REPORT

Wind Energy Development Prospectus:
200 MW Project in Ponorogo, East Java
2024

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

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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 Ponorogo 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
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- Schematic design of transmission and distribution network

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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 Ponorogo Wind Farm, East Java – 200 MW

2.1 Introduction of the wind farm location

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

2.1.1 Geographic location

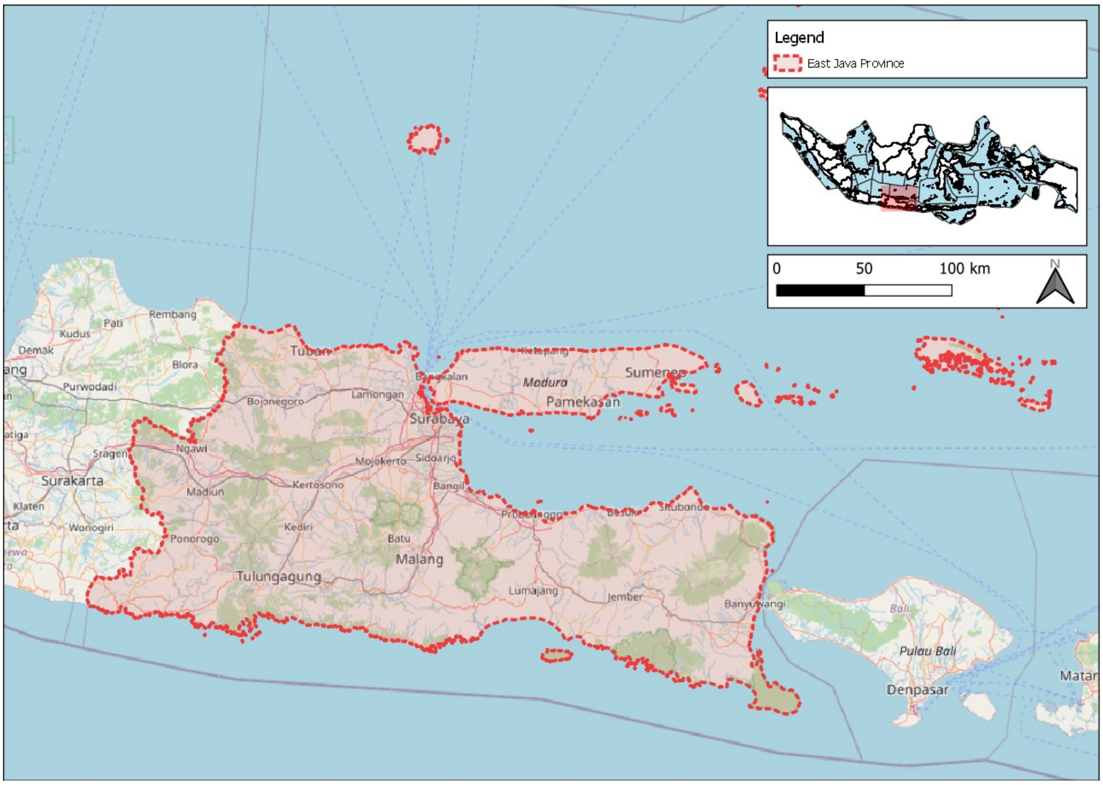

Figure 1. A map of East Java province in which the envisioned Ponorogo wind farm area is located.

Figure 1 shows the East Java, a province situated in the eastern end of Java Island and in the west of Bali Island. On the island, the province is bordering with Central Java province. The eastern tip of East Java is where the Bali Strait is located. East Java has an area of 48,037 km^2. In 2022, the population in this province amounts to roughly 41.1 million[1], making it the third most populous province in the country[2]. In terms of GDP per capita, the province is ranked 11th (IDR 66.36 million)[3]. Moreover, the economic growth in 2023 (c-to-c) is 4.95%[4]. To provide context, Indonesia's economic growth in that year is 5.05% (c-to-c)[5].

[1] https://jatim.bps.go.id/indicator/12/375/1/jumlah-penduduk-provinsi-jawa-timur.html
[2] https://sulut.bps.go.id/indicator/12/958/1/jumlah-penduduk-menurut-provinsi-di-indonesia.html
[3] https://www.statista.com/statistics/1423411/indonesia-per-capita-gdp-at-current-prices-of-provinces/
[4] https://jatim.bps.go.id/id/pressrelease/2024/02/05/1456/ekonomi-jawa-timur-tahun-2023-tumbuh-4-95-persen--ekonomi-jawa-timur-triwulan-iv-2023-tumbuh-4-69-persen--y-on-y---ekonomi-jawa-timur-triwulan-iv-2023-tumbuh--0-89-persen--q-to-q-.html
[5] 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

East Java is one of the biggest economic hubs in central and eastern part of Indonesia. The province contributes to 14% of the national economic growth[6]. There are multiple industrial processing regions in the province, including Surabaya, Sidoarjo, Gresik, Mojokerto, and Pasuruan. New processing facilities are further developed in Nganjuk, Madiun, and Ngawi[6]. Examples of prominent industrial goods produced in East Java are cigarettes, cement, military vehicles, paper, and trainsets. Furthermore, East Java also hosts Indonesia's largest producing oilfield in Cepu block[7], as well as the recently inaugurated Jambaran Tiung Biru gas processing facility.

