REPORT

Wind Energy Development Prospectus: 400 MW Project in Ciracap, West Java

2024

This document is produced as part of the Southeast Asia Energy Transition Partnership's 'Wind Energy Development in Indonesia: Investment Plan' Project

ENERGY TRANSITION PARTNERSHIP
Powering Prosperity and Enabling Sustainability in South East Asia

UNOPS

Pondera

Headquarters Nederland
Amsterdamseweg 13
6814 CM Arnhem
088 – pondera (088-7663372)
info@ponderaconsult.com

Mailbox 919
6800 AX Arnhem

Office South East Asia
Jl. Mampang Prapatan XV no 18
Mampang
Jakarta Selatan 12790
Indonesia

Office North East Asia
Suite 1718, Officia Building 92
Saemunan-ro, Jongno-gu
Seoul Province
Republic of Korea

Office Vietnam
7th Floor, Serepok Building
56 Nguyen Dinh Chieu Street, Da Kao Ward,
District 1 Ho Chi Minh City
Vietnam

Title page

Document type
Wind Farm Prospectus

Project name
Ciracap, West Java – 400 MW

Version number
V5.0

Date
31 August 2024

Client
UNOPS – ETP

Author
Pondera, Witteveen+Bos, BITA, and Quadran

Reviewed by
ETP

ENERGY TRANSITION PARTNERSHIP UNOPS PONDERA

ISO 9001 : 2015
gecertificeerd

Table of Content

List of Figures

List of Tables

1 Introduction of the Wind Farm Prospectus

This wind farm prospectus is one of the deliverables under the project titled *Wind Energy Development in Indonesia: Investment Plan*. The project is initiated by the Ministry of Energy and Mineral Resources of the Republic of Indonesia (MEMR), managed by the Southeast Asia Energy Transition Partnership (ETP), and hosted by the United Nations Office for Project Services (UNOPS). ETP is a multi-donor partnership formed by governmental and philanthropic partners to accelerate sustainable energy transition in Southeast Asia in line with the Paris Agreement and Sustainable Development Goals. UNOPS is the fund manager and host of ETP Secretariat.

Eight potential wind farm locations on Java and Sumatra have been assessed on their techno-economic viability. These locations are Aceh Besar (Aceh), Dairi (North Sumatra), Gunung Kidul (DI Yogyakarta), Kediri (East Java), North Padang Lawas – South Tapanuli (North Sumatra), Ponorogo (East Java), Probolinggo – Lumajang (East Java), and Ciracap (West Java). Findings from the study are consolidated in a wind farm prospectus per location, of which the underlying document is created for the Ciracap wind farm. In each prospectus, the following items are included:

Section 2.1: Introduction of the location

- Geographic location
- The mentioning in PLN Electricity Supply Business Plan (*Rencana Umum Penyediaan Tenaga Listrik*/RUPTL) 2021-2030 and current development status

Section 2.2: Wind resource availability and land use

- Wind characteristics at the envisioned area
- Topography at the envisioned area
- Land use at the envisioned area, including permitting requirements
- Conclusion on the boundaries of the envisioned wind farm area

Section 2.3: Design of the preliminary wind farm layout

Section 2.4: Accessibility

- Transportation to the wind farm, including necessary road adjustments and construction of new infrastructure
- Transportation within the site, including necessary road adjustments and construction of new infrastructure

Section 2.5: Geology and seismicity conditions

Section 2.6: Biodiversity, socio-economic and environmental conditions

Section 2.7: Transmission network design

- Selection of the point of connection at the PLN grid
- Schematic design of transmission and distribution network

Section 2.8: Energy yield assessment, based on the wind resource availability and preliminary wind farm layout

Section 2.9: Business case assessment, based on the wind farm cost and energy yield

Section 3: Overall conclusion on the techno-economic viability of the wind farm and recommended next steps in the development of the wind farm

2 Analysis of Ciracap Wind Farm, West Java – 400 MW

2.1 Introduction of the wind farm location

This section introduces the wind farm location, i.e. West Java (Ciracap) in three parts: (1) geographic location, (2) status in RUPTL, and (3) status of development.

2.1.1 Geographic location

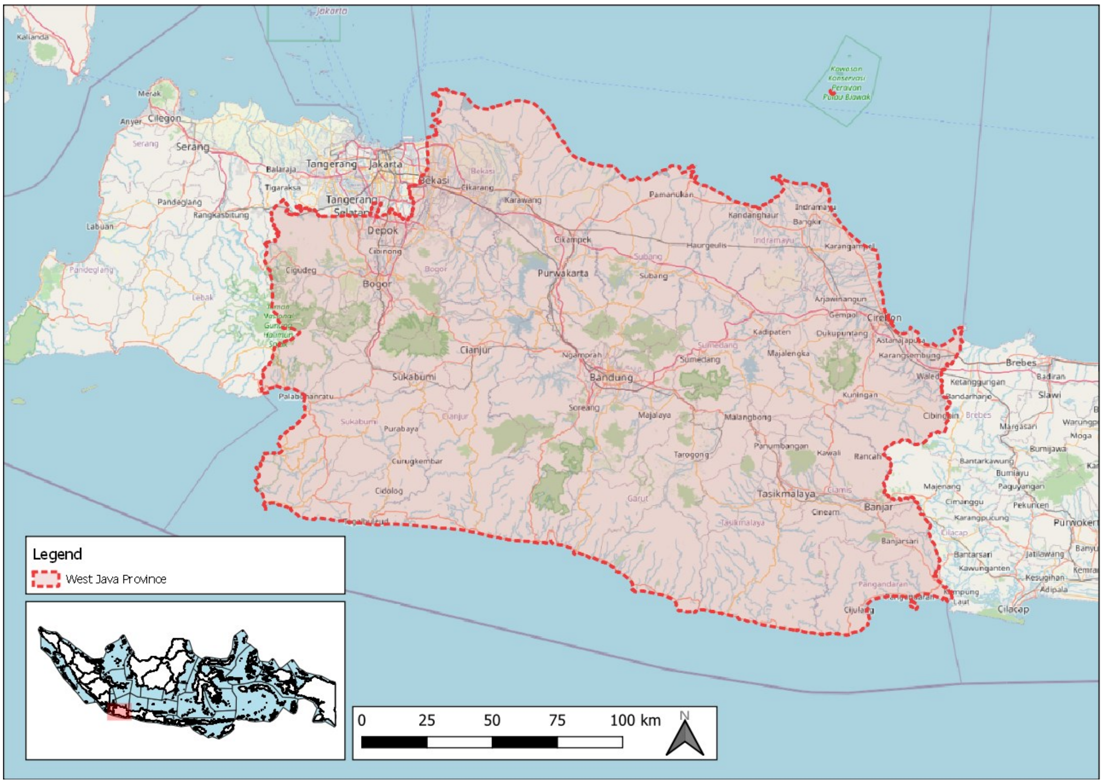

Figure 1. A map of West Java province in which the envisioned Ciracap wind farm area is located.

Figure 1 shows the map of West Java, a province in the western side of Java Island. Provinces right next to West Java are DKI Jakarta, Banten, and Central Java. West Java covers a vast area of 37,040 km^2. The province is one of the provinces with the highest population density in Indonesia, with roughly 49.4 million inhabitants in 2022[1]. In terms of GDP per capital, West Java is ranked 23rd among all provinces in the country (IDR 49.04 million)[2]. Additionally, the economic growth of West Java in 2023 (c-to-c) is 5.0%[3]. To provide context, Indonesia's economic growth in that year is 5.05% (c-to-c)[4].

[1] https://jabar.bps.go.id/indicator/12/36/1/jumlah-penduduk-menurut-jenis-kelamin.html
[2] https://www.statista.com/statistics/1423411/indonesia-per-capita-gdp-at-current-prices-of-provinces/
[3] https://jabar.bps.go.id/news/2024/02/05/657/perekonomian-jawa-barat-tahun-2023.html
[4] https://www.bps.go.id/en/pressrelease/2024/02/05/2379/indonesias-gdp-growth-rate-in-q4-2023-was-5-04-percent--y-on-y-.html

Among others, West Java is known for being one of the largest GDP contributors to the nation (34.5%[5]). A major chunk of West Java's economy is contributed by the major manufacturing industries present in the province, particularly in the areas of Bekasi, Cikarang, Karawang, Subang, and Bandung. To a lesser extent, the agriculture sector also plays a role in the economy. Popular agricultural products include rice, corn, and a wide variety of fruits and vegetables. West Java also hosts some well-known tourist destinations such as Ciater hot springs, Gede Pangrango National Park, Bogor Botanical Garden, and Tangkuban Perahu crater.

As mentioned above, West Java is one of Indonesia's biggest industry hubs. Over 40 Industrial Estates are located in the province. The five biggest Industrial Estates are as follows[6]:

1. Jababeka Industrial Estate (5,600 ha)
2. Greenland International Industrial Center (1,804 ha)
3. MM2100 Industrial Town (1,700 ha)
4. Lippo Cikarang (1,645 ha)
5. Karawang International Industrial City (1,479 ha)

It is noteworthy that some of these estates may already have their own, dedicated power plant(s) to fulfill their respective demand for electricity. Meanwhile, there is only one Special Economic Zone (SEZ) in West Java, namely, Lido SEZ (1,040 ha)[6]. This SEZ was inaugurated recently in 2023 as a tourism SEZ.

In Appendix E of RUPTL PLN 2021-2030, PLN lists the strategy to fulfill new/additional power demand from four 'large' electricity consumers in West Java, namely:

1. Dwipapuri Abad Industrial Estate (170 MW)
2. Karawang New Industry City (150 MVA)
3. Jatiluhur Industrial Smart City or MOS Industrial Estate (255 MW)
4. BCMG Tani Berkah Smelter (0.8 MW)

The next subsection will explain the projected power demand levels of the province, which among others considers the future demand from the abovementioned consumers. The considered wind farm location is located in Sukabumi Regency, in the southwestern region of West Java.

2.1.2 Status in RUPTL PLN 2021-2030

The electricity system of West Java is depicted in Figure 2. The system comprises of existing 70, 150, and 500 kV transmission lines, whereas the extension of these lines and the complementing substations are now either planned or in construction. Moreover, West Java's peak load in 2020 was 7,712 MW based on RUPTL PLN 2021-2030. Projections of energy production and peak load in 2021-2030 are shown in Figure 3. Both energy production and peak load are expected to grow within the period. Additionally, the average annual peak load growth rate is roughly 3.88%.

[5] https://jabarprov.go.id/en/selayang-pandang
[6] https://regionalinvestment.bkpm.go.id/pir/kawasan-industri-kek/

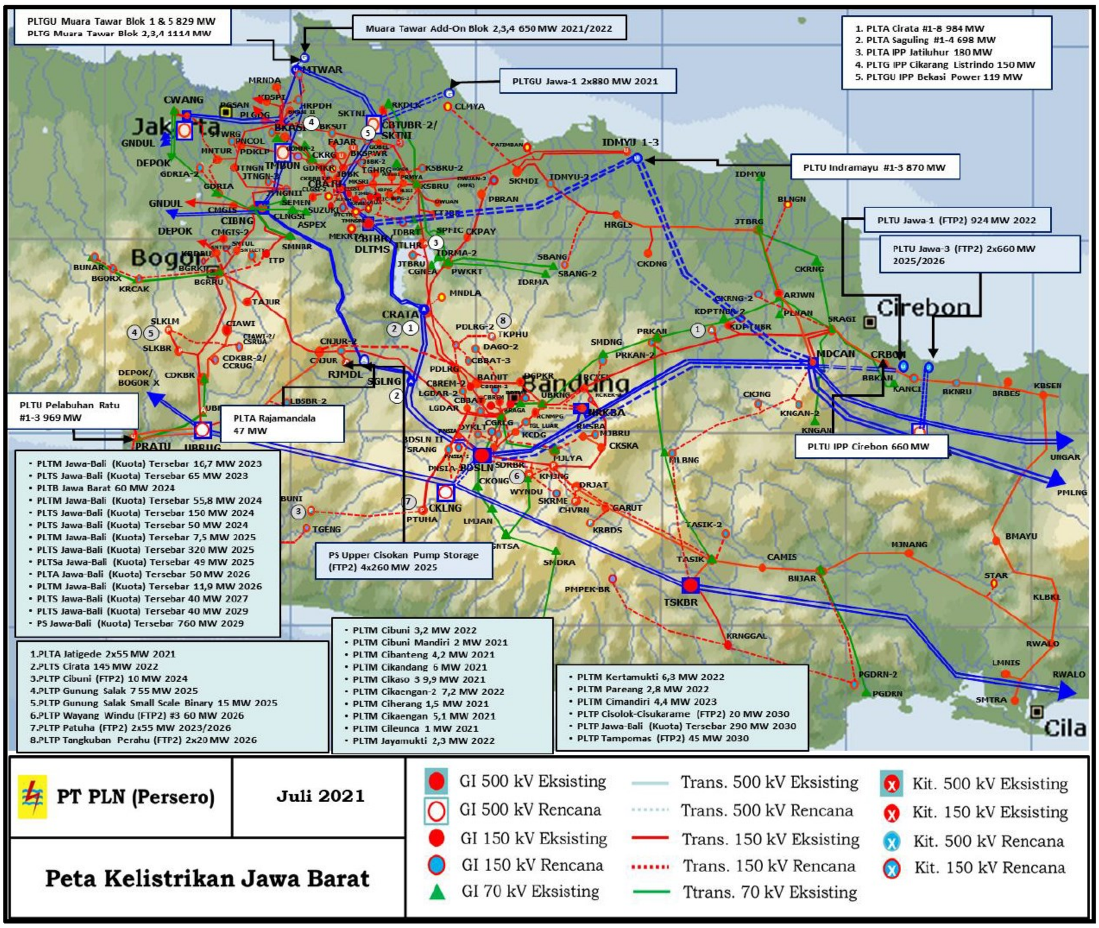

Figure 2. A map of West Java electricity system in RUPTL (Source: RUPTL PLN 2021-2030).

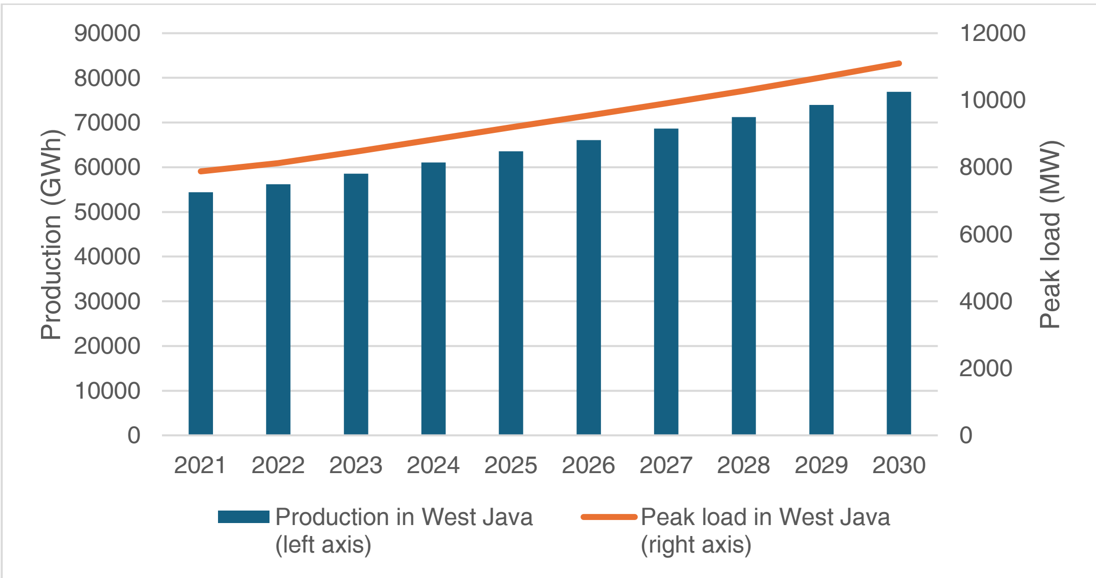

Figure 3. Projected electricity production and peak load in West Java (Source: RUPTL PLN 2021-2030).

The RUPTL document also presents the power generation development planning, which has been summarized in Figure 4. Both conventional and renewable energy power plants are taken into account in the planning. Additional power generation is commonly categorized into three sources, namely, PLN, Independent Power Producer (IPP), and *Wilayah Usaha* cooperation. However, for West Java, only PLN and IPP are listed as the sources.

Among the planned addition of power plants, there is one listing for wind energy, whose amount is 60 MW for COD in 2024. It is expected that an IPP (instead of PLN) will be appointed as the developer. On top of this allocation, the RUPTL also identifies West Java's wind power potential at Cirebon (85 MW), Garut (150 MW), and Sukabumi (670 MW). The analyzed wind farm area in this prospectus is likely to overlap with the latter 670-MW potential.

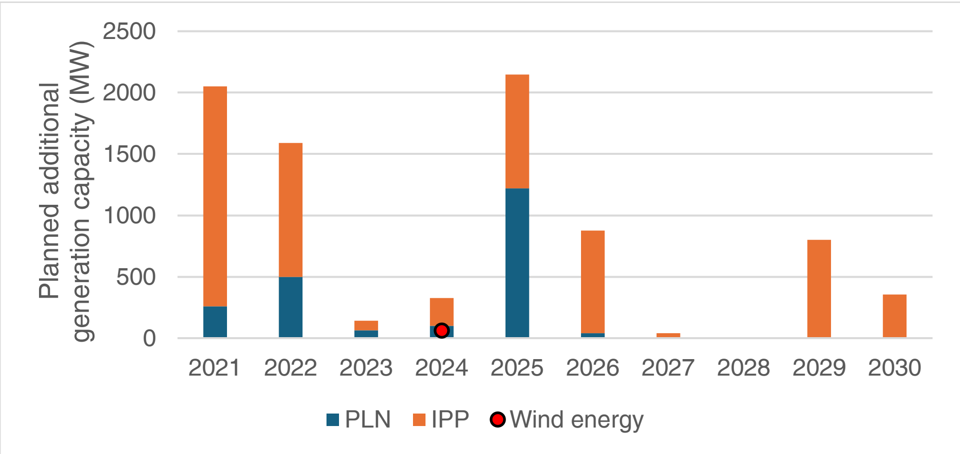

Figure 4. Additional generation capacity being planned for West Java (IPP: Independent Power Producer; Source: RUPTL PLN 2021-2030).

2.1.3 Status of development

To the best of our knowledge, there are several developers active in West Java, including in the Sukabumi Regency. One of these developers is PT Barito Renewables Energy Tbk (BREN), which in early 2024 completed the acquisition of the majority shares of PT UPC Sukabumi Bayu Energi (UPC)[7]. The so-called Ciemas wind farm is now at its late stage of development[8], since its initiation in 2016[9]. According to the insights from UPC, wind measurements have already taken place since then. The project's feasibility study was already submitted to PLN in 2019, before being renewed in 2021[9]. The area of the Ciemas wind farm is not included in the assessment of wind energy potential in this wind farm prospectus, in order to avoid overlapping work with BREN.

