons of carbon emissions production per year if all technically feasible SPHS systems are developed within the region. Papua and Java follow, with the potential to reduce carbon emissions production by 7 million tons and 5 million tons of CO_2 per year, respectively. Sumatra, despite its substantial SPHS potential, is expected to contribute to a lower degree of carbon emission reduction compared to Java and Papua, with a reduction of 3 million tons of CO_2 per year. Smaller regions such as Bali, West Nusa Tenggara, East Nusa Tenggara, Maluku, and North Maluku also show notable carbon emission reduction potential, ranging from 1.5 to 3 million tons of CO_2 annually. These figures highlight the varied opportunities for carbon reduction across different regions of Indonesia through SPHS development.

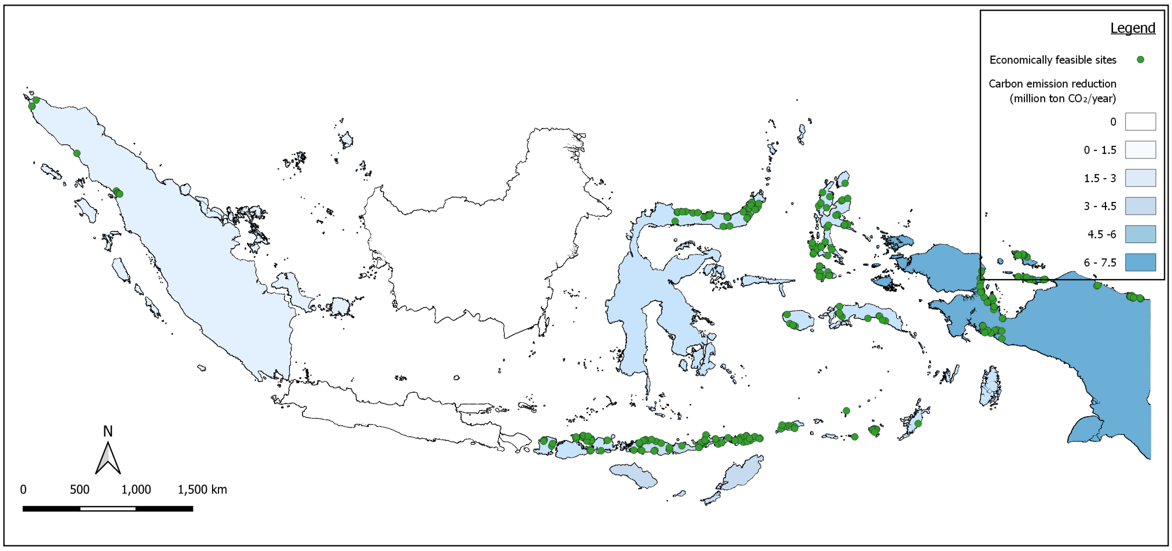


Figure 6.3: The reduction of carbon emission production per year based on the SHPS economical potential in every electrical grid.

Compared to its technical potential, the reduced economic feasibility of SPHS leads to a lower carbon emission reduction potential, particularly in regions with significantly lower economic potential. In Java and Bali, the reduced economic viability renders SPHS incapable of contributing to carbon emission reduction. Similarly, the potential for carbon reduction in Sumatra and Sulawesi, while still at 0.6 and 2 million tons of CO_2 per year, respectively, falls far short of their technical potential, which could achieve a much greater reduction of 3 and 10 million tons per year, respectively. It must be noted that the economic potential of SPHS can increase in the future due to economic growth and the expected rise in the ceiling price of electricity more than predicted in this research. As the overall economy grows and electricity costs are anticipated to rise, the feasibility of SPHS projects may become more favourable.

6.2. Local Environment Impact

The development of SPHS systems presents certain environmental risks, predominantly associated with using seawater near or in the freshwater ecosystem. Seawater intrusion into groundwater is a possible environmental hazard. Seawater intrusion occurs when the draining and storage of seawater displaces or mixes fresh water in underground aquifers, leading to saltwater infiltration into freshwater sources. This phenomenon can have significant effects on ecosystems, agriculture, and the availability of potable water.

Seawater Intrusion

The risk of seawater intrusion into the SPHS system occurs predominantly during the pumping and storage of seawater in the reservoir. The porosity of the soil, the profundity of the groundwater table, and other technical parameters all contribute to this risk—seawater intrusion results from the displacement of freshwater by seawater in underground aquifers. When seawater is pumped into a reservoir, its higher specific gravity than fresh water causes the groundwater table to sink progressively. The impact of saltwater intrusion can be long-term and detrimental. It can lead to a gradual increase in salinity in local freshwater aquifers, affecting groundwater quality. This can impact ecosystems, agriculture, and drinking water supplies. The duration of the impact may be sustained if not mitigated effectively.

Several strategies can be implemented to reduce the risk of seawater intrusion in SPHS systems. A crucial stage is using impermeable materials, such as geomembranes, to line and isolate the reservoir from the surrounding soil, thereby reducing the probability of intrusion. The use of geomembranes has been included in the investment cost calculations in this study. Figure 6.4 shows the implementation of geomembrane in a reservoir. In addition, implementing physical barriers such as slurry walls or impermeable liners around the SPHS site can provide an additional layer of defence against seawater infiltration. To assure the efficacy of these mitigation measures, real-time, continuous monitoring systems of groundwater levels and salinity should be established. Detecting an intrusion as soon as possible is essential for prompt action. When an increase in the salinity of freshwater is detected, the protective coating system should be promptly maintained. In addition, risk considerations must be incorporated into the standard operating procedures for system maintenance and operation to manage and reduce the risk of seawater intrusion effectively.

(a) Before installation **(b)** Installation process **(c)** Lined reservoir

Figure 6.4: Example of geomembrane installation in a reservoir [72]

Corrosion

The use of seawater in SPHS systems poses a significant corrosion risk to various components, including civil works such as penstocks, intake structures, and electromechanical equipment. The corrosive nature of seawater is due to its ability to degrade metal surfaces and encourage corrosion formation. This elevated risk of corrosion is a crucial factor in selecting materials for SPHS construction. Due to its corrosion resistance, GRP penstock material is preferred in this study over steel penstock. By utilising less susceptible materials to seawater's corrosive effects, SPHS systems can extend their operational lifetime and reduce the costs associated with corrosion-related damage.

Beyond these economic concerns, the rust caused by corrosion poses environmental dangers. When these rust particles decompose in water, they can potentially release harmful substances into the surrounding environment, contaminating the delicate marine ecosystem [73]. Furthermore, poor water quality may lead to the decline of fish populations. For the long-term effect, some corrosive byproducts can infiltrate the food chain through bioaccumulation, where toxins become concentrated as they move up the food chain. This can endanger the health of humans who ingest seafood from contaminated waters [74].

Several strategies can be employed to mitigate this risk. First and foremost, the selection of materials is crucial. Using non-corrosive materials, such as Glass Reinforced Plastic (GRP), for penstocks, intake structures, and other components in direct contact with seawater can substantially reduce corrosion-related risks. In addition, applying high-quality anti-corrosion coatings on non-replaceable metal components, such as pump-generator enclosures, can provide an additional layer of protection.

Furthermore, it is essential to implement routine inspection and maintenance protocols. Regularly examining all components for signs of corrosion, erosion, or damage enables prompt detection and repair. By applying corrosion-resistant coatings to vulnerable areas, the corrosion risk can be avoided. Monitoring systems that monitor salinity levels and the condition of metal surfaces can provide data in real-time to continuously evaluate the system's integrity. When corrosion is detected, prompt maintenance or replacement of affected elements is required to prevent additional damage. In addition, designing SPHS facilities with redundancy and backup systems can assure continuous operation and reduce the risk of unscheduled downtime due to corrosion-related failures. In conclusion, a combination of material selection, maintenance practices, and monitoring systems is necessary to mitigate corrosion risk effectively.

Chapter 7

Conclusion and Recommendations

In this chapter, the thesis delves into the conclusions drawn to address the primary research questions and related subquestions, a reflection on the research's limitations, and a set of recommendations for future investigations.

7.1. Conclusion

The methodologies employed in this research have been instrumental in identifying potential locations for SPHS in the coastal regions of Indonesia. As Indonesia strives to integrate renewable energy into its power grid, the intermittent nature of sources like wind and solar can pose a challenge. As an alternative to the energy storage system needs, SPHS offers the ability to store and utilise this intermittent energy, contributing to a more stable and sustainable energy ecosystem. Each sub-question in this study was designed to address particular facets of the research, and the findings from these sub-questions collectively contribute to addressing the main research question.

SQ1: Where are the potential sites for seawater-pumped hydro storage in Indonesia?

The investigation into potential sites for SPHS in Indonesia using the PyQGIS algorithm developed in this research has identified a list of 682 locations. However, it is essential to note that 73 of these sites are located in protected natural areas where the construction of such infrastructure is prohibited. As a result, 609 feasible SPHS sites are dispersed across nearly all of Indonesia's main islands, except Kalimantan, due to its relatively flat terrain near the coast.

The potential sites are dispersed widely, considering Indonesia's diverse geography and coastlines. Sulawesi, renowned for its lengthy coastline, boasts the highest number of potential SPHS locations, totalling 152 sites. Java features 109 potential sites, Papua boasts 98 locations, and Sumatra offers 56 potential SPHS sites. The smaller island regions, including Bali, West Nusa Tenggara, East Nusa Tenggara, Maluku, and North Maluku, collectively house 194 potential SPHS locations. This distribution underlines the rich diversity and potential for seawater-pumped hydro storage throughout the Indonesian archipelago.

SQ2: What is the technical potential of seawater-pumped hydro storage in Indonesia?

609 identified SPHS systems could collectively regenerate a peak power output of 29 GWp from the energy stored in the systems from intermittent energy sources. This peak power production is equivalent to 37% of the projected peak power demand across the nation by 2030. The peak power production of

each potential SPHS site falls within a broad range, spanning from 15 to 316 MWp. Furthermore, the annual energy that can be stored and regenerated from these SPHS systems is 48 TWh of electricity. This annual energy production, amounting to 10% of the projected national energy demand in Indonesia for the year 2030.

SQ3: What is the economical potential of seawater-pumped hydro storage in Indonesia?
The LCOS for SPHS in the country exhibits a range, with values falling between 3 to 10.14 cents €/kWh. To determine the economic feasibility of each SPHS system, an analysis involving the comparison of LCOS and related LCOE with the ceiling price in the respective region was carried out. Among the 609 initially identified technically potential sites, only 297 were found to be economically viable. These sites collectively possess a peak power regeneration potential of 15 GWp and an annual stored and regenerated energy of 24 TWh. It is worth noting that no economically potential sites were identified in Java and Bali due to the relatively low ceiling prices in those regions. Conversely, the economically potential SPHS sites predominantly lie in the eastern regions of Indonesia, as these areas feature higher ceiling prices compared to the western part of the country.

SQ4: How much carbon reduction can be achieved by developing seawater-pumped hydro storage in Indonesia?
The impact of developing SPHS in Indonesia on carbon emissions is in line with the nation's commitment to reducing its carbon footprint. The technical potential of SPHS is particularly promising, potentially reducing carbon emissions by 37 million tons of CO_2 per year. This remarkable reduction constitutes 11% of Indonesia's annual total carbon emissions in the energy sector in 2030.

Furthermore, the economical potential of SPHS presents a noteworthy reduction in carbon emissions, amounting to 19 million tons of CO_2 per year. This reduction contributes to 6% of the total carbon emissions projected for 2030. These findings provide compelling evidence that the development of SPHS aligns harmoniously with Indonesia's goal of achieving a 29% reduction in carbon emissions by 2030.

Main Question: What is the potential for seawater pumped hydro storage in coastal areas of Indonesia?
In summary, this study has identified 609 potential locations for SPHS with a total power capacity regeneration of 29 GWp. Among these sites, 297 have been determined to be economically feasible, resulting in a combined power capacity regeneration of 15 GWp. When evaluating the technological potential scenario, it is evident that these sites could contribute to carbon reduction, with the potential to achieve a reduction of 38% of the 2030 target in carbon emissions reduction. Moreover, within the context of economic potential, these locations can potentially facilitate a carbon reduction of 21% towards the 2030 target.

7.2. Limitations of The Research

While this research has yielded insights and outcomes in capturing SPHS potential in Indonesia, it is necessary to acknowledge its limitations to provide a more comprehensive view of its scope and potential areas for further improvement. The utilisation of high-resolution DEM data from DEMNAS, boasting a resolution of 0.27 arc-seconds (equivalent to 8x8 meters), significantly impacted the research. While this dataset facilitated an in-depth analysis, the computational demands associated with such high-resolution data translated into prolonged processing times for the algorithm. This time-consuming element hindered the ability to delve into other aspects requiring more attention, such as the geology condition of the site and local environmental issues.

Due to resource and time constraints, the research primarily focused on assessing the topographical features of the potential sites. Regrettably, the geological conditions of the sites and the specifics of the penstock line, which could substantially influence the feasibility of each site, were not taken into account. This limitation is a consideration for future studies aiming to provide a more comprehensive evaluation of SPHS sites.

In LCOS assessment, a simplified methodology was employed for estimating CAPEX and OPEX. While this simplified approach offered practicality in this context, it may not always provide the most precise calculations for SPHS projects. The uniqueness and variability of SPHS projects need more customised and accurate financial assessments.

Another limitation of this study is the exclusion of natural hazard considerations, such as earthquakes and tsunamis, from the site selection and evaluation process. Given Indonesia's geographic location, which is prone to seismic activity and tsunamis, further studies should explore the integration of disaster risk assessment and mitigation strategies to ensure the long-term resilience and safety of SPHS project.

7.3. Recommendations

This study has provided the technical and economical potential of SPHS at the national level in Indonesia. However, several key recommendations can be put forward to further advance the practical implementation of this technology.

While this research has identified potential SPHS sites across the nation and provides the picture of SPHS' role at a nationwide level, conducting in-depth assessments on a regional level would be instrumental for the next step of SPHS application. These smaller-level studies should consider the technical and geographical aspects and incorporate precise calculations, including geological conditions, penstock lines, and variations in electricity demand, so that the SPHS projects can be implemented.

Moreover, further studies should aim to refine the economic assessment by employing more tailored financial models. SPHS projects are unique, and a one-size-fits-all approach may not provide the most accurate results. Therefore, a customised financial modelling approach should be explored to ensure the economic feasibility of SPHS projects in each specific site.

Another aspect that can be improved is that future research endeavours should emphasise environmental impact assessments and mitigation strategies. Given the potential risks of seawater intrusion and corrosion associated with SPHS systems, studies focusing on minimising these environmental impacts will be essential. Developing effective mitigation strategies and monitoring systems can safeguard the delicate coastal ecosystems and the longevity of SPHS infrastructure.

Finally, the energy sector in Indonesia faces a challenge to meet the ambitious target of reducing carbon emissions. A steadfast commitment to incorporating more renewable energy into the national grid is necessary. To overcome the obstacles posed by the intermittent nature of renewable energy sources, implementing an efficient energy storage system becomes paramount, and SPHS emerges as an alternative technology that can work in line with other energy storage systems. By embracing SPHS and similar energy storage system innovations, Indonesia can move forward to ensure a resilient and sustainable energy future and make major progress toward its carbon reduction targets.

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Appendix A

SPHS Sites Properties

Detailed information about the properties and characteristics of the identified Seawater Pumped Hydro Storage (SPHS) sites can be found on the following pages of this report.

Identified Seawater-Pumped Hydro Storage (SPHS) Sites Properties

No	Site Code	Peak power (MWp)	Energy (MWh)	Volume (m3)	Area (m2)	Outlet coordinate (x)	Outlet coordinate (y)	Elevation (m)	Distance from coastline (m)	St.dev slope	Distance from transmission line (km)	Penstock diameter (m)	Number of penstock	LCOS (c€/kWh)	Carbon reduction (ton/year)	Economically feasible	Land covering
1	Site_01_aceh_181	40.4	183.5	198,000	30,268	95.3148	5.29858	621	8,103	0.26	18	2	1	4.1	52	Yes	Mosaic cropland/vegetation
2	Site_01_aceh_182	62.5	281.4	308,700	40,672	95.3051	5.29774	579	7,028	0.25	19	3	1	3.7	80	Yes	Mosaic vegetation/cropland
3	Site_01_aceh_235	19.5	108.6	250,200	38,787	95.3654	5.19107	278	6,877	0.57	25	3	1	6.1	31	No	Semi-deciduous forest
4	Site_01_aceh_42	24.3	111.8	361,800	61,455	95.5098	5.55914	200	3,338	0.15	10	3	1	5.6	32	No	Mosaic cropland/vegetation
5	Site_01_aceh_460	23.3	110.4	261,000	37,928	97.1479	3.37687	268	3,859	0.48	10	3	1	5.2	31	Yes	Mosaic cropland/vegetation
6	Site_01_aceh_47	63.2	282.4	535,500	87,929	95.4817	5.55275	334	5,223	0.17	8	4	1	4.3	80	Yes	Rainfed croplands
7	Site_01_aceh_62	29.4	149.7	367,200	59,566	95.5667	5.54247	271	7,317	0.18	15	3	1	5.4	42	No	Mosaic cropland/vegetation
8	Site_01_aceh_77	38.2	198.2	514,800	71,858	95.6273	5.53247	248	7,861	0.13	13	4	1	5.8	56	No	Rainfed croplands
9	Site_02_northsumatra_1031	28.4	144.5	467,763	106,677	98.9151	1.60745	225	8,606	0.27	2	3	1	6.5	41	No	Semi-deciduous forest
10	Site_02_northsumatra_104	18.2	99.7	104,283	16,610	98.53	2.03282	609	8,552	0.20	27	2	1	5.7	28	No	Mosaic vegetation/cropland
11	Site_02_northsumatra_1096	15.5	93.5	309,554	45,972	97.5211	1.31859	200	6,952	0.12	21	3	1	7.1	27	No	Semi-deciduous forest
12	Site_02_northsumatra_1100	37.9	189.8	623,243	130,507	97.5256	1.31499	200	6,779	0.11	20	4	1	6.2	54	No	Semi-deciduous forest
13	Site_02_northsumatra_1104	34.8	181.9	597,970	81,836	97.5204	1.31072	200	7,525	0.12	20	4	1	6.4	52	No	Mosaic vegetation/cropland
14	Site_02_northsumatra_1105	82.5	406.9	1,348,893	164,848	97.5303	1.30449	200	7,052	0.13	19	4	2	5.4	115	No	Semi-deciduous forest
15	Site_02_northsumatra_1118	17.6	98.6	264,557	39,879	97.5504	1.29684	240	6,225	0.13	17	3	1	6.3	28	No	Rainfed croplands
16	Site_02_northsumatra_1145	28.4	134.3	404,756	88,483	97.5663	1.28237	221	5,052	0.18	14	3	1	5.6	38	No	Rainfed croplands
17	Site_02_northsumatra_1149	24.3	110.3	354,678	53,381	97.5872	1.27989	200	3,008	0.22	13	3	1	5.5	31	No	Mosaic cropland/vegetation
18	Site_02_northsumatra_1171	15.3	98.2	307,531	56,982	97.5555	1.24509	213	8,161	0.16	13	3	1	7.2	28	No	Semi-deciduous forest
19	Site_02_northsumatra_1186	15.2	96.8	325,398	58,436	97.5724	1.23151	200	7,937	0.19	10	3	1	7.4	27	No	Rainfed croplands
20	Site_02_northsumatra_1223	28.9	127.7	415,796	59,753	97.6698	1.16003	200	3,036	0.13	2	3	1	5.4	36	No	Mosaic vegetation/cropland
21	Site_02_northsumatra_1554	37.5	158.6	378,801	53,320	97.8696	0.73496	266	2,063	0.21	2	3	1	4.8	45	No	Rainfed croplands
22	Site_02_northsumatra_1661	41.2	181.6	513,412	89,745	97.8673	0.64713	223	2,951	0.25	2	4	1	5.0	51	No	Rainfed croplands
23	Site_02_northsumatra_1685	26.6	118.8	383,313	81,505	97.8689	0.63453	200	2,917	0.15	2	3	1	5.6	34	No	Mosaic cropland/vegetation
24	Site_02_northsumatra_1704	37.7	161.7	493,469	67,863	97.8603	0.62913	218	3,448	0.11	3	3	1	5.2	46	No	Semi-deciduous forest
25	Site_02_northsumatra_313	20.3	119.6	314,797	58,557	98.7089	1.8615	251	8,452	0.26	7	3	1	6.4	34	No	Rainfed croplands
26	Site_02_northsumatra_400	77.4	346.9	595,298	84,169	98.7596	1.83997	372	6,676	0.32	5	4	1	4.2	98	Yes	Semi-deciduous forest
27	Site_02_northsumatra_636	30.9	148.9	118,665	24,019	98.8485	1.77209	797	7,825	0.28	4	2	1	4.8	42	No	Semi-deciduous forest
28	Site_02_northsumatra_648	25.9	117.8	190,695	30,734	98.8154	1.76624	410	4,985	0.22	0	2	1	4.6	33	No	Rainfed croplands
29	Site_02_northsumatra_693	85.7	363.0	567,813	104,869	98.8091	1.75664	402	3,709	0.25	-	4	1	4.0	103	Yes	Semi-deciduous forest
30	Site_02_northsumatra_699	24.7	110.6	183,309	20,628	98.8157	1.75604	395	4,070	0.27	1	2	1	4.5	31	No	Semi-deciduous forest
31	Site_02_northsumatra_703	28.6	129.6	164,565	21,943	98.8287	1.75491	509	4,913	0.25	2	2	1	4.4	37	Yes	Mosaic cropland/vegetation
32	Site_02_northsumatra_782	76.6	341.4	401,030	62,854	98.8908	1.71973	553	8,512	0.32	5	3	1	3.8	97	Yes	Semi-deciduous forest
33	Site_02_northsumatra_799	28.6	141.2	157,605	36,065	98.8947	1.71036	588	8,497	0.29	5	2	1	4.7	40	No	Semi-deciduous forest
34	Site_02_northsumatra_802	47.6	227.9	244,970	50,948	98.8947	1.71021	588	8,489	0.29	5	3	1	4.2	65	Yes	Semi-deciduous forest
35	Site_05_westsumatra_22	22.7	115.2	387,288	52,737	98.4523	-0.46247	200	5,732	0.08	135	3	1	6.3	33	No	Mosaic cropland/vegetation
36	Site_05_westsumatra_28	33.2	171.2	520,059	80,420	98.4403	-0.46689	212	6,658	0.11	135	4	1	6.2	49	No	Mosaic cropland/vegetation
37	Site_07_bengkulu_1049	31.9	146.6	135,244	19,732	103.81	-4.98581	690	5,877	0.24	40	2	1	4.4	42	No	Rainfed croplands
38	Site_07_bengkulu_141	28.2	143.5	410,205	65,560	103.473	-4.79537	239	7,416	0.23	69	3	1	5.8	41	No	Mosaic vegetation/cropland
39	Site_07_bengkulu_234	18.0	90.2	219,253	48,925	103.579	-4.8445	308	7,857	0.27	60	2	1	6.1	26	No	Mosaic vegetation/cropland
40	Site_07_bengkulu_257	23.7	131.8	288,834	55,895	103.59	-4.84795	296	8,187	0.29	59	3	1	5.8	37	No	Mosaic cropland/vegetation
41	Site_07_bengkulu_884	42.5	198.5	317,114	56,232	103.78	-4.94313	401	6,336	0.27	44	3	1	4.3	56	No	Rainfed croplands
42	Site_10_lampung_1129	31.4	136.3	186,145	46,007	103.877	-5.06546	474	3,803	0.15	32	2	1	4.2	39	No	Semi-deciduous forest
43	Site_10_lampung_1398	23.5	127.8	307,426	66,041	105.198	-5.42584	271	7,468	0.18	1	3	1	5.8	36	No	Rainfed croplands
44	Site_10_lampung_1546	16.2	96.5	264,878	46,116	104.257	-5.46491	236	6,987	0.11	16	3	1	6.6	27	No	Rainfed croplands
45	Site_10_lampung_1571	19.3	115.1	272,778	55,628	104.279	-5.46949	274	8,378	0.15	14	3	1	6.3	33	No	Rainfed croplands
46	Site_10_lampung_1573	21.8	125.2	298,507	57,489	104.279	-5.46949	275	8,378	0.15	14	3	1	6.1	36	No	Rainfed croplands
47	Site_10_lampung_1605	34.3	168.7	437,864	72,239	104.292	-5.47879	267	8,144	0.09	14	3	1	5.5	48	No	Mosaic cropland/vegetation
48	Site_10_lampung_1679	19.3	114.6	402,764	53,420	104.33	-5.49634	202	8,883	0.10	13	3	1	7.2	32	No	Semi-deciduous forest
49	Site_10_lampung_1715	106.5	474.6	654,098	131,996	104.801	-5.50624	466	8,879	0.28	12	4	1	3.9	135	No	Semi-deciduous forest
50	Site_10_lampung_1840	18.4	91.9	216,922	37,909	104.81	-5.53016	314	7,650	0.28	14	2	1	5.9	26	No	Mosaic cropland/vegetation
51	Site_10_lampung_1967	36.4	183.7	341,193	46,178	104.854	-5.54839	353	8,552	0.29	19	3	1	4.9	52	No	Rainfed croplands
52	Site_10_lampung_2291	76.4	319.4	577,850	115,710	104.541	-5.60674	347	2,596	0.18	16	4	1	4.4	91	No	Mosaic vegetation/cropland
53	Site_10_lampung_2354	37.4	155.8	281,170	58,095	104.561	-5.61791	347	1,452	0.29	17	3	1	4.3	44	No	Mosaic cropland/vegetation
54	Site_10_lampung_2532	58.3	268.8	840,802	167,107	105.052	-5.65796	221	8,082	0.25	30	4	1	5.7	76	No	Rainfed croplands
55	Site_10_lampung_2897	179.2	723.0	838,303	115,849	105.483	-5.94716	541	1,871	0.18	29	4	1	3.9	205	No	Mosaic vegetation/cropland
56	Site_10_lampung_971	26.4	122.5	152,366	21,315	103.827	-5.00441	518	5,291	0.18	38	2	1	4.5	35	No	Rainfed croplands
57	Site_11_banten_1187	26.0	139.1	278,481	50,540	106.332	-6.91415	322	7,754	0.16	1	3	1	6.1	39	No	Rainfed croplands
58	Site_11_banten_1200	16.6	95.5	243,606	50,059	106.311	-6.91723	251	6,515	0.15	0	3	1	7.3	27	No	Semi-deciduous forest
59	Site_11_banten_1208	39.5	176.1	377,625	58,104	106.473	-6.91708	301	4,243	0.14	2	3	1	5.2	50	No	Semi-deciduous forest
60	Site_11_banten_1241	20.7	93.7	225,212	46,208	106.523	-6.92015	295	5,074	0.18	4	2	1	6.2	27	No	Mosaic cropland/vegetation
61	Site_11_banten_1256	56.8	248.6	426,754	87,945	106.536	-6.92165	380	5,525	0.19	4	3	1	4.7	70	No	Semi-deciduous forest
62	Site_11_banten_1271	46.3	220.8	607,098	98,121	106.358	-6.92571	236	6,349	0.18	0	4	1	6.2	63	No	Rainfed croplands
63	Site_11_banten_1278	70.3	297.0	505,706	96,402	106.548	-6.92465	389	5,414	0.20	4	3	1	4.8	84	No	Semi-deciduous forest
64	Site_11_banten_1298	23.7	122.0	307,692	58,721	106.366	-6.92758	257	6,038	0.21	0	3	1	6.5	35	No	Mosaic cropland/vegetation
65	Site_11_banten_1408	25.6	117.1	238,533	43,042	106.538	-6.94551	309	3,316	0.15	2	3	1	5.5	33	No	Semi-deciduous forest
66	Site_11_banten_1452	43.0	199.6	605,773	110,424	106.352	-6.95016	212	4,899	0.20	2	4	1	6.4	57	No	Rainfed croplands
67	Site_11_banten_1512	27.0	117.8	377,463	39,809	106.553	-6.96381	200	2,336	0.15	1	3	1	6.4	33	No	Semi-deciduous forest
68	Site_11_banten_250	19.3	87.2	248,957	59,592	105.647	-6.54722	220	2,240	0.14	7	3	1	6.4	25	No	Semi-deciduous forest
69	Site_11_banten_519	17.1	101.5	231,094	49,730	106.075	-6.76361	281	7,527	0.11	4	3	1	7.2	29	No	Semi-deciduous forest
70	Site_11_banten_539	15.1	97.8	270,472	49,661	105.615	-6.76714	236	8,277	0.07	27	3	1	8.0	28	No	Mosaic vegetation/cropland
71	Site_11_banten_614	15.1	96.1	274,882	62,109	106.108	-6.78514	228	7,828	0.13	6	3	1	8.1	27	No	Semi-deciduous forest
72	Site_11_banten_756	34.6	158.8	504,810	94,843	106.12	-6.81139	225	6,694	0.14	4	3	1	6.9	45	No	Semi-deciduous forest
73	Site_11_banten_880	15.6	91.6	268,366	48,209	106.176	-6.84845	221	6,481	0.14	2	3	1	7.7	26	No	Mosaic cropland/vegetation
74	Site_11_banten_944	57.7	256.9	780,757	110,923	106.232	-6.87192	217	5,357	0.11	4	4	1	6.1	73	No	Semi-deciduous forest
75	Site_11_banten_984	31.2	152.5	460,796	63,403	106.295	-6.88123	233	7,545	0.16	4	3	1	6.9	43	No	Semi-deciduous forest
76	Site_13_westjava_1055	46.4	225.7	320,194	52,641	106.547	-7.19438	455	8,883	0.19	19	3	1	4.8	64	No	Semi-deciduous forest
77	Site_13_westjava_1056	54.6	238.5	452,776	89,338	106.514	-7.19543	347	5,501	0.17	19	3	1	4.9	68	No	Mosaic cropland/vegetation
78	Site_13_westjava_1126	48.2	238.7	663,687	111,659	106.503	-7.25004	238	8,336	0.11	25	4	1	6.6	68	No	Semi-deciduous forest
79	Site_13_westjava_1219	19.8	111.6	362,320	58,386	107.202	-7.40695	209	7,339	0.14	34	3	1	7.7	32	No	Rainfed croplands
80	Site_13_westjava_1589	24.3	121.9	242,852	43,060	107.552	-7.50026	318	5,600	0.15	13	3	1	5.9	35	No	Semi-deciduous forest
81	Site_13_westjava_1787	20.5	110.0	313,338	60,082	107.685	-7.56462	229	6,163	0.22	1	3	1	7.1	31	No	Semi-deciduous forest
82	Site_13_westjava_2078	25.8	122.5	409,429	78,256	107.879	-7.69296	200	4,738	0.09	19	3	1	7.0	35	No	Rainfed croplands
83	Site_13_westjava_254	25.8	139.0	278,481	50,540	106.332	-6.91415	322	7,901	0.16	1	3	1	6.1	39	No	Rainfed croplands
84	Site_13_westjava_275	39.3	175.8	377,625	58,104	106.473	-6.91708	301	4,409	0.14	2	3	1	5.2	50	No	Semi-deciduous forest
85	Site_13_westjava_323	56.6	248.4	426,754	87,945	106.536	-6.92165	380	5,598	0.19	4	3	1	4.7	70	No	Semi-deciduous forest
86	Site_13_westjava_338	45.3	220.0	607,098	98,121	106.358	-6.92571	236	6,899	0.18	0	4	1	6.4	62	No	Rainfed croplands
87	Site_13_westjava_51	30.9	151.9	460,796	63,403	106.295	-6.88123	233	7,764	0.16	4	3	1	6.9	43	No	Semi-deciduous forest
88	Site_13_westjava_579	26.9	117.7	377,463	39,809	106.553	-6.96381	200	2,400	0.16	1	3	1	6.4	33	No	Semi-deciduous forest
89	Site_14_centraljava1_113	15.3	96.7	318,451	46,888	109.932	-6.99276	204	8,419	0.14	1	3	1	8.8	27	No	Semi-deciduous forest
90	Site_14_centraljava1_117	21.8	122.7	407,646	52,801	109.92	-6.99366	212	8,547	0.13	1	3	1	8.1	35	No	Mosaic cropland/vegetation
91	Site_14_centraljava1_236	40.1	203.2	513,642	64,529	109.447	-7.67375	254	7,429	0.29	3	4	1	6.4	58	No	Mosaic cropland/vegetation