In East Java, there are 9 Industrial Estates. The top five largest estates by area are the following[8]:

1. Maspion Industrial Estate (1,143 ha)
2. Ngoro Industrial Park (600 ha)
3. Pasuruan Industrial Estate Rembang (558.49 ha)
4. Safe N Lock Eco Industrial Park (372.2 ha)
5. Surabaya Industrial Estate Rungkut (332.35 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 are two Special Economic Zones (SEZ) in East Java, namely, Gresik SEZ and Singhasari SEZ. The former SEZ was inaugurated in 2022 and was planned to host a glass factory, a smelter, and a CPO processing facility. This SEZ is also complemented with 800-ha residential area and 400-ha port area as the area is near the Madura Strait[9]. On the other hand, the latter SEZ began its operation in 2022, and is focused on the development of tourism, digital technology, education, and creative industry[10].

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

1. Singhasari SEZ (10 MW)
2. Bangkalan Industrial Estate
3. Maspion Industrial Estate (200 MVA in 2021-2030)
4. Tuban Industrial Estate (80 MVA in 2025)
5. Bromo-Tengger-Semeru Priority Tourism Destination (2 MVA)
6. CV Sumber Mas Smelter (9.8 MW in 2021)
7. PT Freeport Indonesia Smelter (150 MW in 2023)

The next subsection will explain the projected power demand levels of the province, which among others considers the future demand from the abovementioned consumers.

[6] https://www.kompas.id/baca/nusantara/2023/11/19/menakar-resiliensi-ekonomi-jatim-ditengah-resesi-global-dan-tahun-politik
[7] https://www.esdm.go.id/en/media-center/news-archives/terbesar-di-indonesia-produksi-minyak-lapangan-banyu-urip-capai-30-produksi-nasional
[8] https://regionalinvestment.bkpm.go.id/pir/kawasan-industri-kek/
[9] https://www.jiipe.com/en/home/kawasanDetail/id/1
[10] https://singhasari.co.id/aktivitas/

It is noteworthy that there is a strip of mountains across the mid-southern part of East Java. Among others, the mountains include Mount Liman, Mount Kawi, Mount Arjuna, Mount Bromo, Mount Semeru, and Mount Argopuro. The presence of these mountains can result in interesting wind characteristics in the surrounding regions. As part of this study, the wind characteristics in four regencies (Kediri, Ponorogo, and Probolinggo – Lumajang) are analyzed. In this prospectus, the considered wind farm location is located in Ponorogo Regency.

2.1.2 Status in RUPTL PLN 2021-2030

Figure 2 portrays the electricity system of East Java. The system is supported by 500 kV, 150 kV, and 70 kV transmission lines. Furthermore, the system is connected to Madura Island, which is located in the northeast of the province. It is envisioned that in 2025 there will be a 500 kV transmission line connecting Java Island and Bali Island through East Java[11], as shown in the right part of the figure. According to RUPTL PLN 2021-2030, the peak load of this province in 2020 is 5,935 MW. Meanwhile, the level of energy production and peak load is projected to increase steadily in 2021-2030, as shown in Figure 3. This projection is based on the assumption that the average demand growth rate will be 3.7% per year.

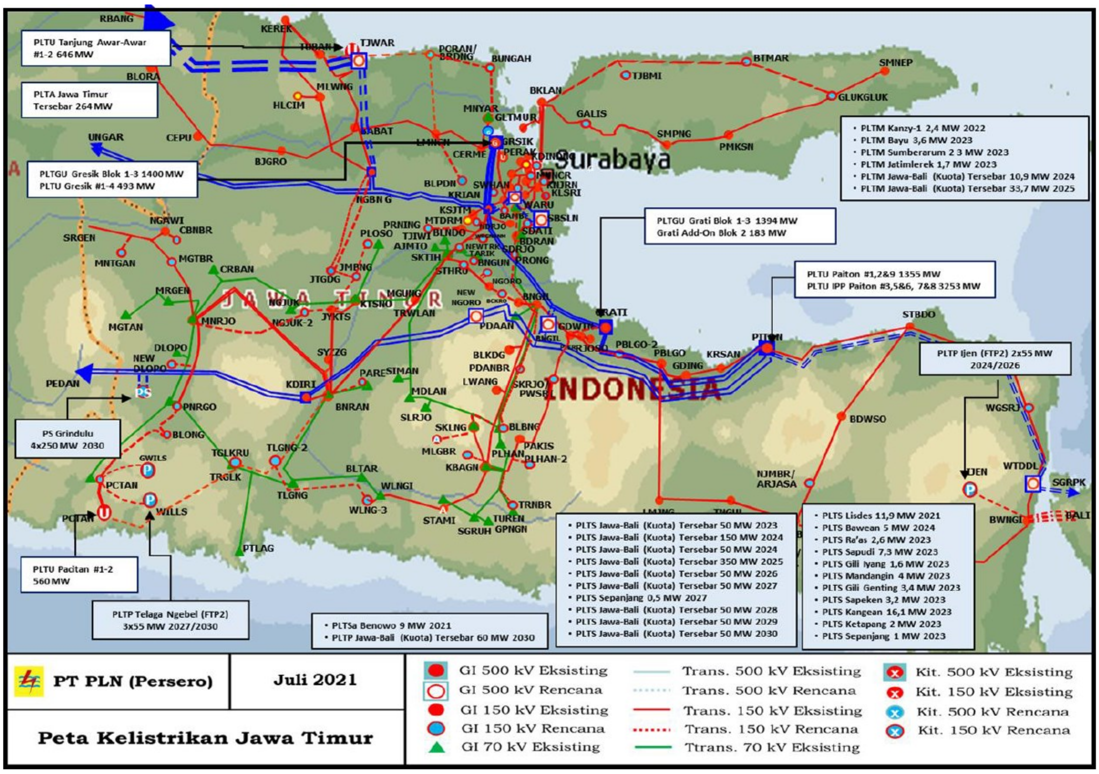

Figure 2. A map of East Java electricity system in RUPTL (Source: RUPTL PLN 2021-2030)