[7] https://investasi.kontan.co.id/news/barito-renewables-bren-rampungkan-akuisisi-saham-pltb-lombok-dan-sukabumi
[8] https://finance.detik.com/bursa-dan-valas/d-7124030/emiten-prajogo-pangestu-caplok-3-aset-pembangkit-kebun-angin-ri
[9] https://www.liputan6.com/regional/read/4653974/pltb-ciemas-hadir-sukabumi-jadi-negeri-kincir-anginnya-asia-tenggara

2.2 Wind resource availability and land use

2.2.1 Approach

To determine the area in which wind turbines can be placed, one of the most important factors to consider is wind speed. This factor largely determines the envisioned boundaries of the area suitable for the construction of wind turbine generators (i.e. WTG-area). In the later process, additional factors were taken into consideration, which led to a final WTG-area. This section provides a concise overview of the factors that have resulted in the final WTG-area. The data used to shape the WTG-areas was based on open-source geo-information. Additional field checks have shown that the open-source data provides a sufficient level of detail in this phase of the project.

The WTG-area selection for this location starts with identifying areas with average wind speeds above 6 m/s at 100 m height. This initial filtering process using wind speed data is followed by the inclusion of further parameters, including land use (roads, railways, residential areas, and buildings) and topography (slopes). Additionally, the volcanic and seismic risks are later taken into consideration in Section 2.5. To summarize, the first set of restriction criteria being applied in the WTG-area selection are as follows:

- Wind speed (> 6 m/s)
- Slopes (< 15 degrees, with a buffer of 100 m around steep ridges)
- Roads (with a buffer of 150 m)
- Railways (with a buffer of 150 m)
- Residential areas and buildings (with a buffer of 250 m)

The next step was to consider the “go/no-go zones.” As the name suggests, these zonal categories indicate whether a particular area either can accommodate wind farm developments without significant restrictions/conditions to be fulfilled (go zone), can accommodate wind farm developments with significant restrictions/conditions to be fulfilled (go zone with restrictions), or cannot accommodate wind farm developments (no go zone). These zones were determined considering the land use, i.e. presence of nature reserves, protected areas, and airports, as well as water ways and water bodies, based on OpenStreetMap (OSM). Furthermore, existing policies (e.g. spatial plans) and regulations (e.g. on permitting) specific to the area are also considered.

A specific buffer distance was applied to each case to minimize the risk of possible nuisance, safety issues, and land use conflicts. This step results in the final WTG-areas. The second set of restriction criteria that were checked thus include:

- Nature reserves and protected areas (with a buffer of 300 m)
- Airports (with a buffer of 3,000 m)
- Water ways and water bodies (with a buffer of 300 m)

Finally, the area in which BREN is developing the Ciemas wind farm was excluded from further analysis.

2.2.2 Wind resource and characteristics

Figure 5 shows the initial search area (bounded by the purple-dash box), in the southwest coast area of West Java in the regency Sukabumi. Within the figure, areas with average wind speeds of more than 6 m/s are indicated by the "pixels" with distinct color as described by the color bar. It can be concluded that promising wind resources are located in an extensive area within the regency.

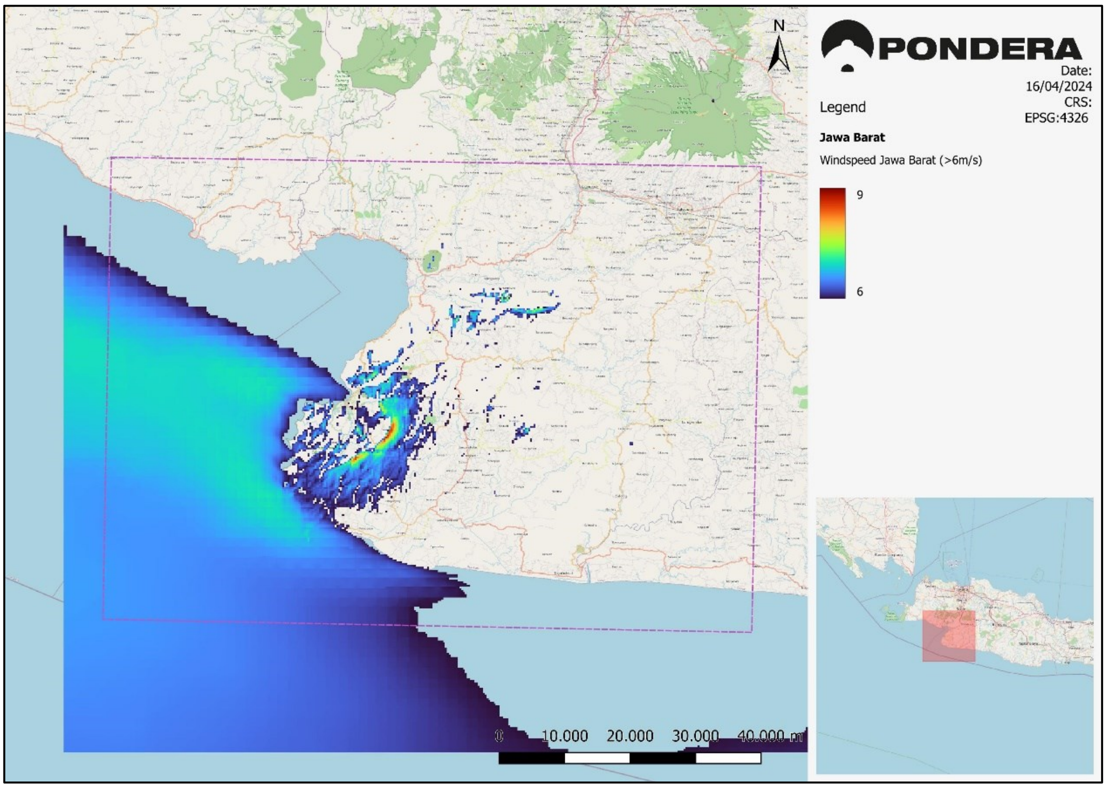

Figure 5. Sukabumi regency search area with wind speed distribution. The purple-dash bounding box shows the full search area. The color bar indicates average wind speeds which are above 6 m/s at 100 m height according to the Global Wind Atlas (GWA) climatology.

Considering the scattered nature of the areas with promising wind speed, the search area was further confined to a single smaller, continuous area to safeguard the project's viability. The reason behind this is to avoid the high cost and complexity of building electrical connections (e.g. distribution lines) between the several sub-sites of wind turbines which are separated by large distances.

Figure 6 shows a zoomed-in map of this continuous area which has been further studied in the subsequent steps. The figure is also complemented by the final WTG-area to give an idea of the level of wind speed at the location.

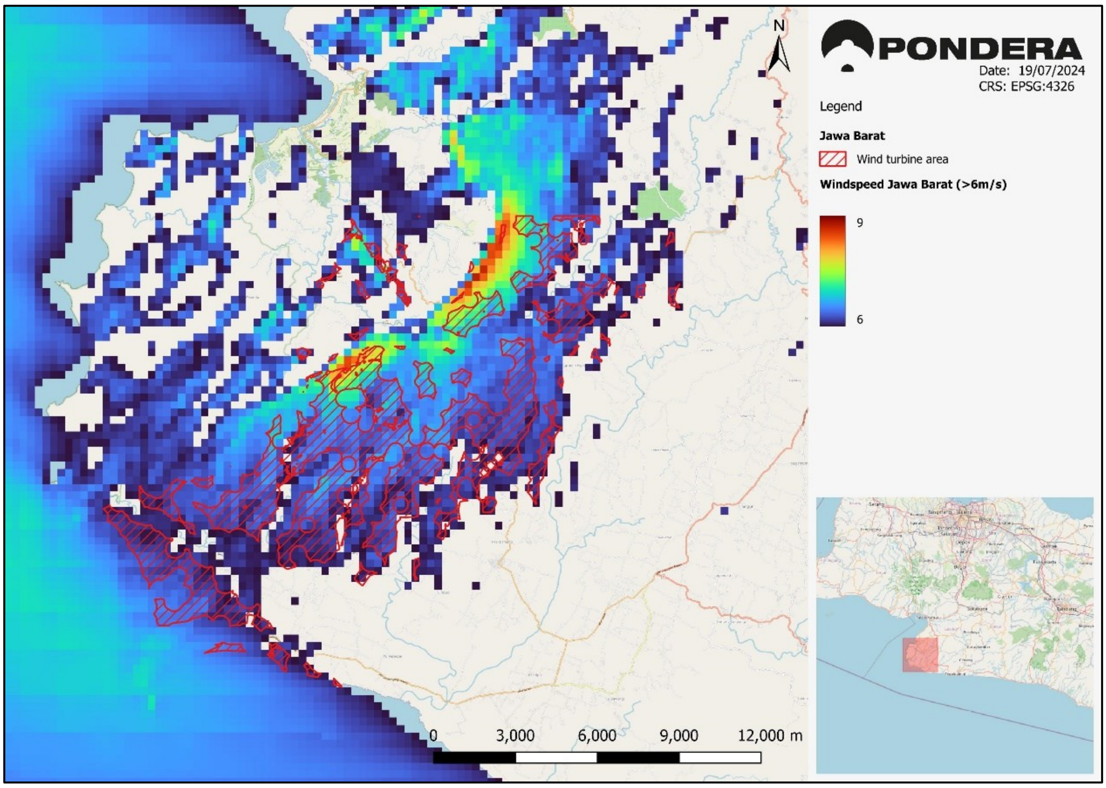

Figure 6. A zoomed-in look at the Sukabumi regency search area, focusing, along with the wind speed distribution. The red, dashed polygons represent the final WTG-area in Ciracap which meets all the criteria. Average wind speeds above the threshold of 6 m/s at 100 m height according to GWA are shown.

Additionally, Figure 7 visualizes the long-term average wind direction distribution for the Sukabumi regency area. As can be interpreted from this figure, the wind climate in the area primarily consists of wind from the Southeastern direction. In Figure 8, the wind speed distribution throughout the day for each month per year is visualized.

The highest wind speeds are observed between May and October, when the intertropical convection zone (ITCZ), is positioned north of the site. Therefore, this period can also be distinguished from the other months by the prevailing southeastern wind directions. Approximately from November until April (though the timing can vary from year to year), when the ITCZ is passing over the site towards the south, the lowest wind speeds are observed. Besides the annual wind speed and direction patterns, which strongly depend on the positioning of the ITCZ, interannual variations are caused by the El Niño and La Niña phenomena. During a strong El Niño year, the trade winds are weaker, while during a La Niña year, they are strengthened, resulting in higher wind speeds over the area.

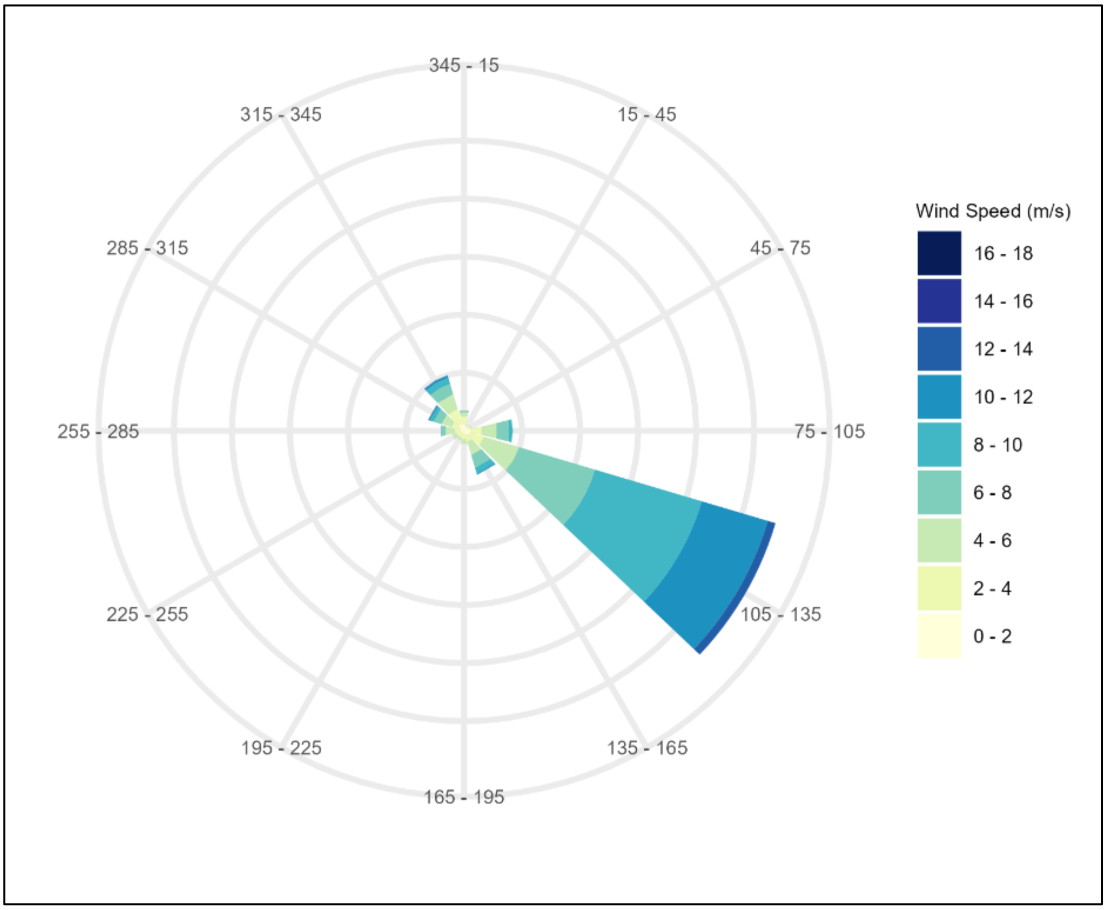

Figure 7. Wind rose diagram with wind directions and wind speed categories based on a 10-year climatology, including the 2004-2015 time series of hourly data. Source: EMD-WRF.

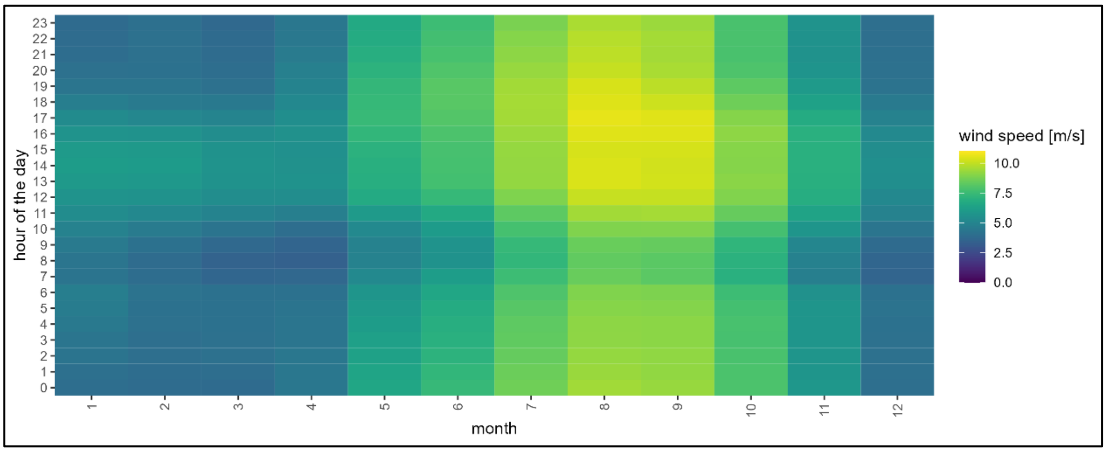

Figure 8. The wind speed distribution throughout the day, visualized per month of the year. Based on a 10-year climatology, including the 2004-2015 time series of hourly data. Source: EMD-WRF.

2.2.3 Topography

Figure 9 shows the topography of the Ciracap search area in the Sukabumi regency. The red, dashed polygons represent the final WTG-area which meets all the criteria. The steepness of the terrain or slope is expressed in degrees. The slope calculations are based on the FABDEM elevation grid which has a resolution of approximately 30 m. In this study, areas with slopes higher than 15 degrees are excluded from further analysis to avoid excessive cost of transportation and construction commonly entailed with wind farm projects at steep terrains. Nevertheless, it is noteworthy that due to the data resolution, this exclusion criterion does not consider small scale (i.e. less than 30 m) fluctuations in elevation.

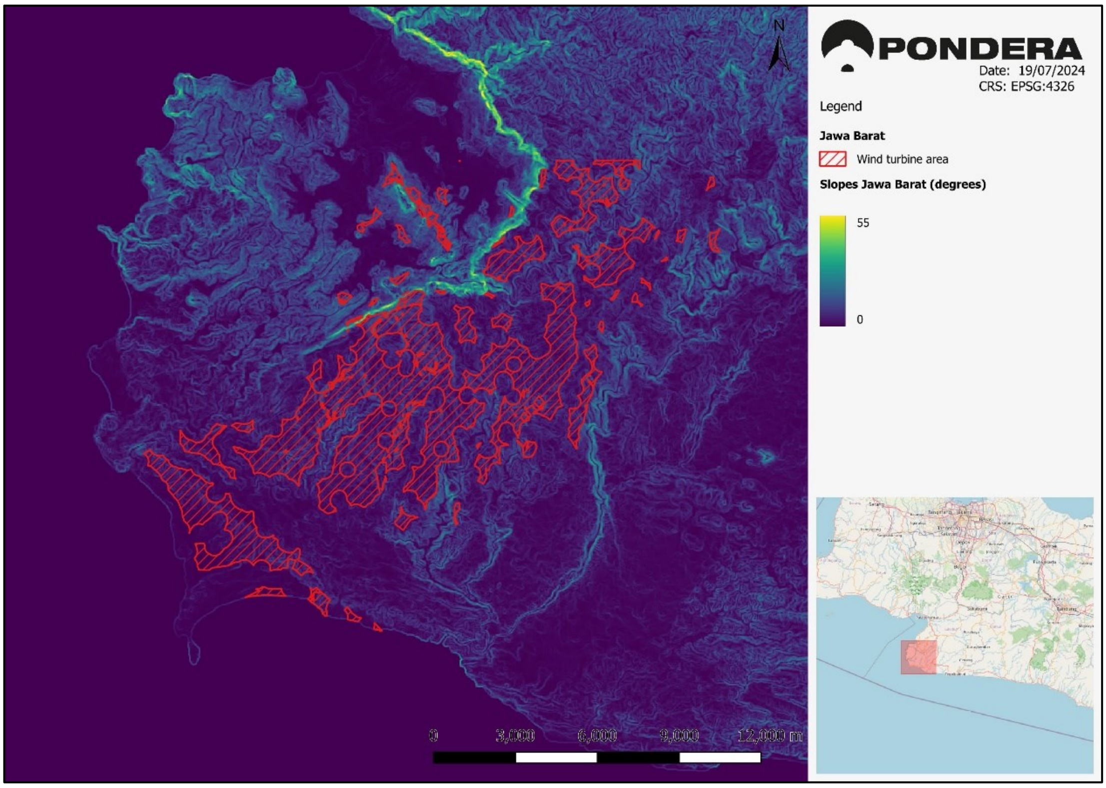

Figure 9. Topography of the Ciracap WTG-area, showing the slope (in degrees; according to calculated based on FABDEM data) at the region.