No	Site Code	Peak power (MWp)	Energy (MWh)	Volume (m3)	Area (m2)	Outlet coordinate (x)	Outlet coordinate (y)	Elevation (m)	Distance from coastline (m)	St.dev slope	Distance from transmission line (km)	Penstock diameter (m)	Number of penstock	LCOS (c€/kWh)	Carbon reduction (ton/year)	Economically feasible	Land covering
92	Site_14_centraljava1_313	24.1	105.1	221,745	35,283	109.43	-7.70503	322	3,974	0.25	7	2	1	5.5	30	No	Semi-deciduous forest
93	Site_14_centraljava1_373	23.2	108.4	260,491	53,195	109.426	-7.73144	263	3,479	0.18	10	3	1	6.1	31	No	Semi-deciduous forest
94	Site_14_centraljava1_54	31.4	146.7	442,623	68,755	109.93	-6.96463	225	5,488	0.25	2	3	1	6.8	42	No	Semi-deciduous forest
95	Site_14_centraljava2_1119	44.4	199.8	606,685	94,135	111.041	-8.21006	211	3,992	0.20	8	4	1	6.2	57	No	Semi-deciduous forest
96	Site_14_centraljava2_1155	56.6	244.7	649,889	91,322	111.032	-8.22011	240	3,362	0.19	9	4	1	5.8	69	No	Semi-deciduous forest
97	Site_14_centraljava2_144	23.3	122.1	429,685	64,421	109.95	-6.98534	200	7,245	0.16	0	3	1	7.9	35	No	Mosaic cropland/vegetation
98	Site_14_centraljava2_189	20.9	113.9	391,906	42,967	110.347	-7.01751	200	7,115	0.09	-	3	1	7.8	32	No	Mosaic cropland/vegetation
99	Site_14_centraljava2_330	45.4	224.0	559,132	74,815	110.777	-8.1262	259	7,418	0.25	23	4	1	6.6	64	No	Shrubland
100	Site_14_centraljava2_611	24.1	124.6	314,883	57,256	110.924	-8.15688	257	6,203	0.23	15	3	1	6.5	35	No	Mosaic cropland/vegetation
101	Site_14_centraljava2_634	26.8	132.2	240,713	43,062	110.918	-8.15995	348	5,693	0.23	16	3	1	6.1	38	No	Mosaic cropland/vegetation
102	Site_14_centraljava2_682	43.3	205.6	348,332	72,683	111.048	-8.16303	383	7,284	0.16	4	3	1	5.0	58	No	Mosaic cropland/vegetation
103	Site_14_centraljava2_762	20.9	113.6	249,905	49,026	110.978	-8.17008	291	6,719	0.27	11	3	1	6.6	32	No	Mosaic cropland/vegetation
104	Site_14_centraljava2_818	71.0	322.9	552,381	93,115	111.039	-8.17293	372	6,845	0.14	6	4	1	4.7	92	No	Shrubland
105	Site_14_centraljava2_829	69.7	308.8	465,036	76,727	111.234	-8.17541	444	8,468	0.21	0	3	1	4.5	88	No	Semi-deciduous forest
106	Site_14_centraljava2_834	20.9	101.0	218,007	31,815	111.027	-8.17713	337	7,357	0.21	7	2	1	6.2	29	No	Semi-deciduous forest
107	Site_14_centraljava2_910	18.2	98.1	137,568	27,015	111.235	-8.18141	465	7,799	0.21	1	2	1	5.9	28	No	Mosaic cropland/vegetation
108	Site_14_centraljava2_922	51.2	241.0	326,906	59,721	111.222	-8.18358	474	8,098	0.18	1	3	1	4.6	68	No	Semi-deciduous forest
109	Site_14_centraljava2_955	48.0	211.1	440,402	99,007	111.041	-8.19326	315	4,993	0.17	7	3	1	5.1	60	No	Mosaic cropland/vegetation
110	Site_16_eastjava1_1089	64.5	285.1	625,160	118,478	111.038	-8.19813	291	4,919	0.19	8	4	1	5.2	81	No	Mosaic cropland/vegetation
111	Site_16_eastjava1_1128	75.8	364.0	1,129,066	161,810	111.271	-8.20023	207	5,320	0.33	2	4	2	6.3	103	No	Semi-deciduous forest
112	Site_16_eastjava1_1232	287.2	1,164.5	2,838,510	402,523	111.059	-8.20713	260	2,482	0.17	6	4	4	5.8	330	No	Mosaic cropland/vegetation
113	Site_16_eastjava1_1279	44.4	199.8	606,685	94,135	111.041	-8.21006	211	3,992	0.20	8	4	1	6.2	57	No	Semi-deciduous forest
114	Site_16_eastjava1_1447	21.3	99.9	283,556	56,288	111.249	-8.21973	224	3,268	0.31	5	3	1	6.5	28	No	Semi-deciduous forest
115	Site_16_eastjava1_1671	24.0	111.3	230,403	40,861	111.21	-8.22956	304	3,527	0.24	6	3	1	5.6	32	No	Semi-deciduous forest
116	Site_16_eastjava1_1715	29.3	137.5	203,722	35,513	111.513	-8.23174	465	7,713	0.22	16	2	1	5.1	39	No	Semi-deciduous forest
117	Site_16_eastjava1_1850	59.0	258.4	840,371	128,545	111.925	-8.23646	205	5,099	0.23	13	4	1	6.5	73	No	Semi-deciduous forest
118	Site_16_eastjava1_1852	36.1	173.9	471,261	102,492	112.131	-8.23991	261	8,356	0.16	16	3	1	6.5	49	No	Mosaic cropland/vegetation
119	Site_16_eastjava1_1928	18.2	95.9	172,344	28,931	111.538	-8.23954	378	7,516	0.26	18	2	1	6.0	27	No	Shrubland
120	Site_16_eastjava1_1951	26.1	127.4	182,750	33,729	112.917	-8.24471	471	7,875	0.31	27	2	1	5.3	36	No	Semi-deciduous forest
121	Site_16_eastjava1_212	45.4	224.0	559,132	74,815	110.777	-8.1262	259	7,418	0.25	23	4	1	6.2	64	No	Shrubland
122	Site_16_eastjava1_2261	44.4	192.3	217,528	29,204	111.664	-8.25536	592	6,406	0.22	14	2	1	4.3	55	No	Semi-deciduous forest
123	Site_16_eastjava1_2328	16.5	87.0	203,948	39,007	112.323	-8.25881	312	8,021	0.19	9	2	1	6.8	25	No	Mosaic cropland/vegetation
124	Site_16_eastjava1_2370	63.3	295.2	682,050	109,616	112.314	-8.26189	284	7,805	0.22	9	4	1	5.6	84	No	Mosaic cropland/vegetation
125	Site_16_eastjava1_2399	38.0	184.2	550,625	73,008	112.926	-8.26339	215	5,599	0.31	28	4	1	6.6	52	No	Semi-deciduous forest
126	Site_16_eastjava1_2459	22.2	114.9	172,536	37,635	112.876	-8.26811	451	8,537	0.17	24	2	1	5.6	33	No	Mosaic cropland/vegetation
127	Site_16_eastjava1_2463	41.1	190.4	454,216	98,372	112.314	-8.26856	286	7,078	0.23	10	3	1	5.8	54	No	Mosaic cropland/vegetation
128	Site_16_eastjava1_2538	24.8	126.7	253,421	31,396	112.328	-8.27584	318	6,114	0.20	11	3	1	5.9	36	No	Shrubland
129	Site_16_eastjava1_2648	47.2	207.0	468,026	90,073	112.316	-8.28559	295	5,185	0.25	12	3	1	5.4	59	No	Shrubland
130	Site_16_eastjava1_2700	26.6	134.5	230,921	49,148	112.387	-8.29669	369	6,401	0.13	13	3	1	5.7	38	No	Mosaic cropland/vegetation
131	Site_16_eastjava1_2916	19.4	102.1	230,131	38,934	112.39	-8.30772	281	5,563	0.12	14	3	1	6.5	29	No	Rainfed croplands
132	Site_16_eastjava1_2999	37.5	171.8	152,911	33,587	112.804	-8.31244	722	6,904	0.31	20	2	1	4.6	49	No	Semi-deciduous forest
133	Site_16_eastjava1_3017	56.0	255.1	228,158	39,687	112.794	-8.31334	702	7,195	0.31	20	3	1	4.3	72	No	Rainfed croplands
134	Site_16_eastjava1_3055	17.3	91.7	210,374	44,348	112.492	-8.31559	326	8,841	0.19	15	2	1	6.8	26	No	Rainfed croplands
135	Site_16_eastjava1_3073	24.0	134.8	263,447	47,089	112.509	-8.31799	329	8,592	0.15	15	3	1	6.3	38	No	Mosaic cropland/vegetation
136	Site_16_eastjava1_3098	23.2	130.1	265,281	46,404	112.465	-8.31844	316	8,268	0.16	16	3	1	6.4	37	No	Mosaic cropland/vegetation
137	Site_16_eastjava1_3158	25.5	137.4	300,807	79,029	112.466	-8.32287	297	7,769	0.16	16	3	1	6.3	39	No	Mosaic cropland/vegetation
138	Site_16_eastjava1_3214	25.8	133.7	304,441	62,784	112.454	-8.33067	284	6,712	0.16	17	3	1	6.3	38	No	Semi-deciduous forest
139	Site_16_eastjava1_3281	60.9	287.2	656,990	140,921	112.546	-8.32842	286	7,969	0.14	15	4	1	5.7	81	No	Mosaic cropland/vegetation
140	Site_16_eastjava1_3345	39.6	183.9	439,316	81,769	112.459	-8.33442	282	6,602	0.19	18	3	1	5.7	52	No	Mosaic cropland/vegetation
141	Site_16_eastjava1_3393	25.4	119.5	164,766	25,360	112.754	-8.33712	474	5,794	0.19	20	2	1	5.1	34	No	Rainfed croplands
142	Site_16_eastjava1_3441	38.4	165.9	228,595	30,843	112.909	-8.33787	454	2,838	0.23	31	3	1	4.4	47	No	Semi-deciduous forest
143	Site_16_eastjava1_3545	21.8	119.9	334,793	55,790	112.597	-8.34485	238	7,306	0.14	17	3	1	7.1	34	No	Mosaic cropland/vegetation
144	Site_16_eastjava1_3722	39.4	181.1	492,295	66,069	112.632	-8.35955	259	7,244	0.24	20	3	1	6.2	51	No	Semi-deciduous forest
145	Site_16_eastjava1_492	24.1	124.6	314,883	57,256	110.924	-8.15688	257	6,203	0.23	15	3	1	6.5	35	No	Mosaic cropland/vegetation
146	Site_16_eastjava1_561	43.3	205.6	348,332	72,683	111.048	-8.16303	383	7,284	0.16	4	3	1	5.0	58	No	Mosaic cropland/vegetation
147	Site_16_eastjava1_616	18.1	100.7	238,272	19,611	110.954	-8.1667	270	6,341	0.20	13	3	1	6.8	29	No	Semi-deciduous forest
148	Site_16_eastjava1_641	20.9	113.6	249,905	49,026	110.978	-8.17008	291	6,719	0.27	11	3	1	6.5	32	No	Mosaic cropland/vegetation
149	Site_16_eastjava1_648	20.0	119.0	231,349	39,152	111.275	-8.16933	329	8,784	0.29	0	3	1	6.7	34	No	Mosaic cropland/vegetation
150	Site_16_eastjava1_670	17.2	94.6	170,589	21,530	111.262	-8.17173	380	8,413	0.30	0	2	1	6.2	27	No	Mosaic cropland/vegetation
151	Site_16_eastjava1_717	47.3	216.2	480,946	68,910	111.019	-8.17668	311	7,980	0.19	8	3	1	5.5	61	No	Semi-deciduous forest
152	Site_16_eastjava1_722	69.7	308.8	465,036	76,727	111.234	-8.17541	444	8,468	0.25	0	3	1	4.5	88	No	Semi-deciduous forest
153	Site_16_eastjava1_727	20.9	101.0	218,007	31,815	111.027	-8.17713	337	7,357	0.17	7	2	1	6.2	29	No	Semi-deciduous forest
154	Site_16_eastjava1_823	18.2	98.1	137,568	27,015	111.235	-8.18141	465	7,799	0.25	1	2	1	5.8	28	No	Mosaic cropland/vegetation
155	Site_16_eastjava1_855	27.1	130.2	242,006	56,224	111.052	-8.18546	340	4,888	0.16	6	3	1	5.5	37	No	Mosaic cropland/vegetation
156	Site_16_eastjava2_1022	21.7	113.1	360,163	73,289	113.061	-8.23211	209	5,982	0.21	20	3	1	7.3	32	No	Mosaic cropland/vegetation
157	Site_16_eastjava2_326	25.2	117.3	378,793	77,765	113.592	-7.75259	202	3,846	0.27	3	3	1	6.8	33	No	Mosaic cropland/vegetation
158	Site_16_eastjava2_561	40.6	200.9	276,924	41,862	113.76	-7.81454	463	8,544	0.23	8	3	1	4.9	57	No	Rainfed croplands
159	Site_16_eastjava2_760	61.6	268.8	473,943	93,068	114.357	-8.07737	378	6,541	0.20	6	3	1	4.8	76	No	Semi-deciduous forest
160	Site_16_eastjava2_842	22.9	106.6	182,198	31,887	114.352	-8.1274	388	5,160	0.19	4	2	1	5.4	30	No	Semi-deciduous forest
161	Site_16_eastjava2_951	52.5	252.9	677,197	128,489	114.311	-8.19468	247	7,884	0.06	3	4	1	6.3	72	No	Semi-deciduous forest
162	Site_16_eastjava2_978	19.0	114.4	250,142	46,347	113.052	-8.21043	294	8,542	0.13	20	3	1	7.0	32	No	Shrubland
163	Site_16_eastjava2_981	18.5	112.0	311,142	51,284	114.307	-8.21036	239	8,372	0.06	2	3	1	7.5	32	No	Mosaic cropland/vegetation
164	Site_16_eastjava2_994	29.1	143.2	483,931	96,808	113.082	-8.21508	216	7,913	0.31	17	3	1	7.5	41	No	Mosaic cropland/vegetation
165	Site_16_eastjava2_996	51.7	242.8	838,147	118,542	113.088	-8.21396	202	8,098	0.12	17	4	1	7.2	69	No	Mosaic cropland/vegetation
166	Site_22_northsulawesi_1040	27.8	131.1	226,652	41,169	124.737	1.38314	364	4,577	0.32	2	3	1	5.8	37	Yes	Mosaic vegetation/cropland
167	Site_22_northsulawesi_1252	24.0	125.1	261,709	42,899	124.725	1.35427	305	6,477	0.18	0	3	1	6.7	35	Yes	Rainfed croplands
168	Site_22_northsulawesi_1462	21.7	123.9	301,466	51,272	124.723	1.33725	269	8,180	0.19	1	3	1	7.5	35	No	Mosaic vegetation/cropland
169	Site_22_northsulawesi_1554	53.7	238.8	246,697	72,237	125.014	1.32952	608	5,478	0.28	6	3	1	4.4	68	Yes	Semi-deciduous forest
170	Site_22_northsulawesi_1976	19.1	102.0	182,190	32,176	124.691	1.24974	389	8,703	0.20	3	2	1	6.5	29	Yes	Rainfed croplands
171	Site_22_northsulawesi_2084	46.7	219.1	300,499	55,218	124.975	1.21127	465	7,184	0.18	14	3	1	5.0	62	Yes	Semi-deciduous forest
172	Site_22_northsulawesi_2100	20.7	94.5	216,758	37,504	124.993	1.20272	304	4,978	0.21	16	2	1	6.6	27	Yes	Mosaic cropland/vegetation
173	Site_22_northsulawesi_2146	29.9	142.9	417,978	66,844	124.635	1.18113	230	5,735	0.17	5	3	1	7.2	41	No	Rainfed croplands
174	Site_22_northsulawesi_2185	60.7	261.4	786,424	107,463	124.99	1.16246	216	3,950	0.21	19	4	1	7.0	74	No	Semi-deciduous forest
175	Site_22_northsulawesi_2276	19.2	99.7	231,579	41,795	124.953	1.12834	273	5,150	0.15	16	3	1	7.1	28	No	Rainfed croplands
176	Site_22_northsulawesi_2328	30.9	162.2	337,194	64,008	124.632	1.12984	317	8,570	0.13	7	3	1	6.5	46	Yes	Mosaic vegetation/cropland
177	Site_22_northsulawesi_2436	41.5	202.8	592,867	115,353	124.594	1.12316	222	6,462	0.19	6	4	1	7.4	58	No	Rainfed croplands
178	Site_22_northsulawesi_2454	39.2	188.6	398,902	70,720	124.517	1.12024	315	7,610	0.33	1	3	1	6.1	53	Yes	Mosaic cropland/vegetation
179	Site_22_northsulawesi_2458	38.6	184.6	471,281	80,408	124.624	1.12091	276	8,561	0.15	7	3	1	6.9	52	No	Rainfed croplands
180	Site_22_northsulawesi_2472	20.0	103.9	193,603	41,311	124.904	1.11956	379	8,504	0.18	13	2	1	6.6	29	Yes	Mosaic vegetation/cropland
181	Site_22_northsulawesi_2505	84.5	376.2	830,049	119,989	124.619	1.11679	305	8,533	0.15	7	4	1	5.8	107	Yes	Rainfed croplands
182	Site_22_northsulawesi_2544	41.8	192.7	505,825	75,564	124.612	1.11341	273	8,377	0.18	8	3	1	6.9	55	No	Rainfed croplands
183	Site_22_northsulawesi_2656	28.5	140.0	315,945	60,549	124.916	1.09654	286	5,734	0.15	15	3	1	6.5	40	Yes	Semi-deciduous forest
184	Site_22_northsulawesi_2731	18.3	97.3	266,400	39,928	124.904	1.08132	234	5,330	0.14	16	3	1	7.7	28	No	Mosaic cropland/vegetation
185	Site_22_northsulawesi_2737	47.7	216.8	505,836	91,481	124.859	1.07607	303	8,451	0.29	13	3	1	6.3	61	Yes	Mosaic vegetation/cropland

No	Site Code	Peak power (MWp)	Energy (MWh)	Volume (m3)	Area (m2)	Outlet coordinate (x)	Outlet coordinate (y)	Elevation (m)	Distance from coastline (m)	St.dev slope	Distance from transmission line (km)	Penstock diameter (m)	Number of penstock	LCOS (c€/kWh)	Carbon reduction (ton/year)	Economically feasible	Land covering
186	Site_22_northsulawesi_2739	117.6	537.6	1,338,899	161,095	124.891	1.0778	261	6,208	0.15	14	4	2	6.2	152	Yes	Mosaic cropland/vegetation
187	Site_22_northsulawesi_3106	29.9	155.7	253,112	48,648	124.377	0.98234	392	8,030	0.23	12	3	1	6.0	44	Yes	Mosaic cropland/vegetation
188	Site_22_northsulawesi_3947	18.9	98.9	281,325	44,428	124.666	0.88899	226	5,149	0.35	20	3	1	7.7	28	No	Rainfed croplands
189	Site_22_northsulawesi_4344	62.2	275.7	348,645	44,152	124.621	0.85449	505	6,139	0.37	16	3	1	4.5	78	Yes	Semi-deciduous forest
190	Site_22_northsulawesi_5039	27.0	117.6	93,713	18,893	123.72	0.82247	784	3,172	0.31	2	2	1	5.3	33	Yes	Rainfed croplands
191	Site_22_northsulawesi_5442	26.8	119.3	86,928	14,741	123.733	0.80058	858	3,957	0.19	3	2	1	5.5	34	Yes	Semi-deciduous forest
192	Site_22_northsulawesi_5861	35.0	159.8	135,132	27,405	123.736	0.77763	752	6,197	0.31	6	2	1	4.8	45	Yes	Mosaic cropland/vegetation
193	Site_22_northsulawesi_6078	38.5	174.9	179,042	22,561	123.753	0.76736	640	7,077	0.35	6	2	1	4.7	50	Yes	Semi-deciduous forest
194	Site_22_northsulawesi_6114	36.1	169.2	150,354	29,412	123.727	0.76526	726	7,821	0.32	7	2	1	4.8	48	Yes	Mosaic cropland/vegetation
195	Site_22_northsulawesi_6170	29.9	144.1	156,082	32,942	123.763	0.76226	601	7,738	0.35	7	2	1	5.2	41	Yes	Mosaic vegetation/cropland
196	Site_22_northsulawesi_6251	40.6	200.1	270,952	21,177	123.745	0.75626	471	8,346	0.37	8	3	1	5.2	57	Yes	Mosaic cropland/vegetation
197	Site_22_northsulawesi_6308	69.5	300.9	451,586	58,686	124.56	0.74786	436	6,226	0.23	16	3	1	4.9	85	Yes	Mosaic cropland/vegetation
198	Site_22_northsulawesi_6374	19.2	97.5	140,609	18,409	124.532	0.72567	450	6,436	0.25	16	2	1	6.0	28	Yes	Semi-deciduous forest
199	Site_22_northsulawesi_8277	35.6	163.5	198,433	26,853	123.826	0.40646	556	7,837	0.36	25	2	1	5.0	46	Yes	Mosaic vegetation/cropland
200	Site_22_northsulawesi_8778	19.2	100.0	105,358	17,095	123.564	0.38741	603	7,280	0.42	48	2	1	6.1	28	Yes	Semi-deciduous forest
201	Site_23_gorontalo_1116	50.1	228.9	438,302	62,696	121.682	0.97334	349	7,405	0.44	66	3	1	5.6	65	Yes	Mosaic cropland/vegetation
202	Site_23_gorontalo_1506	24.2	123.7	122,535	16,954	121.697	0.96247	646	8,317	0.34	64	2	1	5.6	35	Yes	Semi-deciduous forest
203	Site_23_gorontalo_1764	27.2	115.4	139,368	21,729	122.524	0.954	521	2,059	0.29	32	2	1	4.9	33	Yes	Semi-deciduous forest
204	Site_23_gorontalo_2112	21.0	104.8	69,485	10,795	122.326	0.94005	943	7,287	0.23	41	2	1	6.7	30	Yes	Semi-deciduous forest
205	Site_23_gorontalo_2973	113.2	494.3	1,348,407	132,593	123.053	0.88254	235	3,885	0.20	3	4	2	6.6	140	Yes	Mosaic cropland/vegetation
206	Site_23_gorontalo_3093	28.9	139.5	370,244	53,494	123.046	0.87016	248	5,548	0.20	5	3	1	6.9	40	No	Mosaic vegetation/cropland
207	Site_23_gorontalo_3816	29.9	141.7	336,409	60,138	122.954	0.82547	272	4,958	0.23	3	3	1	6.4	40	Yes	Mosaic cropland/vegetation
208	Site_23_gorontalo_3871	20.8	110.4	126,212	20,830	122.989	0.82427	564	8,441	0.28	7	2	1	5.9	31	Yes	Semi-deciduous forest
209	Site_23_gorontalo_4251	24.7	119.5	200,006	35,848	122.779	0.75881	415	7,752	0.26	7	2	1	6.0	34	Yes	Mosaic cropland/vegetation
210	Site_23_gorontalo_469	15.8	16.0	165,497	49,271	122.03	0.99456	313	4,854	0.36	54	2	1	3.0	5	Yes	Semi-deciduous forest
211	Site_23_gorontalo_4742	15.1	18.9	170,661	108,517	121.597	0.60067	304	5,481	0.33	47	2	1	3.0	5	Yes	Mosaic vegetation/cropland
212	Site_23_gorontalo_704	34.8	165.4	94,328	11,972	121.896	0.98849	1,102	8,493	0.29	56	2	1	5.5	47	Yes	Semi-deciduous forest
213	Site_23_gorontalo_755	21.3	103.4	120,446	13,010	121.712	0.98654	546	5,593	0.25	65	2	1	5.7	29	Yes	Semi-deciduous forest
214	Site_24_westsulawesi_1399	23.9	117.5	122,811	17,353	118.985	-2.6959	610	6,784	0.38	6	2	1	5.5	33	No	Semi-deciduous forest
215	Site_24_westsulawesi_1886	39.4	161.9	222,392	45,073	118.79	-2.808	467	2,073	0.30	8	2	1	4.7	46	No	Rainfed croplands
216	Site_24_westsulawesi_2082	17.4	104.8	322,324	36,153	118.948	-2.85637	217	7,726	0.52	7	3	1	8.5	30	No	Mosaic cropland/vegetation
217	Site_24_westsulawesi_2833	20.5	109.1	109,212	17,484	118.906	-3.1641	637	8,503	0.42	8	2	1	6.0	31	No	Rainfed croplands
218	Site_24_westsulawesi_3078	30.0	145.4	123,643	24,185	118.924	-3.27208	749	7,827	0.44	7	2	1	5.2	41	No	Semi-deciduous forest
219	Site_24_westsulawesi_3242	74.9	327.5	879,657	136,189	118.915	-3.34692	252	6,926	0.39	6	4	1	6.5	93	No	Rainfed croplands
220	Site_24_westsulawesi_3367	27.4	125.8	241,765	37,034	118.888	-3.38179	328	3,682	0.35	3	3	1	5.8	36	No	Mosaic cropland/vegetation
221	Site_25_centralsulawesi1_10251	41.3	172.0	411,109	63,119	119.876	0.35577	265	1,766	0.24	119	3	1	6.1	49	No	Rainfed croplands
222	Site_25_centralsulawesi1_1351	55.5	257.8	521,072	62,692	121.331	1.1962	315	6,261	0.27	110	4	1	5.7	73	No	Mosaic cropland/vegetation
223	Site_25_centralsulawesi1_1787	17.3	92.9	171,610	22,973	121.295	1.16748	369	7,724	0.34	110	2	1	6.6	26	No	Semi-deciduous forest
224	Site_25_centralsulawesi1_1959	20.4	94.8	222,241	42,280	121.377	1.14963	306	5,879	0.24	103	2	1	6.8	27	No	Mosaic cropland/vegetation
225	Site_25_centralsulawesi1_2631	31.8	137.2	424,565	69,892	122.062	1.03288	209	2,569	0.32	58	3	1	7.0	39	No	Rainfed croplands
226	Site_25_centralsulawesi1_5145	28.5	133.6	286,325	52,733	120.281	0.86439	297	4,314	0.27	177	3	1	6.1	38	No	Mosaic cropland/vegetation
227	Site_25_centralsulawesi1_7693	23.8	118.4	80,199	10,104	120.44	0.56137	926	7,888	0.35	147	2	1	6.2	34	No	Mosaic cropland/vegetation
228	Site_25_centralsulawesi1_8304	77.0	321.9	182,042	31,144	120.455	0.53821	1,124	4,987	0.33	145	2	1	3.7	91	No	Semi-deciduous forest
229	Site_25_centralsulawesi1_8534	57.0	238.0	179,163	21,731	120.468	0.52883	842	3,468	0.49	145	2	1	3.9	67	No	Mosaic cropland/vegetation
230	Site_25_centralsulawesi1_9033	15.0	94.5	296,552	48,169	120.871	0.50904	210	7,549	0.28	126	3	1	8.9	27	No	Semi-deciduous forest
231	Site_25_centralsulawesi1_9565	35.0	146.5	366,230	74,815	120.846	0.46	252	1,565	0.23	129	3	1	6.3	42	No	Mosaic cropland/vegetation
232	Site_25_centralsulawesi1_9609	68.4	280.2	675,189	97,653	120.834	0.45707	260	1,335	0.27	130	4	1	6.3	79	No	No data
233	Site_25_centralsulawesi1_9953	46.4	210.1	113,599	21,455	120.213	0.41178	1,165	7,674	0.33	126	2	1	4.8	60	No	Mosaic cropland/vegetation
234	Site_25_centralsulawesi2a_1656	96.0	428.0	1,209,704	143,539	119.797	-0.44395	226	3,951	0.27	30	4	2	6.8	121	No	Mosaic cropland/vegetation
235	Site_25_centralsulawesi2a_1686	126.7	543.3	1,609,481	194,131	119.798	-0.4483	220	3,981	0.30	30	4	2	6.9	154	No	Semi-deciduous forest
236	Site_25_centralsulawesi2a_2434	25.6	131.1	371,778	68,169	119.867	-0.60802	235	6,567	0.26	14	3	1	7.5	37	No	Mosaic cropland/vegetation
237	Site_25_centralsulawesi2a_2934	39.9	184.0	169,710	34,326	120.013	-0.70527	708	8,005	0.46	2	2	1	4.7	52	No	Mosaic cropland/vegetation
238	Site_25_centralsulawesi2a_3277	15.6	100.7	240,016	41,661	119.946	-0.76691	270	8,576	0.26	4	3	1	8.2	29	No	Semi-deciduous forest
239	Site_25_centralsulawesi2a_3311	17.0	103.1	284,530	45,675	119.939	-0.77043	237	7,708	0.24	4	3	1	8.2	29	No	Mosaic cropland/vegetation
240	Site_25_centralsulawesi2a_4912	42.3	181.2	472,116	72,174	120.529	-1.09902	252	3,479	0.25	4	3	1	6.5	51	No	Mosaic cropland/vegetation
241	Site_25_centralsulawesi2a_5376	29.1	135.3	312,269	47,329	120.534	-1.26016	277	4,187	0.27	3	3	1	6.2	38	No	Mosaic cropland/vegetation
242	Site_25_centralsulawesi2a_5717	163.2	685.4	1,602,070	194,637	120.611	-1.35952	275	3,593	0.19	2	4	2	6.1	194	No	Mosaic vegetation/cropland
243	Site_25_centralsulawesi2a_5726	50.8	233.7	515,486	73,482	120.595	-1.36251	288	5,365	0.18	4	4	1	5.9	66	No	Mosaic vegetation/cropland
244	Site_25_centralsulawesi2a_5744	40.1	182.3	412,936	58,121	120.595	-1.36551	291	5,378	0.19	4	3	1	6.0	52	No	Mosaic vegetation/cropland
245	Site_25_centralsulawesi2a_6470	63.1	278.2	451,500	61,578	120.833	-1.46854	408	6,984	0.23	6	3	1	5.0	79	No	Mosaic cropland/vegetation
246	Site_25_centralsulawesi2b_10142	69.5	287.7	666,509	110,091	123.039	-1.19507	272	1,922	0.19	36	4	1	6.0	82	No	Rainfed croplands
247	Site_25_centralsulawesi2b_10741	51.0	218.0	602,467	43,801	123.164	-1.22627	229	2,549	0.22	49	4	1	6.5	62	No	Mosaic cropland/vegetation
248	Site_25_centralsulawesi2b_10989	170.7	698.4	1,753,373	120,745	122.964	-1.23692	254	2,137	0.25	32	4	2	6.4	198	No	Rainfed croplands
249	Site_25_centralsulawesi2b_11111	189.3	774.5	853,600	136,937	122.937	-1.24351	577	4,553	0.20	30	4	1	4.4	220	No	Mosaic cropland/vegetation
250	Site_25_centralsulawesi2b_1157	21.9	102.2	129,673	21,869	123.376	-0.72979	502	4,560	0.35	72	2	1	5.5	29	No	Mosaic cropland/vegetation
251	Site_25_centralsulawesi2b_11599	41.6	174.2	194,354	27,885	122.886	-1.27223	573	2,910	0.28	28	2	1	4.3	49	No	Mosaic cropland/vegetation
252	Site_25_centralsulawesi2b_11917	24.8	129.8	261,536	52,380	123.054	-1.28888	317	6,786	0.17	43	3	1	6.6	37	No	Mosaic cropland/vegetation
253	Site_25_centralsulawesi2b_12054	50.8	219.7	518,715	72,377	123.35	-1.29308	267	2,971	0.27	71	4	1	6.1	62	No	Rainfed croplands
254	Site_25_centralsulawesi2b_12093	26.8	118.5	154,187	24,287	122.866	-1.2951	491	3,661	0.19	28	2	1	5.1	34	No	Rainfed croplands
255	Site_25_centralsulawesi2b_12328	26.8	116.8	297,581	51,964	123.09	-1.31003	248	2,167	0.17	47	3	1	6.3	33	No	Mosaic vegetation/cropland
256	Site_25_centralsulawesi2b_12344	29.3	145.1	108,106	11,002	122.923	-1.3107	851	8,845	0.20	34	2	1	5.4	41	No	Semi-deciduous forest
257	Site_25_centralsulawesi2b_1277	17.1	91.9	191,454	32,942	123.093	-0.76174	341	8,235	0.25	43	2	1	7.0	26	No	Semi-deciduous forest
258	Site_25_centralsulawesi2b_13014	42.5	179.8	388,895	61,166	123.067	-1.34302	294	2,434	0.21	48	3	1	5.8	51	No	Rainfed croplands
259	Site_25_centralsulawesi2b_13130	26.4	124.2	175,701	26,847	123.02	-1.34782	467	6,194	0.24	44	2	1	5.4	35	No	Semi-deciduous forest
260	Site_25_centralsulawesi2b_13274	20.7	119.2	387,712	94,655	123.458	-1.35524	214	8,530	0.25	85	3	1	8.8	34	No	Semi-deciduous forest
261	Site_25_centralsulawesi2b_13613	17.7	95.3	173,352	32,658	123.379	-1.36979	377	8,061	0.29	78	2	1	6.6	27	No	Semi-deciduous forest
262	Site_25_centralsulawesi2b_13884	101.5	433.0	529,864	94,446	123.012	-1.38141	514	4,857	0.24	46	4	1	4.5	123	No	Mosaic cropland/vegetation
263	Site_25_centralsulawesi2b_13899	51.5	227.0	282,332	66,216	123.013	-1.38239	507	4,718	0.25	46	3	1	4.5	64	No	Mosaic cropland/vegetation
264	Site_25_centralsulawesi2b_14169	29.5	145.6	114,673	22,349	122.962	-1.39716	807	8,609	0.22	43	2	1	5.4	41	No	Semi-deciduous forest
265	Site_25_centralsulawesi2b_15011	43.4	200.6	310,870	38,262	123.426	-1.43548	412	6,032	0.21	86	3	1	5.1	57	No	Mosaic cropland/vegetation
266	Site_25_centralsulawesi2b_15242	68.7	312.6	233,633	39,507	122.946	-1.44755	841	8,656	0.31	45	3	1	4.2	89	No	Mosaic cropland/vegetation
267	Site_25_centralsulawesi2b_15649	29.5	125.2	257,484	33,072	123.19	-1.46749	304	1,657	0.26	67	3	1	5.6	36	No	Rainfed croplands
268	Site_25_centralsulawesi2b_1654	40.6	168.1	214,756	26,090	122.921	-0.78708	503	2,441	0.18	27	2	1	4.6	48	No	Mosaic cropland/vegetation
269	Site_25_centralsulawesi2b_2006	268.6	1,103.8	1,559,048	307,129	122.885	-0.80253	448	3,324	0.28	24	4	2	4.9	313	No	Rainfed croplands
270	Site_25_centralsulawesi2b_2790	23.4	107.5	148,924	25,329	123.385	-0.82615	463	4,423	0.43	70	2	1	5.4	30	No	Semi-deciduous forest
271	Site_25_centralsulawesi2b_2842	83.1	348.3	311,447	39,169	122.773	-0.82742	702	3,677	0.24	17	3	1	4.0	99	No	Mosaic cropland/vegetation
272	Site_25_centralsulawesi2b_3801	137.5	572.9	314,900	37,024	122.763	-0.84999	1,141	5,356	0.25	15	3	1	3.6	162	No	Mosaic vegetation/cropland
273	Site_25_centralsulawesi2b_3824	42.5	186.6	102,037	18,823	122.762	-0.85059	1,146	5,352	0.26	15	2	1	4.9	53	No	Mosaic vegetation/cropland
274	Site_25_centralsulawesi2b_4590	60.2	262.2	172,542	23,737	122.701	-0.87571	976	7,231	0.22	15	2	1	4.1	74	No	Mosaic cropland/vegetation
275	Site_25_centralsulawesi2b_4698	37.7	175.1	94,680	12,249	122.735	-0.88374	1,161	7,859	0.33	12	2	1	5.3	50	No	Mosaic cropland/vegetation
276	Site_25_centralsulawesi2b_4864	61.7	273.4	152,647	16,124	122.728	-0.88974	1,143	8,457	0.30	12	2	1	4.2	78	No	Rainfed croplands
277	Site_25_centralsulawesi2b_4951	21.9	100.0	291,827	43,182	122.916	-0.89431	218	2,802	0.21	18	3	1	7.1	28	No	Rainfed croplands
278	Site_25_centralsulawesi2b_5600	36.7	169.2	400,321	68,787	123.334	-0.93338	278	5,443	0.22	62	3	1	6.2	48	No	Mosaic cropland/vegetation
279	Site_25_centralsulawesi2b_5995	63.4	284.6	787,652	82,627	123.325	-0.95122	240	6,439	0.24	60	4	1	6.6	81	No	Mosaic vegetation/cropland