[11] https://web.pln.co.id/media/siaran-pers/2022/12/pln-siapkan-pembangunan-transmisi-listrik-jawa-bali-target-proyek-rampung-2025

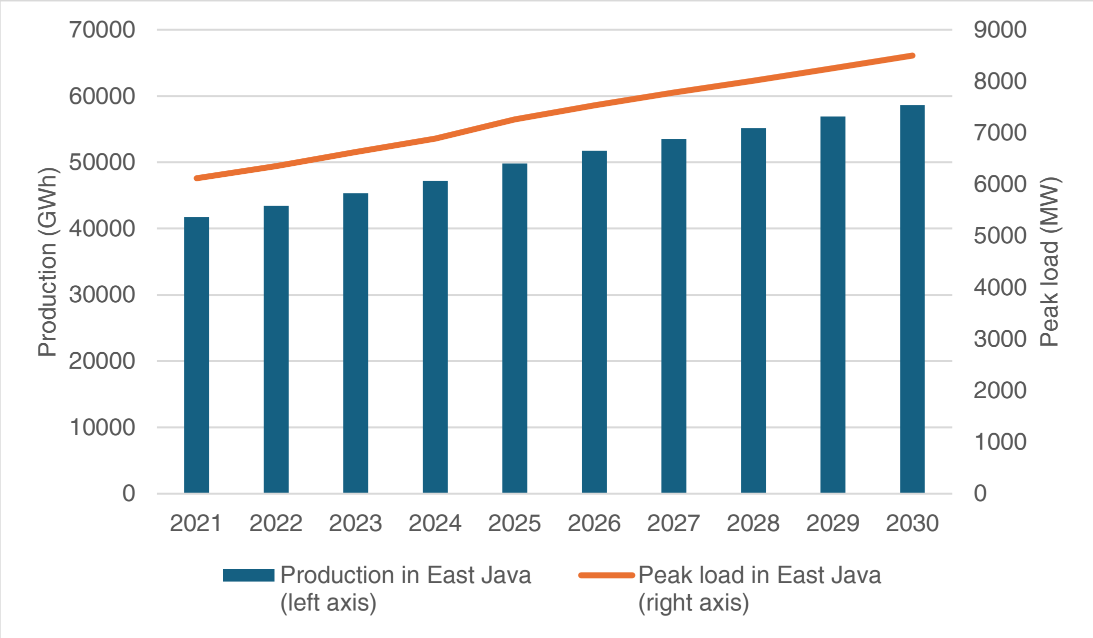

Figure 3. Projected electricity production and peak load in East Java (Source: RUPTL PLN 2021-2030)

A summary of the power generation development planning can be seen in Figure 4. This figure includes both conventional and renewable energy power plants. Additional power generation is categorized into two sources, namely, PLN and Independent Power Producer (IPP). There is no allocation for wind energy in 2021-2030. However, the RUPTL identifies the following wind power potential in East Java:

- Banyuwangi (75 MW)
- Probolinggo (50 MW)
- Tuban (66 MW)
- Tuban (140 MW for solar and wind farm)

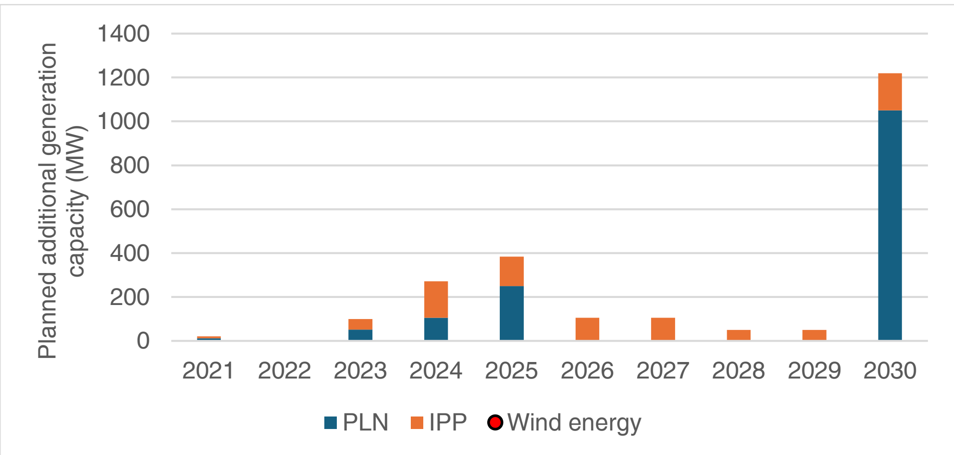

Figure 4. Additional generation capacity being planned for East Java (IPP: Independent Power Producer; Source: RUPTL PLN 2021-2030)

2.1.3 Status of development

There are some ongoing development activities for wind energy in East Java. At the end of 2023, one developer is known to have initiated their development and in the process of obtaining permit in Blitar Regency[12], which is near the southern coast of East Java. In early 2023, a private investor is said to be studying the feasibility of building a wind farm in the coastal area of Munjungan in Trenggalek Regency[13]. Finally, in 2020, PLN were planning to build a 50 MW wind farm in Banyuwangi Regency after having completed their feasibility study[14]. The construction was planned to start in 2021[15], however, there is no further updates on its continuation up to the time of writing.