2.2.4 Land use

As mentioned in the previous subsections, wind farms cannot be realized in areas too close to buildings, infrastructure, nature reserves, and water bodies. Therefore, buffers are applied to these objects to determine suitable WTG areas. Aggregating the aforementioned restriction criteria give the land use exclusion zones (see Figure 10). These exclusion zones were taken out of consideration in the next stages of this study. Consequently, this analysis produces the final WTG-area as marked with the red, dashed polygon in Figure 10.

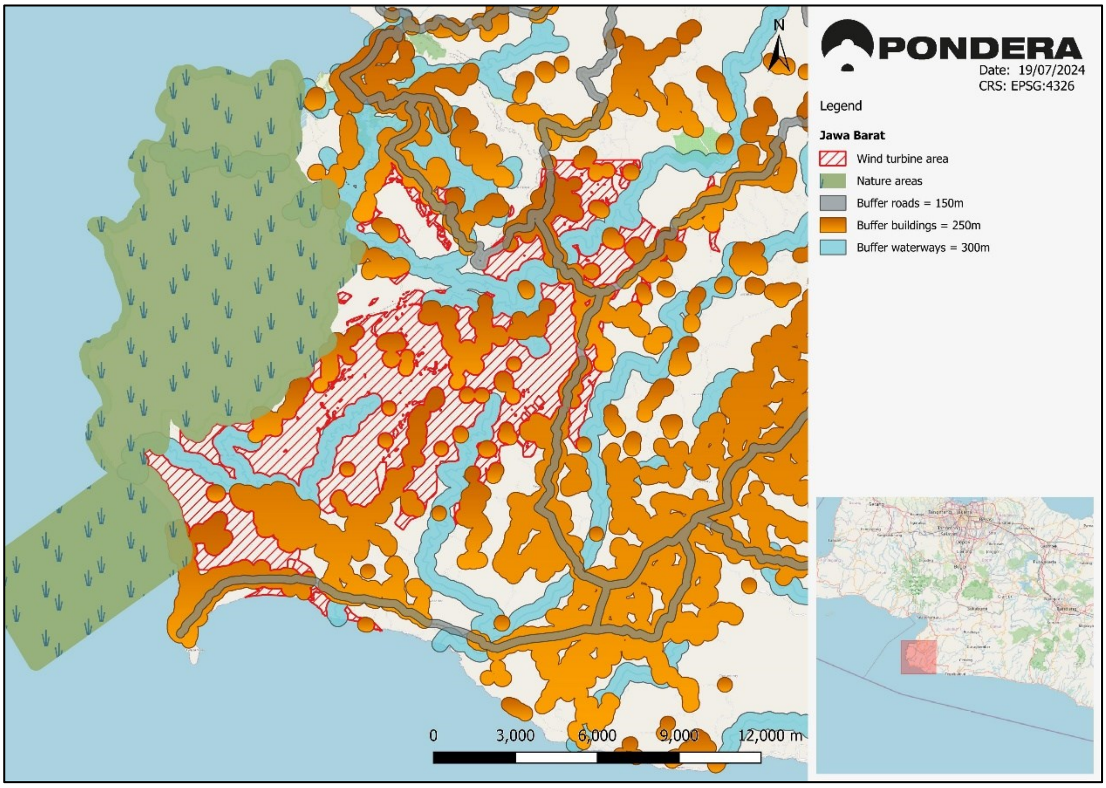

Figure 10. Exclusion zones at the Ciracap district based on land use, topography, and residential areas. Source: calculation based on FABDEM elevation, ESRI, and OSM.

2.2.5 Specific permitting requirements

Sukabumi Regency Spatial Plan (*Rencana Tata Ruang Wilayah* or RTRW) 2012-2032 is used as the basis for the analysis of specific permitting requirements. The analysis is done by overlaying the spatial plan and the final WTG-area (i.e. continuous area with promising wind speed), as shown in Figure 11. Overlaps with the following land use types are observed:

1. Plantation Area (*Kawasan Perkebunan*)
2. Wetland Farming/Agricultural Area (*Kawasan Pertanian Lahan Basah*)
3. Dryland Farming/Agricultural Area (*Kawasan Pertanian Lahan Kering*)
4. Beach Border Area (*Kawasan Sempadan Pantai*)
5. River Border Area (*Kawasan Sempadan Sungai*)
6. Rural Settlement Area (*Kawasan Permukiman Pedesaan*)

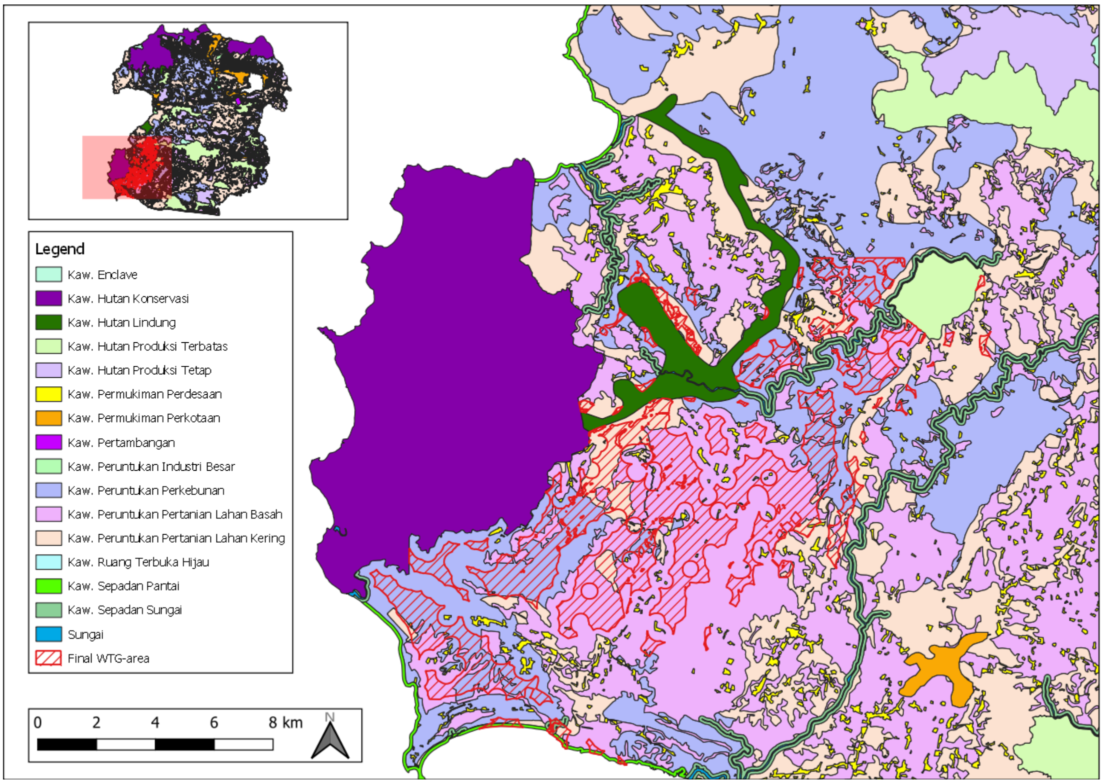

Figure 11. The map of spatial plan of Sukabumi Regency (RTRW 2012-2032) overlaid with the final WTG-area.

A major portion of the final WTG-area is in the Plantation Area. Such an area is usually owned by either a (private or state-owned) company or the local community. The former case is typified by the cultivation of a single type of plant. Conversely, in the latter case, the area is usually cultivated with several types of plants. If the area is not part of the Sustainable Food Agriculture Area (*Kawasan Pertanian Pangan Berkelanjutan*/KPPB), then the Plantation Area can be used for wind farm development (and other types of power generation and transmission activities for public interest) once a purchase or lease agreement is obtained with the landowner[10].

A sizable portion of the final WTG-area also lies in the Wetland Farming/Agricultural Area, whereas a small portion of the final WTG-area is in Dryland Farming/Agricultural Area. For both types of land use, it can be assumed that the relevant area belongs to the community. Hence, wind farm development (as well as other types of power generation and transmission activities for public interest) at the location is possible if the area is not part of the Sustainable Food Agriculture Area, and after purchase or lease agreement is achieved with the landowner[10].

The final WTG-area also, to a much lesser extent, overlaps with Beach Border Area, River Border Area, and Rural Settlement Area. The first two types are owned by the State and can be used for public interest activities (such as power generation). Meanwhile, the latter type can only be used for wind farm development if a purchase or lease agreement is obtained with the landowner.

[10] Referring to Law 22/2019, Presidential Regulation 59/2019, and Government Regulation 1/2011.

There are two additional things to note on this site. First, it is worth mentioning that the wind farm does not interfere with the Aviation Operations Safety Area (*Kawasan Keselamatan Operasi Penerbangan/* KKOP) of Cikembar Airport, based on the analysis of Angkasa Pura in 2019[11]. Second, the RTRW referred to in this analysis may no longer be valid since a new RTRW for the Sukabumi Regency was prepared through Regional Regulation No. 10/2023. However, this latest RTRW has not been officially issued by the regional authorities.

2.2.6 Final WTG-area

An overview of the final WTG-area against the satellite image at the location can be found in Figure 12. This area meets all the criteria as visualized in the previous figures.

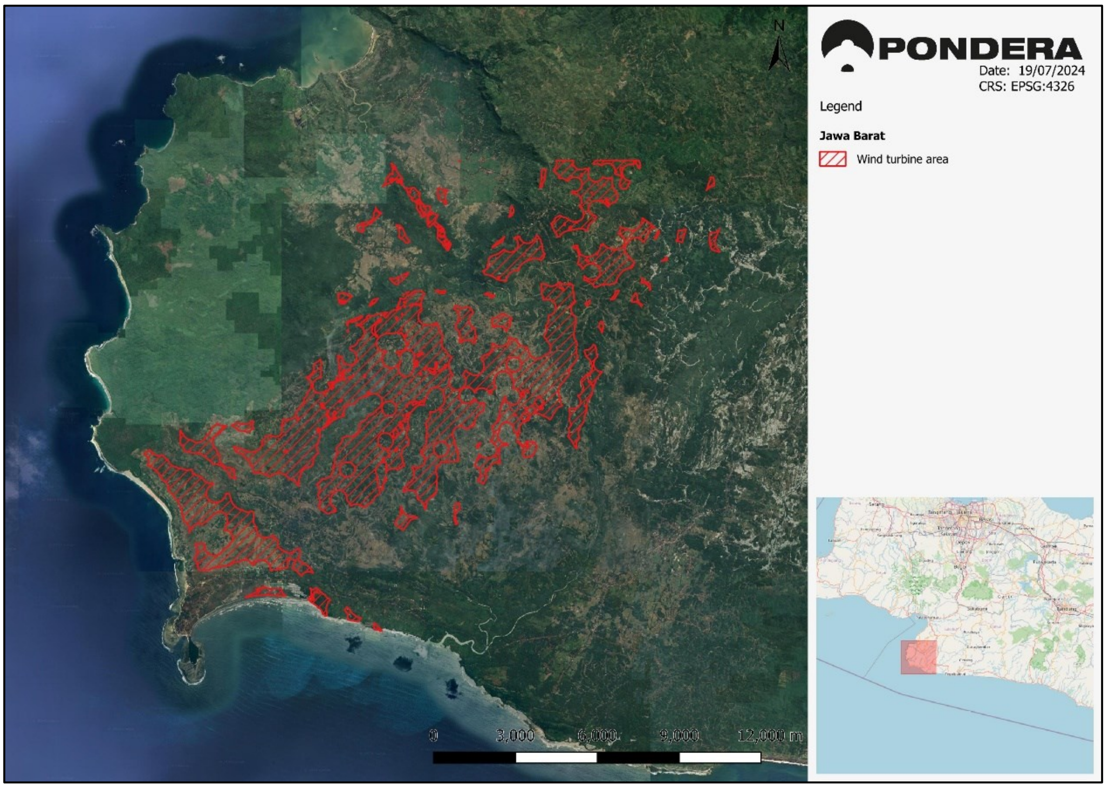

Figure 12. Final WTG-area based on the restriction criteria. Source: Google Satellite Images.

Limitations

As mentioned before, the parameters that have shaped the final WTG-area have been based on open-source geo-information. A site visit to some portions of the area was conducted to obtain a deeper understanding of the area's characteristics (as explained further in Section 2.4 to Section 2.6), from which general conclusions are then drawn to further analyze the final WTG-area. The site visit has shown that in general:

1. The residential areas data derived from the ESRI-database underestimates the buildings in the region, and therefore, in some cases this might necessitate additional exclusion zones in a later stage of the project;

[11] Component 2: Permitting and Regulation Assessment for Onshore Wind

2. In some cases, the water ways were too restrictive (considering the size of the streams), and thus, they were left out of the analysis (i.e. those waterways were not considered as a restriction); and
3. The primary roads data derived from OSM also include small roads; consequently, this dataset might be too restrictive in some cases.

2.3 Preliminary wind farm layout

The wind farm layout is based on the WTG-areas provided in Section 2.2. The preliminary wind farm layout is designed based on bundling of as many wind turbine positions as possible. This prevents for example constructing a road and cables to a single wind turbine location, which is not cost effective.

As the Indonesian wind climate generally consists of areas with lower to medium wind speeds, a wind turbine type that suits these wind conditions should be selected. For a provisional wind farm layout, a 4 MW reference wind turbine with a rotor diameter of almost 170 m and a hub height of 140 m has been used. This makes the total tip height around 220-225 m. To reduce the wake losses and possible negative turbulence influences, a standard distance of five times the rotor diameter was used in the preliminary wind farm layout. During the positioning of the turbines, additional visual checks were performed based on satellite images, taking into account: 1) power lines, 2) buildings, 3) size of the area, with a minimum of three turbines in proximity, 4) accessibility of the area relative to other parts of the WTG-area, 5) minimization of the restriction criteria, 6) selection of the highest wind speed areas and 7) fulfillment of the installed capacity goals as stipulated in RUPTL PLN 2021-2030.

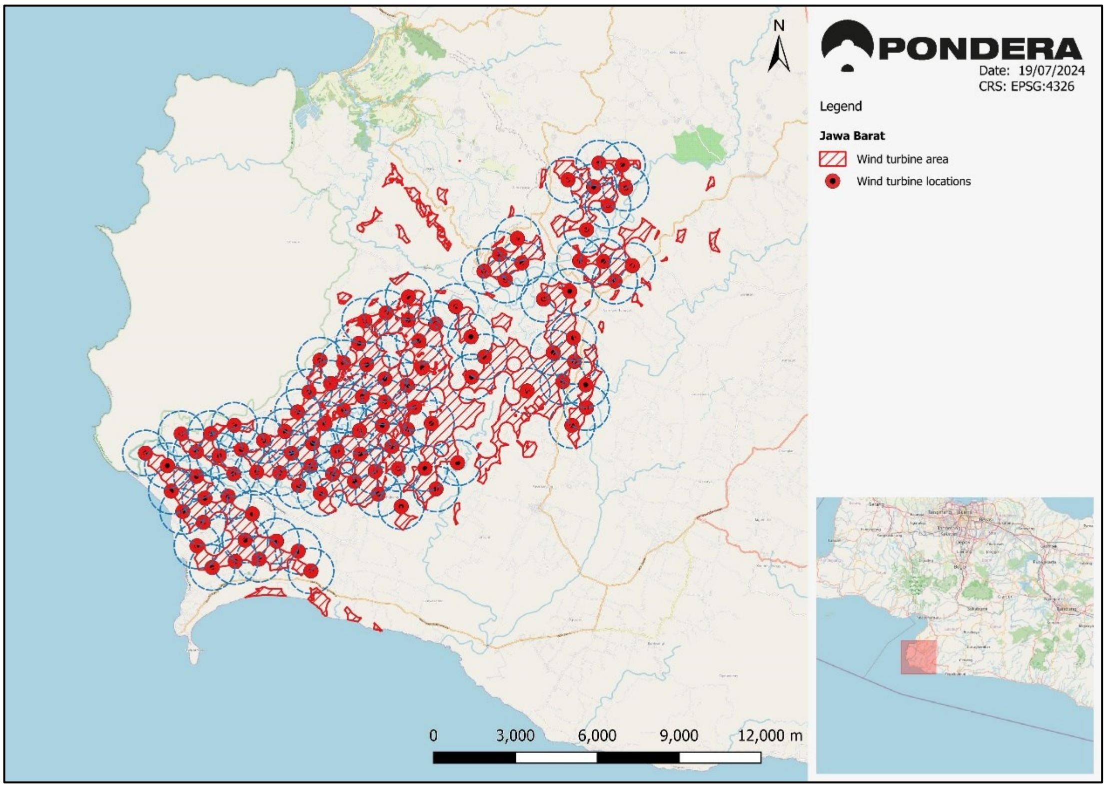

Figure 13. Preliminary wind farm layout at the final WTG-area.

Figure 13 displays an overview of the wind turbine locations in the final WTG-area. A total of 100 wind turbines were positioned into the area, amounting to an envisioned total installed capacity of 400 MW. The red marker (red dots with black centers) indicates the exact location of the individual wind turbines, whereas the blue radial line guarantees a spacing of at least 5 times the rotor diameter.

As becomes visible from Figure 13, there seem to be available locations where wind turbines could be realized. However, site visits have determined that the ESRI database, which is used to determine the location of residencies, was not totally conclusive. Meaning that at locations within the wind turbine area, some wind turbines could not be realized as a result of local residencies.

2.4 Wind farm accessibility

In this section, accessibility of the wind farm is explained through three subsections: (1) the Indonesian transportation setting, (2) port-to-site transportation, and (3) transportation within the site.

2.4.1 The Indonesian transportation setting

Outside of the larger cities, regional road systems are used for almost all transportation (see Figure 14). These roads lead through the center of cities, towns, and villages they are serving. Ring roads around cities are reserved for a few major cities such as Jakarta, Bandung, Medan, Yogyakarta, and Surabaya. In a lot of cases, only one major regional road is available to go from one city to another city. This results in a situation where all traffic is using the same road, i.e. pedestrians (including groups of school children, farmers etc.), motorbikes, cars, ambulances, public transport, smaller local trucks, and large trucks for long distance transportation. While some sections of highways are available on Sumatra and more are planned or under construction, so far only Java has a continuous highway connecting the western to the eastern part of the island. This highway is situated on the northern side of Java which is more densely populated and has flatter terrain.

Figure 14. Typical road layout in rural Indonesia. Winding roads of ~6 to 7 m wide serving both local, regional, and national traffic. Overhead power- and telecommunication cables with poles on both sides of the road. Buildings are in close proximity. Within cities and larger towns, the roads are generally slightly wider, but with more overhead cables, poles, and advertisement billboards.

Usually, general utilities such as electricity distribution lines and telecommunication lines follow the same pathway as the local roads. Overhead cables right next to the road are the standard way of practice throughout Indonesia. The major powerlines and telecommunication cables are situated on one side of the road while serving both sides. This means that for all houses or groups of houses on the other side of the road, all cables have to cross the road, generally at a height of about 5 meters above the road surface. In towns and cities, these overhead crossings are typically present every 20 to 50 meters.

Urban drainage systems are normally buried underground on both sides of the road and are not suitable for the carriage of heavy transport. Buildings are in most cases present within two to five meters from the road, often 1 to 3 stories high.