No	Site Code	Peak power (MWp)	Energy (MWh)	Volume (m3)	Area (m2)	Outlet coordinate (x)	Outlet coordinate (y)	Elevation (m)	Distance from coastline (m)	St.dev slope	Distance from transmission line (km)	Penstock diameter (m)	Number of penstock	LCOS (c€/kWh)	Carbon reduction (ton/year)	Economically feasible	Land covering
280	Site_25_centralsulawesi2b_6980	25.2	126.7	281,280	33,424	123.301	-0.99051	288	5,710	0.23	58	3	1	6.6	36	No	Rainfed croplands
281	Site_25_centralsulawesi2b_7063	23.4	120.6	162,503	30,379	121.527	-0.99464	495	8,679	0.23	96	2	1	5.8	34	No	Rainfed croplands
282	Site_25_centralsulawesi2b_7318	29.0	127.7	328,223	52,938	123.349	-1.00116	247	2,691	0.18	64	3	1	6.3	36	No	Mosaic cropland/vegetation
283	Site_25_centralsulawesi2b_7540	26.0	126.7	372,633	40,690	121.727	-1.00724	224	5,274	0.23	84	3	1	7.3	36	No	Rainfed croplands
284	Site_25_centralsulawesi2b_8410	309.8	1,278.6	2,291,141	413,193	122.742	-1.03588	354	2,859	0.15	1	4	3	5.4	363	No	Mosaic vegetation/cropland
285	Site_25_centralsulawesi2b_8561	77.8	323.1	579,359	106,429	122.742	-1.04255	350	2,253	0.15	1	4	1	5.3	92	No	Mosaic cropland/vegetation
286	Site_25_centralsulawesi2b_8649	38.4	191.8	311,078	45,879	121.749	-1.04608	398	8,461	0.20	79	3	1	5.6	54	No	Rainfed croplands
287	Site_25_centralsulawesi2b_8811	93.4	401.7	250,488	44,218	121.96	-1.05335	1,005	6,498	0.26	61	3	1	3.7	114	No	Mosaic cropland/vegetation
288	Site_25_centralsulawesi2b_8993	204.2	880.0	1,743,009	170,784	121.937	-1.06565	337	7,752	0.43	62	4	2	5.6	250	No	Rainfed croplands
289	Site_25_centralsulawesi3_1095	45.9	192.8	575,717	95,939	123.822	-1.99944	210	1,663	0.34	159	4	1	6.9	55	No	Mosaic cropland/vegetation
290	Site_25_centralsulawesi3_1524	113.5	464.0	695,663	108,206	121.971	-2.60652	419	2,120	0.23	10	4	1	5.0	132	No	Semi-deciduous forest
291	Site_25_centralsulawesi3_1855	126.4	553.8	574,716	99,554	121.93	-2.72094	611	8,626	0.25	6	4	1	4.3	157	No	Mosaic cropland/vegetation
292	Site_25_centralsulawesi3_4082	86.8	378.8	995,128	138,145	122.323	-3.1875	258	5,042	0.37	64	3	2	6.5	107	No	Mosaic cropland/vegetation
293	Site_26_southsulawesi_1026	61.2	292.1	984,528	218,549	119.705	-3.94012	215	7,259	0.11	0	3	2	7.5	83	No	Mosaic cropland/vegetation
294	Site_26_southsulawesi_1257	81.9	339.4	671,088	77,595	119.651	-4.14626	319	2,344	0.23	2	4	1	5.5	96	No	Rainfed croplands
295	Site_26_southsulawesi_1382	17.1	91.9	189,237	26,713	119.702	-4.24096	343	8,164	0.20	6	2	1	7.0	26	No	Semi-deciduous forest
296	Site_26_southsulawesi_1636	86.4	374.2	1,100,460	167,159	120.407	-5.48047	215	2,568	0.14	23	4	2	6.9	106	No	Mosaic cropland/vegetation
297	Site_26_southsulawesi_1640	31.4	147.3	149,741	26,941	119.935	-5.48302	634	6,793	0.14	5	2	1	5.0	42	No	Rainfed croplands
298	Site_26_southsulawesi_1665	17.7	105.7	289,166	47,129	119.987	-5.48841	239	7,705	0.07	3	3	1	8.1	30	No	Mosaic cropland/vegetation
299	Site_26_southsulawesi_1734	22.1	106.3	145,448	20,326	119.934	-5.49449	472	5,524	0.14	4	2	1	5.6	30	No	Mosaic cropland/vegetation
300	Site_26_southsulawesi_1740	17.6	106.4	319,622	68,625	120.043	-5.50079	222	7,950	0.04	5	3	1	8.6	30	No	Semi-deciduous forest
301	Site_27_southeastsulawesi_10360	121.5	513.2	912,125	161,791	122.835	-5.18218	364	3,836	0.15	26	3	2	5.4	146	No	Mosaic cropland/vegetation
302	Site_27_southeastsulawesi_11394	22.3	104.8	64,546	11,992	121.895	-5.31962	1,013	5,652	0.25	67	2	1	6.7	30	No	Mosaic cropland/vegetation
303	Site_27_southeastsulawesi_11614	24.1	112.1	75,414	11,096	121.905	-5.34212	929	5,348	0.25	69	2	1	6.1	32	No	Semi-deciduous forest
304	Site_27_southeastsulawesi_12016	21.8	95.2	223,066	32,940	123.053	-5.39026	290	3,614	0.20	43	2	1	6.4	27	No	Mosaic cropland/vegetation
305	Site_27_southeastsulawesi_12407	171.2	742.8	2,227,539	473,939	122.684	-5.44477	216	3,852	0.14	3	4	3	6.9	211	No	Mosaic cropland/vegetation
306	Site_27_southeastsulawesi_12768	39.0	171.9	413,251	91,981	122.602	-5.51009	271	3,994	0.07	6	3	1	6.1	49	No	Mosaic cropland/vegetation
307	Site_27_southeastsulawesi_2463	307.2	1,269.9	3,578,347	479,277	120.943	-3.56985	230	2,948	0.31	1	4	4	6.7	360	No	Mosaic cropland/vegetation
308	Site_27_southeastsulawesi_287	47.9	210.9	226,990	32,349	121.13	-2.95212	582	4,512	0.27	4	3	1	4.5	60	No	Mosaic cropland/vegetation
309	Site_27_southeastsulawesi_3558	21.7	109.2	175,304	22,028	121.408	-3.92265	420	7,356	0.20	7	2	1	6.0	31	No	Rainfed croplands
310	Site_27_southeastsulawesi_3931	21.0	102.7	300,059	47,640	123.045	-4.03798	219	4,108	0.17	43	3	1	7.5	29	No	Mosaic vegetation/cropland
311	Site_27_southeastsulawesi_5323	35.9	166.2	477,911	84,766	121.647	-4.22537	242	6,525	0.10	16	3	1	7.1	47	No	Mosaic vegetation/cropland
312	Site_27_southeastsulawesi_5380	132.8	549.6	1,159,667	180,644	123.139	-4.22972	297	1,742	0.28	57	4	2	5.7	156	No	Mosaic cropland/vegetation
313	Site_27_southeastsulawesi_5898	38.4	196.1	562,648	78,822	122.606	-4.29653	226	7,440	0.18	26	4	1	7.5	56	No	Semi-deciduous forest
314	Site_27_southeastsulawesi_805	22.8	114.3	126,598	22,047	122.229	-3.09564	579	7,151	0.31	50	2	1	5.7	32	No	Semi-deciduous forest
315	Site_27_southeastsulawesi_8865	40.5	182.8	526,530	79,721	122.866	-4.91673	220	3,707	0.15	17	4	1	6.8	52	No	Semi-deciduous forest
316	Site_27_southeastsulawesi_9042	27.1	126.4	270,323	55,856	122.851	-4.97027	296	4,021	0.18	18	3	1	6.1	36	No	Mosaic vegetation/cropland
317	Site_27_southeastsulawesi_9221	214.9	903.4	2,935,513	413,644	122.607	-5.02163	203	5,320	0.23	10	4	4	7.2	256	No	Mosaic cropland/vegetation
318	Site_28_bali_127	24.8	127.2	357,092	57,533	115.204	-8.13888	236	6,345	0.12	14	3	1	8.3	36	No	Mosaic cropland/vegetation
319	Site_28_bali_1624	23.1	123.0	377,859	58,322	114.878	-8.3795	220	7,082	0.21	7	3	1	8.9	35	No	Semi-deciduous forest
320	Site_28_bali_1696	32.1	165.1	290,914	42,215	115.594	-8.39015	366	8,099	0.29	6	3	1	6.7	47	No	Semi-deciduous forest
321	Site_28_bali_1852	28.9	140.2	425,762	80,244	115.6	-8.4161	224	6,186	0.15	4	3	1	9.0	40	No	Mosaic cropland/vegetation
322	Site_28_bali_2032	46.2	218.7	406,872	91,615	115.001	-8.43703	358	8,279	0.29	3	3	1	6.3	62	No	Semi-deciduous forest
323	Site_28_bali_2065	26.6	137.3	348,467	52,420	115.574	-8.43666	260	6,940	0.12	2	3	1	8.1	39	No	Semi-deciduous forest
324	Site_28_bali_2082	17.5	85.0	134,996	25,353	114.954	-8.43846	404	4,588	0.21	4	2	1	6.6	24	No	Semi-deciduous forest
325	Site_28_bali_2102	191.6	793.2	869,551	100,727	115.511	-8.44078	587	6,899	0.22	5	4	1	4.6	225	No	Semi-deciduous forest
326	Site_28_bali_2111	31.7	165.7	314,613	57,558	115.022	-8.44371	343	8,607	0.20	-	3	1	6.9	47	No	Semi-deciduous forest
327	Site_28_bali_2158	51.9	240.3	310,984	56,461	115.487	-8.44768	493	7,260	0.29	5	3	1	5.2	68	No	Mosaic cropland/vegetation
328	Site_28_bali_2221	30.3	160.2	269,798	40,906	115.456	-8.45233	381	8,607	0.31	7	3	1	6.6	45	No	Mosaic cropland/vegetation
329	Site_28_bali_2257	15.4	94.0	233,133	41,248	115.027	-8.46141	259	7,773	0.09	1	3	1	9.1	27	No	Mosaic cropland/vegetation
330	Site_28_bali_2438	58.5	289.8	970,541	155,522	115.403	-8.49989	219	8,267	0.11	7	3	2	9.0	82	No	Shrubland
331	Site_28_bali_2492	59.5	328.1	1,061,486	171,410	115.324	-8.51421	201	7,809	0.12	5	4	2	9.2	93	No	Shrubland
332	Site_28_bali_2555	26.3	122.2	342,877	65,256	115.543	-8.71111	230	3,848	0.12	8	3	1	7.9	35	No	Rainfed croplands
333	Site_28_bali_2567	58.9	257.6	689,299	93,877	115.533	-8.71636	240	4,141	0.15	7	4	1	7.0	73	No	Rainfed croplands
334	Site_28_bali_2570	16.7	86.1	275,810	38,824	115.507	-8.71621	200	4,249	0.14	4	3	1	9.1	24	No	Mosaic cropland/vegetation
335	Site_28_bali_2606	21.3	101.0	147,115	31,633	115.549	-8.73309	443	4,979	0.20	9	2	1	6.2	29	No	Rainfed croplands
336	Site_28_bali_2627	36.3	161.4	317,089	55,255	115.567	-8.73939	323	3,641	0.17	11	3	1	6.1	46	No	Mosaic vegetation/cropland
337	Site_28_bali_2644	36.9	162.6	361,955	70,933	115.518	-8.74464	287	3,441	0.13	7	3	1	6.5	46	No	Mosaic cropland/vegetation
338	Site_28_bali_2737	34.3	155.0	252,969	37,176	115.574	-8.77066	386	3,987	0.17	14	3	1	5.7	44	No	Rainfed croplands
339	Site_28_bali_37	29.8	134.1	229,427	45,055	115.224	-8.1136	367	3,410	0.16	17	3	1	6.0	38	No	Semi-deciduous forest
340	Site_28_bali_513	26.8	134.3	378,228	77,614	114.587	-8.19671	237	6,237	0.17	4	3	1	8.0	38	No	Semi-deciduous forest
341	Site_28_bali_785	42.9	192.1	193,631	33,868	114.694	-8.21988	656	7,361	0.41	7	2	1	4.8	54	No	Mosaic cropland/vegetation
342	Site_28_bali_829	42.4	202.5	236,699	48,128	114.707	-8.22829	540	7,528	0.35	6	3	1	5.3	57	No	Semi-deciduous forest
343	Site_28_bali_874	25.6	122.6	409,840	69,038	114.92	-8.22896	200	4,895	0.09	2	3	1	8.9	35	No	Semi-deciduous forest
344	Site_28_bali_99	46.8	210.5	267,934	47,522	115.229	-8.13153	495	5,215	0.15	16	3	1	5.1	60	No	Semi-deciduous forest
345	Site_28_bali_994	65.2	290.9	396,313	74,794	115.003	-8.24449	476	7,218	0.22	5	3	1	5.0	82	No	Semi-deciduous forest
346	Site_29_westnusatenggara_1029	47.1	223.2	370,923	64,787	117.806	-8.23001	394	8,031	0.11	48	3	1	5.2	63	Yes	Mosaic cropland/vegetation
347	Site_29_westnusatenggara_1033	42.1	192.0	421,149	89,468	117.545	-8.23084	302	5,895	0.10	33	3	1	5.8	54	Yes	Semi-deciduous forest
348	Site_29_westnusatenggara_1072	24.3	124.5	273,541	78,772	117.554	-8.23541	291	6,091	0.15	33	3	1	6.6	35	Yes	Semi-deciduous forest
349	Site_29_westnusatenggara_1087	34.4	158.6	346,567	38,803	117.535	-8.23549	295	4,754	0.11	32	3	1	5.8	45	Yes	Semi-deciduous forest
350	Site_29_westnusatenggara_1234	35.4	158.9	277,587	58,340	117.538	-8.25146	361	3,897	0.13	31	3	1	5.2	45	Yes	Semi-deciduous forest
351	Site_29_westnusatenggara_1352	85.3	354.3	449,215	89,597	117.556	-8.26609	504	3,765	0.16	30	3	1	4.6	100	Yes	Mosaic cropland/vegetation
352	Site_29_westnusatenggara_1556	26.1	111.8	183,363	28,653	117.56	-8.29182	392	2,571	0.20	28	2	1	5.1	32	Yes	Semi-deciduous forest
353	Site_29_westnusatenggara_1679	29.7	140.5	282,041	49,080	118.149	-8.29302	317	4,783	0.08	32	3	1	5.8	40	Yes	Mosaic cropland/vegetation
354	Site_29_westnusatenggara_1686	29.8	132.6	379,676	51,616	118.17	-8.29242	225	3,125	0.08	31	3	1	6.5	38	Yes	Shrubland
355	Site_29_westnusatenggara_2020	39.2	183.5	353,630	52,230	118.156	-8.31514	336	6,093	0.08	30	3	1	5.5	52	Yes	Rainfed croplands
356	Site_29_westnusatenggara_2289	37.6	176.8	371,288	50,514	116.249	-8.33307	311	6,066	0.06	5	3	1	5.9	50	Yes	Rainfed croplands
357	Site_29_westnusatenggara_2496	70.8	312.5	662,384	149,002	116.232	-8.34627	303	5,427	0.14	4	4	1	5.7	89	Yes	Mosaic cropland/vegetation
358	Site_29_westnusatenggara_2532	74.4	335.8	664,717	122,271	118.835	-8.34882	327	7,047	0.29	14	4	1	5.4	95	Yes	Rainfed croplands
359	Site_29_westnusatenggara_2578	40.4	197.6	600,306	143,311	118.812	-8.35325	214	6,358	0.24	12	4	1	7.4	56	Yes	Mosaic cropland/vegetation
360	Site_29_westnusatenggara_2725	21.9	103.5	202,899	41,807	116.228	-8.36352	352	5,975	0.23	5	2	1	6.1	29	Yes	Mosaic vegetation/cropland
361	Site_29_westnusatenggara_2746	28.3	144.3	440,020	60,448	118.167	-8.36352	231	8,052	0.07	25	3	1	7.7	41	Yes	Mosaic cropland/vegetation
362	Site_29_westnusatenggara_2760	119.4	588.1	1,903,799	314,232	118.183	-8.36412	203	6,595	0.16	23	4	3	7.0	167	Yes	Semi-deciduous forest
363	Site_29_westnusatenggara_3016	24.1	115.2	205,103	26,111	117.986	-8.38303	392	7,215	0.08	32	2	1	5.9	33	Yes	Semi-deciduous forest
364	Site_29_westnusatenggara_3158	18.3	97.4	144,416	32,004	116.224	-8.3927	442	7,477	0.29	7	2	1	6.3	28	Yes	Mosaic cropland/vegetation
365	Site_29_westnusatenggara_321	57.3	243.3	299,529	53,005	117.838	-8.15643	510	3,192	0.18	57	3	1	4.5	69	Yes	Mosaic cropland/vegetation
366	Site_29_westnusatenggara_3225	97.1	436.5	973,906	136,305	118.121	-8.39735	308	7,312	0.06	26	3	2	5.7	124	Yes	Shrubland
367	Site_29_westnusatenggara_3272	42.8	197.5	437,039	58,387	118.115	-8.39863	304	6,822	0.07	26	3	1	5.9	56	Yes	Mosaic cropland/vegetation
368	Site_29_westnusatenggara_331	30.2	134.0	136,420	20,914	117.855	-8.15733	622	4,173	0.17	58	2	1	4.8	38	Yes	Mosaic cropland/vegetation
369	Site_29_westnusatenggara_3325	50.2	245.5	658,485	95,460	118.138	-8.4026	246	8,122	0.06	24	4	1	6.8	70	Yes	Rainfed croplands
370	Site_29_westnusatenggara_3524	83.0	406.6	1,302,502	169,671	118.134	-8.41663	206	6,722	0.09	23	4	2	6.9	115	Yes	Shrubland
371	Site_29_westnusatenggara_4038	20.0	104.1	127,489	20,828	116.594	-8.48361	526	7,435	0.14	6	2	1	5.8	30	Yes	Mosaic cropland/vegetation
372	Site_29_westnusatenggara_4803	43.4	216.4	738,587	91,237	116.55	-8.59012	200	8,277	0.10	3	4	1	8.0	61	Yes	Mosaic cropland/vegetation
373	Site_29_westnusatenggara_5971	91.0	408.4	637,246	97,092	118.119	-8.73181	412	8,086	0.29	8	4	1	4.8	116	Yes	Semi-deciduous forest