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).

[12] https://surabaya.kompas.com/read/2023/12/22/153732378/pemkab-sebut-investor-china-akan-bangun-pltb-rp-125-triliun-di-blitar
[13] https://jatim.antaranews.com/berita/673947/investor-jajaki-potensi-pengembangan-pltb-trenggalek
[14] https://news.detik.com/berita-jawa-timur/d-4912684/pln-akan-bangun-pltb-di-banyuwangi-diklaim-terbesar-di-pulau-jawa
[15] https://www.antaranews.com/berita/1946676/pemkab-banyuwangi-indonesia-power-kembangkan-listrik-tenaga-bayu

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)

2.2.2 Wind resource and characteristics

Figure 5 shows the initial search area (bounded by the purple-dash box) in and around Ponorogo Regency. 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 majorly located in a cluster of areas, with other small areas scattered at lengthy distances.

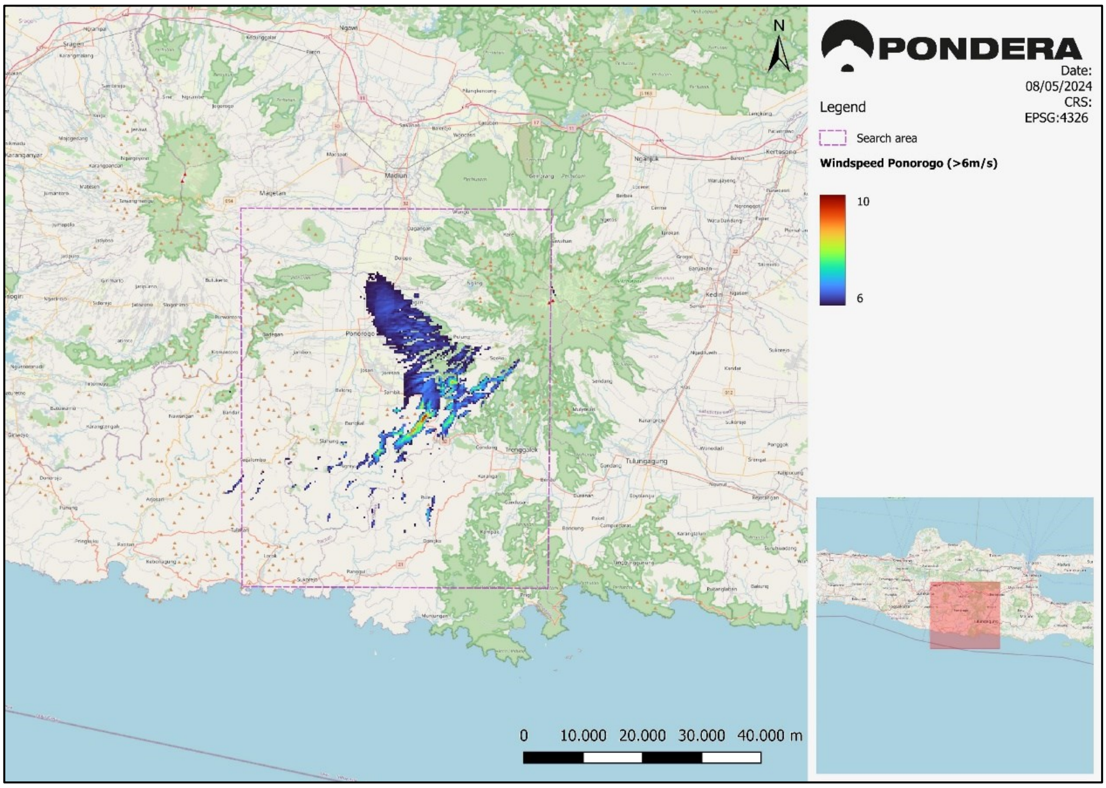

Figure 5. Ponorogo search area with wind speed distribution. The purple-dash bounding box shows the full search area. The color bar indicates average wind speeds which are above 6 m/s at 100 m height according to the Global Wind Atlas (GWA) climatology.

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.