This together means that space on and around Indonesian roads is very limited. Aside from the spatial challenges, there are also significant challenges arising from the duration of the transport. The transport of wind turbine components is a lengthy process. One turbine is transported in individual components (e.g. tower segments, wind turbine blades) on roughly ten trucks, excluding the building material for the foundation. Long term closure of roads may have a significant impact on the functioning of a town as alternative routes are often not available.

Transporting the blades of the wind turbines with a length of 80+ meters may be one of the most critical aspects of wind farm development in Indonesia and must be thoroughly prepared.

2.4.2 Port-to-site transportation

In the nearby area of the Ciracap wind farm, no large commercial, deepwater ports with offloading quays are available. The nearest major commercial port is located in Jakarta or Cilegon. Transport on land from these ports to the site is not realistic. It is most likely that the individual parts of the wind turbines have to be transshipped from the large ship to smaller barges which can dock in the local, smaller ports. This transfer may take place in the open sea or at the above mentioned larger commercial ports.

One port that is potentially large enough is the non-commercial port of PT Cemindo Gemilang Bayah (see Figure 15). By road this port lies 116 km from the project site. The port of the cement factory may also be too far for overland transport but may be an option where the transfer from the larger ship to barges may take place. Nearby the site two smaller ports are present; Pelabuhan Ratu fishing port (see Figure 16) and the port of PLTU Pelabuhan Ratu coal plant (both 60 km over road to project site). The fishing port is regarded as the most logical and therefore favorable port to start road transport, as no approval of the coal plant is required.

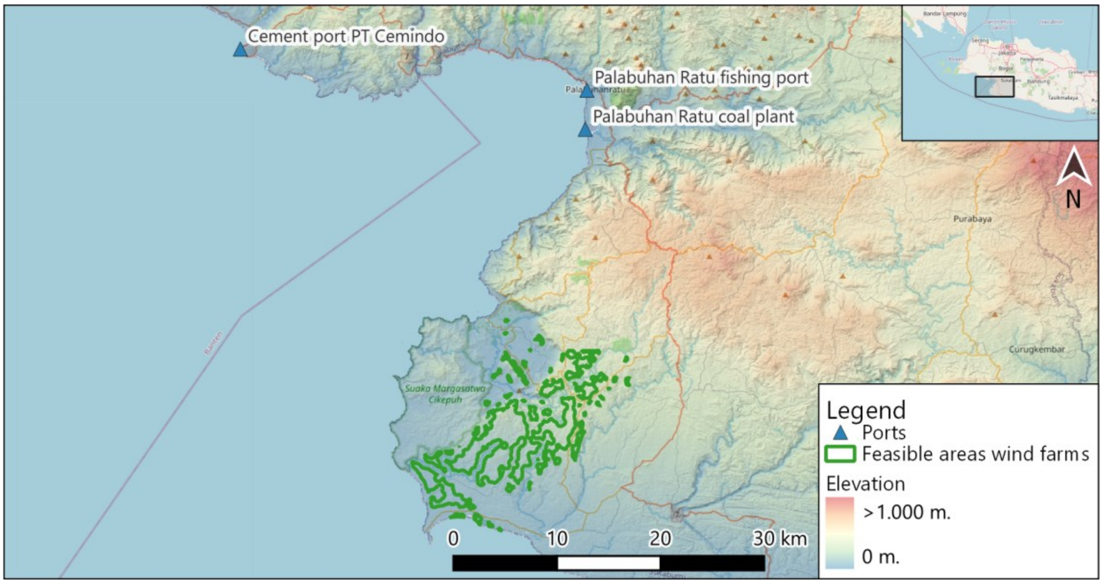

Figure 15. Location of nearby ports. Transfer from larger ships may take place at the open sea or at the cement port. Transfer from barges to land could take place at fishing port or coal plant.

Figure 16. Port of Pelabuhan Ratu

The port consists of two parts, the inner and outer part. The outer part (see Figure 17 and Figure 18) is deeper and less crowded with small fishing boats, measuring a port area of ~160*60 meters. During the site visit the water depth in the outer part of the port was estimated to be about 2 m.

Figure 17. The outer part of the Pelabuhan Ratu fishing port.

Figure 18. Entrance to outer part of the Pelabuhan Ratu fishing port.

During the site visit a temporary earthen jetty was discovered, built by PT Mitra Kartika Karya (see Figure 19). According to online news articles further construction of the jetty was halted by the government because of the lack of permits. This does, however, show that the construction of such (temporary) jetties is possible.

Figure 19. Temporary jetty between Pelabuhan Ratu and site location.

The main road from Pelabuhan Ratu to the south crosses a section of high hills (route A, see Figure 20). This road -including many bends- leads up to an elevation of around 800 m +MSL and after that descends several hundreds of meters to the project site. A smaller road (route C) is present next to the coast which circumnavigates the high hills, but it includes some sections with sharp corners and some very steep slopes.

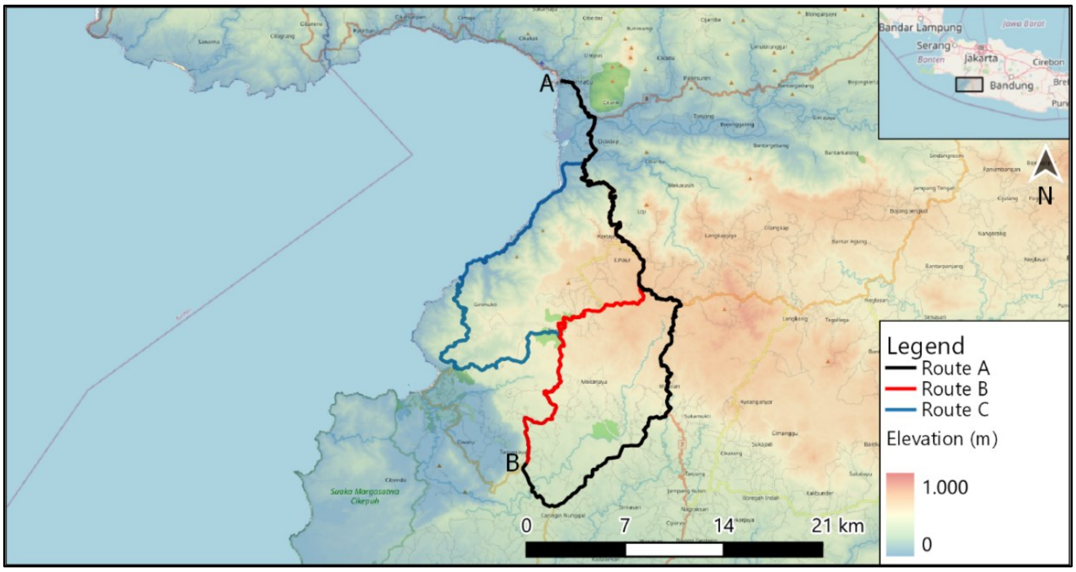

Figure 20. Routes from Pelabuhan Ratu (A) to center of site (B).

During the site visit it was determined that route A is the preferred route. The road width, slope and sharpness of the turns are all more favorable than route B and C. On route B (including the southern part that route C is also using) some sections will have to be upgraded to make them suitable for heavy transport.

In the following figures, the road profile is presented for the routes A, B and C.

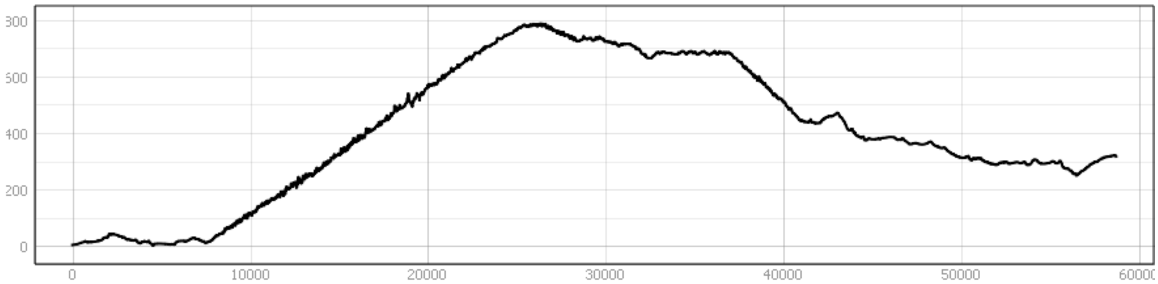

Figure 21. Road profile Route A.

Figure 22. Road profile Route B.

Route A and B lead over the hills. During the long ascent the stable slope amounts to about 4.2% (785 m gain over 18,501 m road), which in itself should be no limiting factor for the heavy transport. Route B differs from route A in the second part where a smaller narrower road to the site is taken. Route B is less favorable than route A and only an option when the second part of route A is not possible.

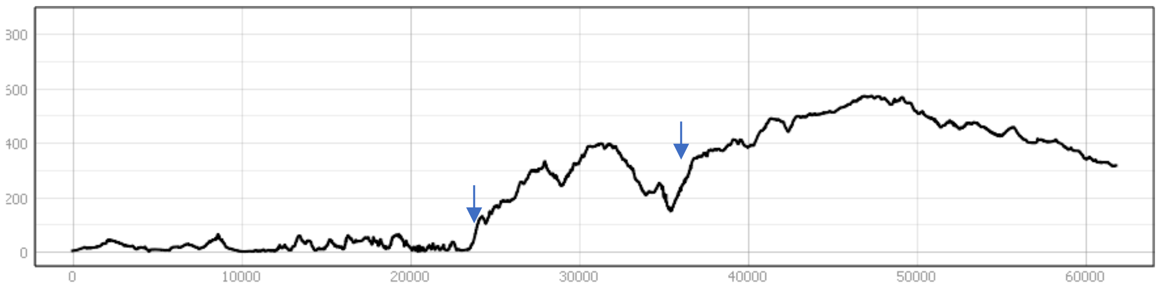

Figure 23. Road profile Route C.

Route C circumnavigates the hills but is very steep in some sections. The mean elevation at the arrows in Figure 23 will be respectively 12.7% (94 gain over 736 m) and 14.4% (195 gain over 1,348 m). Tow trucks will have to be used. Further complicating factor is that several hairpin corners are present, and the road is narrower (about 5 m wide) than road A (6 to 7 m wide). This route is displayed in Figure 24.

Figure 24. Example of road on route C. On steep sections like these road shoulders are paved as well.

Bridges

During the site visit, several bridges were observed on the main road (route A) from Pelabuhan Ratu to the site (see Figure 25 and Figure 26). On first inspection no 'red flags' were seen for heavy transport. According to information on the bridge all were built in 2017.

Four larger bridges have to be crossed from the port to the site and within the site (in Pelabuhan Ratu near the port, two crossing larger rivers just south of Pelabuhan Ratu and the 'Cileteuh bridge/ Jembatan Cileteuh.' Of the larger bridges, two are steel bridges with a 'cage design,' and the others are concrete bridges. Apart from these larger bridges, 9 smaller bridges have to be crossed from Pelabuhan Ratu to the site and within the site.

Figure 25. Bridge on main road.

Figure 26. Impression of bridges within site area which have to be upgraded.

2.4.3 Transport within the site

Whereas the area is primarily developed for agriculture and agroforestry, many (unpaved) roads can be found within the area. They could be used for transportation. Upgrading and improving (secondary) roads, however, is required as many of these smaller roads in rural parts are narrow and in poor condition. Main roads, in general, are in better condition. The main road runs perpendicular to the area with the highest wind intensity. Therefore, the public road can be used as 'backbone' for the internal road structure which reduces construction costs significantly. The proposed road layout can be found in Figure 27.

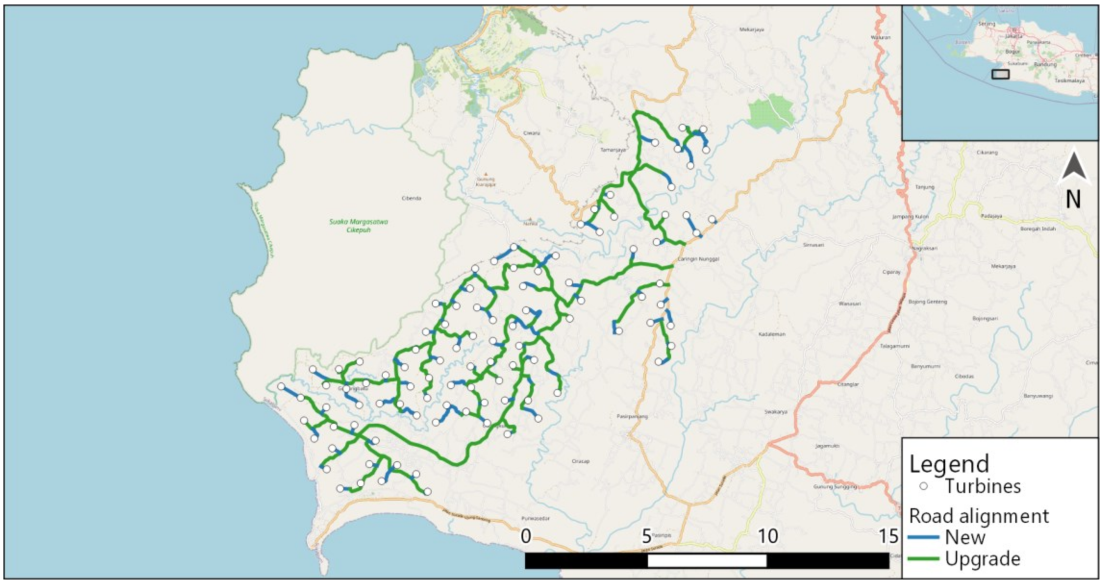

Figure 27. Proposed road layout consisting of ~67 km of new road and ~121 km of upgraded existing road.

The existing roads range from poorly- to well maintained (see Figure 28 and Figure 29). Apart from the primary roads in the area, virtually all secondary roads have to be upgraded to make them suitable for turbine transport. The poorly maintained roads consist of degraded patches of old asphalt, gravel and an uneven road surface. However, this provides a well compacted foundation for the new road.

Figure 28. Example of a poor maintained road

Figure 29. Example of a well-maintained road.

For the feasibility study, we recommend looking into the following points regarding wind turbine transport:

- During the site visit an earthen jetty was found on the west coast, proving that this might be a viable transport route. The usage of such a jetty near the site can drastically shorten the distance of overland transport. However, the cost of building a jetty close to this site and the saved cost of not using the local fish port has to be evaluated during the feasibility study.

2.5 Geology and seismicity conditions

2.5.1 Geology

The general geology in the area is dominated by harder rocks of the Jampang Formation on top of softer rocks of the Ciletuh Formation. The Jampang Formation is characterized by a thin layer of acid tuff containing many clay and limestone fragments and breccia with the main component consisting of andesite (Martodjojo, 1984). The underlying Ciletuh Formation is composed of turbidite deposits in the base with sandstone and conglomerate on top.

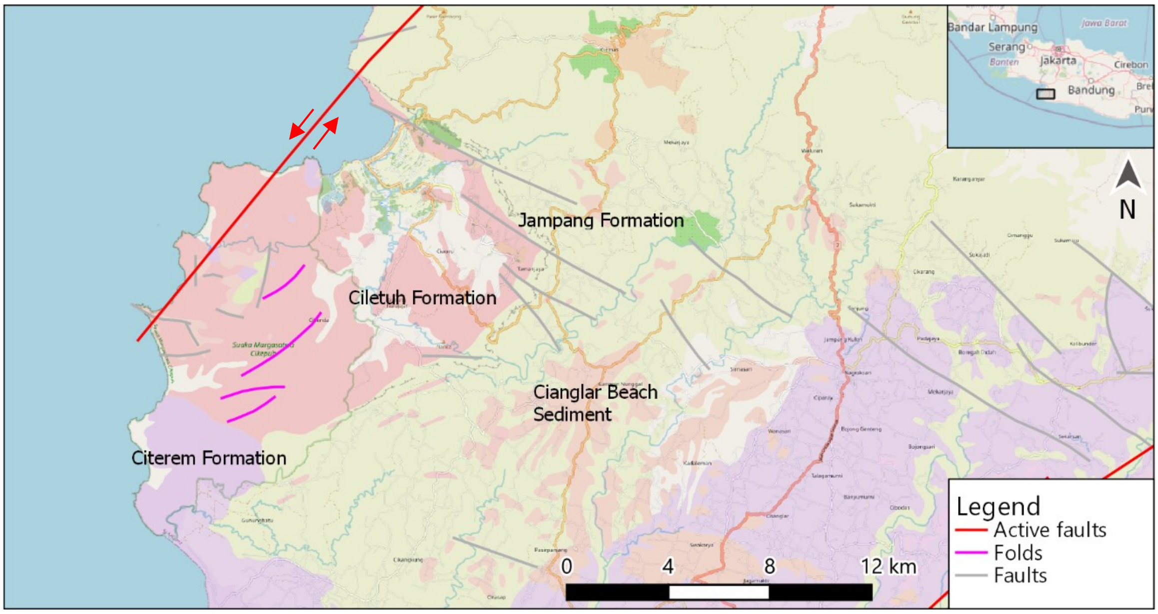

Figure 30. Geological maps (Source: MEMR)

The combination of this stratigraphy and the former stresses in the upper crust a gravitational collapse has occurred which formed the natural amphitheater (see Figure 31). According to scientific papers, the abovementioned gravitational collapse likely happened during the Pleistocene (2.5 mil to 11,500 years BP). These special geological features meant that the area is recognized by UNESCO as a Geopark, and that the amphitheater is branded as a tourist destination. The rim mainly consists of solid hard rock and the risks of landslides are limited. From a geologic perspective, no physical constraints are present for constructing wind turbines close to the rim.

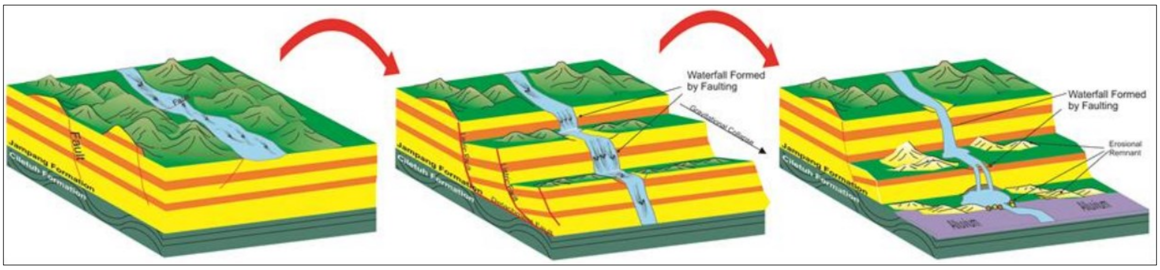

Figure 31. Detail of Gravitational collapse, Jampang Formation (yellow and orange) slides over Ciletuh Formation (grey base) (Ardiansyah, 2019).

The Land Movement Vulnerability Index provides an overview of the susceptibility of ground movement based on the slope steepness, type of soil, rainfall, seismicity, etc. Figure 32 visualizes the Land Movement Vulnerability Index of the soil in and around the WTG-area, as derived from Geological Disaster Mitigation Portal of the Ministry of Energy and Mineral Resources.