No	Site Code	Peak power (MWp)	Energy (MWh)	Volume (m3)	Area (m2)	Outlet coordinate (x)	Outlet coordinate (y)	Elevation (m)	Distance from coastline (m)	St.dev slope	Distance from transmission line (km)	Penstock diameter (m)	Number of penstock	LCOS (c€/kWh)	Carbon reduction (ton/year)	Economically feasible	Land covering
374	Site_29_westnusatenggara_6195	55.7	271.9	568,692	97,083	118.156	-8.76541	309	8,613	0.28	11	4	1	6.0	77	Yes	Semi-deciduous forest
375	Site_29_westnusatenggara_6360	37.0	172.9	505,767	90,507	118.125	-8.78012	248	8,061	0.24	13	3	1	7.2	49	Yes	Semi-deciduous forest
376	Site_29_westnusatenggara_6405	32.9	159.3	447,104	67,299	118.569	-8.77817	247	7,313	0.27	21	3	1	7.0	45	Yes	Mosaic vegetation/cropland
377	Site_29_westnusatenggara_6456	29.9	156.9	228,495	40,461	118.134	-8.78132	435	8,511	0.21	13	3	1	5.8	45	Yes	No data
378	Site_29_westnusatenggara_668	76.8	335.5	139,265	14,399	118.044	-8.18763	1,523	8,880	0.29	48	2	1	4.1	95	Yes	Semi-deciduous forest
379	Site_29_westnusatenggara_855	106.7	456.5	875,110	140,346	117.783	-8.20736	346	7,359	0.12	49	4	1	5.4	129	Yes	Mosaic cropland/vegetation
380	Site_29_westnusatenggara_894	28.7	149.6	304,940	43,125	117.785	-8.21381	318	7,686	0.07	49	3	1	6.3	42	Yes	Rainfed croplands
381	Site_29_westnusatenggara_910	37.2	175.2	438,469	108,052	117.551	-8.21508	271	6,832	0.20	35	3	1	6.5	50	Yes	Semi-deciduous forest
382	Site_30_eastnusatenggara_107	29.9	140.4	235,164	30,241	122.855	-8.13078	376	4,704	0.25	79	3	1	5.9	40	Yes	Mosaic cropland/vegetation
383	Site_30_eastnusatenggara_10870	37.7	189.9	270,527	48,352	121.36	-8.64338	448	8,655	0.28	7	3	1	5.7	54	Yes	Mosaic vegetation/cropland
384	Site_30_eastnusatenggara_10895	55.3	229.3	308,182	48,214	122.581	-8.64458	466	1,919	0.29	27	3	1	4.9	65	Yes	Rainfed croplands
385	Site_30_eastnusatenggara_10929	25.1	105.0	213,072	44,790	122.564	-8.6475	319	1,945	0.25	25	2	1	6.0	30	Yes	Semi-deciduous forest
386	Site_30_eastnusatenggara_12017	60.9	278.6	385,165	68,130	121.352	-8.72453	471	8,240	0.24	15	3	1	5.0	79	Yes	Mosaic cropland/vegetation
387	Site_30_eastnusatenggara_12194	38.0	179.7	294,550	49,641	121.374	-8.73586	389	6,159	0.23	16	3	1	5.7	51	Yes	Mosaic cropland/vegetation
388	Site_30_eastnusatenggara_12740	24.3	117.6	333,052	46,352	120.193	-8.75686	229	4,518	0.10	6	3	1	7.7	33	Yes	Mosaic cropland/vegetation
389	Site_30_eastnusatenggara_12789	32.0	163.5	522,186	77,846	119.908	-8.75806	202	6,196	0.35	19	4	1	8.7	46	Yes	Mosaic cropland/vegetation
390	Site_30_eastnusatenggara_13075	28.2	150.0	270,056	36,286	120.773	-8.76834	357	8,212	0.22	4	3	1	6.6	43	Yes	Mosaic cropland/vegetation
391	Site_30_eastnusatenggara_13289	27.1	128.3	137,510	17,869	120.237	-8.77599	597	6,191	0.24	10	2	1	5.4	36	Yes	Semi-deciduous forest
392	Site_30_eastnusatenggara_13598	38.5	191.2	266,147	49,634	120.734	-8.79189	458	8,246	0.31	0	3	1	5.6	54	Yes	Mosaic vegetation/cropland
393	Site_30_eastnusatenggara_1426	26.4	118.6	172,699	33,731	124.275	-8.22851	445	4,295	0.23	105	2	1	5.6	34	Yes	Mosaic vegetation/cropland
394	Site_30_eastnusatenggara_1724	158.4	679.7	1,095,955	158,089	123.764	-8.24726	391	4,156	0.17	144	4	2	5.4	193	Yes	Semi-deciduous forest
395	Site_30_eastnusatenggara_2066	20.4	107.9	80,431	14,807	124.637	-8.27231	843	8,885	0.33	84	2	1	6.7	31	Yes	Semi-deciduous forest
396	Site_30_eastnusatenggara_2180	17.8	92.7	205,723	35,920	125.035	-8.27809	330	8,314	0.32	84	2	1	7.6	26	Yes	Mosaic cropland/vegetation
397	Site_30_eastnusatenggara_2262	21.6	117.0	292,260	37,565	125.067	-8.28139	260	6,738	0.25	85	3	1	7.8	33	Yes	Rainfed croplands
398	Site_30_eastnusatenggara_2561	35.0	162.9	438,175	106,728	123.241	-8.29422	251	5,981	0.22	106	3	1	7.4	46	Yes	Mosaic cropland/vegetation
399	Site_30_eastnusatenggara_2608	38.0	161.2	422,046	83,009	124.19	-8.30052	245	2,417	0.23	105	3	1	7.0	46	Yes	Rainfed croplands
400	Site_30_eastnusatenggara_2674	26.4	131.6	361,926	42,842	123.251	-8.29812	240	5,912	0.22	107	3	1	7.7	37	Yes	Mosaic cropland/vegetation
401	Site_30_eastnusatenggara_3295	23.5	109.1	284,878	50,037	120.634	-8.31747	243	3,400	0.28	33	3	1	7.3	31	Yes	Rainfed croplands
402	Site_30_eastnusatenggara_3593	20.7	100.6	257,812	36,190	120.393	-8.32384	248	4,000	0.23	30	3	1	7.5	29	Yes	Mosaic cropland/vegetation
403	Site_30_eastnusatenggara_393	71.3	300.6	322,046	59,106	124.51	-8.1646	587	3,559	0.38	99	3	1	4.5	85	Yes	Rainfed croplands
404	Site_30_eastnusatenggara_4547	34.1	150.4	128,457	21,315	122.816	-8.35062	739	4,335	0.33	61	2	1	4.9	43	Yes	Mosaic cropland/vegetation
405	Site_30_eastnusatenggara_4617	107.0	452.6	549,008	89,852	124.205	-8.3519	518	4,462	0.31	99	4	1	4.9	128	Yes	Mosaic cropland/vegetation
406	Site_30_eastnusatenggara_4631	25.9	116.4	101,003	17,408	122.812	-8.3522	723	4,035	0.35	60	2	1	5.5	33	Yes	Mosaic cropland/vegetation
407	Site_30_eastnusatenggara_4874	29.3	127.9	113,710	17,477	122.802	-8.3582	706	3,368	0.23	59	2	1	5.1	36	Yes	Rainfed croplands
408	Site_30_eastnusatenggara_4913	28.3	128.4	132,695	26,455	124.043	-8.36202	614	4,783	0.29	112	2	1	5.3	36	Yes	Mosaic cropland/vegetation
409	Site_30_eastnusatenggara_4931	30.3	128.5	128,730	25,701	122.791	-8.36075	627	2,335	0.22	58	2	1	5.0	36	Yes	Mosaic cropland/vegetation
410	Site_30_eastnusatenggara_4957	33.6	162.5	389,362	40,847	124.527	-8.36037	277	6,577	0.41	79	3	1	6.9	46	Yes	Rainfed croplands
411	Site_30_eastnusatenggara_5067	50.5	212.7	445,510	48,317	124.67	-8.36397	307	2,928	0.25	73	3	1	6.0	60	Yes	Semi-deciduous forest
412	Site_30_eastnusatenggara_5203	97.1	419.2	711,321	120,073	120.499	-8.3675	378	5,994	0.31	26	4	1	5.5	119	Yes	Mosaic vegetation/cropland
413	Site_30_eastnusatenggara_5313	30.7	143.7	213,653	44,753	120.281	-8.3705	474	8,673	0.29	27	2	1	5.9	41	Yes	Rainfed croplands
414	Site_30_eastnusatenggara_535	77.7	327.6	326,245	42,716	124.507	-8.18441	632	3,899	0.22	98	3	1	4.4	93	Yes	Rainfed croplands
415	Site_30_eastnusatenggara_5382	21.8	113.6	172,294	28,304	120.347	-8.37252	447	8,696	0.25	25	2	1	6.3	32	Yes	Mosaic cropland/vegetation
416	Site_30_eastnusatenggara_6045	138.0	615.1	1,231,010	184,822	120.816	-8.39788	319	5,697	0.32	37	4	2	6.0	174	Yes	Mosaic cropland/vegetation
417	Site_30_eastnusatenggara_6199	35.9	156.4	273,733	40,569	124.545	-8.40328	359	2,869	0.28	73	3	1	5.6	44	Yes	Rainfed croplands
418	Site_30_eastnusatenggara_6655	150.6	610.3	768,035	103,542	124.399	-8.4227	499	1,962	0.30	80	4	1	4.8	173	Yes	Shrubland
419	Site_30_eastnusatenggara_6685	27.8	117.7	322,706	50,023	124.377	-8.4245	229	1,480	0.19	81	3	1	7.2	33	Yes	Mosaic cropland/vegetation
420	Site_30_eastnusatenggara_6713	21.1	99.1	212,145	34,194	122.725	-8.4248	329	6,032	0.19	48	2	1	6.9	28	Yes	Mosaic cropland/vegetation
421	Site_30_eastnusatenggara_7098	24.7	123.9	392,393	60,093	122.653	-8.44431	213	5,963	0.22	40	3	1	8.5	35	Yes	Mosaic cropland/vegetation
422	Site_30_eastnusatenggara_7170	25.2	126.2	242,221	24,942	122.728	-8.44618	330	5,712	0.13	47	3	1	6.6	36	Yes	Mosaic cropland/vegetation
423	Site_30_eastnusatenggara_7279	91.5	384.2	475,277	59,270	123.508	-8.44963	524	5,490	0.30	131	3	1	4.9	109	Yes	Semi-deciduous forest
424	Site_30_eastnusatenggara_7460	34.3	148.7	433,963	61,256	120.13	-8.46021	223	2,984	0.30	19	3	1	7.3	42	Yes	Mosaic cropland/vegetation
425	Site_30_eastnusatenggara_7763	19.0	108.3	317,394	50,154	120.17	-8.47003	225	7,149	0.22	20	3	1	8.7	31	Yes	Mosaic cropland/vegetation
426	Site_30_eastnusatenggara_7782	56.7	254.4	280,533	48,167	121.03	-8.47101	573	6,211	0.21	28	3	1	4.6	72	Yes	Mosaic cropland/vegetation
427	Site_30_eastnusatenggara_8346	121.9	576.5	1,101,043	155,181	120.157	-8.49396	335	7,788	0.25	17	4	2	5.8	164	Yes	Rainfed croplands
428	Site_30_eastnusatenggara_8370	217.2	937.9	1,487,736	206,977	120.143	-8.49456	407	6,930	0.22	16	4	2	5.2	266	Yes	Mosaic cropland/vegetation
429	Site_30_eastnusatenggara_8463	22.6	108.7	256,526	38,504	122.757	-8.49899	268	4,075	0.40	48	3	1	7.1	31	Yes	Rainfed croplands
430	Site_30_eastnusatenggara_8536	42.3	190.3	301,739	43,642	123.365	-8.50244	400	4,709	0.14	115	3	1	5.3	54	Yes	Rainfed croplands
431	Site_30_eastnusatenggara_8723	25.8	113.1	202,476	39,393	123.361	-8.50986	369	3,772	0.17	114	2	1	5.9	32	Yes	Rainfed croplands
432	Site_30_eastnusatenggara_904	50.1	209.7	185,524	42,578	124.479	-8.20218	720	3,372	0.36	97	2	1	4.2	59	Yes	Mosaic cropland/vegetation
433	Site_30_eastnusatenggara_914	29.6	128.2	209,166	38,532	124.852	-8.20211	405	3,910	0.29	89	2	1	5.6	36	Yes	Rainfed croplands
434	Site_30_eastnusatenggara_9857	42.0	180.6	212,662	25,687	122.558	-8.57114	561	5,175	0.21	25	2	1	4.8	51	Yes	Semi-deciduous forest
435	Site_30_eastnusatenggara_9958	22.9	119.9	142,236	18,768	121.872	-8.5779	550	8,740	0.31	8	2	1	5.9	34	Yes	Mosaic vegetation/cropland
436	Site_31_maluku_1127	20.3	104.8	138,600	17,069	129.932	-3.27187	491	7,305	0.21	180	2	1	6.2	30	Yes	Rainfed croplands
437	Site_31_maluku_1176	24.7	119.4	174,600	21,811	129.956	-3.28298	455	6,797	0.23	182	2	1	5.9	34	Yes	Mosaic cropland/vegetation
438	Site_31_maluku_1309	15.3	98.4	315,000	40,776	128.416	-3.30409	209	8,150	0.18	28	3	1	9.7	28	Yes	Semi-deciduous forest
439	Site_31_maluku_1585	37.3	171.7	400,500	54,048	129.473	-3.37076	282	5,455	0.36	128	3	1	6.6	49	Yes	Mosaic cropland/vegetation
440	Site_31_maluku_1835	27.3	134.7	363,600	44,563	130.071	-3.43993	244	5,811	0.33	193	3	1	7.6	38	Yes	Mosaic cropland/vegetation
441	Site_31_maluku_19	44.2	185.2	277,200	14,230	128.318	-2.88103	418	1,914	0.22	74	3	1	5.3	53	Yes	Rainfed croplands
442	Site_31_maluku_1927	31.5	162.6	304,200	39,821	130.19	-3.47243	346	8,068	0.18	206	3	1	6.5	46	Yes	Rainfed croplands
443	Site_31_maluku_2148	110.5	462.2	481,500	74,893	126.28	-3.58077	622	6,331	0.21	209	3	1	4.6	131	Yes	Rainfed croplands
444	Site_31_maluku_2385	23.9	129.6	316,800	42,657	126.403	-3.64188	268	7,471	0.30	195	3	1	7.7	37	Yes	Mosaic vegetation/cropland
445	Site_31_maluku_2445	45.6	206.4	405,900	52,136	126.421	-3.66132	333	5,821	0.29	193	3	1	5.9	59	Yes	Semi-deciduous forest
446	Site_31_maluku_2526	134.2	575.2	315,900	55,926	126.505	-3.68577	1,148	8,795	0.30	184	3	1	3.8	163	Yes	Mosaic cropland/vegetation
447	Site_31_maluku_3117	132.5	574.0	1,240,200	192,296	128.599	-7.14611	294	4,016	0.23	386	4	2	6.2	163	Yes	Mosaic cropland/vegetation
448	Site_31_maluku_3310	20.0	101.9	333,000	44,252	131.53	-7.66946	200	4,896	0.14	575	3	1	8.8	29	Yes	Semi-deciduous forest
449	Site_31_maluku_3487	41.6	188.0	257,400	32,950	125.966	-7.7264	460	4,866	0.23	190	3	1	5.1	53	Yes	Mosaic cropland/vegetation
450	Site_31_maluku_3556	117.4	492.0	343,800	52,717	126.24	-7.74751	901	5,312	0.43	210	3	1	3.9	140	Yes	Semi-deciduous forest
451	Site_31_maluku_3678	22.1	115.5	249,300	33,887	126.12	-7.77529	295	6,039	0.52	198	3	1	7.3	33	Yes	Mosaic cropland/vegetation
452	Site_31_maluku_3744	115.2	492.8	448,200	82,831	126.472	-7.79668	714	8,741	0.24	226	3	1	4.3	140	Yes	Mosaic cropland/vegetation
453	Site_31_maluku_3765	29.2	140.4	147,600	25,413	126.48	-7.8064	615	7,338	0.24	226	2	1	5.4	40	Yes	Semi-deciduous forest
454	Site_31_maluku_3810	42.8	199.7	123,300	17,883	126.016	-7.81696	1,027	8,823	0.41	187	2	1	4.9	57	Yes	Semi-deciduous forest
455	Site_31_maluku_4051	24.3	114.0	241,200	24,469	126.481	-7.86891	298	3,797	0.28	222	3	1	6.7	32	Yes	Mosaic cropland/vegetation
456	Site_31_maluku_4055	25.7	125.1	186,300	27,292	129.734	-7.87585	456	7,759	0.13	494	2	1	6.0	35	Yes	Mosaic cropland/vegetation
457	Site_31_maluku_4130	55.8	240.9	311,400	55,522	125.921	-7.88946	488	4,040	0.36	173	3	1	5.0	68	Yes	Mosaic cropland/vegetation
458	Site_31_maluku_4161	32.4	137.4	442,800	63,049	129.832	-7.90168	200	2,088	0.11	501	3	1	8.0	39	Yes	Rainfed croplands
459	Site_31_maluku_4194	46.5	234.6	522,000	98,806	129.701	-7.91196	289	8,463	0.15	497	4	1	7.1	67	Yes	Mosaic vegetation/cropland
460	Site_31_maluku_4211	39.4	180.1	246,600	43,283	129.784	-7.94474	460	5,143	0.13	503	3	1	5.3	51	Yes	Semi-deciduous forest
461	Site_31_maluku_4233	21.8	101.3	244,800	34,815	129.812	-7.93474	261	3,234	0.11	504	3	1	7.1	29	Yes	Semi-deciduous forest
462	Site_31_maluku_4237	40.9	181.8	268,200	44,224	129.676	-7.94196	427	4,124	0.16	499	3	1	5.2	52	Yes	Rainfed croplands
463	Site_31_maluku_4251	45.3	196.2	322,200	45,165	129.67	-7.9453	385	3,407	0.14	499	3	1	5.5	56	Yes	Rainfed croplands
464	Site_31_maluku_4317	31.2	137.1	452,700	84,669	129.748	-8.0203	200	3,316	0.16	510	3	1	8.0	39	Yes	Mosaic cropland/vegetation
465	Site_31_maluku_4344	24.9	106.3	335,700	57,360	128.939	-8.21058	200	1,526	0.26	462	3	1	7.8	30	Yes	Mosaic cropland/vegetation
466	Site_31_maluku_579	18.3	105.0	337,500	54,060	128.305	-3.15048	208	7,053	0.22	44	3	1	9.3	30	Yes	Rainfed croplands
467	Site_31_maluku_828	54.9	232.3	347,400	44,573	126.173	-3.20798	422	2,931	0.22	226	3	1	5.2	66	Yes	Mosaic vegetation/cropland

No	Site Code	Peak power (MWp)	Energy (MWh)	Volume (m3)	Area (m2)	Outlet coordinate (x)	Outlet coordinate (y)	Elevation (m)	Distance from coastline (m)	St.dev slope	Distance from transmission line (km)	Penstock diameter (m)	Number of penstock	LCOS (c€/kWh)	Carbon reduction (ton/year)	Economically feasible	Land covering
468	Site_31_maluku_915	21.3	106.5	345,600	45,521	128.342	-3.2277	202	4,826	0.18	36	3	1	8.6	30	Yes	Mosaic cropland/vegetation
469	Site_32_northmaluku_1017	74.8	311.2	205,200	33,236	127.459	1.23127	972	4,853	0.22	52	2	1	3.8	88	Yes	Semi-deciduous forest
470	Site_32_northmaluku_1103	43.5	190.7	399,600	67,423	127.785	1.15405	308	4,024	0.21	63	3	1	6.1	54	Yes	Semi-deciduous forest
471	Site_32_northmaluku_1420	20.7	100.4	230,400	20,893	128.237	0.87543	275	3,988	0.36	97	3	1	7.2	28	Yes	Semi-deciduous forest
472	Site_32_northmaluku_1457	20.1	105.1	345,600	50,335	128.169	0.84238	201	5,520	0.29	89	3	1	8.9	30	Yes	Mosaic cropland/vegetation
473	Site_32_northmaluku_1861	20.5	114.0	269,100	35,142	128.568	0.49793	273	7,079	0.21	136	3	1	7.8	32	Yes	Rainfed croplands
474	Site_32_northmaluku_1895	26.5	119.4	282,600	52,238	128.65	0.47015	267	3,007	0.20	145	3	1	6.8	34	Yes	Mosaic cropland/vegetation
475	Site_32_northmaluku_1904	28.2	128.0	278,100	29,443	128.648	0.46681	291	3,426	0.20	146	3	1	6.4	36	Yes	Semi-deciduous forest
476	Site_32_northmaluku_1908	18.3	110.1	383,400	64,585	128.596	0.46348	201	8,571	0.18	140	3	1	10.0	31	Yes	Semi-deciduous forest
477	Site_32_northmaluku_1917	83.9	429.9	1,271,700	211,801	128.521	0.4582	224	8,434	0.26	132	4	2	7.7	122	Yes	Mosaic cropland/vegetation
478	Site_32_northmaluku_1942	23.2	111.7	366,300	49,389	127.863	0.43987	200	4,320	0.20	65	3	1	8.5	32	Yes	Semi-deciduous forest
479	Site_32_northmaluku_1959	34.4	152.9	473,400	81,682	128.496	0.43126	218	4,461	0.19	130	3	1	7.8	43	Yes	Semi-deciduous forest
480	Site_32_northmaluku_2043	20.3	115.7	406,800	63,636	127.798	0.35515	201	8,317	0.40	65	3	1	9.8	33	Yes	Semi-deciduous forest
481	Site_32_northmaluku_2283	30.4	142.9	233,100	21,845	127.732	-0.23792	386	4,840	0.49	118	3	1	5.9	41	Yes	Mosaic cropland/vegetation
482	Site_32_northmaluku_2330	35.3	152.9	370,800	63,637	127.199	-0.28209	263	2,724	0.30	116	3	1	6.6	43	Yes	Semi-deciduous forest
483	Site_32_northmaluku_2446	115.0	480.1	791,100	88,331	127.233	-0.37348	388	4,378	0.21	126	4	1	5.4	136	Yes	Semi-deciduous forest
484	Site_32_northmaluku_2477	52.8	236.3	365,400	57,937	127.216	-0.38265	416	5,847	0.21	127	3	1	5.3	67	Yes	Semi-deciduous forest
485	Site_32_northmaluku_2562	35.3	170.8	336,600	56,037	127.203	-0.4132	329	6,615	0.25	130	3	1	6.3	48	Yes	Semi-deciduous forest
486	Site_32_northmaluku_2666	40.9	187.3	452,700	62,686	127.384	-0.44543	280	6,402	0.20	134	3	1	6.8	53	Yes	Mosaic cropland/vegetation
487	Site_32_northmaluku_2683	24.5	114.1	216,000	27,544	127.567	-0.45126	373	6,820	0.29	136	2	1	6.5	32	Yes	Semi-deciduous forest
488	Site_32_northmaluku_2759	44.7	197.1	303,300	56,987	127.967	-0.47987	411	4,158	0.34	153	3	1	5.3	56	Yes	Rainfed croplands
489	Site_32_northmaluku_2844	36.5	176.0	274,500	35,142	127.416	-0.53015	408	6,666	0.29	143	3	1	5.8	50	Yes	Semi-deciduous forest
490	Site_32_northmaluku_2882	31.4	143.8	234,900	27,543	128.003	-0.56209	385	4,157	0.35	163	3	1	5.7	41	Yes	Mosaic cropland/vegetation
491	Site_32_northmaluku_3002	22.5	102.7	323,100	38,939	127.266	-0.6946	203	2,833	0.15	162	3	1	8.0	29	Yes	Mosaic cropland/vegetation
492	Site_32_northmaluku_3074	46.8	202.1	592,200	84,526	127.238	-0.74126	216	2,692	0.12	167	4	1	7.5	57	Yes	Mosaic cropland/vegetation
493	Site_32_northmaluku_311	25.6	118.8	243,900	34,170	128.545	2.15268	307	3,699	0.22	202	3	1	6.5	34	Yes	Semi-deciduous forest
494	Site_32_northmaluku_3175	54.0	233.2	530,100	107,318	127.835	-0.80432	277	3,066	0.27	181	4	1	6.5	66	Yes	Mosaic cropland/vegetation
495	Site_32_northmaluku_3238	51.3	218.3	607,500	122,498	127.506	-1.23072	227	2,407	0.15	222	4	1	7.2	62	Yes	Mosaic cropland/vegetation
496	Site_32_northmaluku_3244	34.4	145.9	476,100	72,169	127.5	-1.24461	200	2,438	0.11	223	3	1	8.1	41	Yes	Mosaic vegetation/cropland
497	Site_32_northmaluku_3375	70.0	287.3	911,700	206,994	127.45	-1.45433	200	1,122	0.14	246	3	2	8.0	81	Yes	Shrubland
498	Site_32_northmaluku_3400	55.9	238.3	261,000	18,041	127.846	-1.46989	572	3,359	0.29	237	3	1	4.7	68	Yes	Mosaic cropland/vegetation
499	Site_32_northmaluku_3447	73.1	319.8	459,000	68,363	127.537	-1.51434	461	7,656	0.27	243	3	1	5.0	91	Yes	Semi-deciduous forest
500	Site_32_northmaluku_3546	26.8	133.2	181,800	49,371	127.909	-1.60517	497	8,786	0.37	221	2	1	5.9	38	Yes	Mosaic cropland/vegetation
501	Site_32_northmaluku_3580	22.3	120.8	310,500	34,180	127.887	-1.62017	254	6,925	0.30	220	3	1	7.9	34	Yes	Mosaic cropland/vegetation
502	Site_32_northmaluku_3647	29.7	135.1	453,600	70,257	127.491	-1.66128	201	4,448	0.24	230	3	1	8.4	38	Yes	Mosaic cropland/vegetation
503	Site_32_northmaluku_3661	18.9	99.5	231,300	37,027	127.605	-1.66906	273	5,414	0.22	224	3	1	7.7	28	Yes	Rainfed croplands
504	Site_32_northmaluku_566	26.2	108.4	338,400	46,519	127.62	1.77823	201	899	0.24	116	3	1	7.8	31	Yes	Mosaic cropland/vegetation
505	Site_32_northmaluku_670	35.9	176.4	402,300	50,321	127.917	1.60656	295	7,863	0.20	111	3	1	6.9	50	Yes	Mosaic cropland/vegetation
506	Site_32_northmaluku_703	36.9	173.9	557,100	69,312	128.65	1.53795	200	4,599	0.20	166	4	1	8.2	49	Yes	Mosaic vegetation/cropland
507	Site_32_northmaluku_774	30.7	141.9	502,200	91,153	128.439	1.47239	202	6,117	0.16	143	3	1	9.0	40	Yes	Semi-deciduous forest
508	Site_32_northmaluku_784	53.0	260.9	927,900	122,487	128.427	1.45989	200	6,779	0.15	141	3	2	8.5	74	Yes	Semi-deciduous forest
509	Site_32_northmaluku_798	27.0	128.8	440,100	79,760	128.387	1.4335	200	5,371	0.12	135	3	1	8.8	37	Yes	Semi-deciduous forest
510	Site_32_northmaluku_895	20.6	117.7	294,300	37,982	127.554	1.34405	261	7,747	0.15	67	3	1	8.1	33	Yes	Rainfed croplands
511	Site_32_northmaluku_900	89.5	443.6	1,129,500	165,223	127.55	1.33711	254	7,474	0.13	66	4	2	6.8	126	Yes	Rainfed croplands
512	Site_34_westpapua_1010	316.5	1,354.4	1,156,500	154,615	134.618	-2.98298	739	8,015	0.24	300	4	2	4.4	384	Yes	Shrubland
513	Site_34_westpapua_1165	125.9	556.9	1,330,200	224,725	134.987	-3.37826	269	4,917	0.23	243	4	2	7.0	158	Yes	Semi-deciduous forest
514	Site_34_westpapua_1220	26.5	133.9	158,400	28,438	134.159	-3.6616	558	8,854	0.39	313	2	1	5.9	38	Yes	No data
515	Site_34_westpapua_1386	80.6	411.4	1,020,600	186,708	134.261	-3.82438	259	7,742	0.36	296	4	2	7.2	117	Yes	Semi-deciduous forest
516	Site_34_westpapua_1499	35.8	172.3	519,300	92,875	134.408	-3.86938	212	5,108	0.17	279	4	1	8.5	49	No	No data
517	Site_34_westpapua_1589	170.6	715.7	507,600	60,652	134.821	-3.87883	883	6,070	0.36	236	4	1	4.1	203	Yes	Semi-deciduous forest
518	Site_34_westpapua_1629	52.1	220.0	127,800	15,163	134.704	-3.88605	1,079	3,587	0.52	248	2	1	4.5	62	Yes	Semi-deciduous forest
519	Site_34_westpapua_1823	29.0	124.1	289,800	51,172	134.251	-3.94049	269	1,857	0.37	292	3	1	6.8	35	Yes	Mosaic cropland/vegetation
520	Site_34_westpapua_1848	38.9	164.5	289,800	39,800	134.255	-3.95411	356	2,023	0.33	292	3	1	5.9	47	Yes	Semi-deciduous forest
521	Site_34_westpapua_1863	21.7	107.7	306,900	29,376	134.515	-3.95994	226	4,589	0.11	264	3	1	8.3	31	No	Semi-deciduous forest
522	Site_34_westpapua_1890	34.2	145.3	447,300	62,541	134.496	-3.97716	210	2,320	0.14	265	3	1	8.2	41	No	Semi-deciduous forest
523	Site_34_westpapua_1957	20.6	109.1	135,000	38,840	134.952	-4.20439	525	8,242	0.33	210	2	1	6.4	31	Yes	Rainfed croplands
524	Site_34_westpapua_262	148.1	612.9	1,258,200	121,522	134.069	-1.7274	306	1,969	0.44	313	4	2	6.5	174	Yes	Mosaic cropland/vegetation
525	Site_34_westpapua_316	126.5	584.9	1,497,600	149,036	134.065	-1.95546	260	7,757	0.33	321	4	2	7.3	166	Yes	Semi-deciduous forest
526	Site_34_westpapua_356	61.0	269.8	557,100	77,836	134.061	-2.05935	307	4,611	0.36	325	4	1	6.3	77	Yes	Mosaic cropland/vegetation
527	Site_34_westpapua_408	36.6	152.4	275,400	37,965	134.113	-2.21463	346	1,418	0.41	337	3	1	6.0	43	Yes	Rainfed croplands
528	Site_34_westpapua_425	127.9	522.1	858,600	121,485	134.115	-2.24935	386	2,777	0.24	339	4	1	5.7	148	Yes	Mosaic cropland/vegetation
529	Site_34_westpapua_432	28.8	127.9	199,800	48,404	134.102	-2.26241	425	4,795	0.24	338	2	1	5.9	36	Yes	Mosaic cropland/vegetation
530	Site_34_westpapua_452	148.4	619.7	904,500	127,175	134.122	-2.29685	439	3,678	0.31	341	3	2	5.4	176	Yes	Mosaic cropland/vegetation
531	Site_34_westpapua_512	32.3	169.4	550,800	66,430	134.136	-2.4088	200	7,000	0.28	349	4	1	9.4	48	No	Mosaic cropland/vegetation
532	Site_34_westpapua_52	36.8	165.3	396,900	51,286	135.563	-0.7271	271	4,336	0.15	410	3	1	6.9	47	Yes	Semi-deciduous forest
533	Site_34_westpapua_584	61.5	257.7	821,700	125,258	134.561	-2.51658	202	2,661	0.22	332	4	1	8.5	73	No	Semi-deciduous forest
534	Site_34_westpapua_642	17.3	94.7	309,600	53,137	134.269	-2.57297	200	5,654	0.27	358	3	1	9.6	27	No	No data
535	Site_34_westpapua_679	23.8	106.7	341,100	45,545	134.309	-2.60797	200	2,638	0.18	352	3	1	8.4	30	No	Semi-deciduous forest
536	Site_34_westpapua_683	24.0	113.8	90,900	9,489	134.604	-2.61075	786	5,889	0.43	323	2	1	6.0	32	Yes	Mosaic cropland/vegetation
537	Site_34_westpapua_835	210.0	892.9	2,514,600	258,060	134.367	-2.74492	232	4,111	0.25	338	4	3	7.7	253	No	Mosaic cropland/vegetation
538	Site_34_westpapua_87	56.4	236.4	180,000	12,346	135.578	-0.77849	834	3,737	0.29	404	2	1	4.2	67	Yes	Semi-deciduous forest
539	Site_34_westpapua_919	19.2	104.7	349,200	46,485	134.384	-2.83269	200	6,219	0.19	331	3	1	9.6	30	No	Mosaic cropland/vegetation
540	Site_34_westpapua_954	21.6	98.5	207,900	27,510	134.632	-2.88797	323	4,706	0.23	305	2	1	7.0	28	Yes	Mosaic vegetation/cropland
541	Site_35_papua_1071	22.1	108.2	74,700	18,987	136.214	-1.79462	907	6,914	0.40	272	2	1	6.7	31	Yes	Semi-deciduous forest
542	Site_35_papua_1075	80.7	397.1	1,183,500	216,453	136.641	-1.79406	218	6,546	0.38	258	4	2	7.9	113	Yes	Mosaic cropland/vegetation
543	Site_35_papua_1309	19.4	101.3	261,000	39,868	138.87	-2.01712	248	5,275	0.18	144	3	1	8.3	29	Yes	Mosaic vegetation/cropland
544	Site_35_papua_1327	63.5	304.8	528,300	76,887	138.83	-2.03907	369	8,879	0.14	147	4	1	6.1	86	Yes	Semi-deciduous forest
545	Site_35_papua_133	29.1	137.6	298,800	15,196	135.859	-0.7671	294	4,695	0.21	392	3	1	6.8	39	Yes	Mosaic cropland/vegetation
546	Site_35_papua_1392	36.6	152.4	275,400	37,965	134.113	-2.21463	346	1,418	0.41	337	3	1	6.0	43	Yes	Rainfed croplands
547	Site_35_papua_1408	127.9	522.1	858,600	121,485	134.115	-2.24935	386	2,777	0.24	339	4	1	5.7	148	Yes	Mosaic cropland/vegetation
548	Site_35_papua_141	90.2	386.6	820,800	28,492	135.851	-0.77238	308	5,766	0.23	393	4	1	6.4	110	Yes	Semi-deciduous forest
549	Site_35_papua_1413	44.3	186.1	441,900	64,538	134.128	-2.26379	270	2,412	0.23	341	3	1	6.8	53	Yes	Mosaic cropland/vegetation
550	Site_35_papua_1415	28.8	127.9	199,800	48,404	134.102	-2.26241	425	4,795	0.24	338	2	1	5.9	36	Yes	Mosaic cropland/vegetation
551	Site_35_papua_1420	24.6	133.9	280,800	51,251	134.075	-2.27185	308	7,877	0.29	336	3	1	7.5	38	Yes	Semi-deciduous forest
552	Site_35_papua_1431	87.1	389.2	603,000	76,875	134.088	-2.29018	412	7,285	0.27	338	4	1	5.4	110	Yes	Semi-deciduous forest
553	Site_35_papua_1440	28.6	147.8	253,800	33,217	134.089	-2.3038	371	7,430	0.34	339	3	1	6.7	42	Yes	Mosaic cropland/vegetation
554	Site_35_papua_157	25.6	138.6	285,300	60,782	135.83	-0.77932	314	7,962	0.19	393	3	1	7.4	39	Yes	Semi-deciduous forest
555	Site_35_papua_159	64.5	277.9	908,100	195,644	135.755	-0.78293	200	2,729	0.18	395	3	2	8.5	79	Yes	Semi-deciduous forest
556	Site_35_papua_1599	57.2	234.0	468,000	44,602	140.268	-2.43796	317	1,618	0.28	15	3	1	6.2	66	Yes	Mosaic cropland/vegetation
557	Site_35_papua_160	20.8	104.9	158,400	22,793	135.622	-0.78488	437	6,846	0.33	401	2	1	6.4	30	Yes	Semi-deciduous forest
558	Site_35_papua_161	31.9	155.5	365,400	80,727	135.857	-0.78849	280	6,432	0.21	391	3	1	7.3	44	Yes	Mosaic cropland/vegetation
559	Site_35_papua_1620	49.3	218.0	435,600	69,275	140.182	-2.44908	329	5,384	0.28	12	3	1	6.3	62	Yes	Mosaic cropland/vegetation
560	Site_35_papua_164	34.9	173.3	367,200	57,933	135.839	-0.78599	312	7,726	0.21	392	3	1	7.0	49	Yes	Semi-deciduous forest
561	Site_35_papua_1662	299.8	1,252.0	3,000,600	118,620	140.189	-2.46019	273	6,109	0.29	12	4	4	6.9	355	Yes	Mosaic cropland/vegetation

Appendix B

SPHS Classification

The information about the identified Seawater Pumped Hydro Storage (SPHS) classification can be found on the following pages of this report.