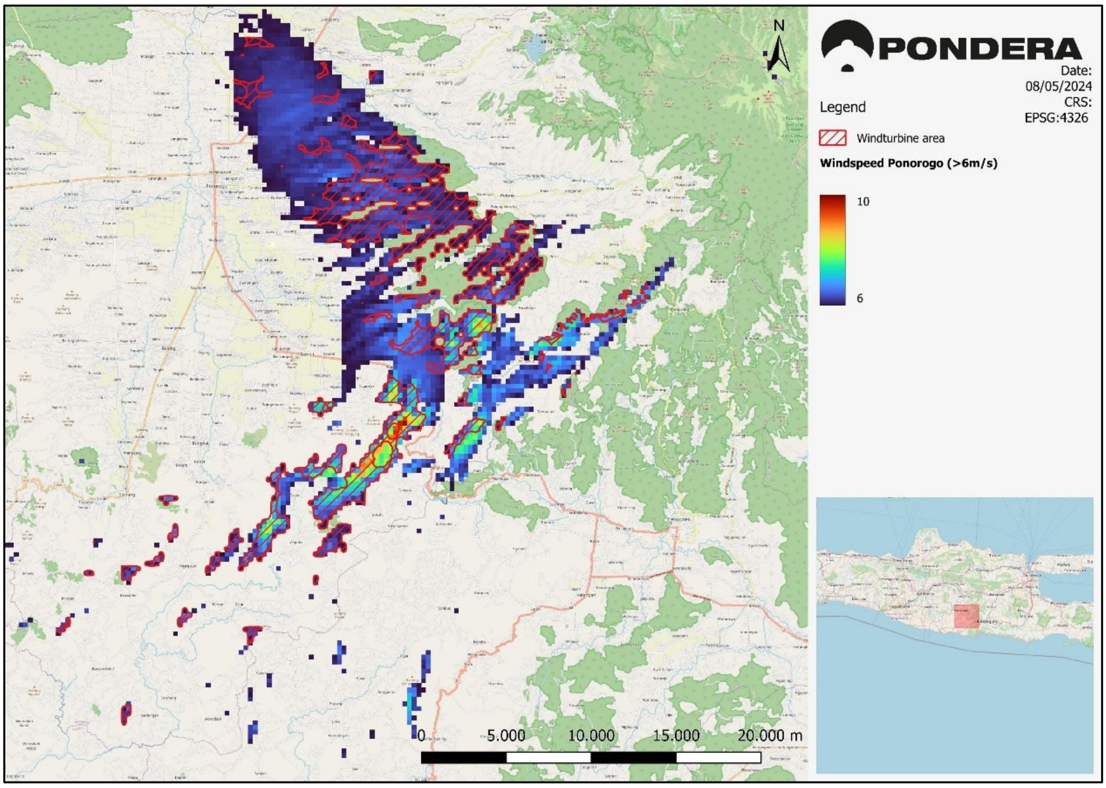

Figure 6. A zoomed-in look at the Ponorogo search area along with the wind speed distribution. The red, dashed polygons represent the final WTG-area which meets all the criteria. Average wind speeds above the threshold of 6 m/s at 100 m height according to GWA are shown.

Additionally, Figure 7 visualizes the long-term average wind direction distribution for the Ponorogo 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. As expected, during these months most of the eastern and northeastern winds 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.

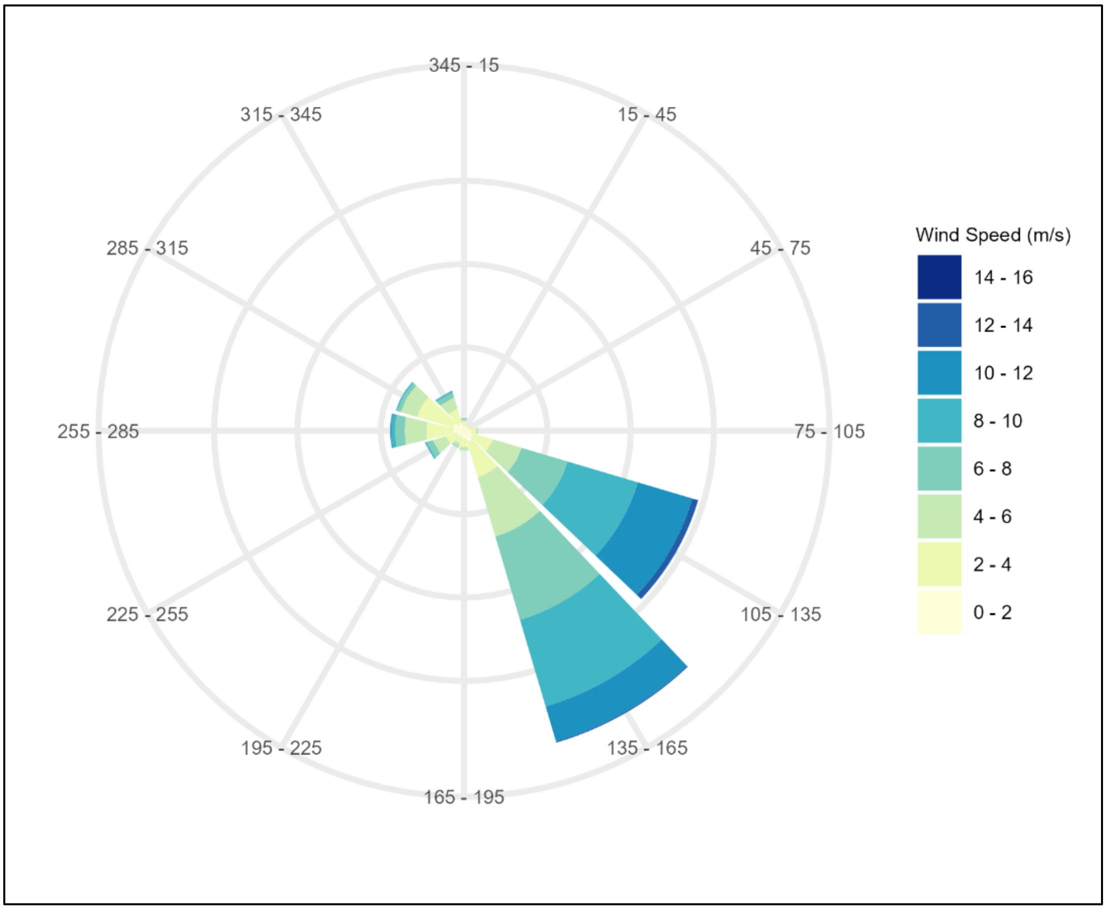

Figure 7. Windrose diagram with wind directions and wind speed categories based on a 10-year climatology, including the 2004-2015 time series of hourly data. Source: EMD-WRF.