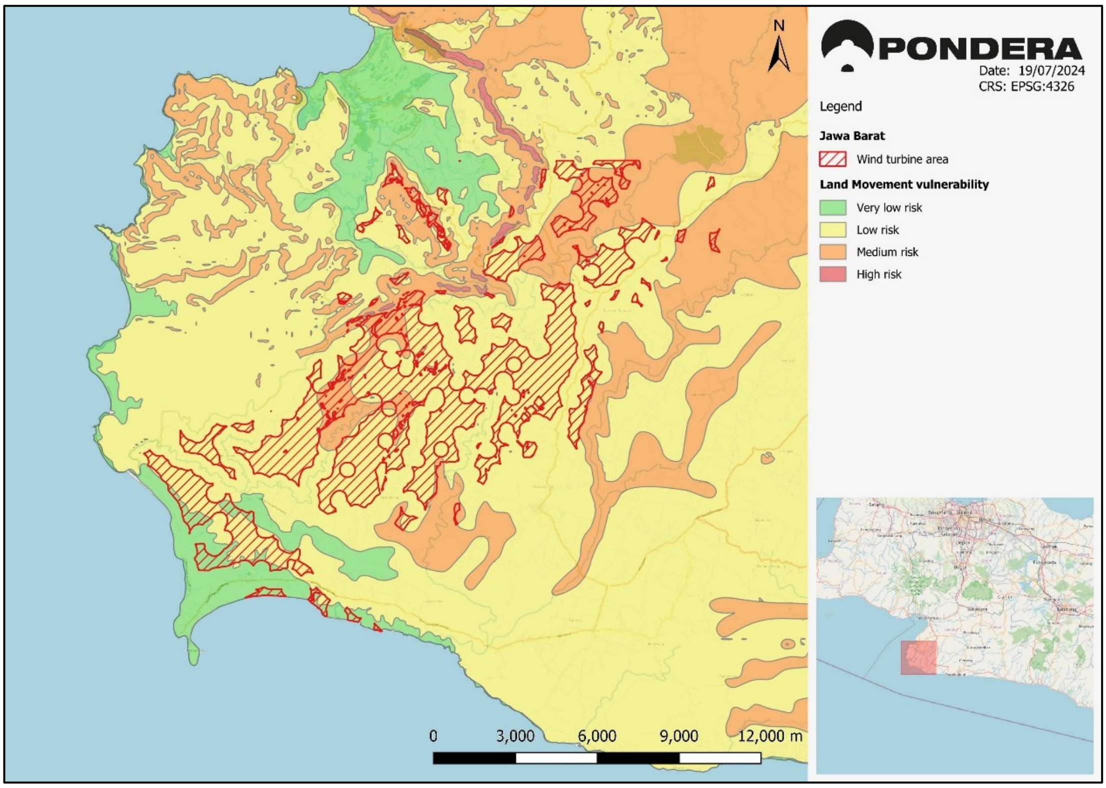

Figure 32. Land Movement Vulnerability Index for Ciracap WTG-area (Source: Geological Disaster Mitigation Portal of the Ministry of Energy and Mineral Resources)

According to the Land Movement Vulnerability Index, areas with steeper slopes are more vulnerable to land movement/landslides. In the feasibility stage, the stability of the slope needs to be investigated further by a geotechnical soil investigation, which determines several soil characteristics (e.g. shear strength, density, permeability etc.), and a following soil stability analysis in combination with the LiDAR-study for a more precise mapping of the topography.

2.5.2 Seismicity

Like in most of Indonesia earthquakes can be expected. According to the Ministry of Energy and Mineral Resources (MEMR) large portions of the area have the potential to be hit by strong earthquakes with an intensity larger than VIII on the Modified Mercalli Intensity (MMI) scale. Figure 33 provides a visual representation of the earthquake risk level in and around the WTG-area.

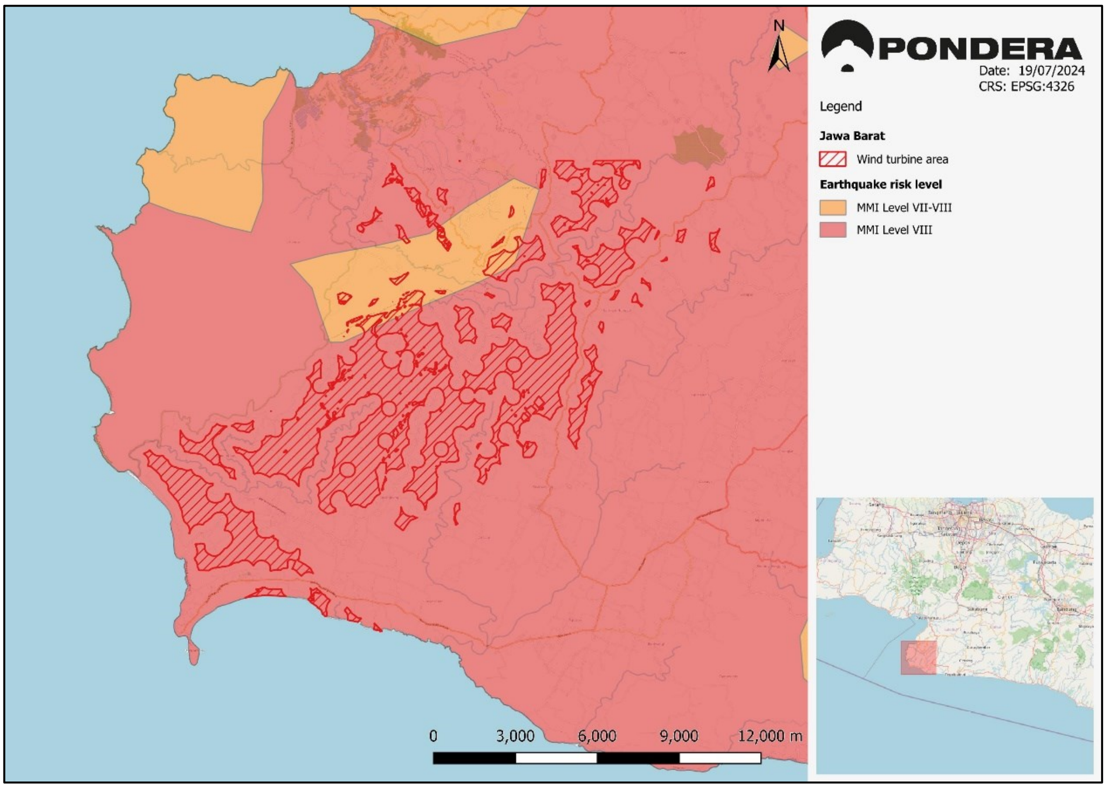

Figure 33. Earthquake hazard and risk level at the Ciracap WTG-area.

The MMI scale classifies earthquakes based on the impact on the surface rather than the energy released (like Richter's scale). The intensity of VIII is defined as:

"Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage is great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Motorists are disturbed."

According to the geological maps of MEMR, several faults are present near the site. Parallel to the coastline a sinistral strike-slip fault is present, with another sinistral strike-slip fault approximately 30 km southeast of the site. Within the site, several smaller strike slips and normal faults are documented (see Figure 34).

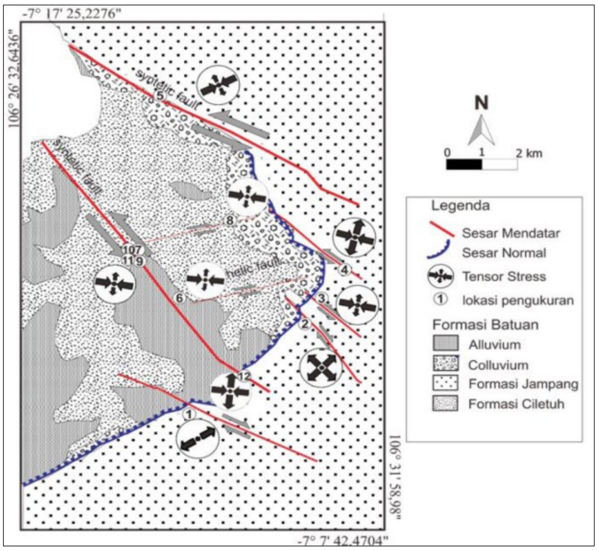

Figure 34. Detailed map of the amphitheater ancient with stress tensors, strike-slip faults (red) and normal faults (blue). These indicate that the area has been under influence of both a strike-slip regime followed by extension stress regime (Nugraha, 2023).

Most of the earthquakes (as shown in Figure 35 and Figure 36) occur at greater depth in the earth's crust, between 40-100 km which reduces their impact at the surface. The listed earthquakes above just give a general impression of the magnitude of earthquakes that can be expected. In later stages, the maximum expected peak ground acceleration should be calculated for more precise hazard assessment due to earthquakes.

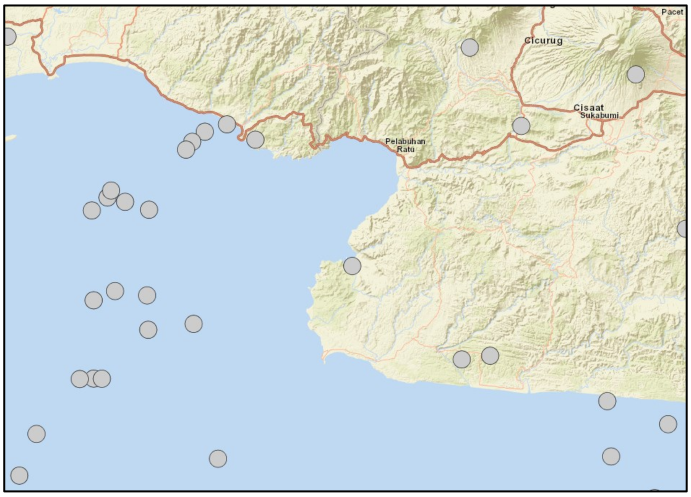

Figure 35. All earthquakes of Magnitude >5.0 in the last 20 years (Source: USGS).

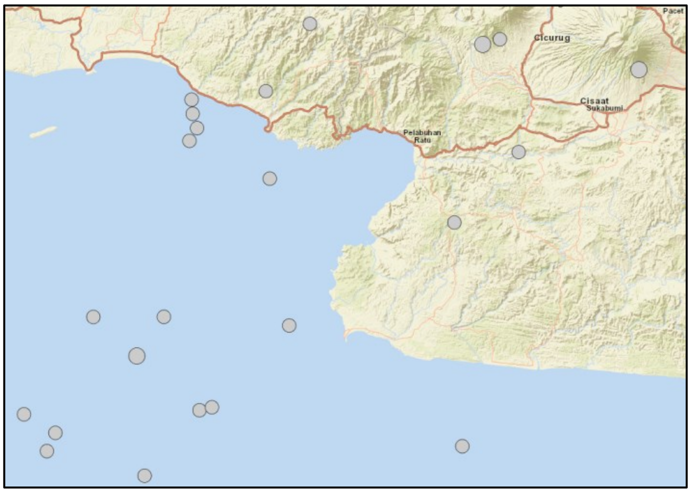

Figure 36. All earthquakes last 20 years at <10 km depth, all between M4.0-5.2 (Source: USGS).

Liquefaction

Due to earthquakes liquefaction can occur. This is a phenomenon where the soil/sediment after an earthquake can behave as a liquid/sludge and flow to lower elevations (10's to 100's of meters). During an earthquake the sediment grains are reshuffled, moving slightly closer to each other. Now less space is available between the grains for groundwater, increasing the pore water pressure. If the pressure is high enough it will overtake the contact stresses between the grains of the soil and make it behave as a sludge.

According to the maps in the MEMR One Map Geoportal for Disaster[12] only a small portion in the area (see Figure 37) is 'intermediately' (yellow) prone to liquefaction. Some beach sections are marked as 'high' (red) risk areas.

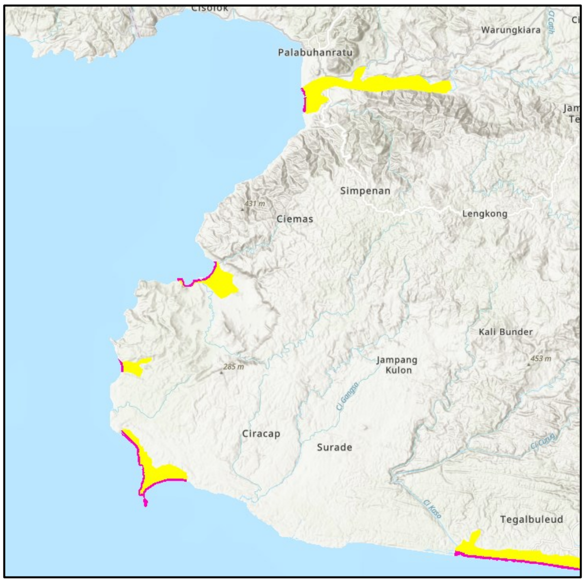

Figure 37. Risk of liquefaction (Source: MEMR One Map Geoportal for Disaster).

[12] https://geoportal.esdm.go.id/kebencanaan/

In the nearby area, no active volcanoes are present. The nearest volcanoes are situated north of the area at distances of 50-70 km (Mount Gagak, Mount Perbakti, Mount Salak. and Mount Gede). On these distances, there is no risk of lava, pyroclastic or lahar flow as a result of an eruption.

However, tephra (also known as volcanic ash) can be transported over larger areas. In an article published in *(Wardman, Wilson, Bodger et al, Bulletin of Volcanology, 2012)* the impact of tephra on electric power system is reviewed[13]. Tephra is the product of explosive volcanic eruptions and composed of rock, minerals and glass. Fine grained tephra (defined as < 2 mm particle diameter) can be dispersed large distances by wind.

As active volcanoes are present in large parts of Indonesia, wind farms may be prone to the impact of tephra deposits depending on the distance to active volcanoes, the amount of material emitted and the wind strength and direction during an eruption, both near the surface and on higher altitudes. For the wind turbine selection at a later stage, protection against inflow of tephra deposits into the generator should be included.

2.6 Biodiversity, socio-economic and environmental conditions

2.6.1 General impression

Large parts of the area are used for plantations (rice, mango, banana) and agroforestry (soy, rubber, tropical hardwood). Spread over the area small villages and scattered houses are present. The density of villages decreases in the southern direction. The area has only a few natural areas, most of the land is in use for either agriculture or agroforestry, however the steep slopes of the natural amphitheater are covered with primary forest . These are closely related to the steepness of the terrain, as they are too steep to cultivate. Figure 38 and Figure 39 show general impressions of the site nearby the amphitheater.

Figure 38. Impression of the site. On the right is the depression in the landscape and steep slopes with forest and primary forest. This area is surrounded by agroforests, plantations and small villages.

[13] See https://core.ac.uk/download/pdf/35468652.pdf

Figure 39. Impression of the site. On the right is the depression in the landscape and steep slopes with forest and primary forest. This area is surrounded by agroforests, plantations and small villages.

In the central part the terrain is less hilly, and mostly used for rice paddies. On the southern side, hills are less high and mainly used for larger plantations (see Figure 40).

Figure 40. Impression of east side of the site

2.6.2 Biodiversity and environmental impact

Most of the area is used for plantations and agroforestry. Only on the steep slopes of the amphitheater, unsuitable for cultivation or wind turbine construction, some primal forest is left. A potential wind farm in this area will not be built in existing primal forest. Unlike primal forests, biodiversity is considered to be relatively low on the plantations and agroforests surrounding the amphitheater. It is expected that wind turbines will have no large impact on biodiversity. Impact will mainly consist of:

Biodiversity impact:

- Bird & bat strikes (turbines)

Environmental impact:

- Erosion and landslide risks (roads, platforms)
- Increased turbidity in streams and rivers due to erosion
- Visual impacts of turbines
- Flickering & low-frequency noise

Observed flora and fauna:
According to the online biodiversity database of Global Biodiversity Information Facility (GBIF), several animal and plant species were observed in the area (see Figure 41) that are categorized in the IUCN global red list category (International Union for Conservation of Nature's Red List of Threatened Species). The categorization is generally based on the rate of population decline, the geographic range, if the species has a small population size, if the species lives in a confined area or is very small, and if a quantitative analysis shows high probability of the species being extinct in the wild[14]. Ordered from the most to the least severely threatened, the categories are as follows: Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD), and Not Evaluated (NE).

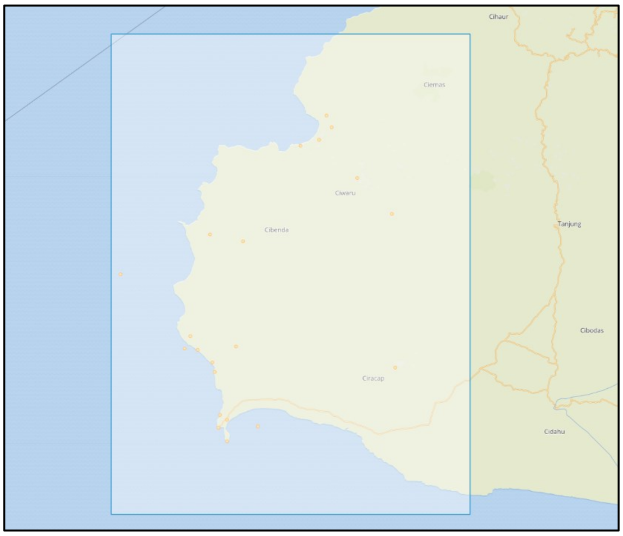

Figure 41. The area in which the above-mentioned flora and fauna has been observed (covering the envisioned wind farm location and nearby surroundings).

[14] https://www.britannica.com/topic/IUCN-Red-List-of-Threatened-Species

In the following tables, the observed flora and fauna that are categorized as at least ‘near threatened’ are listed. Some sightings are dated (between 1890 and 2000) and shown in grey as the current status is unknown and during this stage of research not further investigated.

Table 1. List of observed fauna (source: GBIF) which are at least near threatened according to the IUCN global red list category. Species in grey are undated or observed before the year 2000 (ranging from 1890-2000).

Animals	English Name	Status
Nycticebus javanicus	Javan Slow Loris	Critically Endangered (CR)
Manis javanica	Malayan Pangolin	Critically Endangered (CR)
Chelonia mydas	Green Sea Turtle	Endangered (EN)
Chloropsis cochinchinensis	Blue-winged Leafbird	Endangered (EN)
Nisaetus bartelsi	Javan Hawk-Eagle	Endangered (EN)
Macaca fascicularis	Con Song Long-tailed Macaque	Endangered (EN)
Panthera pardus subsp. melas	Javan Leopard	Endangered (EN)
Pavo muticus	Green Peafowl	Endangered (EN)
Fregata andrewsi	Andrew's Frigatebird	Vulnerable (VU)
Trachypithecus mauritius	West Javan Ebony Langur	Vulnerable (VU)
Panthera pardus	Leopard	Vulnerable (VU)
Amblonyx cinereus	Asian Small-clawed Otter	Vulnerable (VU)
Buceros rhinoceros	Rhinoceros Hornbill	Vulnerable (VU)
Lestes praecellens	-	Vulnerable (VU)
Rhyticeros undulatus	Wreathed hornbill	Vulnerable (VU)
Limosa limosa	Black-Tailed Godwit	Near threatened (NT)
Ratufa bicolor	Ardilla gigante negra	Near threatened (NT)
Teinobasis euglena	-	Near threatened (NT)
Anthracoceros coronatus	Malabar Pied Hornbill	Near threatened (NT)
Megalaima javensis	Black-banded Barbet	Near threatened (NT)

Table 2. List of observed flora (source: GBIF) which are at least near threatened according to the IUCN global red list category. Species in grey are undated or observed before the year 2000 (ranging from 1890-2000).