Classification of Identified Seawater-Pumped Hydro Storage (SPHS) Sites

No	Site Code	Outlet coordinate (x)	Outlet coordinate (y)	St.dev slope	Peak power (MWp)	Land covering	Distance from transmission line (km)	LCOS (c€/kWh)	Inundation area (Ha)	Distance from coastline (m)	Relative closeness (CP-TOPSIS)	Rank	Classifi-cation
1	Site_34_westpapua_1010	134.618	-2.98298	0.24	316.5	Shrubland	300	4.4	15.5	8,015	0.92	1	1
2	Site_25_centralsulawesi2b_8410	122.742	-1.03588	0.15	309.8	Mosaic vegetation/cropland	1	5.4	41.3	2,859	0.91	2	1
3	Site_16_eastjava1_1232	111.059	-8.20713	0.17	287.2	Mosaic cropland/vegetation	6	5.8	40.3	2,482	0.87	3	1
4	Site_25_centralsulawesi2b_2006	122.885	-0.80253	0.28	268.6	Rainfed croplands	24	4.9	30.7	3,324	0.86	4	1
5	Site_35_papua_1662	140.189	-2.46019	0.29	299.8	Mosaic cropland/vegetation	12	6.9	11.9	6,109	0.82	5	1
6	Site_30_eastnusatenggara_8370	120.143	-8.49456	0.22	217.2	Mosaic cropland/vegetation	16	5.2	20.7	6,930	0.76	6	1
7	Site_27_southeastsulawesi_2463	120.943	-3.56985	0.31	307.2	Mosaic cropland/vegetation	1	6.7	47.9	2,948	0.75	7	1
8	Site_28_bali_2102	115.511	-8.44078	0.22	191.6	Semi-deciduous forest	5	4.6	10.1	6,899	0.71	8	1
9	Site_25_centralsulawesi2b_11111	122.937	-1.24351	0.20	189.3	Mosaic cropland/vegetation	30	4.4	13.7	4,553	0.69	9	1
10	Site_34_westpapua_835	134.367	-2.74492	0.25	210.0	Mosaic cropland/vegetation	338	7.7	25.8	4,111	0.68	10	1
11	Site_30_eastnusatenggara_1724	123.764	-8.24726	0.17	158.4	Semi-deciduous forest	144	5.4	15.8	4,156	0.65	11	1
12	Site_27_southeastsulawesi_9221	122.607	-5.02163	0.23	214.9	Mosaic cropland/vegetation	10	7.2	41.4	5,320	0.64	12	1
13	Site_35_papua_1974	140.617	-2.57213	0.16	204.9	Semi-deciduous forest	0	8.7	35.0	8,417	0.64	13	1
14	Site_27_southeastsulawesi_12407	122.684	-5.44477	0.14	171.2	Mosaic cropland/vegetation	3	6.9	47.4	3,852	0.62	14	1
15	Site_25_centralsulawesi2a_5717	120.611	-1.35952	0.19	163.2	Mosaic vegetation/cropland	2	6.1	19.5	3,593	0.62	15	1
16	Site_25_centralsulawesi2b_10989	122.964	-1.23692	0.25	170.7	Rainfed croplands	32	6.4	12.1	2,137	0.60	16	1
17	Site_35_papua_1870	134.234	-2.51963	0.22	142.3	Semi-deciduous forest	363	6.7	17.4	5,891	0.59	17	1
18	Site_29_westnusatenggara_855	117.783	-8.20736	0.12	106.7	Mosaic cropland/vegetation	49	5.4	14.0	7,359	0.58	18	1
19	Site_29_westnusatenggara_3225	118.121	-8.39735	0.06	97.1	Shrubland	26	5.7	13.6	7,312	0.58	19	1
20	Site_31_maluku_3117	128.599	-7.14611	0.23	132.5	Mosaic cropland/vegetation	386	6.2	19.2	4,016	0.58	20	1
21	Site_27_southeastsulawesi_10360	122.835	-5.18218	0.15	121.5	Mosaic cropland/vegetation	26	5.4	16.2	3,836	0.58	21	1
22	Site_34_westpapua_425	134.115	-2.24935	0.24	127.9	Mosaic cropland/vegetation	339	5.7	12.1	2,777	0.57	22	1
23	Site_35_papua_1408	134.115	-2.24935	0.24	127.9	Mosaic cropland/vegetation	339	5.7	12.1	2,777	0.57	22	1
24	Site_30_eastnusatenggara_6655	124.399	-8.4227	0.30	150.6	Shrubland	80	4.8	10.4	1,962	0.57	24	1
25	Site_32_northmaluku_2446	127.233	-0.37348	0.21	115.0	Semi-deciduous forest	126	5.4	8.8	4,378	0.57	25	1
26	Site_10_lampung_2897	105.483	-5.94716	0.18	179.2	Mosaic vegetation/cropland	29	3.9	11.6	1,871	0.57	26	1
27	Site_31_maluku_2148	126.28	-3.58077	0.21	110.5	Rainfed croplands	209	4.6	7.5	6,331	0.57	27	1
28	Site_34_westpapua_1589	134.821	-3.87883	0.36	170.6	Semi-deciduous forest	236	4.1	6.1	6,070	0.57	28	1
29	Site_35_papua_299	135.978	-0.85571	0.15	107.9	Mosaic cropland/vegetation	379	7.8	24.3	4,214	0.57	29	1
30	Site_25_centralsulawesi2b_3801	122.763	-0.84999	0.25	137.5	Mosaic vegetation/cropland	15	3.6	3.7	5,356	0.56	30	1
31	Site_34_westpapua_1165	134.987	-3.37826	0.23	125.9	Semi-deciduous forest	243	7.0	22.5	4,917	0.56	31	1
32	Site_34_westpapua_452	134.122	-2.29685	0.31	148.4	Mosaic cropland/vegetation	341	5.4	12.7	3,678	0.56	32	1
33	Site_31_maluku_3744	126.472	-7.79668	0.24	115.2	Mosaic cropland/vegetation	226	4.3	8.3	8,741	0.56	33	1
34	Site_35_papua_1918	140.311	-2.53852	0.25	127.3	Rainfed croplands	7	5.8	16.2	8,548	0.56	34	1
35	Site_32_northmaluku_900	127.55	1.33711	0.13	89.5	Rainfed croplands	66	6.8	16.5	7,474	0.56	35	1
36	Site_22_northsulawesi_2739	124.891	1.0778	0.15	117.6	Mosaic cropland/vegetation	14	6.2	16.1	6,208	0.56	36	1
37	Site_29_westnusatenggara_1352	117.556	-8.26609	0.16	85.3	Mosaic cropland/vegetation	30	4.6	9.0	3,765	0.56	37	1
38	Site_31_maluku_2526	126.505	-3.68577	0.30	134.2	Mosaic cropland/vegetation	184	3.8	5.6	8,795	0.56	38	1
39	Site_29_westnusatenggara_3524	118.134	-8.41663	0.09	83.0	Shrubland	23	6.9	17.0	6,722	0.55	39	1
40	Site_29_westnusatenggara_2760	118.183	-8.36412	0.16	119.4	Semi-deciduous forest	23	7.0	31.4	6,595	0.55	40	1
41	Site_29_westnusatenggara_3325	118.138	-8.4026	0.06	50.2	Rainfed croplands	24	6.8	9.5	8,122	0.55	41	1
42	Site_32_northmaluku_3375	127.45	-1.45433	0.14	70.0	Shrubland	246	8.0	20.7	1,122	0.55	42	1
43	Site_29_westnusatenggara_3272	118.115	-8.39863	0.07	42.8	Mosaic cropland/vegetation	26	5.9	5.8	6,822	0.55	43	1
44	Site_29_westnusatenggara_2496	116.232	-8.34627	0.14	70.8	Mosaic cropland/vegetation	4	5.7	14.9	5,427	0.55	44	1
45	Site_29_westnusatenggara_2289	116.249	-8.33307	0.06	37.6	Rainfed croplands	5	5.9	5.1	6,066	0.55	45	1
46	Site_30_eastnusatenggara_8346	120.157	-8.49396	0.25	121.9	Rainfed croplands	17	5.8	15.5	7,788	0.55	46	1
47	Site_16_eastjava2_951	114.311	-8.19468	0.06	52.5	Semi-deciduous forest	3	6.3	12.8	7,884	0.55	47	1
48	Site_14_centraljava2_818	111.039	-8.17293	0.14	71.0	Shrubland	6	4.7	9.3	6,845	0.55	48	1
49	Site_29_westnusatenggara_2020	118.156	-8.31514	0.08	39.2	Rainfed croplands	30	5.5	5.2	6,093	0.55	49	1
50	Site_28_bali_2438	115.403	-8.49989	0.11	58.5	Shrubland	7	9.0	15.6	8,267	0.55	50	1
51	Site_25_centralsulawesi3_1855	121.93	-2.72094	0.25	126.4	Mosaic cropland/vegetation	6	4.3	10.0	8,626	0.55	51	1
52	Site_29_westnusatenggara_1029	117.806	-8.23001	0.11	47.1	Mosaic cropland/vegetation	48	5.2	6.5	8,031	0.54	52	1
53	Site_35_papua_1327	138.83	-2.03907	0.14	63.5	Semi-deciduous forest	147	6.1	7.7	8,879	0.54	53	1
54	Site_35_papua_561	135.602	-1.67156	0.14	65.2	Semi-deciduous forest	315	8.3	12.2	1,104	0.54	54	1
55	Site_32_northmaluku_3074	127.238	-0.74126	0.12	46.8	Mosaic cropland/vegetation	167	7.5	8.5	2,692	0.54	55	1
56	Site_29_westnusatenggara_1033	117.545	-8.23084	0.10	42.1	Semi-deciduous forest	33	5.8	8.9	5,895	0.54	56	1
57	Site_28_bali_874	114.92	-8.22896	0.09	25.6	Semi-deciduous forest	2	8.9	6.9	4,895	0.54	57	1
58	Site_29_westnusatenggara_894	117.785	-8.21381	0.07	28.7	Rainfed croplands	49	6.3	4.3	7,686	0.54	58	1
59	Site_29_westnusatenggara_1679	118.149	-8.29302	0.08	29.7	Mosaic cropland/vegetation	32	5.8	4.9	4,783	0.54	59	1
60	Site_29_westnusatenggara_1686	118.17	-8.29242	0.08	29.8	Shrubland	31	6.5	5.2	3,125	0.54	60	1
61	Site_29_westnusatenggara_2746	118.167	-8.36352	0.07	28.3	Mosaic cropland/vegetation	25	7.7	6.0	8,052	0.54	61	1
62	Site_29_westnusatenggara_3016	117.986	-8.38303	0.08	24.1	Semi-deciduous forest	32	5.9	2.6	7,215	0.54	62	2
63	Site_32_northmaluku_3244	127.5	-1.24461	0.11	34.4	Mosaic vegetation/cropland	223	8.1	7.2	2,438	0.54	63	2
64	Site_28_bali_2257	115.027	-8.46141	0.09	15.4	Mosaic cropland/vegetation	1	9.1	4.1	7,773	0.54	64	2
65	Site_28_bali_2492	115.324	-8.51421	0.12	59.5	Shrubland	5	9.2	17.1	7,809	0.54	65	2
66	Site_31_maluku_4161	129.832	-7.90168	0.11	32.4	Rainfed croplands	501	8.0	6.3	2,088	0.54	66	2
67	Site_28_bali_2644	115.518	-8.74464	0.13	36.9	Mosaic cropland/vegetation	7	6.5	7.1	3,441	0.54	67	2
68	Site_28_bali_2567	115.533	-8.71636	0.15	58.9	Rainfed croplands	7	7.0	9.4	4,141	0.54	68	2
69	Site_28_bali_99	115.229	-8.13153	0.15	46.8	Semi-deciduous forest	16	5.1	4.8	5,215	0.54	69	2
70	Site_29_westnusatenggara_4803	116.55	-8.59012	0.10	43.4	Mosaic cropland/vegetation	3	8.0	9.1	8,277	0.54	70	2
71	Site_11_banten_944	106.232	-6.87192	0.11	57.7	Semi-deciduous forest	4	6.1	11.1	5,357	0.54	71	2
72	Site_29_westnusatenggara_1087	117.535	-8.23549	0.11	34.4	Semi-deciduous forest	32	5.8	3.9	4,754	0.54	72	2
73	Site_31_maluku_4211	129.784	-7.94474	0.13	39.4	Semi-deciduous forest	503	5.3	4.3	5,143	0.54	73	2
74	Site_16_eastjava2_981	114.307	-8.21036	0.06	18.5	Mosaic cropland/vegetation	2	7.5	5.1	8,372	0.54	74	2
75	Site_31_maluku_4233	129.812	-7.93474	0.11	21.8	Semi-deciduous forest	504	7.1	3.5	3,234	0.54	75	2
76	Site_31_maluku_4251	129.67	-7.9453	0.14	45.3	Rainfed croplands	499	5.5	4.5	3,407	0.54	76	2
77	Site_32_northmaluku_3238	127.506	-1.23072	0.15	51.3	Mosaic cropland/vegetation	222	7.2	12.2	2,407	0.54	77	2
78	Site_28_bali_2555	115.543	-8.71111	0.12	26.3	Rainfed croplands	8	7.9	6.5	3,848	0.54	78	2

No	Site Code	Outlet coordinate (x)	Outlet coordinate (y)	St.dev slope	Peak power (MWp)	Land covering	Distance from transmission line (km)	LCOS (c€/kWh)	Inundation area (Ha)	Distance from coastline (m)	Relative closeness (CP-TOPSIS)	Rank	Classifi-cation
79	Site_25_centralsulawesi3_1524	121.971	-2.60652	0.23	113.5	Semi-deciduous forest	10	5.0	10.8	2,120	0.54	79	2
80	Site_28_bali_2065	115.574	-8.43666	0.12	26.6	Semi-deciduous forest	2	8.1	5.2	6,940	0.54	80	2
81	Site_28_bali_127	115.204	-8.13888	0.12	24.8	Mosaic cropland/vegetation	14	8.3	5.8	6,345	0.54	81	2
82	Site_30_eastnusatenggara_12740	120.193	-8.75686	0.10	24.3	Mosaic cropland/vegetation	6	7.7	4.6	4,518	0.54	82	2
83	Site_13_westjava_1126	106.503	-7.25004	0.11	48.2	Semi-deciduous forest	25	6.6	11.2	8,336	0.54	83	2
84	Site_32_northmaluku_798	128.387	1.4335	0.12	27.0	Semi-deciduous forest	135	8.8	8.0	5,371	0.54	84	2
85	Site_31_maluku_4194	129.701	-7.91196	0.15	46.5	Mosaic vegetation/cropland	497	7.1	9.9	8,463	0.54	85	2
86	Site_16_eastjava1_3281	112.546	-8.32842	0.14	60.9	Mosaic cropland/vegetation	15	5.7	14.1	7,969	0.54	86	2
87	Site_11_banten_539	105.615	-6.76714	0.07	15.1	Mosaic vegetation/cropland	27	8.0	5.0	8,277	0.54	87	2
88	Site_34_westpapua_1863	134.515	-3.95994	0.11	21.7	Semi-deciduous forest	264	8.3	2.9	4,589	0.54	88	2
89	Site_29_westnusatenggara_1234	117.538	-8.25146	0.13	35.4	Semi-deciduous forest	31	5.2	5.8	3,897	0.54	89	2
90	Site_14_centraljava2_189	110.347	-7.01751	0.09	20.9	Mosaic cropland/vegetation	-	7.8	4.3	7,115	0.54	90	2
91	Site_30_eastnusatenggara_8536	123.365	-8.50244	0.14	42.3	Rainfed croplands	115	5.3	4.4	4,709	0.54	91	2
92	Site_31_maluku_4055	129.734	-7.87585	0.13	25.7	Mosaic cropland/vegetation	494	6.0	2.7	7,759	0.54	92	2
93	Site_23_gorontalo_2973	123.053	0.88254	0.20	113.2	Mosaic cropland/vegetation	3	6.6	13.3	3,885	0.54	93	2
94	Site_13_westjava_2078	107.879	-7.69296	0.09	25.8	Rainfed croplands	19	7.0	7.8	4,738	0.54	94	2
95	Site_26_southsulawesi_1636	120.407	-5.48047	0.14	86.4	Mosaic cropland/vegetation	23	6.9	16.7	2,568	0.54	95	2
96	Site_32_northmaluku_784	128.427	1.45989	0.15	53.0	Semi-deciduous forest	141	8.5	12.2	6,779	0.53	96	2
97	Site_25_centralsulawesi2b_8561	122.742	-1.04255	0.15	77.8	Mosaic cropland/vegetation	1	5.3	10.6	2,253	0.53	97	2
98	Site_34_westpapua_1890	134.496	-3.97716	0.14	34.2	Semi-deciduous forest	265	8.2	6.3	2,320	0.53	98	2
99	Site_35_papua_3342	134.496	-3.97716	0.14	34.2	Semi-deciduous forest	265	8.2	6.3	2,320	0.53	98	2
100	Site_16_eastjava2_996	113.088	-8.21396	0.12	51.7	Mosaic cropland/vegetation	17	7.2	11.9	8,098	0.53	100	2
101	Site_35_papua_300	135.97	-0.85599	0.13	30.2	Semi-deciduous forest	379	7.8	7.6	4,660	0.53	101	2
102	Site_22_northsulawesi_2505	124.619	1.11679	0.15	84.5	Rainfed croplands	7	5.8	12.0	8,533	0.53	102	2
103	Site_28_bali_1852	115.6	-8.4161	0.15	28.9	Mosaic cropland/vegetation	4	9.0	8.0	6,186	0.53	103	2
104	Site_31_maluku_3310	131.53	-7.66946	0.14	20.0	Semi-deciduous forest	575	8.8	4.4	4,896	0.53	104	2
105	Site_31_maluku_4237	129.676	-7.94196	0.16	40.9	Rainfed croplands	499	5.2	4.4	4,124	0.53	105	2
106	Site_11_banten_519	106.075	-6.76361	0.11	17.1	Semi-deciduous forest	4	7.2	5.0	7,527	0.53	106	2
107	Site_32_northmaluku_1017	127.459	1.23127	0.22	74.8	Semi-deciduous forest	52	3.8	3.3	4,853	0.53	107	2
108	Site_29_westnusatenggara_321	117.838	-8.15643	0.18	57.3	Mosaic cropland/vegetation	57	4.5	5.3	3,192	0.53	108	2
109	Site_35_papua_141	135.851	-0.77238	0.23	90.2	Semi-deciduous forest	393	6.4	2.8	5,766	0.53	109	2
110	Site_30_eastnusatenggara_7170	122.728	-8.44618	0.13	25.2	Mosaic cropland/vegetation	47	6.6	2.5	5,712	0.53	110	2
111	Site_34_westpapua_52	135.563	-0.7271	0.15	36.8	Semi-deciduous forest	410	6.9	5.1	4,336	0.53	111	2
112	Site_35_papua_982	136.719	-1.77712	0.15	40.7	Semi-deciduous forest	258	8.1	7.5	4,224	0.53	112	2
113	Site_28_bali_2570	115.507	-8.71621	0.14	16.7	Mosaic cropland/vegetation	4	9.1	3.9	4,249	0.53	113	2
114	Site_28_bali_37	115.224	-8.1136	0.16	29.8	Semi-deciduous forest	17	6.0	4.5	3,410	0.53	114	2
115	Site_35_papua_2825	134.216	-3.81827	0.15	35.0	Semi-deciduous forest	301	6.9	5.4	3,066	0.53	115	2
116	Site_32_northmaluku_3002	127.266	-0.6946	0.15	22.5	Mosaic cropland/vegetation	162	8.0	3.9	2,833	0.53	116	2
117	Site_32_northmaluku_895	127.554	1.34405	0.15	20.6	Rainfed croplands	67	8.1	3.8	7,747	0.53	117	2
118	Site_16_eastjava1_2916	112.39	-8.30772	0.12	19.4	Rainfed croplands	14	6.5	3.9	5,563	0.53	118	2
119	Site_28_bali_2627	115.567	-8.73939	0.17	36.3	Mosaic vegetation/cropland	11	6.1	5.5	3,641	0.53	119	2
120	Site_11_banten_1208	106.473	-6.91708	0.14	39.5	Semi-deciduous forest	2	5.2	5.8	4,243	0.53	120	2
121	Site_13_westjava_275	106.473	-6.91708	0.14	39.3	Semi-deciduous forest	2	5.2	5.8	4,409	0.53	121	2
122	Site_16_eastjava1_2700	112.387	-8.29669	0.13	26.6	Mosaic cropland/vegetation	13	5.7	4.9	6,401	0.53	122	2
123	Site_27_southeastsulawesi_12768	122.602	-5.51009	0.07	39.0	Mosaic cropland/vegetation	6	6.1	9.2	3,994	0.53	123	3
124	Site_29_westnusatenggara_4038	116.594	-8.48361	0.14	20.0	Mosaic cropland/vegetation	6	5.8	2.1	7,435	0.53	124	3
125	Site_35_papua_159	135.755	-0.78293	0.18	64.5	Semi-deciduous forest	395	8.5	19.6	2,729	0.53	125	3
126	Site_16_eastjava2_978	113.052	-8.21043	0.13	19.0	Shrubland	20	7.0	4.6	8,542	0.53	126	3
127	Site_31_maluku_4317	129.748	-8.0203	0.16	31.2	Mosaic cropland/vegetation	510	8.0	8.5	3,316	0.53	127	3
128	Site_11_banten_614	106.108	-6.78514	0.13	15.1	Semi-deciduous forest	6	8.1	6.2	7,828	0.53	128	3
129	Site_30_eastnusatenggara_535	124.507	-8.18441	0.22	77.7	Rainfed croplands	98	4.4	4.3	3,899	0.53	129	3
130	Site_16_eastjava1_561	111.048	-8.16303	0.16	43.3	Mosaic cropland/vegetation	4	5.0	7.3	7,284	0.53	130	3
131	Site_14_centraljava2_682	111.048	-8.16303	0.16	43.3	Mosaic cropland/vegetation	4	5.0	7.3	7,284	0.53	131	3
132	Site_28_bali_2737	115.574	-8.77066	0.17	34.3	Rainfed croplands	14	5.7	3.7	3,987	0.53	132	3
133	Site_14_centraljava1_117	109.92	-6.99366	0.13	21.8	Mosaic cropland/vegetation	1	8.1	5.3	8,547	0.53	133	3
134	Site_26_southsulawesi_1740	120.043	-5.50079	0.04	17.6	Semi-deciduous forest	5	8.6	6.9	7,950	0.53	134	3
135	Site_29_westnusatenggara_1072	117.554	-8.23541	0.15	24.3	Semi-deciduous forest	33	6.6	7.9	6,091	0.53	135	3
136	Site_32_northmaluku_774	128.439	1.47239	0.16	30.7	Semi-deciduous forest	143	9.0	9.1	6,117	0.53	136	3
137	Site_27_southeastsulawesi_5380	123.139	-4.22972	0.28	132.8	Mosaic cropland/vegetation	57	5.7	18.1	1,742	0.53	137	3
138	Site_11_banten_756	106.12	-6.81139	0.14	34.6	Semi-deciduous forest	4	6.9	9.5	6,694	0.53	138	3
139	Site_13_westjava_1056	106.514	-7.19543	0.17	54.6	Mosaic cropland/vegetation	19	4.9	8.9	5,501	0.53	139	3
140	Site_16_eastjava1_1089	111.038	-8.19813	0.19	64.5	Mosaic cropland/vegetation	8	5.2	11.8	4,919	0.53	140	3
141	Site_28_bali_994	115.003	-8.24449	0.22	65.2	Semi-deciduous forest	5	5.0	7.5	7,218	0.53	141	3
142	Site_16_eastjava1_3545	112.597	-8.34485	0.14	21.8	Mosaic cropland/vegetation	17	7.1	5.6	7,306	0.53	142	3
143	Site_28_bali_513	114.587	-8.19671	0.17	26.8	Semi-deciduous forest	4	8.0	7.8	6,237	0.53	143	3
144	Site_11_banten_1278	106.548	-6.92465	0.20	70.3	Semi-deciduous forest	4	4.8	9.6	5,414	0.53	144	3
145	Site_11_banten_250	105.647	-6.54722	0.14	19.3	Semi-deciduous forest	7	6.4	6.0	2,240	0.53	145	3
146	Site_29_westnusatenggara_331	117.855	-8.15733	0.17	30.2	Mosaic cropland/vegetation	58	4.8	2.1	4,173	0.53	146	3
147	Site_35_papua_332	135.976	-0.90043	0.16	16.0	Mosaic cropland/vegetation	374	10.1	4.6	7,104	0.53	147	3
148	Site_34_westpapua_1499	134.408	-3.86938	0.17	35.8	No data	279	8.5	9.3	5,108	0.53	148	3
149	Site_14_centraljava2_955	111.041	-8.19326	0.17	48.0	Mosaic cropland/vegetation	7	5.1	9.9	4,993	0.53	149	3
150	Site_11_banten_1408	106.538	-6.94551	0.15	25.6	Semi-deciduous forest	2	5.5	4.3	3,316	0.53	150	3
151	Site_14_centraljava1_113	109.932	-6.99276	0.14	15.3	Semi-deciduous forest	1	8.8	4.7	8,419	0.53	151	3
152	Site_13_westjava_1219	107.202	-7.40695	0.14	19.8	Rainfed croplands	34	7.7	5.8	7,339	0.53	152	3
153	Site_11_banten_880	106.176	-6.84845	0.14	15.6	Mosaic cropland/vegetation	2	7.7	4.8	6,481	0.53	153	3
154	Site_16_eastjava1_3073	112.509	-8.31799	0.15	24.0	Mosaic cropland/vegetation	15	6.3	4.7	8,592	0.53	154	3
155	Site_26_southsulawesi_1665	119.987	-5.48841	0.07	17.7	Mosaic cropland/vegetation	3	8.1	4.7	7,705	0.53	155	3
156	Site_11_banten_1512	106.553	-6.96381	0.15	27.0	Semi-deciduous forest	1	6.4	4.0	2,336	0.52	156	3
157	Site_14_centraljava2_829	111.234	-8.17541	0.21	69.7	Semi-deciduous forest	0	4.5	7.7	8,468	0.52	157	3
158	Site_26_southsulawesi_1026	119.705	-3.94012	0.11	61.2	Mosaic cropland/vegetation	0	7.5	21.9	7,259	0.52	158	3

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159	Site_13_westjava_1589	107.552	-7.50026	0.15	24.3	Semi-deciduous forest	13	5.9	4.3	5,600	0.52	159	3
160	Site_31_maluku_1927	130.19	-3.47243	0.18	31.5	Rainfed croplands	206	6.5	4.0	8,068	0.52	160	3
161	Site_30_eastnusatenggara_8723	123.361	-8.50986	0.17	25.8	Rainfed croplands	114	5.9	3.9	3,772	0.52	161	3
162	Site_16_eastjava1_855	111.052	-8.18546	0.16	27.1	Mosaic cropland/vegetation	6	5.5	5.6	4,888	0.52	162	3
163	Site_16_eastjava1_1852	112.131	-8.23991	0.16	36.1	Mosaic cropland/vegetation	16	6.5	10.2	8,356	0.52	163	3
164	Site_27_southeastsulawesi_5323	121.647	-4.22537	0.10	35.9	Mosaic vegetation/cropland	16	7.1	8.5	6,525	0.52	164	3
165	Site_14_centraljava2_922	111.222	-8.18358	0.18	51.2	Semi-deciduous forest	1	4.6	6.0	8,098	0.52	165	3
166	Site_25_centralsulawesi2b_13884	123.012	-1.38141	0.24	101.5	Mosaic cropland/vegetation	46	4.5	9.4	4,857	0.52	166	3
167	Site_13_westjava_579	106.553	-6.96381	0.16	26.9	Semi-deciduous forest	1	6.4	4.0	2,400	0.52	167	3
168	Site_16_eastjava2_760	114.357	-8.07737	0.20	61.6	Semi-deciduous forest	6	4.8	9.3	6,541	0.52	168	3
169	Site_31_maluku_1309	128.416	-3.30409	0.18	15.3	Semi-deciduous forest	28	9.7	4.1	8,150	0.52	169	3
170	Site_35_papua_325	135.845	-0.88766	0.17	52.2	Semi-deciduous forest	380	9.3	15.3	7,770	0.52	170	3
171	Site_11_banten_1200	106.311	-6.91723	0.15	16.6	Semi-deciduous forest	0	7.3	5.0	6,515	0.52	171	3
172	Site_16_eastjava1_3214	112.454	-8.33067	0.16	25.8	Semi-deciduous forest	17	6.3	6.3	6,712	0.52	172	3
173	Site_11_banten_1256	106.536	-6.92165	0.19	56.8	Semi-deciduous forest	4	4.7	8.8	5,525	0.52	173	3
174	Site_13_westjava_323	106.536	-6.92165	0.19	56.6	Semi-deciduous forest	4	4.7	8.8	5,598	0.52	174	3
175	Site_14_centraljava2_144	109.95	-6.98534	0.16	23.3	Mosaic cropland/vegetation	0	7.9	6.4	7,245	0.52	175	3
176	Site_34_westpapua_679	134.309	-2.60797	0.18	23.8	Semi-deciduous forest	352	8.4	4.6	2,638	0.52	176	3
177	Site_14_centraljava2_1155	111.032	-8.22011	0.19	56.6	Semi-deciduous forest	9	5.8	9.1	3,362	0.52	177	3
178	Site_11_banten_984	106.295	-6.88123	0.16	31.2	Semi-deciduous forest	4	6.9	6.3	7,545	0.52	178	3
179	Site_13_westjava_51	106.295	-6.88123	0.16	30.9	Semi-deciduous forest	4	6.9	6.3	7,764	0.52	179	3
180	Site_30_eastnusatenggara_7782	121.03	-8.47101	0.21	56.7	Mosaic cropland/vegetation	28	4.6	4.8	6,211	0.52	180	3
181	Site_32_northmaluku_1908	128.596	0.46348	0.18	18.3	Semi-deciduous forest	140	10.0	6.5	8,571	0.52	181	3
182	Site_16_eastjava1_3158	112.466	-8.32287	0.16	25.5	Mosaic cropland/vegetation	16	6.3	7.9	7,769	0.52	182	3
183	Site_32_northmaluku_1959	128.496	0.43126	0.19	34.4	Semi-deciduous forest	130	7.8	8.2	4,461	0.52	183	3
184	Site_31_maluku_915	128.342	-3.2277	0.18	21.3	Mosaic cropland/vegetation	36	8.6	4.6	4,826	0.52	184	4
185	Site_32_northmaluku_2477	127.216	-0.38265	0.21	52.8	Semi-deciduous forest	127	5.3	5.8	5,847	0.52	185	4
186	Site_11_banten_1187	106.332	-6.91415	0.16	26.0	Rainfed croplands	1	6.1	5.1	7,754	0.52	186	4
187	Site_16_eastjava1_3098	112.465	-8.31844	0.16	23.2	Mosaic cropland/vegetation	16	6.4	4.6	8,268	0.52	187	4
188	Site_13_westjava_254	106.332	-6.91415	0.16	25.8	Rainfed croplands	1	6.1	5.1	7,901	0.52	188	4
189	Site_30_eastnusatenggara_6045	120.816	-8.39788	0.32	138.0	Mosaic cropland/vegetation	37	6.0	18.5	5,697	0.52	189	4
190	Site_16_eastjava1_2459	112.876	-8.26811	0.17	22.2	Mosaic cropland/vegetation	24	5.6	3.8	8,537	0.52	190	4
191	Site_16_eastjava1_717	111.019	-8.17668	0.19	47.3	Semi-deciduous forest	8	5.5	6.9	7,980	0.52	191	4
192	Site_32_northmaluku_1103	127.785	1.15405	0.21	43.5	Semi-deciduous forest	63	6.1	6.7	4,024	0.52	192	4
193	Site_32_northmaluku_2666	127.384	-0.44543	0.20	40.9	Mosaic cropland/vegetation	134	6.8	6.3	6,402	0.52	193	4
194	Site_31_maluku_828	126.173	-3.20798	0.22	54.9	Mosaic vegetation/cropland	226	5.2	4.5	2,931	0.52	194	4
195	Site_16_eastjava1_727	111.027	-8.17713	0.17	20.9	Semi-deciduous forest	7	6.2	3.2	7,357	0.52	195	4
196	Site_13_westjava_1055	106.547	-7.19438	0.19	46.4	Semi-deciduous forest	19	4.8	5.3	8,883	0.52	196	4
197	Site_35_papua_1871	134.558	-2.52019	0.22	78.1	Semi-deciduous forest	332	8.4	17.6	2,975	0.52	197	4
198	Site_32_northmaluku_1904	128.648	0.46681	0.20	28.2	Semi-deciduous forest	146	6.4	2.9	3,426	0.52	198	4
199	Site_11_banten_1271	106.358	-6.92571	0.18	46.3	Rainfed croplands	0	6.2	9.8	6,349	0.52	199	4
200	Site_35_papua_1309	138.87	-2.01712	0.18	19.4	Mosaic vegetation/cropland	144	8.3	4.0	5,275	0.52	200	4
201	Site_35_papua_157	135.83	-0.77932	0.19	25.6	Semi-deciduous forest	393	7.4	6.1	7,962	0.52	201	4
202	Site_32_northmaluku_670	127.917	1.60656	0.20	35.9	Mosaic cropland/vegetation	111	6.9	5.0	7,863	0.52	202	4
203	Site_35_papua_551	135.629	-1.66184	0.19	36.0	Semi-deciduous forest	315	8.2	12.0	2,619	0.52	203	4
204	Site_13_westjava_338	106.358	-6.92571	0.18	45.3	Rainfed croplands	0	6.4	9.8	6,899	0.52	204	4
205	Site_30_eastnusatenggara_6685	124.377	-8.4245	0.19	27.8	Mosaic cropland/vegetation	81	7.2	5.0	1,480	0.52	205	4
206	Site_32_northmaluku_703	128.65	1.53795	0.20	36.9	Mosaic vegetation/cropland	166	8.2	6.9	4,599	0.52	206	4
207	Site_35_papua_847	135.986	-1.74656	0.19	25.0	Semi-deciduous forest	287	5.9	1.8	5,947	0.52	207	4
208	Site_34_westpapua_919	134.384	-2.83269	0.19	19.2	Mosaic cropland/vegetation	331	9.6	4.6	6,219	0.52	208	4
209	Site_35_papua_2311	134.384	-2.83269	0.19	19.2	Mosaic cropland/vegetation	331	9.6	4.6	6,219	0.52	208	4
210	Site_28_bali_2111	115.022	-8.44371	0.20	31.7	Semi-deciduous forest	-	6.9	5.8	8,607	0.52	210	4
211	Site_32_northmaluku_1895	128.65	0.47015	0.20	26.5	Mosaic cropland/vegetation	145	6.8	5.2	3,007	0.52	211	4
212	Site_32_northmaluku_1942	127.863	0.43987	0.20	23.2	Semi-deciduous forest	65	8.5	4.9	4,320	0.52	212	4
213	Site_28_bali_2606	115.549	-8.73309	0.20	21.3	Rainfed croplands	9	6.2	3.2	4,979	0.52	213	4
214	Site_35_papua_86	135.797	-0.74043	0.22	56.5	Semi-deciduous forest	398	7.1	10.1	2,294	0.52	214	4
215	Site_31_maluku_19	128.318	-2.88103	0.22	44.2	Rainfed croplands	74	5.3	1.4	1,914	0.52	215	4
216	Site_22_northsulawesi_2328	124.632	1.12984	0.13	30.9	Mosaic vegetation/cropland	7	6.5	6.4	8,570	0.52	216	4
217	Site_29_westnusatenggara_910	117.551	-8.21508	0.20	37.2	Semi-deciduous forest	35	6.5	10.8	6,832	0.52	217	4
218	Site_27_southeastsulawesi_8865	122.866	-4.91673	0.15	40.5	Semi-deciduous forest	17	6.8	8.0	3,707	0.52	218	4
219	Site_30_eastnusatenggara_9857	122.558	-8.57114	0.21	42.0	Semi-deciduous forest	25	4.8	2.6	5,175	0.52	219	4
220	Site_11_banten_1241	106.523	-6.92015	0.18	20.7	Mosaic cropland/vegetation	4	6.2	4.6	5,074	0.51	220	4
221	Site_16_eastjava1_3345	112.459	-8.33442	0.19	39.6	Mosaic cropland/vegetation	18	5.7	8.2	6,602	0.51	221	4
222	Site_14_centraljava1_373	109.426	-7.73144	0.18	23.2	Semi-deciduous forest	10	6.1	5.3	3,479	0.51	222	4
223	Site_34_westpapua_584	134.561	-2.51658	0.22	61.5	Semi-deciduous forest	332	8.5	12.5	2,661	0.51	223	4
224	Site_22_northsulawesi_2458	124.624	1.12091	0.15	38.6	Rainfed croplands	7	6.9	8.0	8,561	0.51	224	4
225	Site_26_southsulawesi_1640	119.935	-5.48302	0.14	31.4	Rainfed croplands	5	5.0	2.7	6,793	0.51	225	4
226	Site_30_eastnusatenggara_6713	122.725	-8.4248	0.19	21.1	Mosaic cropland/vegetation	48	6.9	3.4	6,032	0.51	226	4
227	Site_14_centraljava2_1119	111.041	-8.21006	0.20	44.4	Semi-deciduous forest	8	6.2	9.4	3,992	0.51	227	4
228	Site_16_eastjava1_1279	111.041	-8.21006	0.20	44.4	Semi-deciduous forest	8	6.2	9.4	3,992	0.51	227	4
229	Site_16_eastjava1_3393	112.754	-8.33712	0.19	25.4	Rainfed croplands	20	5.1	2.5	5,794	0.51	229	4
230	Site_35_papua_998	136.089	-1.77906	0.22	53.3	Mosaic cropland/vegetation	279	7.5	6.9	7,205	0.51	230	4
231	Site_29_westnusatenggara_1556	117.56	-8.29182	0.20	26.1	Semi-deciduous forest	28	5.1	2.9	2,571	0.51	231	4
232	Site_35_papua_164	135.839	-0.78599	0.21	34.9	Semi-deciduous forest	392	7.0	5.8	7,726	0.51	232	4
233	Site_26_southsulawesi_1734	119.934	-5.49449	0.14	22.1	Mosaic cropland/vegetation	4	5.6	2.0	5,524	0.51	233	4
234	Site_28_bali_1624	114.878	-8.3795	0.21	23.1	Semi-deciduous forest	7	8.9	5.8	7,082	0.51	234	4
235	Site_25_centralsulawesi2b_10142	123.039	-1.19507	0.19	69.5	Rainfed croplands	36	6.0	11.0	1,922	0.51	235	4
236	Site_35_papua_133	135.859	-0.7671	0.21	29.1	Mosaic cropland/vegetation	392	6.8	1.5	4,695	0.51	236	4
237	Site_28_bali_2082	114.954	-8.43846	0.21	17.5	Semi-deciduous forest	4	6.6	2.5	4,588	0.51	237	4
238	Site_22_northsulawesi_2731	124.904	1.08132	0.14	18.3	Mosaic cropland/vegetation	16	7.7	4.0	5,330	0.51	238	4