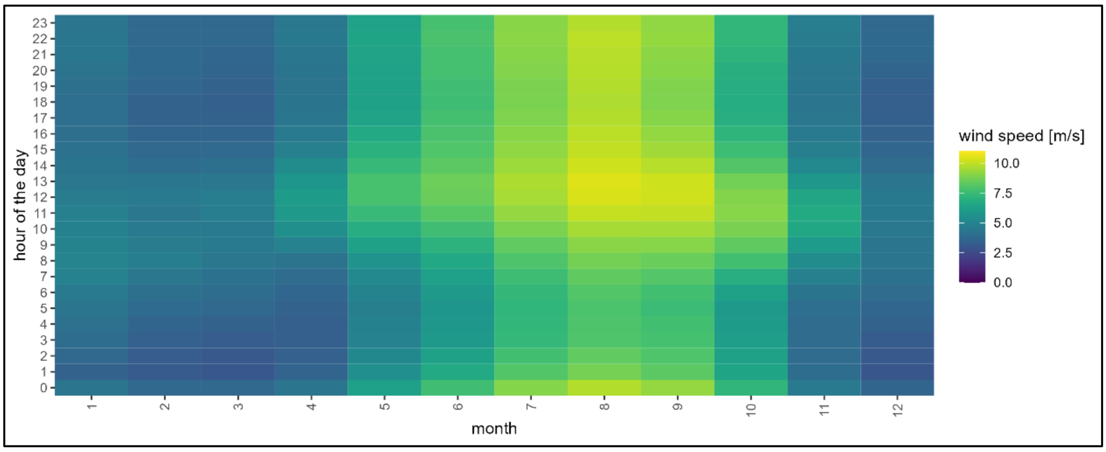

Figure 8. The wind speed distribution throughout the day, visualized per month of the year. Based on a 10-year climatology, including the 2004-2015 time series of hourly data. Source: EMD-WRF.

2.2.3 Topography

Figure 9 shows the topography of the search area in the Ponorogo region. 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.

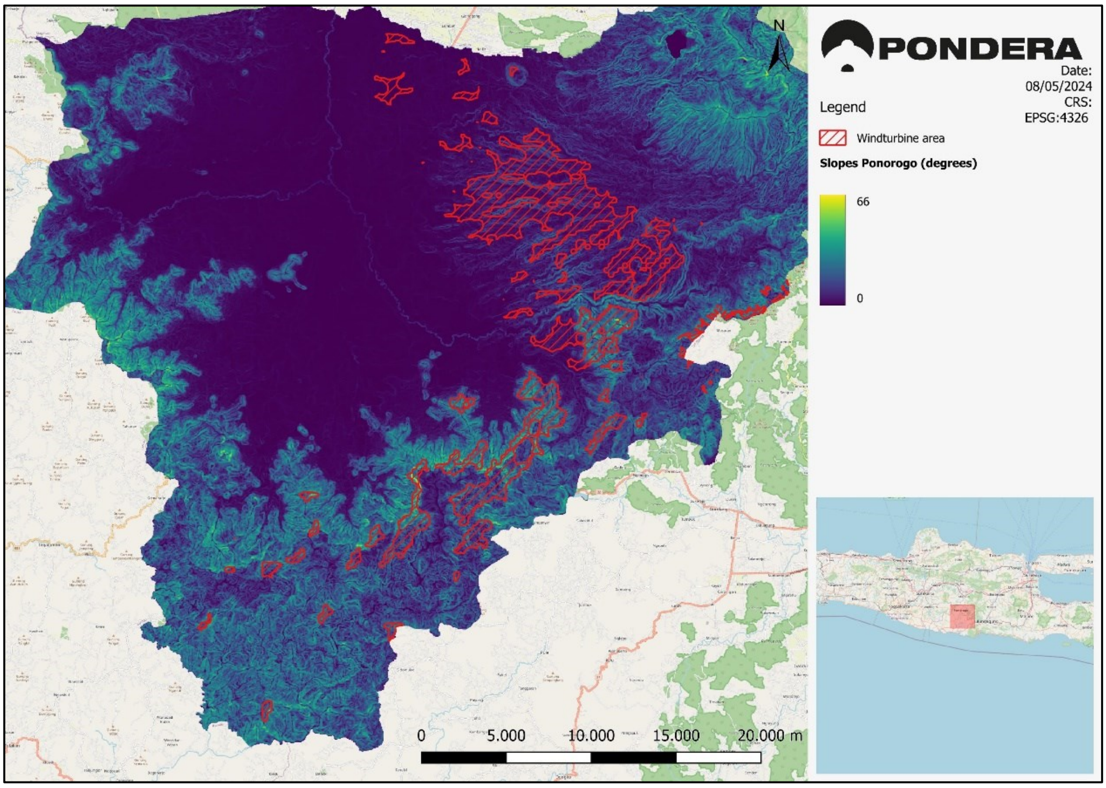

Figure 9. Topography of the Ponorogo WTG-area, showing the slope (in degrees; according to calculated based on FABDEM data) at the region.