Plants	English Name	Status
Dipterocarpus hasseltii	-	Endangered (EN)
Horsfieldia glabra	-	Vulnerable (VU)
Knema intermedia	-	Near threatened (NT)
Aglaia pachyphylla Miq.	-	Near threatened (NT)
Dipterocarpus hasseltii	-	Endangered (EN)

The impact on biodiversity and environment can be minimized when the following points are taken into account:

- Reuse as much of the existing infrastructure as possible, such as the existing powerline connection to the electrical grid and access roads;

- Avoid construction of roads and/or powerlines in such a way that the existing forest is cut up in separate sections, and use the same layout for road and the electrical grid between the turbines to avoid habitat fragmentation;
- Ideally only one access point should be made to enter the wind farm to limit the opening of the area for other activities such as illegal logging and hunting/poaching; and
- Limiting the amount of forest cleared around each wind turbine (generally between 50 to 100 x 100 m area). This space is used for the crane and storage. By using self-climbing cranes instead of traditional cranes this space can be minimized. With careful planning, temporary storage of wind blades next to the road instead of next to the turbine might also reduce the required area around the wind turbines.

As part of an Environmental and Social Impact Assessment, a biodiversity baseline study, risk assessment and mitigation measures should be carried out during the feasibility phase.

2.6.3 Social impact

In large parts of the region, villages and scattered houses are present (see Figure 42). On sites with high expected wind speeds (closer to Ciletuh), the turbines will always be placed close (<1,000 m) to existing settlements. Still, the international standard buffer of 300 m between houses to a turbine can be maintained. In some situations, one single house can be present within this 300 m buffer around a turbine. In these cases, the function of this building should be evaluated and in case of permanent habitation the option of voluntary relocation might be considered. In all cases, the placement of the wind turbines will have to be done carefully and it might not be possible to plan the turbines in an optimal way from a revenue perspective.

The people in this area mainly consist of farmers and plantation workers. In the center of the villages, there are some small shops- and restaurants owners. Meanwhile, some fishermen live near the (south) coast. Near Ciletuh, small hotels and homestays are present. During the site visit, locals said that many young adults move to larger cities (e.g. Sukabumi and Jakarta) to find work, which is too far for daily or even weekly commute.

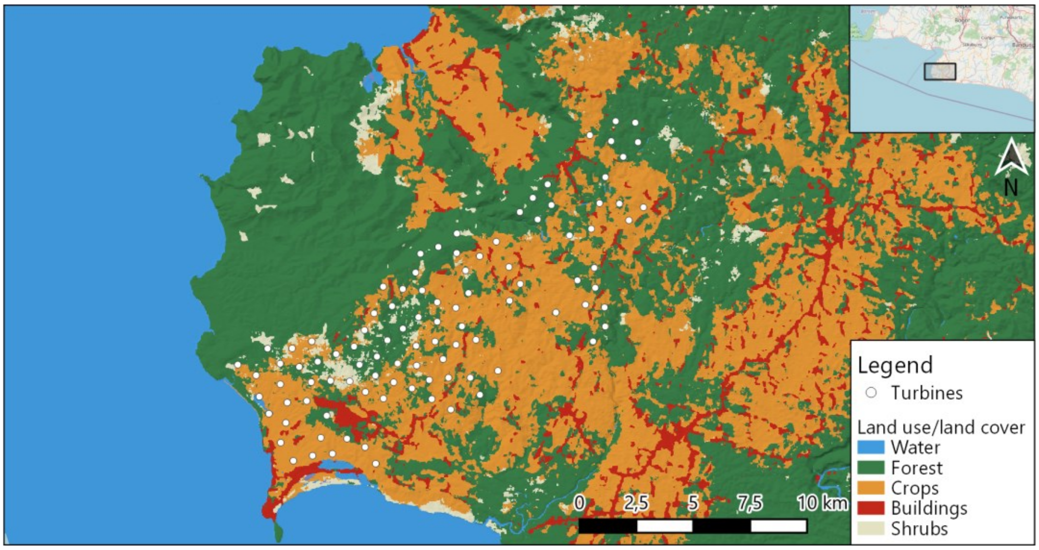

Figure 42. Land use map based on satellite imagery (ESRI/Sentinel 2, 2022).

Because of the density of villages and houses in the area, an extensive road network is already present. In many cases, only a short section of road from the existing network to a turbine will have to be built. Using the local road network as much as possible will minimize the land use change and hence the social and environmental impact.

The social impact can be divided into several aspects:

- Loss of agricultural land to be used for new roads or platforms
- Temporary construction on roads, platforms and turbines (decreased accessibility and noise)
- Temporary transport of building materials and turbines (decreased accessibility and noise)
- Long term visual impact of turbines in the area
- Increased mobility between certain areas and to the main road when access roads are improved

Geopark

The special geological features (see Section 2.5) and resulting topography makes that the area is branded as a tourist destination. The area is recognized as a Geopark by UNESCO. In Indonesia 10 Geoparks are present (i.e. Raja Ampat, Mount Ijen, Mount Rinjani). Around the rim of the natural amphitheater and inside the amphitheater (the Cileteuh village) many hotels and resorts can be found. The rim is a natural feature which is conspicuous from most areas in Cilteuh. Wind turbines located on the rim (where wind is abundant) will therefore be also highly visible from a long distance. This may lead to local resistance from the hospitality industry. Positioning them away from the rim may be necessary.

According to online information from *geoparktoolkit.org* the goal of Geoparks is to *'stimulate economic activity within the framework of sustainable development. (...) All Geoparks therefore have a remit, with UNESCO's assistance, to foster socio-economic development that is culturally and environmentally sustainable.'*

With the right approach it is expected that a wind farm could fit within the abovementioned framework.

Overall, the social impact may be reduced when the following points are taken into account:

- New road construction is minimized by using the local road network as much as possible. This way the least amount of land has to be bought and changed their use from agricultural into infrastructure, and the roads will improve mobility of the local population.
- The turbines are placed away from the rim of the amphitheater to not disrupt the view and the biodiversity in the primal forest. The distance could be determined at a later stage in corporation with local authorities and the hospitality industry.

The next paragraphs provide an overview of the population and employment statistics in the regency.

Population

The graph of population and annual population growth rate is shown in Figure 43. The annual population growth rate in the regency declined from 1.32% in 2021 to 1.02% in 2023. Meanwhile, the population increased from 2,761,480 people in 2021 to 2,802,400 people in 2023.

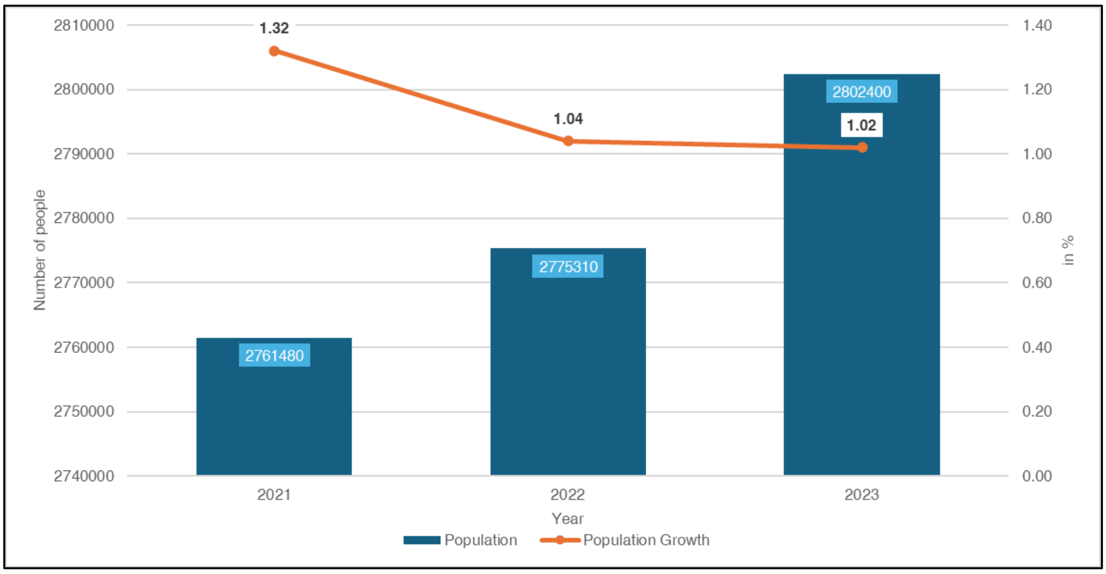

Figure 43. Population and annual population growth rate in Sukabumi Regency in 2021-2023 (Source: [Statistics of Sukabumi Regency (bps.go.id)]).

The regency's population pyramid is shown in Figure 44. Moreover, the gender ratio in the regency is 1.03 in 2023.

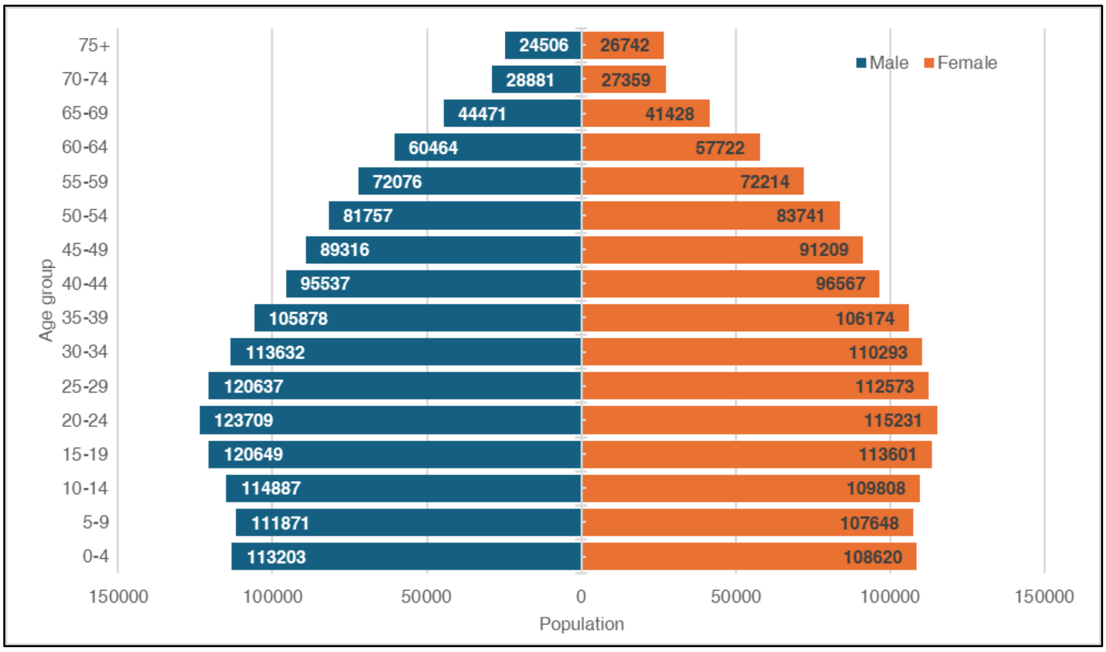

Figure 44. Population pyramid in Sukabumi Regency in 2023 (Source: [Statistics of Sukabumi Regency (bps.go.id)]).

Employment, education, and development

The labor force participation rate (TPAK) is an estimation of the proportion of the working-age population actively engaged in the workforce. The unemployment rate (TPT) is the proportion of the working-age population inactively engaged in the workforce. These rates are displayed in Table 3. In 2021-2023, the labor force participation rate experienced an overall increase, despite the decline from 2022 to 2023. Meanwhile, there is a consistent decline in the unemployment rate from 2021 to 2023.

Table 3. Labor force participation rate and unemployment rate in Sukabumi Regency in 2021-2023 (Source: BPS Jawa Barat).

Metric (in %)	Year		
	2021	2022	2023
Labor force participation rate	64.93	69.11	67.75
Unemployment rate	9.51	7.77	7.32

The number of workers according to highest education from in 2023 is presented in Table 4. Overall, the workforce was dominated by graduates of primary school. The second largest group is the graduates of high school, followed by middle school.

Table 4. Workers according to highest education (people) in Sukabumi Regency from 2023 (Source: BPS Kabupaten Sukabumi).

Educational attainment	Working	Unemployed	Economically Active	Percentage of Working to Economically Active (%)
Primary school (SD)	656,284	17,600	673,884	97.39
Middle school (SMP)	279,899	23,978	303,877	92.11
High school (SMA)	328,957	58,717	387,674	84.85
University	78,904	5,934	84,838	93.01
Total	**1,344,044**	**106,229**	**1,450,273**	**92.68**

The pure participation rate in demographic data represents the ratio of enrollment for the age group corresponding to official school age in primary or secondary levels, to the total population of the same age group in a given year. These rates are shown in Table 5.

Table 5. Pure participation rate in Sukabumi Regency in 2022-2023 (Source: BPS Kabupaten Sukabumi).

Pure participation rate	Year	
Educational level	**2022**	**2023**
Primary school	99.96	99.49
Middle school	82.20	82.37
High school	52.25	56.73
University	14.05	13.21

Table 6 shows the number of educational facilities in Sukabumi Regency. Among the different education levels. The largest number of educational facilities is that of (Islamic) kindergarten, followed by primary school.

Table 6. Educational facilities in Sukabumi Regency in 2021 (Source: Statistics of Sukabumi Regency (bps.go.id)).

Type of school	Number of facilities
Kindergarten (*in 2020*)	284
Primary school	383
Middle School	339
High School	168
Vocational High School	153
University	16

The Human Development Index (HDI) measures human development achievements based on a number of basic components of quality of life, which is based on three dimensions:

- A long and healthy life (through life expectancy at birth);
- Knowledge (through indicators of literacy rates and average years of schooling), and
- A decent life (through indicators of people's purchasing power for a number of basic needs).

Human Development Index in the regency from 2021 to 2023 has an increasing trend, as shown in Table 7.

Table 7. Human Development Index, Gender Empowerment Index, and Gender Development Index in Sukabumi Regency in 2021-2023 (Source: BPS Kabupaten Sukabumi).

Metric	Year		
	2021	2022	2023
Human Development Index	67.07	68.87	69.71
Gender Empowerment Index	57.45	61.52	62.28
Gender Development Index	88.04	88.29	89.02

Gender Empowerment Index (GEI) measures gender inequality in three fundamental dimensions:

- Economic participation and decision-making;
- Political participation and decision-making; and
- Power over economic resources.

GEI of this regency within the 2021-2023 period increased, as shown in Table 7.

Gender Development Index is a measure of gender inequalities based on achievement in three fundamental dimensions:

- Health (through female and male life expectancy at birth);
- Education, (through female and male expected years of schooling for children, and female and male mean years of schooling for adults ages 25 years and older); and
- Command over economic resources (through female and male estimated earned income).

GDI of this regency within the 2021-2023 period visibly increased, as shown in Table 7.

2.7 Transmission network design

2.7.1 Point of connection

Based on the location of the envisioned preliminary wind farm layout, the closest point of connection to the existing PLN grid has been determined. The Pelabuhan Ratu Baru 150 kV PLN substation is selected for this, located in the east side of the Sukabumi regency. The aerial photo of this substation is included in Figure 45. Because the current study does not include a grid impact study, it is assumed that the wind farm can be connected to the existing grid, does not negatively influence the functioning of the grid and therefore no battery system is required. Furthermore, it is assumed that a busbar is available at the substation for connecting the wind farm at the substation.

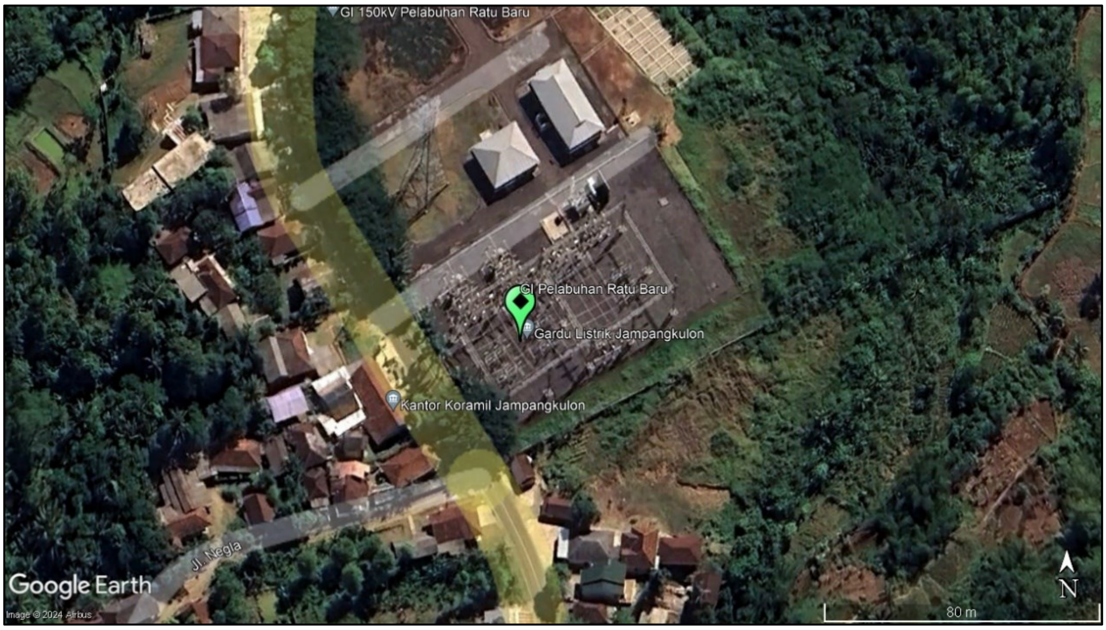

Figure 45. Location of the Pelabuhan Ratu Baru 150 kV PLN substation. Source: Google Maps.

2.7.2 Schematic design transmission and distribution network

In Figure 46, the schematic design of the transmission and distribution network is illustrated. The 100 wind turbines will each have a 20 kV output (via a 5 MVA transformer per wind turbine) which is distributed via distribution cables. Per string of maximum 10 wind turbines, the generated electricity is distributed to one of the twenty substations within the wind farm. In these substations, the voltage is transformed to 150 kV. From the substation, the 150 kV cables come together and are connected to the powerhouse at the border of the wind farm. Overhead transmission lines transport the generated electricity from the powerhouse to the point of connection, the Pelabuhan Ratu Baru substation.