No	Site Code	Outlet coordinate (x)	Outlet coordinate (y)	St.dev slope	Peak power (MWp)	Land covering	Distance from transmission line (km)	LCOS (c€/kWh)	Inundation area (Ha)	Distance from coastline (m)	Relative closeness (CP-TOPSIS)	Rank	Classification
239	Site_31_maluku_1127	129.932	-3.27187	0.21	20.3	Rainfed croplands	180	6.2	1.7	7,305	0.51	239	4
240	Site_16_eastjava1_3055	112.492	-8.31559	0.19	17.3	Rainfed croplands	15	6.8	4.4	8,841	0.51	240	4
241	Site_29_westnusatenggara_6456	118.134	-8.78132	0.21	29.9	No data	13	5.8	4.0	8,511	0.51	241	4
242	Site_16_eastjava2_842	114.352	-8.1274	0.19	22.9	Semi-deciduous forest	4	5.4	3.2	5,160	0.51	242	4
243	Site_32_northmaluku_311	128.545	2.15268	0.22	25.6	Semi-deciduous forest	202	6.5	3.4	3,699	0.51	243	4
244	Site_35_papua_161	135.857	-0.78849	0.21	31.9	Mosaic cropland/vegetation	391	7.3	8.1	6,432	0.51	244	4
245	Site_35_papua_863	136.018	-1.75823	0.21	26.3	Semi-deciduous forest	285	6.0	2.9	6,714	0.51	245	5
246	Site_22_northsulawesi_2656	124.916	1.09654	0.15	28.5	Semi-deciduous forest	15	6.5	6.1	5,734	0.51	246	5
247	Site_16_eastjava1_2370	112.314	-8.26189	0.22	63.3	Mosaic cropland/vegetation	9	5.6	11.0	7,805	0.51	247	5
248	Site_32_northmaluku_1861	128.568	0.49793	0.21	20.5	Rainfed croplands	136	7.8	3.5	7,079	0.51	248	5
249	Site_16_eastjava1_2538	112.328	-8.27584	0.20	24.8	Shrubland	11	5.9	3.1	6,114	0.51	249	5
250	Site_11_banten_1452	106.352	-6.95016	0.20	43.0	Rainfed croplands	2	6.4	11.0	4,899	0.51	250	5
251	Site_35_papua_213	135.789	-0.80793	0.22	45.8	Semi-deciduous forest	391	7.8	9.0	4,450	0.51	251	5
252	Site_22_northsulawesi_2276	124.953	1.12834	0.15	19.2	Rainfed croplands	16	7.1	4.2	5,150	0.51	252	5
253	Site_16_eastjava1_2328	112.323	-8.25881	0.19	16.5	Mosaic cropland/vegetation	9	6.8	3.9	8,021	0.51	253	5
254	Site_35_papua_1431	134.088	-2.29018	0.27	87.1	Semi-deciduous forest	338	5.4	7.7	7,285	0.51	254	5
255	Site_35_papua_1822	134.225	-2.50519	0.21	20.2	Semi-deciduous forest	363	8.4	5.7	6,334	0.51	255	5
256	Site_16_eastjava1_2261	111.664	-8.25536	0.22	44.4	Semi-deciduous forest	14	4.3	2.9	6,406	0.51	256	5
257	Site_31_maluku_579	128.305	-3.15048	0.22	18.3	Rainfed croplands	44	9.3	5.4	7,053	0.51	257	5
258	Site_25_centralsulawesi2a_5726	120.595	-1.36251	0.18	50.8	Mosaic vegetation/cropland	4	5.9	7.3	5,365	0.51	258	5
259	Site_26_southsulawesi_1257	119.651	-4.14626	0.23	81.9	Rainfed croplands	2	5.5	7.8	2,344	0.51	259	5
260	Site_31_maluku_3487	125.966	-7.7264	0.23	41.6	Mosaic cropland/vegetation	190	5.1	3.3	4,866	0.51	260	5
261	Site_22_northsulawesi_2084	124.975	1.21127	0.18	46.7	Semi-deciduous forest	14	5.0	5.5	7,184	0.51	261	5
262	Site_35_papua_1413	134.128	-2.26379	0.23	44.3	Mosaic cropland/vegetation	341	6.8	6.5	2,412	0.51	262	5
263	Site_30_eastnusatenggara_12017	121.352	-8.72453	0.24	60.9	Mosaic cropland/vegetation	15	5.0	6.8	8,240	0.51	263	5
264	Site_35_papua_622	135.845	-1.69351	0.22	21.4	Semi-deciduous forest	300	8.7	6.5	3,383	0.51	264	5
265	Site_32_northmaluku_3447	127.537	-1.51434	0.27	73.1	Semi-deciduous forest	243	5.0	6.8	7,656	0.51	265	5
266	Site_32_northmaluku_3661	127.605	-1.66906	0.22	18.9	Rainfed croplands	224	7.7	3.7	5,414	0.51	266	5
267	Site_16_eastjava1_722	111.234	-8.17541	0.25	69.7	Semi-deciduous forest	0	4.5	7.7	8,468	0.51	267	5
268	Site_35_papua_925	136.042	-1.76601	0.22	27.0	Semi-deciduous forest	283	5.8	2.7	6,184	0.51	268	5
269	Site_35_papua_2426	134.62	-3.00742	0.22	27.6	Semi-deciduous forest	299	5.9	2.0	8,879	0.51	269	5
270	Site_35_papua_738	135.926	-1.72045	0.24	49.8	Semi-deciduous forest	293	4.7	3.4	4,088	0.51	270	5
271	Site_16_eastjava1_616	110.954	-8.1667	0.20	18.1	Semi-deciduous forest	13	6.8	2.0	6,341	0.51	271	5
272	Site_25_centralsulawesi2b_12328	123.09	-1.31003	0.17	26.8	Mosaic vegetation/cropland	47	6.3	5.2	2,167	0.51	272	5
273	Site_30_eastnusatenggara_2561	123.241	-8.29422	0.22	35.0	Mosaic cropland/vegetation	106	7.4	10.7	5,981	0.51	273	5
274	Site_14_centraljava2_834	111.027	-8.17713	0.21	20.9	Semi-deciduous forest	7	6.2	3.2	7,357	0.51	274	5
275	Site_11_banten_1298	106.366	-6.92758	0.21	23.7	Mosaic cropland/vegetation	0	6.5	5.9	6,038	0.51	275	5
276	Site_30_eastnusatenggara_13075	120.773	-8.76834	0.22	28.2	Mosaic cropland/vegetation	4	6.6	3.6	8,212	0.51	276	5
277	Site_31_maluku_1176	129.956	-3.28298	0.23	24.7	Mosaic cropland/vegetation	182	5.9	2.2	6,797	0.51	277	5
278	Site_25_centralsulawesi2b_1654	122.921	-0.78708	0.18	40.6	Mosaic cropland/vegetation	27	4.6	2.6	2,441	0.51	278	5
279	Site_25_centralsulawesi2b_11917	123.054	-1.28888	0.17	24.8	Mosaic cropland/vegetation	43	6.6	5.2	6,786	0.51	279	5
280	Site_30_eastnusatenggara_12194	121.374	-8.73586	0.23	38.0	Mosaic cropland/vegetation	16	5.7	5.0	6,159	0.51	280	5
281	Site_30_eastnusatenggara_4617	124.205	-8.3519	0.31	107.0	Mosaic cropland/vegetation	99	4.9	9.0	4,462	0.51	281	5
282	Site_30_eastnusatenggara_4931	122.791	-8.36075	0.22	30.3	Mosaic cropland/vegetation	58	5.0	2.6	2,335	0.51	282	5
283	Site_25_centralsulawesi2b_7318	123.349	-1.00116	0.18	29.0	Mosaic cropland/vegetation	64	6.3	5.3	2,691	0.51	283	5
284	Site_22_northsulawesi_2146	124.635	1.18113	0.17	29.9	Rainfed croplands	5	7.2	6.7	5,735	0.50	284	5
285	Site_27_southeastsulawesi_3931	123.045	-4.03798	0.17	21.0	Mosaic vegetation/cropland	43	7.5	4.8	4,108	0.50	285	5
286	Site_25_centralsulawesi2b_2842	122.773	-0.82742	0.24	83.1	Mosaic cropland/vegetation	17	4.0	3.9	3,677	0.50	286	5
287	Site_22_northsulawesi_2544	124.612	1.11341	0.18	41.8	Rainfed croplands	8	6.9	7.6	8,377	0.50	287	5
288	Site_25_centralsulawesi2b_8811	121.96	-1.05335	0.26	93.4	Mosaic cropland/vegetation	61	3.7	4.4	6,498	0.50	288	5
289	Site_25_centralsulawesi2b_8993	121.937	-1.06565	0.43	204.2	Rainfed croplands	62	5.6	17.1	7,752	0.50	289	5
290	Site_29_westnusatenggara_2725	116.228	-8.36352	0.23	21.9	Mosaic vegetation/cropland	5	6.1	4.2	5,975	0.50	290	5
291	Site_16_eastjava1_1850	111.925	-8.23646	0.23	59.0	Semi-deciduous forest	13	6.5	12.9	5,099	0.50	291	5
292	Site_14_centraljava2_910	111.235	-8.18141	0.21	18.2	Mosaic cropland/vegetation	1	5.9	2.7	7,799	0.50	292	5
293	Site_16_eastjava1_1715	111.513	-8.23174	0.22	29.3	Semi-deciduous forest	16	5.1	3.6	7,713	0.50	293	5
294	Site_29_westnusatenggara_5971	118.119	-8.73181	0.29	91.0	Semi-deciduous forest	8	4.8	9.7	8,086	0.50	294	5
295	Site_30_eastnusatenggara_2674	123.251	-8.29812	0.22	26.4	Mosaic cropland/vegetation	107	7.7	4.3	5,912	0.50	295	5
296	Site_16_eastjava2_1022	113.061	-8.23211	0.21	21.7	Mosaic cropland/vegetation	20	7.3	7.3	5,982	0.50	296	5
297	Site_27_southeastsulawesi_5898	122.606	-4.29653	0.18	38.4	Semi-deciduous forest	26	7.5	7.9	7,440	0.50	297	5
298	Site_27_southeastsulawesi_9042	122.851	-4.97027	0.18	27.1	Mosaic vegetation/cropland	18	6.1	5.6	4,021	0.50	298	5
299	Site_30_eastnusatenggara_4874	122.802	-8.3582	0.23	29.3	Rainfed croplands	59	5.1	1.7	3,368	0.50	299	5
300	Site_16_eastjava2_561	113.76	-7.81454	0.23	40.6	Rainfed croplands	8	4.9	4.2	8,544	0.50	300	5
301	Site_30_eastnusatenggara_7763	120.17	-8.47003	0.22	19.0	Mosaic cropland/vegetation	20	8.7	5.0	7,149	0.50	301	5
302	Site_30_eastnusatenggara_7098	122.653	-8.44431	0.22	24.7	Mosaic cropland/vegetation	40	8.5	6.0	5,963	0.50	302	5
303	Site_32_northmaluku_566	127.62	1.77823	0.24	26.2	Mosaic cropland/vegetation	116	7.8	4.7	899	0.50	303	5
304	Site_22_northsulawesi_2472	124.904	1.11956	0.18	20.0	Mosaic vegetation/cropland	13	6.6	4.1	8,504	0.50	304	5
305	Site_22_northsulawesi_6308	124.56	0.74786	0.23	69.5	Mosaic cropland/vegetation	16	4.9	5.9	6,226	0.50	305	5
306	Site_30_eastnusatenggara_2608	124.19	-8.30052	0.23	38.0	Rainfed croplands	105	7.0	8.3	2,417	0.50	306	6
307	Site_22_northsulawesi_1252	124.725	1.35427	0.18	24.0	Rainfed croplands	0	6.7	4.3	6,477	0.50	307	6
308	Site_16_eastjava1_3441	112.909	-8.33787	0.23	38.4	Semi-deciduous forest	31	4.4	3.1	2,838	0.50	308	6
309	Site_30_eastnusatenggara_1426	124.275	-8.22851	0.23	26.4	Mosaic vegetation/cropland	105	5.6	3.4	4,295	0.50	309	6
310	Site_25_centralsulawesi2a_5744	120.595	-1.36551	0.19	40.1	Mosaic vegetation/cropland	4	6.0	5.8	5,378	0.50	310	6
311	Site_22_northsulawesi_5442	123.733	0.80058	0.19	26.8	Semi-deciduous forest	3	5.5	1.5	3,957	0.50	311	6
312	Site_13_westjava_1787	107.685	-7.56462	0.22	20.5	Semi-deciduous forest	1	7.1	6.0	6,163	0.50	312	6
313	Site_22_northsulawesi_2436	124.594	1.12316	0.19	41.5	Rainfed croplands	6	7.4	11.5	6,462	0.50	313	6
314	Site_30_eastnusatenggara_3593	120.393	-8.32384	0.23	20.7	Mosaic cropland/vegetation	30	7.5	3.6	4,000	0.50	314	6
315	Site_34_westpapua_954	134.632	-2.88797	0.23	21.6	Mosaic vegetation/cropland	305	7.0	2.8	4,706	0.50	315	6
316	Site_35_papua_2347	134.632	-2.88797	0.23	21.6	Mosaic vegetation/cropland	305	7.0	2.8	4,706	0.50	315	6
317	Site_35_papua_2609	134.974	-3.37215	0.24	20.9	Semi-deciduous forest	245	6.7	3.5	4,955	0.50	317	6
318	Site_29_westnusatenggara_2578	118.812	-8.35325	0.24	40.4	Mosaic cropland/vegetation	12	7.4	14.3	6,358	0.50	318	6

No	Site Code	Outlet coordinate (x)	Outlet coordinate (y)	St.dev slope	Peak power (MWp)	Land covering	Distance from transmission line (km)	LCOS (c€/kWh)	Inundation area (Ha)	Distance from coastline (m)	Relative closeness (CP-TOPSIS)	Rank	Classi-fication
319	Site_31_maluku_3765	126.48	-7.8064	0.24	29.2	Semi-deciduous forest	226	5.4	2.5	7,338	0.50	319	6
320	Site_25_centralsulawesi2b_8649	121.749	-1.04608	0.20	38.4	Rainfed croplands	79	5.6	4.6	8,461	0.50	320	6
321	Site_32_northmaluku_1917	128.521	0.4582	0.26	83.9	Mosaic cropland/vegetation	132	7.7	21.2	8,434	0.50	321	6
322	Site_16_eastjava1_492	110.924	-8.15688	0.23	24.1	Mosaic cropland/vegetation	15	6.5	5.7	6,203	0.50	322	6
323	Site_14_centraljava2_611	110.924	-8.15688	0.23	24.1	Mosaic cropland/vegetation	15	6.5	5.7	6,203	0.50	323	6
324	Site_32_northmaluku_3647	127.491	-1.66128	0.24	29.7	Mosaic cropland/vegetation	230	8.4	7.0	4,448	0.50	324	6
325	Site_22_northsulawesi_2185	124.99	1.16246	0.21	60.7	Semi-deciduous forest	19	7.0	10.7	3,950	0.50	325	6
326	Site_30_eastnusatenggara_13289	120.237	-8.77599	0.24	27.1	Semi-deciduous forest	10	5.4	1.8	6,191	0.50	326	6
327	Site_25_centralsulawesi2b_4590	122.701	-0.87571	0.22	60.2	Mosaic cropland/vegetation	15	4.1	2.4	7,231	0.50	327	6
328	Site_32_northmaluku_2562	127.203	-0.4132	0.25	35.3	Semi-deciduous forest	130	6.3	5.6	6,615	0.50	328	6
329	Site_29_westnusatenggara_6360	118.125	-8.78012	0.24	37.0	Semi-deciduous forest	13	7.2	9.1	8,061	0.50	329	6
330	Site_16_eastjava1_2463	112.314	-8.26856	0.23	41.1	Mosaic cropland/vegetation	10	5.8	9.8	7,078	0.50	330	6
331	Site_34_westpapua_432	134.102	-2.26241	0.24	28.8	Mosaic cropland/vegetation	338	5.9	4.8	4,795	0.50	331	6
332	Site_35_papua_1415	134.102	-2.26241	0.24	28.8	Mosaic cropland/vegetation	338	5.9	4.8	4,795	0.50	331	6
333	Site_14_centraljava2_634	110.918	-8.15995	0.23	26.8	Mosaic cropland/vegetation	16	6.1	4.3	5,693	0.50	333	6
334	Site_25_centralsulawesi2b_12093	122.866	-1.2951	0.19	26.8	Rainfed croplands	28	5.1	2.4	3,661	0.50	334	6
335	Site_22_northsulawesi_1462	124.723	1.33725	0.19	21.7	Mosaic vegetation/cropland	1	7.5	5.1	8,180	0.50	335	6
336	Site_30_eastnusatenggara_5067	124.67	-8.36397	0.25	50.5	Semi-deciduous forest	73	6.0	4.8	2,928	0.50	336	6
337	Site_25_centralsulawesi2b_15011	123.426	-1.43548	0.21	43.4	Mosaic cropland/vegetation	86	5.1	3.8	6,032	0.50	337	6
338	Site_25_centralsulawesi2a_6470	120.833	-1.46854	0.23	63.1	Mosaic cropland/vegetation	6	5.0	6.2	6,984	0.50	338	6
339	Site_35_papua_1907	140.593	-2.53213	0.33	111.1	Semi-deciduous forest	5	4.1	4.6	8,428	0.50	339	6
340	Site_32_northmaluku_3175	127.835	-0.80432	0.27	54.0	Mosaic cropland/vegetation	181	6.5	10.7	3,066	0.50	340	6
341	Site_30_eastnusatenggara_7279	123.508	-8.44963	0.30	91.5	Semi-deciduous forest	131	4.9	5.9	5,490	0.50	341	6
342	Site_25_centralsulawesi2b_13014	123.067	-1.34302	0.21	42.5	Rainfed croplands	48	5.8	6.1	2,434	0.50	342	6
343	Site_23_gorontalo_3093	123.046	0.87016	0.20	28.9	Mosaic vegetation/cropland	5	6.9	5.3	5,548	0.50	343	6
344	Site_22_northsulawesi_1976	124.691	1.24974	0.20	19.1	Rainfed croplands	3	6.5	3.2	8,703	0.50	344	6
345	Site_27_southeastsulawesi_12016	123.053	-5.39026	0.20	21.8	Mosaic cropland/vegetation	43	6.4	3.3	3,614	0.50	345	6
346	Site_16_eastjava1_2648	112.316	-8.28559	0.25	47.2	Shrubland	12	5.4	9.0	5,185	0.50	346	6
347	Site_25_centralsulawesi2b_12344	122.923	-1.3107	0.20	29.3	Semi-deciduous forest	34	5.4	1.1	8,845	0.49	347	6
348	Site_30_eastnusatenggara_107	122.855	-8.13078	0.25	29.9	Mosaic cropland/vegetation	79	5.9	3.0	4,704	0.49	348	6
349	Site_35_papua_491	134.124	-1.43878	0.28	67.1	Mosaic cropland/vegetation	312	5.8	3.5	8,457	0.49	349	6
350	Site_16_eastjava1_3722	112.632	-8.35955	0.24	39.4	Semi-deciduous forest	20	6.2	6.6	7,244	0.49	350	6
351	Site_25_centralsulawesi2b_10741	123.164	-1.22627	0.22	51.0	Mosaic cropland/vegetation	49	6.5	4.4	2,549	0.49	351	6
352	Site_27_southeastsulawesi_3558	121.408	-3.92265	0.20	21.7	Rainfed croplands	7	6.0	2.2	7,356	0.49	352	6
353	Site_30_eastnusatenggara_5203	120.499	-8.3675	0.31	97.1	Mosaic vegetation/cropland	26	5.5	12.0	5,994	0.49	353	6
354	Site_16_eastjava1_212	110.777	-8.1262	0.25	45.4	Shrubland	23	6.2	7.5	7,418	0.49	354	6
355	Site_14_centraljava2_330	110.777	-8.1262	0.25	45.4	Shrubland	23	6.6	7.5	7,418	0.49	355	6
356	Site_26_southsulawesi_1382	119.702	-4.24096	0.20	17.1	Semi-deciduous forest	6	7.0	2.7	8,164	0.49	356	6
357	Site_16_eastjava1_1671	111.21	-8.22956	0.24	24.0	Semi-deciduous forest	6	5.6	4.1	3,527	0.49	357	6
358	Site_30_eastnusatenggara_5382	120.347	-8.37252	0.25	21.8	Mosaic cropland/vegetation	25	6.3	2.8	8,696	0.49	358	6
359	Site_22_northsulawesi_2100	124.993	1.20272	0.21	20.7	Mosaic cropland/vegetation	16	6.6	3.8	4,978	0.49	359	6
360	Site_25_centralsulawesi2b_4951	122.916	-0.89431	0.21	21.9	Rainfed croplands	18	7.1	4.3	2,802	0.49	360	6
361	Site_30_eastnusatenggara_2262	125.067	-8.28139	0.25	21.6	Rainfed croplands	85	7.8	3.8	6,738	0.49	361	6
362	Site_14_centraljava1_54	109.93	-6.96463	0.25	31.4	Semi-deciduous forest	2	6.8	6.9	5,488	0.49	362	6
363	Site_30_eastnusatenggara_10929	122.564	-8.6475	0.25	25.1	Semi-deciduous forest	25	6.0	4.5	1,945	0.49	363	6
364	Site_35_papua_963	136.683	-1.77212	0.27	59.6	Mosaic cropland/vegetation	259	7.9	15.2	4,642	0.49	364	6
365	Site_31_maluku_4344	128.939	-8.21058	0.26	24.9	Mosaic cropland/vegetation	462	7.8	5.7	1,526	0.49	365	6
366	Site_34_westpapua_316	134.065	-1.95546	0.33	126.5	Semi-deciduous forest	321	7.3	14.9	7,757	0.49	366	6
367	Site_25_centralsulawesi2b_5600	123.334	-0.93338	0.22	36.7	Mosaic cropland/vegetation	62	6.2	6.9	5,443	0.49	367	7
368	Site_29_westnusatenggara_668	118.044	-8.18763	0.29	76.8	Semi-deciduous forest	48	4.1	1.4	8,880	0.49	368	7
369	Site_16_eastjava1_823	111.235	-8.18141	0.25	18.2	Mosaic cropland/vegetation	1	5.8	2.7	7,799	0.49	369	7
370	Site_14_centraljava1_313	109.43	-7.70503	0.25	24.1	Semi-deciduous forest	7	5.5	3.5	3,974	0.49	370	7
371	Site_35_papua_1690	140.17	-2.47019	0.26	24.0	Semi-deciduous forest	10	7.4	3.7	8,073	0.49	371	7
372	Site_32_northmaluku_3400	127.846	-1.46989	0.29	55.9	Mosaic cropland/vegetation	237	4.7	1.8	3,359	0.49	372	7
373	Site_25_centralsulawesi2a_1686	119.798	-0.4483	0.30	126.7	Semi-deciduous forest	30	6.9	19.4	3,981	0.49	373	7
374	Site_25_centralsulawesi2b_5995	123.325	-0.95122	0.24	63.4	Mosaic vegetation/cropland	60	6.6	8.3	6,439	0.49	374	7
375	Site_29_westnusatenggara_2532	118.835	-8.34882	0.29	74.4	Rainfed croplands	14	5.4	12.2	7,047	0.49	375	7
376	Site_35_papua_1599	140.268	-2.43796	0.28	57.2	Mosaic cropland/vegetation	15	6.2	4.5	1,618	0.49	376	7
377	Site_29_westnusatenggara_6195	118.156	-8.76541	0.28	55.7	Semi-deciduous forest	11	6.0	9.7	8,613	0.49	377	7
378	Site_35_papua_183	135.584	-0.79738	0.27	41.6	Semi-deciduous forest	402	4.7	2.5	2,968	0.49	378	7
379	Site_25_centralsulawesi2b_14169	122.962	-1.39716	0.22	29.5	Semi-deciduous forest	43	5.4	2.2	8,609	0.49	379	7
380	Site_28_bali_2158	115.487	-8.44768	0.29	51.9	Mosaic cropland/vegetation	5	5.2	5.6	7,260	0.49	380	7
381	Site_23_gorontalo_3816	122.954	0.82547	0.23	29.9	Mosaic cropland/vegetation	3	6.4	6.0	4,958	0.49	381	7
382	Site_34_westpapua_87	135.578	-0.77849	0.29	56.4	Semi-deciduous forest	404	4.2	1.2	3,737	0.48	382	7
383	Site_35_papua_1736	140.198	-2.47963	0.27	35.3	Mosaic cropland/vegetation	10	6.8	6.3	7,548	0.48	383	7
384	Site_25_centralsulawesi2a_1656	119.797	-0.44395	0.27	96.0	Mosaic cropland/vegetation	30	6.8	14.4	3,951	0.48	384	7
385	Site_25_centralsulawesi2b_13899	123.013	-1.38239	0.25	51.5	Mosaic cropland/vegetation	46	4.5	6.6	4,718	0.48	385	7
386	Site_25_centralsulawesi2b_7540	121.727	-1.00724	0.23	26.0	Rainfed croplands	84	7.3	4.1	5,274	0.48	386	7
387	Site_22_northsulawesi_3106	124.377	0.98234	0.23	29.9	Mosaic cropland/vegetation	12	6.0	4.9	8,030	0.48	387	7
388	Site_25_centralsulawesi2b_6980	123.301	-0.99051	0.23	25.2	Rainfed croplands	58	6.6	3.3	5,710	0.48	388	7
389	Site_25_centralsulawesi1_9565	120.846	0.46	0.23	35.0	Mosaic cropland/vegetation	129	6.3	7.5	1,565	0.48	389	7
390	Site_31_maluku_4051	126.481	-7.86891	0.28	24.3	Mosaic cropland/vegetation	222	6.7	2.4	3,797	0.48	390	7
391	Site_30_eastnusatenggara_10895	122.581	-8.64458	0.29	55.3	Rainfed croplands	27	4.9	4.8	1,919	0.48	391	7
392	Site_25_centralsulawesi2b_7063	121.527	-0.99464	0.23	23.4	Rainfed croplands	96	5.8	3.0	8,679	0.48	392	7
393	Site_23_gorontalo_2112	122.326	0.94005	0.23	21.0	Semi-deciduous forest	41	6.7	1.1	7,287	0.48	393	7
394	Site_35_papua_1620	140.182	-2.44908	0.28	49.3	Mosaic cropland/vegetation	12	6.3	6.9	5,384	0.48	394	7
395	Site_34_westpapua_642	134.269	-2.57297	0.27	17.3	No data	358	9.6	5.3	5,654	0.48	395	7
396	Site_30_eastnusatenggara_10870	121.36	-8.64338	0.28	37.7	Mosaic vegetation/cropland	7	5.7	4.8	8,655	0.48	396	7
397	Site_29_westnusatenggara_6405	118.569	-8.77817	0.27	32.9	Mosaic vegetation/cropland	21	7.0	6.7	7,313	0.48	397	7
398	Site_16_eastjava1_1928	111.538	-8.23954	0.26	18.2	Shrubland	18	6.0	2.9	7,516	0.48	398	7