The topography in the region is complex compared to other regions in Indonesia, and closely related to the geological history. The site lies on the northern edge of the 'Southern Mountains of East Java,' which is a mountainous region in the south of Ponorogo to the Indian Ocean. The mountains are an uplifted block of mostly volcanic rocks, and are older than most other regions.

Most of the turbines are envisioned on a 'plateau' which is an area elevated 850-1,000 meters above sea level, which is also 650-800 meters above the plains around Ponorogo. The elevated plateau itself is a hilly area with elevation changes of about 150-200 m. Slopes are generally steep and many cliffs are present (see Figure 9). These cliffs are not represented in the open source height models (FABDEM or DEMNAS).

This terrain, both from the Ponorogo plains to the plateau and within the site area, will have a high impact on the accessibility and cost of road construction. More illustrations of the terrain can be found in Figure 10, Figure 11, Figure 12, and Figure 13.

Figure 10. Existing road from Bungkal, which connects the plains around Ponorogo to the plateau (650-800 height difference). The cliffs on the left and the right side of the road are not represented in height models. Inclination of the road is estimated to be over 20% in some sections.

Figure 11. A view from the plateau edge to the plains surrounding Ponorogo (650-800 m height difference).

Figure 12. A view of the steep hills and mountainous topography within the plateau.

Figure 13. Another view of the steep hills and mountainous topography within the plateau.

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 14). 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 14.

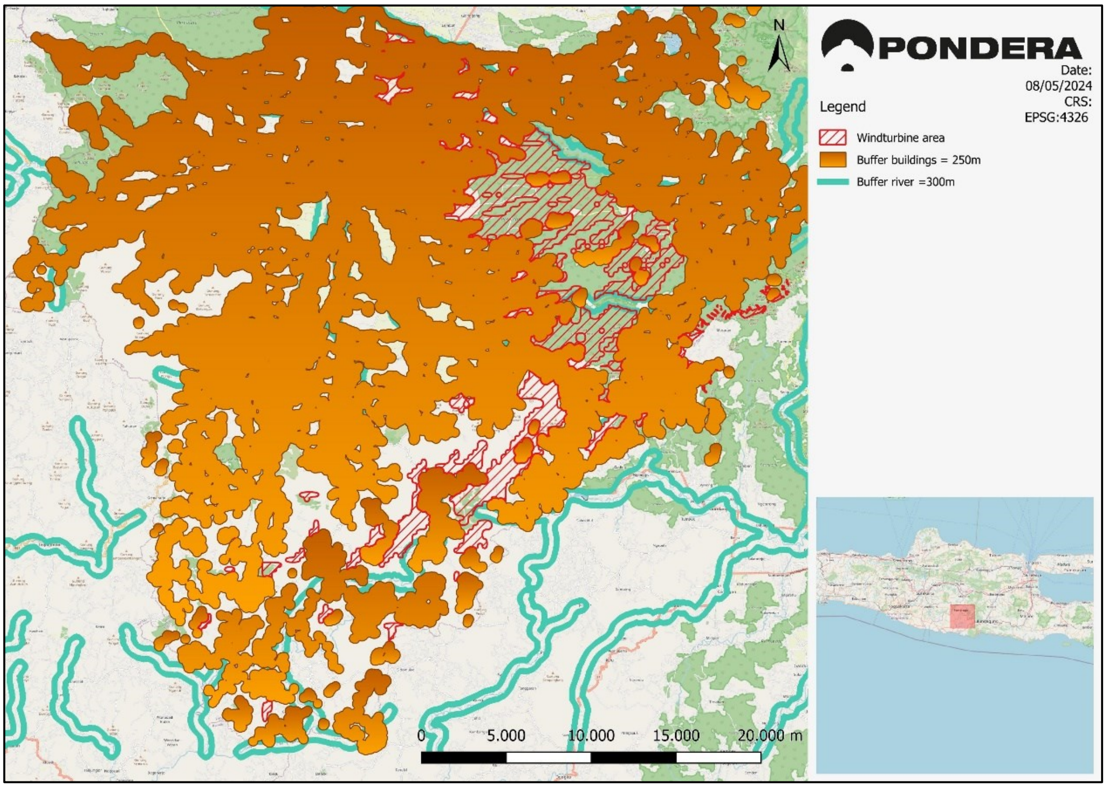

Figure 14. Exclusion zones at the Ponorogo area based on land use and residential areas. Source: ESRI and OSM.

2.2.5 Specific permitting requirements

The overlay between Ponorogo Regency Spatial Plan (*Rencana Tata Ruang Wilayah* or RTRW) 2012-2032 and the WTG area is shown in Figure 15. As inferred by the figure, the continuous area with promising wind speed is located in the following land use types:

1. Plantation Area (*Kawasan Perkebunan*)
2. Wetland Food Agriculture Area (*Kawasan Pertanian Pangan Lahan Basah*)
3. Urban Settlement Area (*Kawasan Permukiman Perkotaan*)
4. Rural Settlement Area (*Kawasan Permukiman Pedesaan*)
5. Irrigated Agriculture Area (*Kawasan Pertanian Beririgasi*)
6. Medium Industrial Area (*Kawasan Industri Menengah*)
7. River Border Area (*Kawasan Sempadan Sungai*)
8. Grassland/Shrub Area (*Kawasan Padang Rumput / Semak*)
9. Protected Forest Area (*Kawasan Hutan Lindung*)