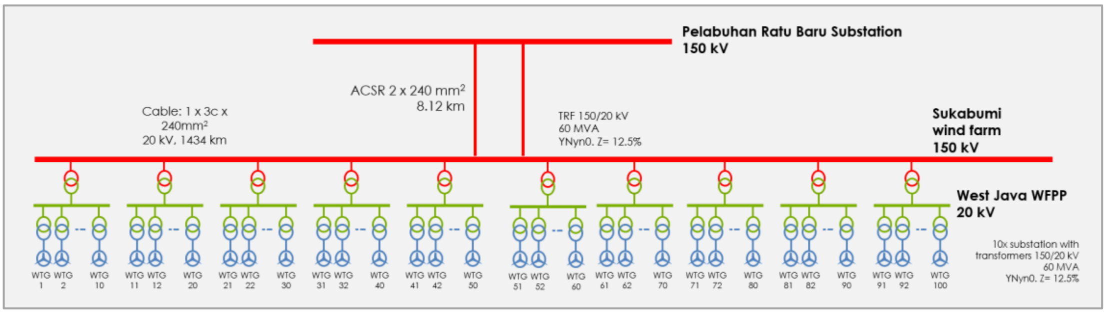

Figure 46. A schematic design of the transmission and distribution network at the envisioned Ciracap wind farm.

The overhead transmission line between the powerhouse and the substation is assumed to be a straight line between both locations, covering 8 km as visualized in Figure 47. A total of 22 towers are planned with an intermediating distance between the towers of 340-450 m.

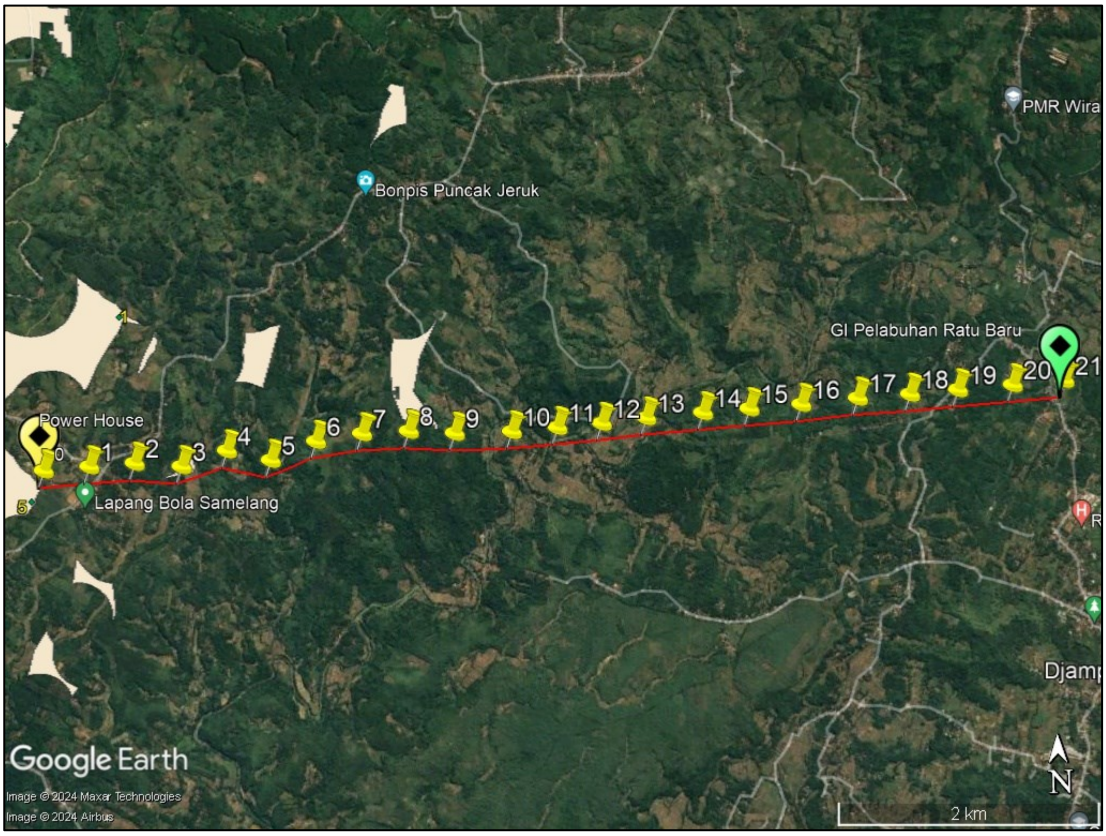

Figure 47. A schematic representation of the position of overhead transmission line between the powerhouse and the Pelabuhan Ratu Baru substation.

2.8 Energy yield assessment

The energy yield is presented as an annual average and is therefore called the Annual Energy Production (AEP). The gross AEP is modelled by combining the calculated long term wind climate and the wind turbine specifications from the power curves.

For the energy yield assessment of the Ciracap site, the long-term wind speeds are determined based on the Global Wind Atlas (GWA) generalized wind climate and windPRO modelling. The mesoscale grid points from the GWA provide a first global look into the flow patterns and wind speeds in the region.

Figure 48 shows the resulting climatology at the locations of the WTGs. The modeled long-term wind speed, averaged over all WTGs at the planned hub height of 140 m, is 6.2 m/s. In the northeastern part of the WTG area the wind speeds are below the 6 m/s threshold. During future research the layout of the WTG area could be reconsidered; the wind speed is highest close to the steep ridge in the western part of the area and close to the southern coastline.

The AEP is subsequently calculated based on the power curve of a 4 MW reference WTG with a rotor diameter of nearly 170 m and a hub height of 140 m.

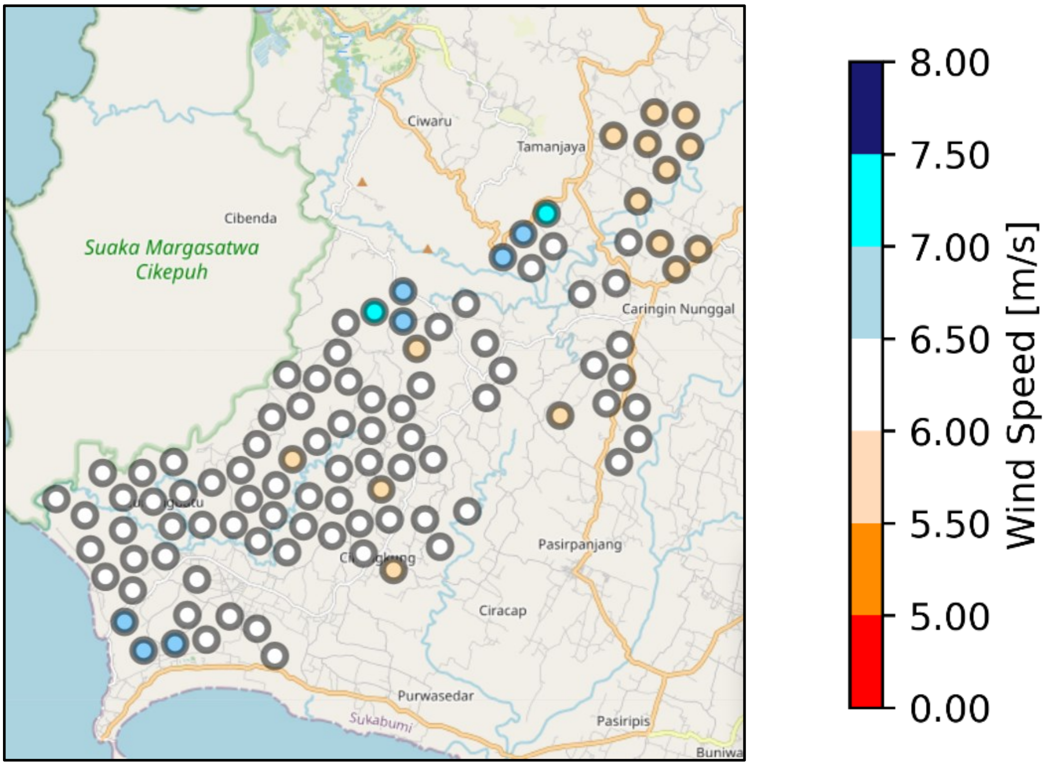

Figure 48. Long-term average wind speed results from windPRO, based on the GWA climatology, at a height of 140 m at the turbine locations. The black-bordered circles represent the wind turbines, whereas the colors within the circle indicate the respective long-term average wind speed. © OpenStreetMap.

2.8.1 Energy losses

The net AEP is calculated by subtracting energy production losses from the gross AEP. These are losses due to a plurality of causes, such as wind turbine unavailability and performance related losses or electrical losses. These losses are determined either by calculations or by expert judgment and are included as percentage values of the AEP excluding wake losses.

In this report, the net AEP is displayed as the P50 AEP. The P50 value is a statistical level of confidence suggesting a value for AEP that may be exceeded with 50% probability. In other words, the P50 AEP is the average annual energy production that is expected over the wind farm's lifetime. Table 8 presents the estimated losses on the wind farm level.

Table 8. Expected losses on the wind farm level

Category	Types of energy loss	Amount	Explanation
Interaction	Wake losses [%]	10.4%	The wake effect is the aggregated influence on the energy production of the wind farm, which results from the changes in wind speed caused by the downwind impact of the wind turbines on each other. The wake losses are modelled using the standard NO Jensen (RISØ/EMD) model (PARK2 – 2018 version) in windPRO, resulting in an overall wake loss of 10.4%.
	Blockage losses [%]	0.0%	Wind farms do not only interact with downstream wind speeds (i.e. the wake effect), but also interact with decreased upstream wind speeds. This upstream wind speed reduction is called the blockage effect. The Self Similar model by Forsting (2016)[15] with linear parametrization is used to calculate blockage. 0% blockage is expected for the layout.
Availability	Non-availability [%]	4.0%	This production loss concerns the periods of a wind turbine that it is not in operation due to maintenance, malfunctioning and re-orientation of the nacelle. For onshore wind farms with more than 5 WTGs, 4.0% loss is considered.
	Balance of Plant [%]	0.1%	Balance of Plant losses occur due to the unavailability of the transformer station or access roads and therefore hinder normal wind farm operation.
	Grid downtime [%]	0.5%	Grid downtime losses are caused by grid non-availability from grid operator.
Performance	Power curve losses [%]	2.0%	Performance losses are the result of sub-optimal operation of the wind turbine. This occurs when wind turbines are operational outside the design conditions of the power curve. A conservative 2.0% performance loss is assumed since no site-specific power curve is available.

[15] Meyer Forsting, A. R., Troldborg, N., & Gaunaa, M. (2016). The flow upstream of a row of aligned wind turbine rotors and its effect on power production. Wind Energy, 20(1), 63–77.

Category	Types of energy loss	Amount	Explanation
	High wind hysteresis [%]	0.5%	At the cut-out wind speed, wind turbines are switched-off due to safety precautions. The calculation model assumes that the wind turbines are fully operational until cut-out wind speed and are turned off from exactly that point. In reality, if the wind speed fluctuates around the cut-out wind speed, the wind turbine will shut down until the wind speed is below the re-cut in wind speed. A loss of 0.5% is assumed.
	Yaw misalignment [%]	0.0%	Yaw misalignment losses are caused by the inability of the WTG to align itself completely with the actual wind direction and therefore losing production potential. The reason could be an older operating system that is not able to measure the current wind direction accurately. It is assumed this will not occur.
Electrical	Electrical losses [%]	2.0%	Electrical losses in power cables occur due to cable resistance, which increases the temperature of the cables and results in these power losses. A conservative value of 2.0% is assumed.
	Transformer losses [%]	1.0%	The WTG transformers consume energy as the voltage level is increased. Since the transformer losses are not incorporated in the P-V curve, a loss of 1.0% is assumed.
	Electricity consumption WTGs [%]	0.1%	Wind turbines need electricity to support operational activities such as software systems. A 0.1% energy loss is assumed.
Environmental	Shutdown due to icing, lightning etc. [%]	0.3%	Shutdown is a necessary safety precaution during cold periods when ice accumulates on the blades or during thunderstorms. No icing is expected at this site. Losses due to lightning of 0.3% are assumed.
	Blade degradation [%]	1.3%	Over time, the aerodynamic efficiency of wind turbine blades decreases due to degradation. For onshore wind turbines, this is mainly due to organic matter, dust particles, and other particulate matter accumulating on the blade. These effects accumulate over time. 0.1% annual degradation losses are assumed. Over a lifetime of 25 years, 1.3% losses are expected.
	High and low temperature [%]	2.0%	Temperature de-rating occurs when the wind turbine operates outside of the operating temperature range. The losses are expected to be 2.0%.
	Tree growth & felling [%]	0.0%	The wind turbines are positioned in a forest and changes in tree height or tree felling might lead to different roughness and changes in wind speed. However, due to a limited tree

Category	Types of energy loss	Amount	Explanation
			height (of approximately 15 m), and no substantial tree felling expected, in this case no additional loss is accounted for.
Curtailment	Grid curtailment [%]	0.0%	Losses due to grid curtailment are not considered for this wind farm.
	Noise curtailment [%]	0.0%	Wind turbines operate in noise-reduced power modes to minimize noise levels on nearby homes. Since this site is located in a remote area, no losses are expected.
	Shadow flicker curtailment [%]	0.0%	Shadow flicker is the effect when rotor blades periodically cast a shadow over a certain area. Shadow flicker curtailment is introduced with the purpose of mitigating significant effects on houses. Since this site is located in a remote area, no losses are expected.
	Bird/bat mitigation [%]	0.0%	A full analysis of the potential habitats of protected birds and/or bats is to be conducted in the feasibility study. At this moment the losses are assumed to be 0.0%.
	Wind sector management [%]	0.0%	To safeguard the expected WTG lifetime a so-called Site Assessment study is undertaken by the WTG manufacturer. When this Site Assessment shows exceeding loads on WTG components, based on certain climatic conditions, there is a need to change the WTG's normal operation mode to an alternative program. This often includes the application of reduced power modes which often results in production losses. At this moment it is assumed to be 0.0%.
Sub-total non-interaction losses [%]		**13.0%**	The accumulation of all of the above-mentioned losses, excluding wake losses. Based on 1-(1-loss A)*(1-loss B)*(1-loss C)*…etc.
Total losses [%]		**22.1%**	The accumulation of all of the above-mentioned losses, including wake losses. Based on 1-(1-loss A)*(1-loss B)*(1-loss C)*…etc.

2.8.2 Energy yield including uncertainties

Incorporating model uncertainties leads to an increase of the reliability of wind resource assessment. Typically, the P90 AEP is used to express the impact of uncertainties. The P90 is a statistical level of confidence suggesting an AEP value that may be exceeded with 90% probability. When a normal probability distribution is assumed, the Pxx value is found through the following formula:
$P_{90} = P_{50} * (1 - 1.28*\sigma)$. The uncertainty [in %] is expressed as σ.

Here, we assume a conservative uncertainty to be 20% since the calculations are purely based on numerical models and no measurements have been performed on-site at this stage. The resulting P90 value is given in Table 4.

Table 9. Energy yield for all WTGs at the Ciracap wind farm

Parameter [Unit]	**Amount**
Number of new WTGs	100
Rated Power per WTG [MW]	4.0
Total rated Power [MW]	400.0
Rotor diameter [m]	~170
Hub height [m]	140
Air density [kg/m3]	1.145
Wind speed [m/s]	6.2
Gross result [MWh/yr]	1,452,438
Gross results including wake effects [MWh/yr]	1,301,068
P50 [MWh/yr]	**1,131,551**
P90 (25 yr) [MWh/yr]	**841,523**
P50 [hrs/yr]	**2,829**
P90 (25 yr) [hrs/yr]	**2,104**

2.8.3 Power output variation

In Subsection 2.8.2, we have provided an estimate of the P50 annual production, equal to 1,131,551 MWh per year. Previously, during the first wind resource assessment we have shown that for this site there is a large variation in wind speed throughout the year, with the highest wind speeds during the summer months. This variability has a direct effect on the wind farm's total power output at specific moments of the year. Figure 39 shows the average wind farm power output for each month, subdivided into the hours over a full day. The input data for this figure is derived from the windPRO results combined with the EMD-WRF average variability in wind speeds throughout the year. This graphic illustration is relevant to take into account for a grid impact study in subsequent studies for this project location.

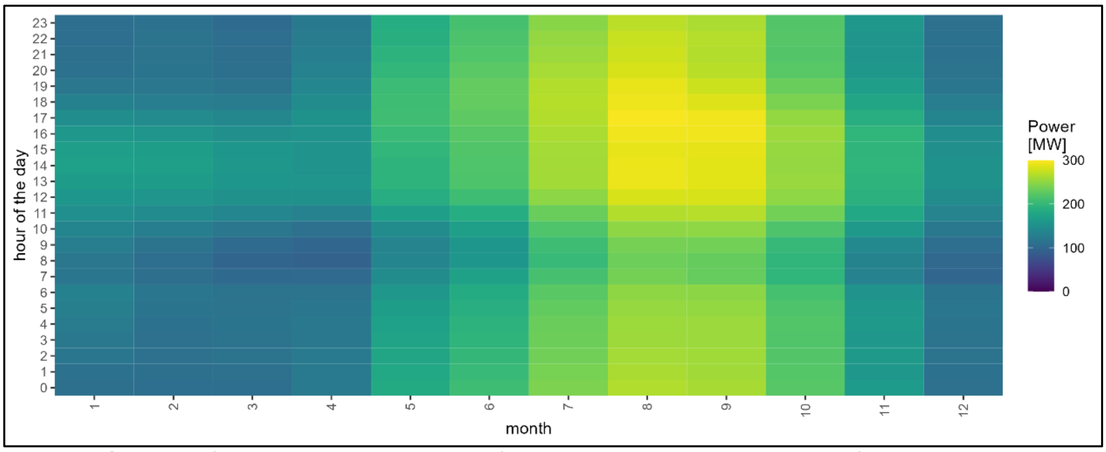

Figure 39. Overview of the monthly variation in wind farm average power output per hour of the day based on the P50 values from Subsection 2.8.2 in combination with the monthly and hourly variation in wind speed from EMD-WRF.

2.9 Business case assessment

2.9.1 Component assumptions

In order to determine the business case for the wind farm, it is necessary to quantify the input cost parameters and define the assumptions used. This is categorized in:

- Preparation works
- Wind turbines
- Civil works
- Electrical work
- Operational expenditure

In the following subparagraphs, each of the above categories is further explained.

Preparation works

The following preparation works should be executed before the start of a large part of the design works and definitely before the start of the construction The cost for these preparation works is included in the business case:

- Pre-feasibility study
- Full feasibility study

- Grid impact assessment
- Permit application
- Surveys
    - Topographical
    - Port evaluation
    - Road conditions
    - Geological
    - Geotechnical
    - Environmental
    - Social
- Wind measurements: 10 met masts, duration 1 year.
- Land acquisition, assuming IDR 200,000 /m^2 + 5% tax for low-quality soils, IDR 520,000 /m^2 + 5% for moderate fertile areas, to be used for:
    - New road surface
    - Rotor diameter surface
    - Road upgrade surface
    - Powerhouse and substation surface
    - Transmission tower surface

Wind turbines

The quantities which are relevant for the installation of 100 wind turbines at the wind farm are shown in Table 10.

Table 10. Wind turbine quantities relevant for the envisioned Ciracap wind farm.