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399	Site_28_bali_2032	115.001	-8.43703	0.29	46.2	Semi-deciduous forest	3	6.3	9.2	8,279	0.48	399	7
400	Site_32_northmaluku_2844	127.416	-0.53015	0.29	36.5	Semi-deciduous forest	143	5.8	3.5	6,666	0.48	400	7
401	Site_25_centralsulawesi1_10251	119.876	0.35577	0.24	41.3	Rainfed croplands	119	6.1	6.3	1,766	0.48	401	7
402	Site_30_eastnusatenggara_6199	124.545	-8.40328	0.28	35.9	Rainfed croplands	73	5.6	4.1	2,869	0.48	402	7
403	Site_25_centralsulawesi1_1959	121.377	1.14963	0.24	20.4	Mosaic cropland/vegetation	103	6.8	4.2	5,879	0.48	403	7
404	Site_31_maluku_2445	126.421	-3.66132	0.29	45.6	Semi-deciduous forest	193	5.9	5.2	5,821	0.48	404	7
405	Site_16_eastjava1_641	110.978	-8.17008	0.27	20.9	Mosaic cropland/vegetation	11	6.5	4.9	6,719	0.48	405	7
406	Site_14_centraljava2_762	110.978	-8.17008	0.27	20.9	Mosaic cropland/vegetation	11	6.6	4.9	6,719	0.48	406	7
407	Site_25_centralsulawesi2a_3311	119.939	-0.77043	0.24	17.0	Mosaic cropland/vegetation	4	8.2	4.6	7,708	0.48	407	7
408	Site_35_papua_2197	134.359	-2.71436	0.28	36.9	Mosaic cropland/vegetation	341	8.3	7.5	3,309	0.48	408	7
409	Site_25_centralsulawesi1_9609	120.834	0.45707	0.27	68.4	No data	130	6.3	9.8	1,335	0.48	409	7
410	Site_32_northmaluku_2683	127.567	-0.45126	0.29	24.5	Semi-deciduous forest	136	6.5	2.8	6,820	0.48	410	7
411	Site_35_papua_615	135.968	-1.68739	0.28	33.5	Semi-deciduous forest	294	6.8	6.9	3,636	0.48	411	7
412	Site_25_centralsulawesi2b_13130	123.02	-1.34782	0.24	26.4	Semi-deciduous forest	44	5.4	2.7	6,194	0.48	412	7
413	Site_34_westpapua_512	134.136	-2.4088	0.28	32.3	Mosaic cropland/vegetation	349	9.4	6.6	7,000	0.48	413	7
414	Site_28_bali_1696	115.594	-8.39015	0.29	32.1	Semi-deciduous forest	6	6.7	4.2	8,099	0.48	414	7
415	Site_35_papua_1876	140.332	-2.52158	0.29	40.9	Semi-deciduous forest	8	5.6	3.2	6,238	0.48	415	7
416	Site_16_eastjava2_326	113.592	-7.75259	0.27	25.2	Mosaic cropland/vegetation	3	6.8	7.8	3,846	0.48	416	7
417	Site_25_centralsulawesi2a_4912	120.529	-1.09902	0.25	42.3	Mosaic cropland/vegetation	4	6.5	7.2	3,479	0.47	417	7
418	Site_30_eastnusatenggara_3295	120.634	-8.31747	0.28	23.5	Rainfed croplands	33	7.3	5.0	3,400	0.47	418	7
419	Site_35_papua_1420	134.075	-2.27185	0.29	24.6	Semi-deciduous forest	336	7.5	5.1	7,877	0.47	419	7
420	Site_22_northsulawesi_6374	124.532	0.72567	0.25	19.2	Semi-deciduous forest	16	6.0	1.8	6,436	0.47	420	7
421	Site_27_southeastsulawesi_11614	121.905	-5.34212	0.25	24.1	Semi-deciduous forest	69	6.1	1.1	5,348	0.47	421	7
422	Site_25_centralsulawesi1_1351	121.331	1.1962	0.27	55.5	Mosaic cropland/vegetation	110	5.7	6.3	6,261	0.47	422	7
423	Site_29_westnusatenggara_3158	116.224	-8.3927	0.29	18.3	Mosaic cropland/vegetation	7	6.3	3.2	7,477	0.47	423	7
424	Site_30_eastnusatenggara_5313	120.281	-8.3705	0.29	30.7	Rainfed croplands	27	5.9	4.5	8,673	0.47	424	7
425	Site_32_northmaluku_1457	128.169	0.84238	0.29	20.1	Mosaic cropland/vegetation	89	8.9	5.0	5,520	0.47	425	7
426	Site_27_southeastsulawesi_11394	121.895	-5.31962	0.25	22.3	Mosaic cropland/vegetation	67	6.7	1.2	5,652	0.47	426	7
427	Site_25_centralsulawesi2b_12054	123.35	-1.29308	0.27	50.8	Rainfed croplands	71	6.1	7.2	2,971	0.47	427	7
428	Site_35_papua_2238	134.335	-2.75658	0.29	24.1	Mosaic cropland/vegetation	340	10.1	7.9	7,870	0.47	428	8
429	Site_14_centraljava1_236	109.447	-7.67375	0.29	40.1	Mosaic cropland/vegetation	3	6.4	6.5	7,429	0.47	429	8
430	Site_25_centralsulawesi2b_13274	123.458	-1.35524	0.25	20.7	Semi-deciduous forest	85	8.8	9.5	8,530	0.47	430	8
431	Site_25_centralsulawesi2b_3824	122.762	-0.85059	0.26	42.5	Mosaic vegetation/cropland	15	4.9	1.9	5,352	0.47	431	8
432	Site_35_papua_1716	140.213	-2.47491	0.30	37.2	Semi-deciduous forest	10	6.1	5.0	6,423	0.47	432	8
433	Site_23_gorontalo_755	121.712	0.98654	0.25	21.3	Semi-deciduous forest	65	5.7	1.3	5,593	0.47	433	8
434	Site_30_eastnusatenggara_4913	124.043	-8.36202	0.29	28.3	Mosaic cropland/vegetation	112	5.3	2.6	4,783	0.47	434	8
435	Site_25_centralsulawesi2b_1277	123.093	-0.76174	0.25	17.1	Semi-deciduous forest	43	7.0	3.3	8,235	0.47	435	8
436	Site_30_eastnusatenggara_914	124.852	-8.20211	0.29	29.6	Rainfed croplands	89	5.6	3.9	3,910	0.47	436	8
437	Site_31_maluku_2385	126.403	-3.64188	0.30	23.9	Mosaic vegetation/cropland	195	7.7	4.3	7,471	0.47	437	8
438	Site_25_centralsulawesi2a_2434	119.867	-0.60802	0.26	25.6	Mosaic cropland/vegetation	14	7.5	6.8	6,567	0.47	438	8
439	Site_32_northmaluku_2330	127.199	-0.28209	0.30	35.3	Semi-deciduous forest	116	6.6	6.4	2,724	0.47	439	8
440	Site_32_northmaluku_3580	127.887	-1.62017	0.30	22.3	Mosaic cropland/vegetation	220	7.9	3.4	6,925	0.47	440	8
441	Site_25_centralsulawesi2b_15649	123.19	-1.46749	0.26	29.5	Rainfed croplands	67	5.6	3.3	1,657	0.47	441	8
442	Site_25_centralsulawesi2a_3277	119.946	-0.76691	0.26	15.6	Semi-deciduous forest	4	8.2	4.2	8,576	0.47	442	8
443	Site_23_gorontalo_4251	122.779	0.75881	0.26	24.7	Mosaic cropland/vegetation	7	6.0	3.6	7,752	0.47	443	8
444	Site_30_eastnusatenggara_7460	120.13	-8.46021	0.30	34.3	Mosaic cropland/vegetation	19	7.3	6.1	2,984	0.47	444	8
445	Site_22_northsulawesi_1554	125.014	1.32952	0.28	53.7	Semi-deciduous forest	6	4.4	7.2	5,478	0.47	445	8
446	Site_27_southeastsulawesi_287	121.13	-2.95212	0.27	47.9	Mosaic cropland/vegetation	4	4.5	3.2	4,512	0.47	446	8
447	Site_25_centralsulawesi1_5145	120.281	0.86439	0.27	28.5	Mosaic cropland/vegetation	177	6.1	5.3	4,314	0.47	447	8
448	Site_16_eastjava1_648	111.275	-8.16933	0.29	20.0	Mosaic cropland/vegetation	0	6.7	3.9	8,784	0.47	448	8
449	Site_25_centralsulawesi2a_5376	120.534	-1.26016	0.27	29.1	Mosaic cropland/vegetation	3	6.2	4.7	4,187	0.46	449	8
450	Site_16_eastjava1_3017	112.794	-8.31334	0.31	56.0	Rainfed croplands	20	4.3	4.0	7,195	0.46	450	8
451	Site_25_centralsulawesi2b_11599	122.886	-1.27223	0.28	41.6	Mosaic cropland/vegetation	28	4.3	2.8	2,910	0.46	451	8
452	Site_30_eastnusatenggara_13598	120.734	-8.79189	0.31	38.5	Mosaic vegetation/cropland	0	5.6	5.0	8,246	0.46	452	8
453	Site_28_bali_2221	115.456	-8.45233	0.31	30.3	Mosaic cropland/vegetation	7	6.6	4.1	8,607	0.46	453	8
454	Site_30_eastnusatenggara_9958	121.872	-8.5779	0.31	22.9	Mosaic vegetation/cropland	8	5.9	1.9	8,740	0.46	454	8
455	Site_16_eastjava1_670	111.262	-8.17173	0.30	17.2	Mosaic cropland/vegetation	0	6.2	2.2	8,413	0.46	455	8
456	Site_16_eastjava1_2999	112.804	-8.31244	0.31	37.5	Semi-deciduous forest	20	4.6	3.4	6,904	0.46	456	8
457	Site_22_northsulawesi_2737	124.859	1.07607	0.29	47.7	Mosaic vegetation/cropland	13	6.3	9.1	8,451	0.46	457	8
458	Site_16_eastjava1_1447	111.249	-8.21973	0.31	21.3	Semi-deciduous forest	5	6.5	5.6	3,268	0.46	458	8
459	Site_35_papua_2958	134.368	-3.85994	0.32	23.9	Semi-deciduous forest	283	6.5	3.0	3,653	0.46	459	8
460	Site_23_gorontalo_3871	122.989	0.82427	0.28	20.8	Semi-deciduous forest	7	5.9	2.1	8,441	0.46	460	8
461	Site_16_eastjava1_1951	112.917	-8.24471	0.31	26.1	Semi-deciduous forest	27	5.3	3.4	7,875	0.46	461	8
462	Site_25_centralsulawesi1_9033	120.871	0.50904	0.28	15.0	Semi-deciduous forest	126	8.9	4.8	7,549	0.45	462	8
463	Site_16_eastjava1_2399	112.926	-8.26339	0.31	38.0	Semi-deciduous forest	28	6.6	7.3	5,599	0.45	463	8
464	Site_23_gorontalo_704	121.896	0.98849	0.29	34.8	Semi-deciduous forest	56	5.5	1.2	8,493	0.45	464	8
465	Site_25_centralsulawesi2b_4864	122.728	-0.88974	0.30	61.7	Rainfed croplands	12	4.2	1.6	8,457	0.45	465	8
466	Site_25_centralsulawesi2b_15242	122.946	-1.44755	0.31	68.7	Mosaic cropland/vegetation	45	4.2	4.0	8,656	0.45	466	8
467	Site_25_centralsulawesi2b_13613	123.379	-1.36979	0.29	17.7	Semi-deciduous forest	78	6.6	3.3	8,061	0.45	467	8
468	Site_16_eastjava2_994	113.082	-8.21508	0.31	29.1	Mosaic cropland/vegetation	17	7.5	9.7	7,913	0.45	468	8
469	Site_10_lampung_1605	104.292	-5.47879	0.09	34.3	Mosaic cropland/vegetation	14	5.5	7.2	8,144	0.45	469	8
470	Site_23_gorontalo_1764	122.524	0.954	0.29	27.2	Semi-deciduous forest	32	4.9	2.2	2,059	0.45	470	8
471	Site_31_maluku_1835	130.071	-3.43993	0.33	27.3	Mosaic cropland/vegetation	193	7.6	4.5	5,811	0.45	471	8
472	Site_30_eastnusatenggara_2180	125.035	-8.27809	0.32	17.8	Mosaic cropland/vegetation	84	7.6	3.6	8,314	0.45	472	8
473	Site_05_westsumatra_22	98.4523	-0.46247	0.08	22.7	Mosaic cropland/vegetation	135	6.3	5.3	5,732	0.45	473	8
474	Site_30_eastnusatenggara_4547	122.816	-8.35062	0.33	34.1	Mosaic cropland/vegetation	61	4.9	2.1	4,335	0.45	474	8
475	Site_34_westpapua_1848	134.255	-3.95411	0.33	38.9	Semi-deciduous forest	292	5.9	4.0	2,023	0.45	475	8
476	Site_24_westsulawesi_1886	118.79	-2.808	0.30	39.4	Rainfed croplands	8	4.7	4.5	2,073	0.45	476	8
477	Site_32_northmaluku_2759	127.967	-0.47987	0.34	44.7	Rainfed croplands	153	5.3	5.7	4,158	0.45	477	8
478	Site_35_papua_160	135.622	-0.78488	0.33	20.8	Semi-deciduous forest	401	6.4	2.3	6,846	0.45	478	8

No	Site Code	Outlet coordinate (x)	Outlet coordinate (y)	St.dev slope	Peak power (MWp)	Land covering	Distance from transmission line (km)	LCOS (c€/kWh)	Inundation area (Ha)	Distance from coastline (m)	Relative closeness (CP-TOPSIS)	Rank	Classifi-cation
479	Site_02_northsumatra_1704	97.8603	0.62913	0.11	37.7	Semi-deciduous forest	3	5.2	6.8	3,448	0.45	479	8
480	Site_25_centralsulawesi1_8304	120.455	0.53821	0.33	77.0	Semi-deciduous forest	145	3.7	3.1	4,987	0.45	480	8
481	Site_34_westpapua_1957	134.952	-4.20439	0.33	20.6	Rainfed croplands	210	6.4	3.9	8,242	0.45	481	8
482	Site_10_lampung_1679	104.33	-5.49634	0.10	19.3	Semi-deciduous forest	13	7.2	5.3	8,883	0.45	482	8
483	Site_05_westsumatra_28	98.4403	-0.46689	0.11	33.2	Mosaic cropland/vegetation	135	6.2	8.0	6,658	0.45	483	8
484	Site_02_northsumatra_1100	97.5256	1.31499	0.11	37.9	Semi-deciduous forest	20	6.2	13.1	6,779	0.44	484	8
485	Site_10_lampung_1546	104.257	-5.46491	0.11	16.2	Rainfed croplands	16	6.6	4.6	6,987	0.44	485	8
486	Site_16_eastjava1_1128	111.271	-8.20023	0.33	75.8	Semi-deciduous forest	2	6.3	16.2	5,320	0.44	486	8
487	Site_02_northsumatra_1104	97.5204	1.31072	0.12	34.8	Mosaic vegetation/cropland	20	6.4	8.2	7,525	0.44	487	8
488	Site_01_aceh_77	95.6273	5.53247	0.13	38.2	Rainfed croplands	13	5.8	7.2	7,861	0.44	488	8
489	Site_02_northsumatra_1096	97.5211	1.31859	0.12	15.5	Semi-deciduous forest	21	7.1	4.6	6,952	0.44	489	9
490	Site_35_papua_1440	134.089	-2.3038	0.34	28.6	Mosaic cropland/vegetation	339	6.7	3.3	7,430	0.44	490	9
491	Site_30_eastnusatenggara_2066	124.637	-8.27231	0.33	20.4	Semi-deciduous forest	84	6.7	1.5	8,885	0.44	491	9
492	Site_02_northsumatra_1105	97.5303	1.30449	0.13	82.5	Semi-deciduous forest	19	5.4	16.5	7,052	0.44	492	9
493	Site_22_northsulawesi_5039	123.72	0.82247	0.31	27.0	Rainfed croplands	2	5.3	1.9	3,172	0.44	493	9
494	Site_35_papua_2682	134.176	-3.67549	0.34	44.8	Semi-deciduous forest	311	5.8	7.0	8,267	0.44	494	9
495	Site_02_northsumatra_1118	97.5504	1.29684	0.13	17.6	Rainfed croplands	17	6.3	4.0	6,225	0.44	495	9
496	Site_32_northmaluku_2882	128.003	-0.56209	0.35	31.4	Mosaic cropland/vegetation	163	5.7	2.8	4,157	0.44	496	9
497	Site_27_southeastsulawesi_805	122.229	-3.09564	0.31	22.8	Semi-deciduous forest	50	5.7	2.2	7,151	0.44	497	9
498	Site_02_northsumatra_1223	97.6698	1.16003	0.13	28.9	Mosaic vegetation/cropland	2	5.4	6.0	3,036	0.44	498	9
499	Site_10_lampung_2291	104.541	-5.60674	0.18	76.4	Mosaic vegetation/cropland	16	4.4	11.6	2,596	0.44	499	9
500	Site_22_northsulawesi_5861	123.736	0.77763	0.31	35.0	Mosaic cropland/vegetation	6	4.8	2.7	6,197	0.44	500	9
501	Site_28_bali_829	114.707	-8.22829	0.35	42.4	Semi-deciduous forest	6	5.3	4.8	7,528	0.44	501	9
502	Site_01_aceh_47	95.4817	5.55275	0.17	63.2	Rainfed croplands	8	4.3	8.8	5,223	0.44	502	9
503	Site_10_lampung_1129	103.877	-5.06546	0.15	31.4	Semi-deciduous forest	32	4.2	4.6	3,803	0.44	503	9
504	Site_22_northsulawesi_6114	123.727	0.76526	0.32	36.1	Mosaic cropland/vegetation	7	4.8	2.9	7,821	0.44	504	9
505	Site_34_westpapua_356	134.061	-2.05935	0.36	61.0	Mosaic cropland/vegetation	325	6.3	7.8	4,611	0.44	505	9
506	Site_02_northsumatra_1685	97.8689	0.63453	0.15	26.6	Mosaic cropland/vegetation	2	5.6	8.2	2,917	0.44	506	9
507	Site_10_lampung_1573	104.279	-5.46949	0.15	21.8	Rainfed croplands	14	6.1	5.7	8,378	0.44	507	9
508	Site_01_aceh_42	95.5098	5.55914	0.15	24.3	Mosaic cropland/vegetation	10	5.6	6.1	3,338	0.44	508	9
509	Site_10_lampung_1571	104.279	-5.46949	0.15	19.3	Rainfed croplands	14	6.3	5.6	8,378	0.44	509	9
510	Site_31_maluku_4130	125.921	-7.88946	0.36	55.8	Mosaic cropland/vegetation	173	5.0	5.6	4,040	0.44	510	9
511	Site_34_westpapua_1386	134.261	-3.82438	0.36	80.6	Semi-deciduous forest	296	7.2	18.7	7,742	0.44	511	9
512	Site_22_northsulawesi_1040	124.737	1.38314	0.32	27.8	Mosaic vegetation/cropland	2	5.8	4.1	4,577	0.43	512	9
513	Site_25_centralsulawesi1_2631	122.062	1.03288	0.32	31.8	Rainfed croplands	58	7.0	7.0	2,569	0.43	513	9
514	Site_30_eastnusatenggara_904	124.479	-8.20218	0.36	50.1	Mosaic cropland/vegetation	97	4.2	4.3	3,372	0.43	514	9
515	Site_30_eastnusatenggara_4631	122.812	-8.3522	0.35	25.9	Mosaic cropland/vegetation	60	5.5	1.7	4,035	0.43	515	9
516	Site_35_papua_1823	140.255	-2.50852	0.37	65.7	Semi-deciduous forest	7	5.0	5.7	8,702	0.43	516	9
517	Site_02_northsumatra_1171	97.5555	1.24509	0.16	15.3	Semi-deciduous forest	13	7.2	5.7	8,161	0.43	517	9
518	Site_30_eastnusatenggara_12789	119.908	-8.75806	0.35	32.0	Mosaic cropland/vegetation	19	8.7	7.8	6,196	0.43	518	9
519	Site_31_maluku_1585	129.473	-3.37076	0.36	37.3	Mosaic cropland/vegetation	128	6.6	5.4	5,455	0.43	519	9
520	Site_22_northsulawesi_2454	124.517	1.12024	0.33	39.2	Mosaic cropland/vegetation	1	6.1	7.1	7,610	0.43	520	9
521	Site_25_centralsulawesi1_9953	120.213	0.41178	0.33	46.4	Mosaic cropland/vegetation	126	4.8	2.1	7,674	0.43	521	9
522	Site_34_westpapua_262	134.069	-1.7274	0.44	148.1	Mosaic cropland/vegetation	313	6.5	12.2	1,969	0.43	522	9
523	Site_35_papua_761	134.069	-1.7274	0.44	147.2	Mosaic cropland/vegetation	313	6.5	12.0	1,969	0.43	523	9
524	Site_30_eastnusatenggara_393	124.51	-8.1646	0.38	71.3	Rainfed croplands	99	4.5	5.9	3,559	0.43	524	9
525	Site_32_northmaluku_1420	128.237	0.87543	0.36	20.7	Semi-deciduous forest	97	7.2	2.1	3,988	0.43	525	9
526	Site_25_centralsulawesi2b_4698	122.735	-0.88374	0.33	37.7	Mosaic cropland/vegetation	12	5.3	1.2	7,859	0.43	526	9
527	Site_10_lampung_971	103.827	-5.00441	0.18	26.4	Rainfed croplands	38	4.5	2.1	5,291	0.43	527	9
528	Site_01_aceh_62	95.5667	5.54247	0.18	29.4	Mosaic cropland/vegetation	15	5.4	6.0	7,317	0.43	528	9
529	Site_32_northmaluku_3546	127.909	-1.60517	0.37	26.8	Mosaic cropland/vegetation	221	5.9	4.9	8,786	0.43	529	9
530	Site_02_northsumatra_1145	97.5663	1.28237	0.18	28.4	Rainfed croplands	14	5.6	8.8	5,052	0.42	530	9
531	Site_23_gorontalo_4742	121.597	0.60067	0.33	15.1	Mosaic vegetation/cropland	47	3.0	10.9	5,481	0.42	531	9
532	Site_10_lampung_1398	105.198	-5.42584	0.18	23.5	Rainfed croplands	1	5.8	6.6	7,468	0.42	532	9
533	Site_34_westpapua_1823	134.251	-3.94049	0.37	29.0	Mosaic cropland/vegetation	292	6.8	5.1	1,857	0.42	533	9
534	Site_02_northsumatra_1186	97.5724	1.23151	0.19	15.2	Rainfed croplands	10	7.4	5.8	7,937	0.42	534	9
535	Site_31_maluku_3556	126.24	-7.74751	0.43	117.4	Semi-deciduous forest	210	3.9	5.3	5,312	0.42	535	9
536	Site_25_centralsulawesi3_1095	123.822	-1.99944	0.34	45.9	Mosaic cropland/vegetation	159	6.9	9.6	1,663	0.42	536	9
537	Site_02_northsumatra_104	98.53	2.03282	0.20	18.2	Mosaic vegetation/cropland	27	5.7	1.7	8,552	0.42	537	9
538	Site_25_centralsulawesi1_1787	121.295	1.16748	0.34	17.3	Semi-deciduous forest	110	6.6	2.3	7,724	0.42	538	9
539	Site_02_northsumatra_693	98.8091	1.75664	0.25	85.7	Semi-deciduous forest	-	4.0	10.5	3,709	0.42	539	9
540	Site_35_papua_1075	136.641	-1.79406	0.38	80.7	Mosaic cropland/vegetation	258	7.9	21.6	6,546	0.42	540	9
541	Site_22_northsulawesi_6078	123.753	0.76736	0.35	38.5	Semi-deciduous forest	6	4.7	2.3	7,077	0.42	541	9
542	Site_02_northsumatra_1554	97.8696	0.73496	0.21	37.5	Rainfed croplands	2	4.8	5.3	2,063	0.41	542	9
543	Site_23_gorontalo_1506	121.697	0.96247	0.34	24.2	Semi-deciduous forest	64	5.6	1.7	8,317	0.41	543	9
544	Site_22_northsulawesi_6170	123.763	0.76226	0.35	29.9	Mosaic vegetation/cropland	7	5.2	3.3	7,738	0.41	544	9
545	Site_22_northsulawesi_3947	124.666	0.88899	0.35	18.9	Rainfed croplands	20	7.7	4.4	5,149	0.41	545	9
546	Site_25_centralsulawesi3_4082	122.323	-3.1875	0.37	86.8	Mosaic cropland/vegetation	64	6.5	13.8	5,042	0.41	546	9
547	Site_25_centralsulawesi2b_1157	123.376	-0.72979	0.35	21.9	Mosaic cropland/vegetation	72	5.5	2.2	4,560	0.41	547	9
548	Site_02_northsumatra_1149	97.5872	1.27989	0.22	24.3	Mosaic cropland/vegetation	13	5.5	5.3	3,008	0.41	548	9
549	Site_25_centralsulawesi1_7693	120.44	0.56137	0.35	23.8	Mosaic cropland/vegetation	147	6.2	1.0	7,888	0.41	549	9
550	Site_10_lampung_1715	104.801	-5.50624	0.28	106.5	Semi-deciduous forest	12	3.9	13.2	8,879	0.41	550	10
551	Site_22_northsulawesi_4344	124.621	0.85449	0.37	62.2	Semi-deciduous forest	16	4.5	4.4	6,139	0.41	551	10
552	Site_24_westsulawesi_3367	118.888	-3.38179	0.35	27.4	Mosaic cropland/vegetation	3	5.8	3.7	3,682	0.41	552	10
553	Site_02_northsumatra_648	98.8154	1.76624	0.22	25.9	Rainfed croplands	0	4.6	3.1	4,985	0.41	553	10
554	Site_07_bengkulu_141	103.473	-4.79537	0.23	28.2	Mosaic vegetation/cropland	69	5.8	6.6	7,416	0.41	554	10
555	Site_34_westpapua_1220	134.159	-3.6616	0.39	26.5	No data	313	5.9	2.8	8,854	0.41	555	10
556	Site_35_papua_2670	134.159	-3.6616	0.39	26.5	No data	313	5.9	2.8	8,854	0.41	555	10
557	Site_22_northsulawesi_8277	123.826	0.40646	0.36	35.6	Mosaic vegetation/cropland	25	5.0	2.7	7,837	0.40	557	10
558	Site_01_aceh_182	95.3051	5.29774	0.25	62.5	Mosaic vegetation/cropland	19	3.7	4.1	7,028	0.40	558	10