Main component	Quantity
Nacelle incl. generator (4 MW)	100 pcs
Blade (85 m)	300 pcs
Tower segments (total 140 m height)	600 pcs

Furthermore, the following (cost) assumptions are used in the business case:

- A Chinese wind turbine manufacturer is used as reference turbine. This manufacturer has so far, a limited track record outside of China but can offer competitive pricing. Quality assurance through client references, international certification, factory acceptance tests, site acceptance tests, quality guarantees, etc. are necessary.
- All wind turbine components are shipped from China to the Port of Pelabuhan Ratu and via road transport (Route A) brought the wind farm site;
- Import duty of 5% apply for the generator and blades, and 15% for tower parts are assumed[16];
- The cost includes transport, crane rental, installation, and commissioning.

[16] Assumption based on a report by PwC titled *Power in Indonesia: Investment and Taxation Guide* (August 2023, 7th Edition)

Civil works

The quantities which are relevant for the civil works necessary for the installation of 100 wind turbines at the wind farm are shown in Table 11.

Table 11. A list of assumptions on civil works components.

Main component	Sub-component	Quantity
Roads (incl. design, materials, transport, labor)	Construction of new gravel road within the wind farm site	67 km
	Upgrading existing road	121 km
Strengthening bridges (incl. design, materials, transport, labor)	Concrete bridge strengthening	11 bridges
	Steel bridge strengthening	2 bridges
Foundations (incl. design, materials, transport, labor)	Anchors (72 per foundation)	7,200 pcs
	Anchor cages	100 pcs
	Concrete (230 m^3 per foundation)	23,00 m^3
	Steel (35 tons per foundation)	3,500 tons
Crane hardstands (incl. design, materials, transport, labor)	Crane hardstands (50 x 100 m) using gravel	100 hardstands

Furthermore, the following (cost) assumptions are used in the business case:

- In the cost assumptions a fixed amount of USD 300,000 is included for dredging the fishing port of Pelabuhan Ratu and increasing the accessibility;
- Civil works are including design, materials, transport and labor;
- Large parts of the road from port to site are in good condition, however the road winds through the mountains with numerous curves.
- Within the site, a large network of small roads is already available. However, upgrade of these public roads is necessary to use them and/or leave them in good condition after work has ended.
- There is a risk of substantial (hidden) additional costs. For example, the need to strengthen offloading quays in the port or to create a large lay-down area due to logistical challenges at the port. This requires further analysis in the subsequent feasibility study;
- Cost amounts used in the business case are based on best practices, desk research and a limited site visit which entails significant uncertainty in the cost assumptions.

Electrical works

The following limited bill of quantities for the electrical works has been determined for the wind farm in Table 12.

Table 12. A list of assumptions on the electrical works components.

Main component	Sub-component	Quantity
Transmission line (8 km, 22 towers)	Transmission towers	22 pcs
	Conductor	1 set
	Insulator and Fitting; Type Normal	1 set
	ACSR Hawk 240 mm^2 cable	1 set
	GSW 70 mm^2 cable	1 set
	OPGW 70 mm^2 cable	1 set
Powerhouse (1 for the entire wind farm)	Incoming MV switchgear	100pcs
	LV switchgear	1 pc
	DC Supplies	1 pc
	Lightning protection	1 pc
	2x3C 300 mm cable	567 m
Wind farm electrical works (between the powerhouse, substations, and wind turbines)	Transformers 20 kV (5 MVA)	100 pcs
	Switchgear	100 pcs
	MVAC Cable (1 x 3c x 240) 50 and 300 meters	1,434 km
	Earthing System	1 set
	Control & Monitoring System	1 set
	Fire Protection System	1 set
	Hydrant system	1 set
	Water Facility (Clean and Dirty)	1 set
Substations (twenty for the entire wind farm)	Transformer 150/20 kV 30 MVA	10 pcs
	Neutral Grounding Resistor	10 pcs
	Switchyard	1 pc
	In/outgoing bays, coupler, busbars, Panel RCP	10 sets
	LV switchgear	1 set
	SAS/ SCADA system	1 set

Furthermore, the following (cost) assumptions are used in the business case:

- Electrical works are including design, materials, transport and labor;
- Because the current study does not include a grid impact study, it is assumed that the wind farm can be connected to the existing grid, does not negatively influence the functioning of the grid and therefore no battery system is required; and
- It is assumed that a busbar is available at the substation for connecting the wind farm at the substation.

Operational expenditure

The following expenses are expected to be incurred when the wind farm becomes operational (also referred to as CoD) until the end of the design lifetime of the wind farm (25 years):

- Maintenance and service cost of the wind turbines, civil works and electrical works
- Business operation cost, e.g. asset management, financial management, PPA management, etc.
- No compensation for the use of forest is required
- Insurances (e.g. machine breakdown insurance, third party liability)

2.9.2 Cost assumptions

In Table 13, the cost assumptions per cost component are listed which serve as input for the business case. The business case distinguishes between DEVEX (development expenditure, before CoD), CAPEX (capital expenditure) and OPEX (operational expenditure). Because of the uncertainty and limited information on which the cost assumptions are based, a cost range (as a percentage of the baseline cost) is defined for each of the cost components. The cost range spread dependents on the uncertainty of the cost assumptions. For example, for civil works, the cost assumptions have high uncertainty because of the effect that physical surveys have on the design decisions and therefore construction price. The wind turbine cost has a smaller spread because the uncertainty is mainly caused by global fluctuations, not by design decisions (it is a serial product).

The accumulation of the cost ranges eventually leads to the lower-, baseline-, and upper bound total investment cost. From this a cost per MW is calculated, which is an indication how high the investment for this particular wind farm is compared to the global average (being in 2024 USD 1.3M / MW[17]) and to the other 7 locations.

Table 13. Cost assumptions per cost component.

Cost component	Baseline cost including VAT	Comment	Cost range
Preparation works	USD 8,020,000	DEVEX: Prior to Financial Close	90% - baseline -120%
Project management	USD 28,955,195	DEVEX: Until CoD	Baseline
Wind turbines	USD 278,728,338	CAPEX: Including transport and installation	90% - baseline -120%

[17] Source: https://www.iea.org/data-and-statistics/charts/actual-and-forecast-onshore-wind-costs-2016-2025

Cost component	Baseline cost including VAT	Comment	Cost range
Civil works: foundations	USD 40,071,000	CAPEX	80% - baseline -150%
Civil works: roads	USD 24,689,000	CAPEX	80% - baseline -150%
Civil works: crane hardstands	USD 6,875,000	CAPEX	80% - baseline -150%
Electrical works	USD 130,842,000	CAPEX	90% - baseline -120%
Land acquisition	USD 89,879,000	CAPEX	90% - baseline -150%
Risk contingencies	USD 46,328,000	DEVEX + CAPEX	Baseline
Lower bound total investment cost (DEVEX + CAPEX)	**USD 589,312,000**	**Investment cost per MW: USD 1,473,000**	
Baseline total investment cost (DEVEX + CAPEX)	**USD 654,386,000**	**Investment cost per MW: USD 1,635,000**	
Upper bound total investment cost (DEVEX + CAPEX)	**USD 818,661,000**	**Investment cost per MW: USD 2,045,000**	
Baseline operational expenditure (OPEX)	**USD 11,778,000 / year**	**Operational cost per MW / year: USD 29,000**	

2.9.3 Financial parameters

The following financial parameters assumptions are applied in the business case:

- The wind farm has a design lifetime of 25 years;
- A depreciation period of 25 years;
- The construction starts in the year 2028,
- The procurement of the wind farm components is assumed in 2026, for which a yearly indexation of 3% is used on the 2024 price level;
- The operational expenditure is to be indexed at 5%;
- A gearing of 70% loan, 30% equity;
- The debt tenure is 10 years, annuity repayment structure;
- The interest rate on the debt is 9.0%;
- Property taxes and company taxes are included;
- All costs are including VAT;
- The project management cost on behalf of the developer until CoD is assumed to be 5% of the total cost;
- A risk contingencies budget is assumed to be 8% of the total cost including project management cost;
- After 25 years the remaining residual value of the wind farm is transferred at USD 0 to PLN;
- The tariff structure in accordance with Presidential Regulation 112/2022 is used. This defines the following:
    - Ceiling tariff per kWh in year 1-10 for wind farms >20 MW = 9.54 x location factor (being 1.0 for the Jamali grid) = USD cent 9.54 / kWh
    - Ceiling tariff per kWh in year 11-25 for wind farms >20 MW = USD cent 5.73 / kWh

- The business case assumes a PPA on the above ceiling tariffs. In practice, it is likely that a developer must negotiate with PLN about this which will lead to a lower PPA tariff.
    - No separation in components for the tariff structure is used, i.e. on O&M and electrical works.
- In the PPA no Annual Contracted Energy (ACE) applies.

2.9.4 Results of business case assessment

Based on the calculated energy yield in Subsection 2.8.2, the cost assumptions as listed in Subsection 2.9.2, and the assumed financial parameters in Subsection 2.9.3, the business case of the wind farm has been determined for the lower-, baseline- and upper-bound cost scenario. This leads to the following results:

Table 14. Results of business case assessment.

Business case outcome	Lower bound cost scenario	Baseline bound cost scenario	Upper bound cost scenario
Project (before taxes) Internal Rate of Return (IRR) at P50	10.50%	8.70%	5.29%
Average Debt Service Coverage Ratio (DSCR) at P90	1.16	1.06	0.88
Net profit at P50 over 25 years	USD 394,436,000	USD 324,240,000	USD 161,459,000

3 Conclusion and Recommendations

Based on the conducted analysis, it is concluded that the overall techno-economic viability of a Ciracap wind farm in the Sukabumi regency requires improvement. The main cause for this is the lower wind speeds than expected at specific wind turbine locations. Although the initial wind resource assessment only included areas with wind speeds above 6 m/s, during the wind modelling stage the wind speed at some wind turbine locations turned out to be below this number (see Figure 48). This is likely caused by the low resolution of the wind speed map based on Global Wind Atlas. Without wind measurements and/or detailed wind modelling, there is a high uncertainty in the wind speed level from this source. Solely based on this wind map, it seems that less promising wind speeds are found on the northeastern corner of the envisioned wind farm. Although this requires further validation through wind measurements, it could be recommended to reconsider the site layout during a follow up study. Still, when the northeastern area and other wind turbine locations with lower windspeed are excluded from future development it could still lead to a wind farm size of approximately 300-350 MW. Whereas the current business outcome requires improvement, selecting the wind turbine locations with the highest yield and lowest cost is vital in future assessments.

Aside from the lack of wind resources at several wind turbine locations, the envisioned wind farm does entail other risks that should be taken into account by the developer and investor. This can be summarized in the following non-limitative risk list, including the respective recommendation of mitigating measures:

- **Wind resource:** There is still significant uncertainty on the wind resource in the area as determined by this study. The variety in outcome between the different models shows that validation of the wind resource early in the development process is vital. We recommend placing at least ten met masts for data gathering for at least one year, see Figure 49. In the background of the figure are the wind speeds from the Global Wind Atlas (GWA) shown. The elevation is shown with contour lines. The red dots indicate the wind turbine locations. The yellow icons show the global positioning of recommended met mast locations.

  The met masts are spread over the site in order to capture the spatial variability. Especially on the ridge it is recommended to additionally measure with an ultrasonic 3D anemometer, as on the ridge the turbines will most likely experience up and downdrafts. Using the ultrasonic 3D anemometer the horizontal velocity and vertical velocity will be measured.

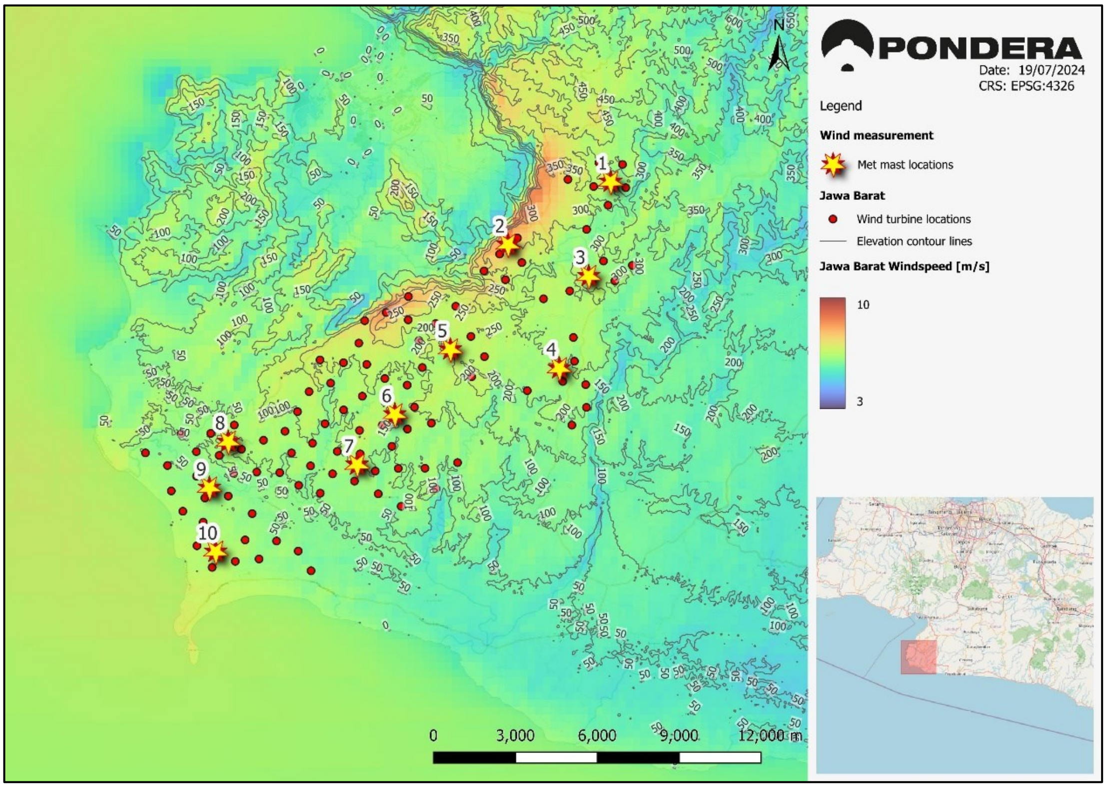

Figure 49. Recommended met mast locations.

- **Land use and permitting:** As can be derived from Figure 42 and Subsection 2.2.5, the wind farm is planned in a combination of Plantation Area (majority), Wet- and Dryland Farming/Agricultural Area. For any of this land use, a deal will need to be struck with the landowner to either acquire or lease the land. Before this can be executed, it is important for the developer to assess the land use / ownership in greater detail early on in the development process. The developer is recommended to firstly start consulting the authorities about the willingness and possibility to issue (if required) approvals and permits, and to approach the relevant landowners about the possibility of arriving at an agreement on the land.

Transport: A limited accessibility analysis has been conducted for this prospectus concluding that the fishing port in Pelabuhan Ratu is the most suitable starting point for the transport over land. To ensure that the port in Pelabuhan Ratu is suitable for offloading and storing the wind turbine components, a more extensive assessment needs to be conducted on the port which could entail a consultation with the port owner. During the site visit an earthen jetty was found on the west coast, proving that this might be a viable transport route. The usage of such a jetty near the site can drastically shorten the distance of overland transport. However, the cost of building a jetty close to this site and the saved cost of not using the local fishing port has to be evaluated during the feasibility study.

Furthermore, large parts of the road from port to site are in good condition, however the road winds through the mountains with numerous curves. Within the site, a large network of small roads is already available. However, upgrade of these public roads is necessary to use them and/or leave them in good condition after work has ended. A more extensive logistical survey is recommended to be conducted as part of the future feasibility study to obtain more details of the required infrastructure (adjustments).

- **Geology:** Based on the level of the study conducted for this prospectus, there are still significant uncertainties included in the design and construction of the foundations, roads, and crane hardstands, due to the geological circumstances and the impact of these circumstances. Therefore, it is recommended to further investigate the stability and capability of the soil to carry wind turbines closer to the caldera edge (where higher wind speeds are expected) during the feasibility stage. This can be done by a geotechnical soil investigation (determining soil characteristics such as shear strength, density, permeability, etc.), and subsequently, a soil stability analysis.

- **Seismicity:** The envisioned wind farm is planned in an area with earthquake risk (similar to many other locations in Indonesia). During the feasibility study, the maximum expected peak ground acceleration should be calculated for more precise hazard assessment due to earthquakes. The study should also look at the possible ways to mitigate the identified earthquake risk. The foundation design should at least comply with the international standards for mitigating earthquake risks.

- **Environment:** A part of the area is an important tourist destination and could be affected by the wind turbines nearby with a tip height of more than 200 m. Especially the area that is recognized as a Geopark. The presence of this wind farm could cause opposition from local stakeholders and environmental groups on the wind farm development. Therefore, it is recommended to involve these stakeholders early in the wind farm development, to identify and mitigate specific objections from each stakeholder.

- **Flora and fauna:** It is expected that (critically) endangered and vulnerable flora and fauna species are present in the envisioned wind farm area. Several animal and plant species were observed in the area that are categorized in the IUCN global red list category. It is likely that the wind farm development will have an effect on biodiversity. Also to be considered, international funding for development is not granted easily. Consequently, it is advised that as part of an Environmental and Social Impact Assessment, a biodiversity baseline study, and risk assessment and mitigation measures are carried out during the feasibility study.

- **Grid connection and PPA:** The wind farm is designed to be connected to the PLN grid. This assumes that the grid can integrate 400 MW of wind energy (with variable output), and that the substation in Pelabuhan Ratu Baru is suitable to facilitate the wind farm's grid connection. These assumptions should be verified during the feasibility study. Additionally, the current result of business case assessment is based on the assumption that the PPA uses the ceiling electricity tariff as stipulated in Presidential Regulation 112/2022, and that no Annual Contracted Energy (ACE) is applied. The actual PPA conditions depend on PLN and on how the tender process is set-up. An early alignment with PLN on these PPA conditions and tender process set-up is recommended.

Based on the above list of risks and recommended mitigating measures, and as the subsequent step in the wind farm development, it is recommended to prioritize the execution of on-site wind measurements to validate the actual wind speeds at the area. In parallel with the measurements, it is important to start engaging and aligning with the relevant stakeholders and local authorities about their willingness to collaborate in wind energy development at this location.

4 Disclaimer

This wind farm prospectus has been written with due care based on assessments conducted by four experienced parties in the wind energy sector (Pondera, Witteveen+Bos, Quadran, and BITA). However, aside from a two-day site visit to the area, the assessments have been executed through a desk study based on publicly available data and information. The nature and accuracy of the data and information used for the report largely determines the accuracy and uncertainties of the recommendations and outcomes of this report. Furthermore, verification and validation through physical surveys, measurements, design, calculations, and stakeholder consultations are required to determine the definitive techno-economic viability of the wind farm. Therefore, no rights can be derived from any of the presented information and results. For some sites, developers have already initiated follow up studies and therefore might come to different considerations and conclusions based on their acquired data. The use of this wind farm prospectus is limited to informing the Indonesian government, developers, and investors about the indicative potential of the presented location for wind energy development. The authors of this report are not responsible for any consequences that may arise from the improper use of the report.

ENERGY TRANSITION PARTNERSHIP
Powering Prosperity and Enabling Sustainability in South East Asia

UNOPS

This document is produced as part of the Southeast Asia Energy Transition Partnership's 'Wind Energy Development in Indonesia: Investment Plan' Project