Appendix C

Preprocessing Python Script

Listing C.1: The preprocessing python script

```python
"""
Model exported as python.
Name : 01_preprocessing
Group :
With QGIS : 32810
"""

from qgis.core import QgsProcessing
from qgis.core import QgsProcessingAlgorithm
from qgis.core import QgsProcessingMultiStepFeedback
from qgis.core import QgsProcessingParameterExtent
from qgis.core import QgsProcessingParameterVectorLayer
from qgis.core import QgsProcessingParameterCrs
from qgis.core import QgsProcessingParameterRasterLayer
from qgis.core import QgsProcessingParameterFile
from qgis.core import QgsProcessingParameterString
import processing
import os
from operator import itemgetter
import csv
from pcraster import*

class preprocessing(QgsProcessingAlgorithm):

    def initAlgorithm(self, config=None):
        self.addParameter(QgsProcessingParameterExtent('extent', 'Extent', defaultValue=None))
        self.addParameter(QgsProcessingParameterVectorLayer('input_coastline_shp_file', 'Input coastline SHP file', types=[QgsProcessing.TypeVectorLine], defaultValue=None))
        self.addParameter(QgsProcessingParameterCrs('input_crs', 'Input CRS', defaultValue='EPSG:4326'))
        self.addParameter(QgsProcessingParameterRasterLayer('input_dem', 'Input DEM', defaultValue=None))
        self.addParameter(QgsProcessingParameterFile('working_directory', 'Working directory', behavior=QgsProcessingParameterFile.Folder, fileFilter='All files (*.*)', defaultValue=None))
```

```
        self.addParameter(QgsProcessingParameterString('regional', 'Regional', multiLine=False, defaultValue='Indonesia'))

    def processAlgorithm(self, parameters, context, model_feedback):
        # Use a multi-step feedback, so that individual child algorithm progress reports are adjusted for the
        # overall progress through the model
        feedback = QgsProcessingMultiStepFeedback(23, model_feedback)
        results = {}
        outputs = {}
        os.chdir(parameters['working_directory'])

        # Reproject layer
        alg_params = {
            'INPUT': parameters['input_coastline_shp_file'],
            'OPERATION': '',
            'TARGET_CRS': parameters['input_crs'],
            'OUTPUT': 'temp_projected'}
        outputs['ReprojectLayer'] = processing.run('native:reprojectlayer', alg_params, context=context, feedback=feedback, is_child_algorithm=True)

        feedback.setCurrentStep(1)
        if feedback.isCanceled():
            return {}

        # Buffer with 200 meters distance from coastline
        fn_buffer = "buffer_" + parameters['regional'] + ".shp"
        alg_params = {
            'DISSOLVE': True,
            'DISTANCE': 0.08, #in degree
            'END_CAP_STYLE': 0,  # Round
            'INPUT': parameters['input_coastline_shp_file'],
            'JOIN_STYLE': 0,  # Round
            'MITER_LIMIT': 1,
            'OUTPUT': fn_buffer,
            'SEGMENTS': 100,
            'OUTPUT': fn_buffer}
        outputs['Buffer'] = processing.run('native:buffer', alg_params, context=context, feedback=feedback, is_child_algorithm=True)

        feedback.setCurrentStep(2)
        if feedback.isCanceled():
            return {}

        # line to polygon the coastline shp
        fn_poly = "poly_" + parameters['regional'] + ".shp"
        fn_poly_fixed = "poly_fixed_" + parameters['regional'] + ".shp"
        outputs['Poly'] = processing.run("qgis:linestopolygons", {'INPUT':parameters['input_coastline_shp_file'],'OUTPUT':fn_poly})
        outputs['Poly_fixed'] = processing.run("native:fixgeometries", {'INPUT':outputs['Poly']['OUTPUT'],'METHOD':1,'OUTPUT':fn_poly_fixed})

        feedback.setCurrentStep(3)
        if feedback.isCanceled():
            return {}

        # Rename layer
```

```
        name1 = "DEM_" + parameters['regional']
        alg_params = {
            'INPUT': parameters['input_dem'],
            'NAME': name1}
        outputs['RenameLayer'] = processing.run('native:renamelayer', alg_params,
            context=context, feedback=feedback, is_child_algorithm=True)

        feedback.setCurrentStep(4)
        if feedback.isCanceled():
            return {}

        # Raster calculator to eliminate area with elevation < 200 meters
        expression1 = "'" + '"' + name1 + "@1" + '"' + ">=200" "'"
        alg_params = {
            'CELLSIZE': 0,
            'CRS': parameters['input_crs'],
            'EXPRESSION': expression1,
            'EXTENT': parameters['extent'],
            'LAYERS': parameters['input_dem'],
            'OUTPUT': 'temp_raster_calculator1.tif'}
        outputs['RasterCalculator'] = processing.run('qgis:rastercalculator',
            alg_params, context=context, feedback=feedback, is_child_algorithm=True)

        feedback.setCurrentStep(5)
        if feedback.isCanceled():
            return {}

        # Polygonize (raster to vector) the study area
        alg_params = {
            'BAND': 1,
            'EIGHT_CONNECTEDNESS': False,
            'EXTRA': '',
            'FIELD': 'DN',
            'INPUT': outputs['RasterCalculator']['OUTPUT'],
            'OUTPUT': 'temp_polygonize1.shp'}
        outputs['PolygonizeRasterToVector'] = processing.run('gdal:polygonize',
            alg_params, context=context, feedback=feedback, is_child_algorithm=True)

        feedback.setCurrentStep(6)
        if feedback.isCanceled():
            return {}

        # Select and delete DN, remain the study area into a shp file
        fn_elev = "elev_200_" + parameters['regional'] + ".shp"
        alg_params = {
            'Extract': fn_elev,
            'Input␣vector': outputs['PolygonizeRasterToVector']['OUTPUT'],
            'Select␣DN␣to␣retain': '1',
            'Extract': fn_elev}
        outputs['SelectAndDeleteDn'] = processing.run('script:Select␣and␣delete␣DN',
            alg_params, context=context, feedback=feedback, is_child_algorithm=True)

        feedback.setCurrentStep(7)
        if feedback.isCanceled():
            return {}

        #make a shp file of the study area boundary
```

```
        fn_clip1 = 'clip1.shp'
        alg_params = {
            'INPUT':  outputs['Poly_fixed']['OUTPUT'],
            'OVERLAY': outputs['Buffer']['OUTPUT'],
            'OUTPUT': fn_clip1}
        outputs['clip1'] = processing.run("native:clip", alg_params)

        feedback.setCurrentStep(8)
        if feedback.isCanceled():
            return {}

        fn_clip2 = 'clip2.shp'
        alg_params = {
            'INPUT':  outputs['clip1']['OUTPUT'],
            'OVERLAY': outputs['SelectAndDeleteDn']['Extract'],
            'OUTPUT': fn_clip2}
        outputs['clip2'] = processing.run("native:clip", alg_params)

        feedback.setCurrentStep(9)
        if feedback.isCanceled():
            return {}

        # Clip raster by mask layer, cut DEM into study area step 1
        alg_params = {
            'ALPHA_BAND': False,
            'CROP_TO_CUTLINE': True,
            'DATA_TYPE': 0,  # Use Input Layer Data Type
            'EXTRA': '',
            'INPUT': parameters['input_dem'],
            'KEEP_RESOLUTION': True,
            'MASK': outputs['clip2']['OUTPUT'],
            'MULTITHREADING': False,
            'NODATA': -999999999,
            'OPTIONS': '',
            'SET_RESOLUTION': False,
            'SOURCE_CRS': parameters['input_crs'],
            'TARGET_CRS': parameters['input_crs'],
            'TARGET_EXTENT': parameters['extent'],
            'X_RESOLUTION': None,
            'Y_RESOLUTION': None,
            'OUTPUT': 'temp_clipped.tif'}
        outputs['ClipRasterByMaskLayer'] = processing.run('gdal:cliprasterbymasklayer',
             alg_params, context=context, feedback=feedback, is_child_algorithm=True)

        feedback.setCurrentStep(10)
        if feedback.isCanceled():
            return {}

        # Convert to PCRaster Format
        fn_map = "study_area_" + parameters['regional'] + ".map"
        alg_params = {
            'INPUT': outputs['ClipRasterByMaskLayer']['OUTPUT'],
            'INPUT2': 3,  # Scalar
            'OUTPUT': fn_map,
            'OUTPUT': fn_map}
        outputs['ConvertToPcrasterFormat'] = processing.run('pcraster:
            converttopcrasterformat', alg_params, context=context, feedback=feedback,
```

```
                is_child_algorithm=True)

        feedback.setCurrentStep(11)
        if feedback.isCanceled():
            return {}

        # Load DEM in PCRaster format layer into project
        alg_params = {
            'INPUT': fn_map,
            'NAME': 'study_area_' + parameters['regional']}
        outputs['LoadLayerIntoProject'] = processing.run('native:loadlayer', alg_params
            , context=context, feedback=feedback, is_child_algorithm=True)

        feedback.setCurrentStep(12)
        if feedback.isCanceled():
            return {}

        #Create LDD map for calculation in PCRaster
        fn_ldd = "ldd_" + parameters['regional'] + ".map"
        alg_params = {
            'INPUT': outputs['ConvertToPcrasterFormat']['OUTPUT'],
            'INPUT0': 0,  # No
            'INPUT1': 0,  # Map units
            'INPUT2': 9999999,
            'INPUT3': 9999999,
            'INPUT4': 9999999,
            'INPUT5': 9999999,
            'OUTPUT': fn_ldd,
            'OUTPUT': fn_ldd}
        outputs['Lddcreate'] = processing.run('pcraster:lddcreate', alg_params, context
            =context, feedback=feedback, is_child_algorithm=True)

        feedback.setCurrentStep(13)
        if feedback.isCanceled():
            return {}

        # Load LDD layer into project
        alg_params = {
            'INPUT': fn_ldd,
            'NAME': 'ldd_' + parameters['regional']}
        outputs['LoadLayerIntoProject'] = processing.run('native:loadlayer', alg_params
            , context=context, feedback=feedback, is_child_algorithm=True)

        feedback.setCurrentStep(14)
        if feedback.isCanceled():
            return {}

        # streamorder
        fn_so = "streamorder_" + parameters['regional'] + ".map"
        alg_params = {
            'INPUT': outputs['Lddcreate']['OUTPUT'],
            'OUTPUT': fn_so}
        outputs['Streamorder'] = processing.run('pcraster:streamorder', alg_params,
            context=context, feedback=feedback, is_child_algorithm=True)

        feedback.setCurrentStep(15)
        if feedback.isCanceled():
```

```
            return {}

        # spatial
        alg_params = {
            'INPUT': 5,
            'INPUT1': 2,  # Ordinal
            'INPUT2': outputs['Streamorder']['OUTPUT'],
            'OUTPUT': 'temp_spatial.map'}
        outputs['Spatial'] = processing.run('pcraster:spatial', alg_params, context=
            context, feedback=feedback, is_child_algorithm=True)

        feedback.setCurrentStep(16)
        if feedback.isCanceled():
            return {}

        # comparison operators
        alg_params = {
            'INPUT': outputs['Streamorder']['OUTPUT'],
            'INPUT1': 0,  # ==
            'INPUT2': outputs['Spatial']['OUTPUT'],
            'OUTPUT': 'temp_comparison.map'}
        outputs['ComparisonOperators'] = processing.run('pcraster:comparisonoperators',
             alg_params, context=context, feedback=feedback, is_child_algorithm=True)

        feedback.setCurrentStep(17)
        if feedback.isCanceled():
            return {}

        # if then
        alg_params = {
            'INPUT': outputs['ComparisonOperators']['OUTPUT'],
            'INPUT1': outputs['Streamorder']['OUTPUT'],
            'OUTPUT': 'temp_ifthen.map'}
        outputs['IfThen'] = processing.run('pcraster:ifthen', alg_params, context=
            context, feedback=feedback, is_child_algorithm=True)

        feedback.setCurrentStep(18)
        if feedback.isCanceled():
            return {}

        # clump
        fn_gc = "group_channel_" + parameters['regional'] + ".map"
        alg_params = {
            'INPUT': outputs['IfThen']['OUTPUT'],
            'INPUT1': 0,  # Diagonal (8 cell)
            'OUTPUT': fn_gc,
            'OUTPUT': fn_gc}
        outputs['Clump'] = processing.run('pcraster:clump', alg_params, context=context
            , feedback=feedback, is_child_algorithm=True)

        feedback.setCurrentStep(19)
        if feedback.isCanceled():
            return {}

        # Load channel (clumped) layer into project
        alg_params = {
            'INPUT': fn_gc,
```

```
            'NAME': 'group_channel_' + parameters['regional']}
        outputs['LoadLayerIntoProject2'] = processing.run('native:loadlayer', alg_params, context=context, feedback=feedback, is_child_algorithm=True)

        feedback.setCurrentStep(20)
        if feedback.isCanceled():
            return {}

        # Hiilshade
        fn_hillshade = "hillshade_" + parameters['regional'] + ".tif"
        alg_params = {
                'INPUT':parameters['input_dem'],
                'BAND':1,
                'Z_FACTOR':1,
                'SCALE':1,
                'AZIMUTH':315,
                'ALTITUDE':45,
                'COMPUTE_EDGES':False,
                'ZEVENBERGEN':False,
                'COMBINED':False,
                'MULTIDIRECTIONAL':False,
                'OPTIONS':'',
                'EXTRA':'',
                'OUTPUT':fn_hillshade}
        outputs['Hillshade'] = processing.run("gdal:hillshade", alg_params)

        feedback.setCurrentStep(21)
        if feedback.isCanceled():
            return {}

        # Load hillshade layer into project
        alg_params = {
            'INPUT': fn_hillshade,
            'NAME': 'hillshade_' + parameters['regional']}
        outputs['LoadLayerIntoProject1'] = processing.run('native:loadlayer', alg_params, context=context, feedback=feedback, is_child_algorithm=True)

        feedback.setCurrentStep(22)
        if feedback.isCanceled():
            return {}

        # map2col channel
        expression3 = '"map2col ' + fn_gc + ' ' + 'channel_' + parameters['regional'] + '.txt"'
        os.system(expression3)

        return results
        os.remove('temp_ifthen.map')
        os.remove('temp_raster_calculator1')
        os.remove('temp_comparison.map')

    def name(self):
        return '01_preprocessing'

    def displayName(self):
        return '01_preprocessing'
```

```python
    def group(self):
        return ''

    def groupId(self):
        return ''

    def createInstance(self):
        return preprocessing()
```

Appendix D

Main Processing Python Script

Listing D.1: The mainprocessing python script

```
"""
Model exported as python.
Name : 02_mainprocessing
Group :
With QGIS : 32810
"""

from qgis.core import QgsProcessing
from qgis.core import QgsProcessingAlgorithm
from qgis.core import QgsProcessingParameterNumber
from qgis.core import QgsProcessingParameterRasterLayer
from qgis.core import QgsProcessingParameterVectorLayer
from qgis.core import QgsProcessingParameterFile
from qgis.core import QgsProcessingParameterString
from qgis.core import QgsVectorLayer
from qgis.core import QgsProject
import processing
import numpy as np
from pcraster import*
import os

class Model(QgsProcessingAlgorithm):

    def initAlgorithm(self, config=None):
        self.addParameter(QgsProcessingParameterFile('working_directory', 'Working directory', behavior=QgsProcessingParameterFile.Folder, fileFilter='All files (*.*)', defaultValue=None))
        self.addParameter(QgsProcessingParameterVectorLayer('input_coastline', 'Input coastline SHP file', types=[QgsProcessing.TypeVectorLine], defaultValue=None))
        self.addParameter(QgsProcessingParameterString('regional', 'Regional', multiLine=False, defaultValue='Indonesia'))
        self.addParameter(QgsProcessingParameterNumber('damheight', 'Dam height [meters]', type=QgsProcessingParameterNumber.Integer, minValue=1, maxValue=99, defaultValue=15))
        self.addParameter(QgsProcessingParameterNumber('cellsize', 'Cell size [meters]', type=QgsProcessingParameterNumber.Integer, minValue=1, maxValue=99, defaultValue=8.25))
```

```
        self.addParameter(QgsProcessingParameterNumber('min_energy', 'Minimum energy [MWh]', type=QgsProcessingParameterNumber.Integer, minValue=1, maxValue=1000, defaultValue=140))
        self.addParameter(QgsProcessingParameterNumber('duration', 'Duration of power generation [hours]', type=QgsProcessingParameterNumber.Integer, minValue=1, maxValue=24, defaultValue=8))

    def processAlgorithm(self, parameters, context, model_feedback):
        os.chdir(parameters['working_directory'])

        #call the files needed
        fn_map = "study_area_" + parameters['regional'] + ".map"
        study_area_map = readmap(fn_map)
        DEM = readmap(fn_map)
        fn_gc = "group_channel_" + parameters['regional'] + ".map"
        fn_gc_txt = "channel_" + parameters['regional'] + ".txt"
        channel_all = readmap(fn_gc)
        fn_ldd = "ldd_" + parameters['regional'] + ".map"
        fn_outlet = 'gully_outlet_' + parameters['regional'] + '.txt'
        fn_outlet_map = 'outlet_coord_' + parameters['regional'] + '.map'
        fn_outlet_shp = 'outlet_coord_' + parameters['regional'] + '.shp'
        fn_energy = 'DG_Vol_Energy_' + parameters['regional'] + '.txt'
        fn_inundation_map = 'inundation_' + parameters['regional'] + ".map"
        fn_inundation_txt = 'inundation_' + parameters['regional'] + ".txt"
        fn_inundation_true_map = 'inundation_true_' + parameters['regional'] + ".map"
        fn_sample_code = 'sample_code_ok_' + parameters['regional'] + '.txt'
        fn_sample_code_notokay = 'sample_code_no_' + parameters['regional'] + '.txt'

        outputs = {}
        results = {}

        #define parameters
        damheight = parameters['damheight']
        cellsize = parameters['cellsize']
        min_energy = parameters['min_energy']

        #make a list of sample location code
        list1 = open(fn_gc_txt, 'r').readlines()
        list2 = []
        for n in range(len(list1)):
            a = list1[n].split()[2].strip)
            list2.append(float(a))
        max_code = np.min(list2)
        sample = np.linspace(1, max_code, max_code)

        code_storage = open(fn_sample_code, 'w')
        code_storage.write('channel_code DG_volume elev DG_energy power' + '\n')
        code_storage_notokay = open(fn_sample_code_notokay, 'w')

        for i in range(len(sample)):
            #build a raster layer that represent the same channel code and store the data into a txt file
            channel_code = int(sample[i])
            fn_spatial = 'temp_chan_spatial_' + parameters['regional'] + '.map'
            alg_params = {'INPUT':channel_code,'INPUT1':1,'INPUT2':fn_gc,'OUTPUT':fn_spatial}
            outputs['spatial'] = processing.run("pcraster:spatial", alg_params)
```

```python
            fn_channel_class_map = "channel_class_" + parameters['regional'] + ".map"
            alg_params = {'INPUT':fn_spatial,'INPUT1':0,'INPUT2':fn_gc,'OUTPUT':fn_channel_class_map}
            processing.run("pcraster:comparisonoperators", alg_params)

            fn_chan_shp1 = 'temp_chan1_' + parameters['regional'] + '_' + str(sample[i]) + '.gpkg'
            alg_params = {'INPUT':fn_channel_class_map,'BAND':1,'FIELD':'DN','EIGHT_CONNECTEDNESS':True,'EXTRA':'','OUTPUT':fn_chan_shp1}
            outputs['Polygonize1'] = processing.run("gdal:polygonize", alg_params)

            fn_chan_shp2 = 'temp_chan2_' + parameters['regional'] + '_' + str(sample[i]) + '.gpkg'
            alg_params = {'EXPRESSION': f'DN={1}','INPUT': fn_chan_shp1,'OUTPUT':fn_chan_shp2}
            outputs['ExtractByExpression1'] = processing.run('native:extractbyexpression', alg_params)

            channel_layer = QgsVectorLayer(fn_chan_shp2, '', 'ogr')
            ext  = str(channel_layer.extent())
            x1 = float(ext.split(' ')[1])
            y1 = float(ext.split(' ')[2].split(',')[0])
            x2 = float(ext.split(' ')[3])
            y2 = float(ext.split(' ')[4].split('>')[0])
            x1_new = x1 - 0.03
            x2_new = x2 + 0.03
            y1_new = y1 - 0.03
            y2_new = y2 + 0.03
            new_extent = str(x1_new) + "," + str(x2_new) + "," + str(y1_new) + "," + str(y2_new) + " [EPSG:4326]"
            QgsProject.instance().removeMapLayers([channel_layer.id()])
            QgsProject.instance().removeMapLayers([channel_layer.id()])
            channel_layer = None

            fn_study_area_clipped = "study_area_clipped_" + parameters['regional'] + ".map"
            alg_params = {'INPUT':fn_map,'PROJWIN':new_extent,'OVERCRS':False,'NODATA':-999999999.000000,'OPTIONS':'','DATA_TYPE':0,'EXTRA':'','OUTPUT':fn_study_area_clipped}
            outputs['clipstudyarea'] = processing.run("gdal:cliprasterbyextent", alg_params)

            fn_channel_class_map_clipped = "channel_class_clipped_" + parameters['regional'] + ".map"
            alg_params = {'INPUT':fn_channel_class_map,'PROJWIN':new_extent,'OVERCRS':False,'NODATA':-999999999.000000,'OPTIONS':'','DATA_TYPE':0,'EXTRA':'','OUTPUT':fn_channel_class_map_clipped}
            outputs['clipchannel'] = processing.run("gdal:cliprasterbyextent", alg_params)

            fn_ldd_clipped = "ldd_clipped_" + parameters['regional'] + ".map"
            alg_params = {'INPUT':fn_ldd,'PROJWIN':new_extent,'OVERCRS':False,'NODATA':-999999999.000000,'OPTIONS':'','DATA_TYPE':0,'EXTRA':'','OUTPUT':fn_ldd_clipped}
            outputs['clipldd'] = processing.run("gdal:cliprasterbyextent", alg_params)

            channel_map_clipped = readmap(fn_channel_class_map_clipped)
```

```
            study_area_map_clipped = readmap(fn_study_area_clipped)
            group_name = 'class_map_' + parameters['regional'] +'.map'
            outputs['ifthen'] = processing.run("pcraster:ifthen", {'INPUT':
                fn_channel_class_map_clipped,'INPUT1':fn_study_area_clipped,'OUTPUT':
                group_name})

            group_text = 'class_' + parameters['regional'] + '.txt'
            alg = 'map2col␣' + group_name + '␣' + group_text
            os.system(alg)

            #define the outlet coordinate of the channel
            attribute = open(group_text, 'r').readlines()
            elev = []
            for n in range(len(attribute)):
                el = attribute[n].split()[2].strip()
                elev.append(float(el))
            index = elev.index(np.min(elev))

            gully_outlet_point = attribute[index]
            x_outlet = gully_outlet_point.split()[0].strip()
            y_outlet = gully_outlet_point.split()[1].strip()
            elev_outlet = gully_outlet_point.split()[2].strip()
            elev_float = float(elev_outlet)
            list = str(x_outlet) + "␣" + str(y_outlet)+ "␣" + str(1) + "\n"
            outlet = open(fn_outlet, 'w')
            outlet.write(list)
            outlet.close()
            outlet = open(fn_outlet, 'w')
            outlet.write(list)
            outlet.close()

            #run the "catchment" feature from PCRaster to deliniate the catchment of
                the channel
            alg = 'col2map␣-N␣' + fn_outlet + '␣' + fn_outlet_map + '␣--clone␣' +
                fn_ldd_clipped
            os.system(alg)
            alg_params = {'INPUT':fn_outlet_map,'BAND':1,'FIELD':'DN','
                EIGHT_CONNECTEDNESS':False,'EXTRA':'','OUTPUT':fn_outlet_shp}
            outputs['polygonizeoutlet'] = processing.run("gdal:polygonize", alg_params)
            outlet_coord = readmap(fn_outlet_map)
            gullycatchment = catchment(fn_ldd_clipped, outlet_coord)
            fn_catchment = 'gully_catchment_' + parameters['regional'] + ".map"
            report(gullycatchment, fn_catchment)

            #crop the DEM by the catcment
            catchment1 = readmap(fn_catchment)
            catch = catchment1 == 1
            topo = ifthen(catch, study_area_map_clipped)
            report(topo, 'temp_topo')

            #crop the previous DEM with elevation more than elevation on the outlet +
                dam height
            y = elev_float + damheight
            cal_map = topo < y
            is_cal_map = cal_map == 1
            topo_cal_map = ifthen(is_cal_map, topo)
            report(topo_cal_map, 'temp_topocal')
```

```

#make a map file of inundation
h = y - topo_cal_map
volume_cell = h * (cellsize**2)
report(volume_cell, fn_inundation_map)
alg = 'map2col ' + fn_inundation_map + ' ' + fn_inundation_txt
os.system(alg)

#calculate volume and energy in the storage (calculation is done per cell)
vol_lines = open(fn_inundation_txt, 'r').readlines()
vol_lines_sum = 0
for n in vol_lines:
    if n.strip():
        vol = n.split()[-1].strip()
        vol_lines_sum += float(vol)
y_energy = elev_float + (damheight/2)
energy = (vol_lines_sum * y_energy * 9.81 * 1000 * 0.8) / (3600 * 1000000)
energy_float = float(energy)
list = str(channel_code) + ' ' + str(x_outlet) + ' ' + str(y_outlet) + ' ' + str(elev_float) + ' ' + str(vol_lines_sum) + ' ' + str(energy_float) + '\n'
energy_save = open(fn_energy, 'w')
energy_save.write(list)
energy_save.close
energy_save = open(fn_energy, 'w')
energy_save.write(list)
energy_save.close

#create shp file(s) that represent the inundation, complete with the volume and energy storage
read_energy = open(fn_energy, 'r').readlines()
if float(read_energy[0].split()[-1].strip()) >= min_energy:
    DG_volume = float(read_energy[0].split()[4].strip())
    DG_energy = float(read_energy[0].split()[5].strip())
    water = readmap(fn_inundation_map)
    inundation = water > 0
    report(inundation, fn_inundation_true_map)

#calculate average discharge
    discharge = DG_volume / 3600 / parameters['duration']

#make new shp files representing the gullies
    fn_inundation_shp = 'DG_' + parameters['regional'] + '_' + str(channel_code) + '.shp'
    fn_inundation_temp1 = 'temp_DG1.shp'
    fn_inundation_temp2 = 'temp_DG2.shp'

    alg1 = {
        'INPUT':fn_inundation_true_map,
        'BAND':1,
        'FIELD':'DN',
        'EIGHT_CONNECTEDNESS':True,
        'EXTRA':'',
        'OUTPUT':fn_inundation_temp2}
    outputs['inundation_temp'] = processing.run("gdal:polygonize", alg1)

#fix geometry
```

```
                alg_fix = {
                    'INPUT':fn_inundation_temp2,
                    'METHOD':1,
                    'OUTPUT':fn_inundation_temp1}

                outputs['inundation_temp1'] = processing.run("native:fixgeometries",
                    alg_fix)

            #calculate shortest distance from coastline
                fn_line = 'shortline_' + parameters['regional'] + '_' + str(
                    channel_code) + '.shp'
                alg_line = {
                    'SOURCE':fn_outlet_shp,
                    'DESTINATION':parameters['input_coastline'],
                    'METHOD':0,
                    'NEIGHBORS':1,
                    'DISTANCE':None,
                    'OUTPUT':fn_line}
                outputs['short_line'] = processing.run("native:shortestline", alg_line)

                short_line = QgsVectorLayer(fn_line, '', 'ogr')
                feat = short_line.getFeature(0)
                distance_coastline = float(feat['distance']) * 111139 #convert from
                    degree to meters
                slope = elev_float / distance_coastline #calculating slope
                power = energy_float / parameters['duration'] #calculating power

            #add attribute (DG code, volume, energy)
                alg2 = {
                    'INPUT':fn_inundation_temp1,
                    'FIELD_NAME':'DG_Code',
                    'FIELD_TYPE':0,
                    'FIELD_LENGTH':4,
                    'FIELD_PRECISION':0,
                    'OUTPUT':fn_inundation_temp2}
                outputs['inundation_temp2'] = processing.run("native:
                    addfieldtoattributestable", alg2)

                alg3 = {
                    'INPUT':fn_inundation_temp2,
                    'FIELD_NAME':'Volume_m3',
                    'FIELD_TYPE':1,
                    'FIELD_LENGTH':10,
                    'FIELD_PRECISION':5,
                    'OUTPUT':fn_inundation_temp1}
                outputs['inundation_temp3'] = processing.run("native:
                    addfieldtoattributestable", alg3)

                alg3 = {
                    'INPUT':fn_inundation_temp1,
                    'FIELD_NAME':'Area_m2',
                    'FIELD_TYPE':1,
                    'FIELD_LENGTH':10,
                    'FIELD_PRECISION':5,
                    'OUTPUT':fn_inundation_temp2}
                outputs['inundation_temp3'] = processing.run("native:
                    addfieldtoattributestable", alg3)
```

```

        alg4 = {
            'INPUT':fn_inundation_temp2,
            'FIELD_NAME':'Disc_m3/s',
            'FIELD_TYPE':1,
            'FIELD_LENGTH':10,
            'FIELD_PRECISION':5,
            'OUTPUT':fn_inundation_temp1}
        outputs['inundation_temp3'] = processing.run("native:
            addfieldtoattributestable", alg4)

        alg5 = {
            'INPUT':fn_inundation_temp1,
            'FIELD_NAME':'Energy_MWh',
            'FIELD_TYPE':1,
            'FIELD_LENGTH':10,
            'FIELD_PRECISION':5,
            'OUTPUT':fn_inundation_temp2}
        outputs['inundation_temp4'] = processing.run("native:
            addfieldtoattributestable", alg5)

        alg6 = {
            'INPUT':fn_inundation_temp2,
            'FIELD_NAME': 'x_outlet',
            'FIELD_TYPE':1,
            'FIELD_LENGTH':10,
            'FIELD_PRECISION':5,
            'OUTPUT':fn_inundation_temp1}
        outputs['inundation_temp5'] = processing.run("native:
            addfieldtoattributestable", alg6)

        alg7 = {
            'INPUT':fn_inundation_temp1,
            'FIELD_NAME': 'y_outlet',
            'FIELD_TYPE':1,
            'FIELD_LENGTH':10,
            'FIELD_PRECISION':5,
            'OUTPUT':fn_inundation_temp2}
        outputs['inundation_temp5'] = processing.run("native:
            addfieldtoattributestable", alg7)

        alg8 = {
            'INPUT':fn_inundation_temp2,
            'FIELD_NAME': 'Elevation',
            'FIELD_TYPE':1,
            'FIELD_LENGTH':10,
            'FIELD_PRECISION':5,
            'OUTPUT':fn_inundation_temp1}
        outputs['inundation_temp5'] = processing.run("native:
            addfieldtoattributestable", alg8)

        alg9 = {
            'INPUT':fn_inundation_temp1,
            'FIELD_NAME': 'Dist_m',
            'FIELD_TYPE':1,
            'FIELD_LENGTH':10,
            'FIELD_PRECISION':5,
```

```
                    'OUTPUT':fn_inundation_temp2}
                outputs['inundation_temp6'] = processing.run("native:
                    addfieldtoattributestable", alg9)

                alg10 = {
                    'INPUT':fn_inundation_temp2,
                    'FIELD_NAME': 'Slope',
                    'FIELD_TYPE':1,
                    'FIELD_LENGTH':10,
                    'FIELD_PRECISION':5,
                    'OUTPUT':fn_inundation_temp1}
                outputs['inundation_temp7'] = processing.run("native:
                    addfieldtoattributestable", alg10)

                alg11 = {
                    'INPUT':fn_inundation_temp1,
                    'FIELD_NAME': 'Loss',
                    'FIELD_TYPE':1,
                    'FIELD_LENGTH':10,
                    'FIELD_PRECISION':5,
                    'OUTPUT':fn_inundation_temp2}
                outputs['inundation_temp8'] = processing.run("native:
                    addfieldtoattributestable", alg11)

                alg12 = {
                    'INPUT':fn_inundation_temp2,
                    'FIELD_NAME': 'Eff_Energy',
                    'FIELD_TYPE':1,
                    'FIELD_LENGTH':10,
                    'FIELD_PRECISION':5,
                    'OUTPUT':fn_inundation_temp1}
                outputs['inundation_temp9'] = processing.run("native:
                    addfieldtoattributestable", alg12)

                alg13 = {
                    'INPUT':fn_inundation_temp1,
                    'FIELD_NAME': 'Power_MW',
                    'FIELD_TYPE':1,
                    'FIELD_LENGTH':10,
                    'FIELD_PRECISION':5,
                    'OUTPUT':fn_inundation_temp2}
                outputs['inundation_shp'] = processing.run("native:
                    addfieldtoattributestable", alg13)

                alg14 = {
                    'INPUT':fn_inundation_temp2,
                    'FIELD_NAME': 'Grid_dist',
                    'FIELD_TYPE':1,
                    'FIELD_LENGTH':10,
                    'FIELD_PRECISION':5,
                    'OUTPUT':fn_inundation_temp1}
                outputs['inundation_shp'] = processing.run("native:
                    addfieldtoattributestable", alg14)

                #calculate area
                alg15 = {
                    'INPUT':fn_inundation_temp1,
```

```
                    'FIELD_NAME':'Area_m2',
                    'FIELD_TYPE':0,
                    'FIELD_LENGTH':10,
                    'FIELD_PRECISION':5,
                    'FORMULA':' $area ',
                    'OUTPUT':fn_inundation_shp}
                processing.run("native:fieldcalculator", alg15)

            #store data for volume, energy, coordinate for outlet, minimum elevation and distance from coastline into shp field
                layer = QgsVectorLayer(fn_inundation_shp, '', 'ogr')
                prov = layer.dataProvider()
                DG_code = layer.fields().lookupField('DG_Code')
                vol = layer.fields().lookupField('Volume_m3')
                disch = layer.fields().lookupField('Disc_m3/s')
                en = layer.fields().lookupField('Energy_MWh')
                xc = layer.fields().lookupField('x_outlet')
                yc = layer.fields().lookupField('y_outlet')
                min_elev = layer.fields().lookupField('Elevation')
                distance = layer.fields().lookupField('Dist_m')
                slope_att = layer.fields().lookupField('Slope')
                power_att = layer.fields().lookupField('Power_MW')
                atts = {DG_code: channel_code,
                        vol: DG_volume,
                        disch: discharge,
                        en: DG_energy,
                        xc: x_outlet,
                        yc: y_outlet,
                        min_elev: elev_float,
                        distance: distance_coastline,
                        slope_att: slope,
                        power_att: power}
                feat = layer.getFeature(1)
                prov.changeAttributeValues({feat.id(): atts})

                DG_data = str(channel_code) + ' ' + str(DG_volume) + ' ' + str(elev_float) + ' '+ str(DG_energy) + ' '+ str(power) + '\n'
                code_storage.write(DG_data) #save the gully code

                os.remove(fn_inundation_temp1)
                os.remove(fn_inundation_temp2)

            else:
                code_storage_notokay.write(str(channel_code) + '\n')

            os.remove(fn_outlet_shp)
            os.remove(fn_chan_shp1)
            os.remove(fn_chan_shp2)

        return results

    def name(self):
        return '02_mainprocessing'

    def displayName(self):
        return '02_mainprocessing'

```

```python
    def group(self):
        return ''

    def groupId(self):
        return ''

    def createInstance(self):
        return Model()
```