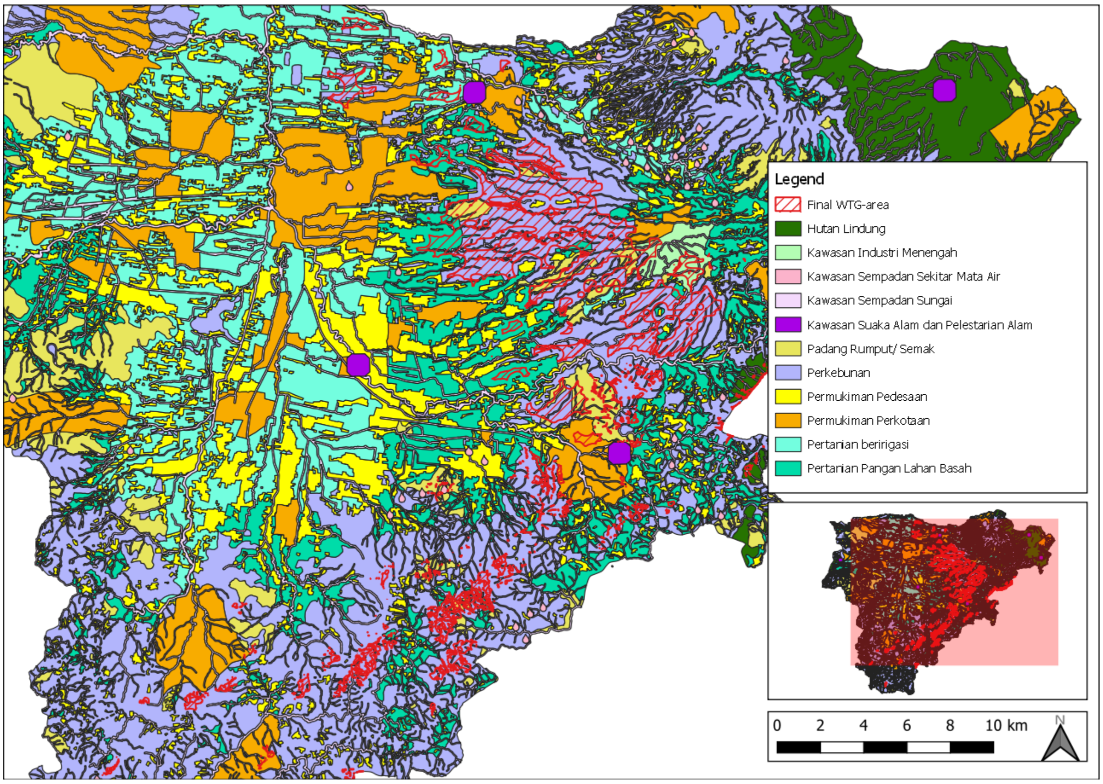

Figure 15. The map of spatial plan of Ponorogo Regency (RTRW 2012-2032) overlaid with the final WTG-area.

A majority of the WTG area is located in Plantation Area. This area is typically 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[16].

Parts of WTG-area which are in Urban Settlement Area and Rural Settlement Area are assumed to belong to the community. Construction of wind power plants at these locations is possible as long as a purchase or lease agreement is achieved with the landowner.

Parts of WTG area in Wetland Food Agriculture Area and Irrigated Agriculture Area are assumed to be owned by the community, private companies, or state-owned companies. Wind farm development (as well as other types of power generation and transmission activities for public interest) in this area is possible if the area is not part of the Sustainable Food Agriculture Area, and after purchase or lease agreement is reached with the landowner[16].

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

Since the actual ownership is not known in this analysis, WTG area within Medium Industrial Area can be assumed to be owned by private or state-owned companies. It may be beneficial for the industry to have a captive power plant near the location. Nevertheless, the presence of a wind farm within or in the vicinity of the industrial area can also disturb economic activities occurring inside the area. Hence, an agreement shall be reached between the landowner and the wind farm developer before wind farm development can take place.

It can be assumed that WTG area within River Border Area and Grassland/Shrub Area is under the ownership of the Government or the community. As long as these areas are not part of the conservation area, then they may be used for wind power plant development in accordance with the applicable regulations.

Finally, a small part of the WTG area coincides with Protected Forest Area. According to Government Regulation 23/2021, a Forest Area Utilization Permit (*Izin Pinjam Pakai Kawasan Hutan* or IPPKH), or what is now known as Forest Area Use Approval (*Persetujuan Penggunaan Kawasan Hutan or* PPKH) is needed to develop a wind farm at the area. This permit is issued by the Ministry of Environment and Forestry (MoEF), and thus, the future wind farm developer must apply for this permit.

Regulation of the Minister of Environment and Forestry 7/2021 stipulates the conditions to obtain the permit for activities in the electricity sector. Depending on the amount of forest area in the province, the permit owner may eventually be obliged to, among others, pay a compensation non-tax state income, pay non-tax state income for utilizing the forest area, and rehabilitation planting at river basin with a ratio of at least 1:1.

Later in Section 2.3, it will be shown that the envisioned wind turbines are placed in the mid-southern section of the final WTG-area. Thus, the relevant land use types for Ponorogo wind farm are Plantation Area, Wetland Food Agriculture Area, River Border Area, Urban Settlement Area, and Grassland/Shrub Area. The values/costs of these land use types are taken into account in the business case calculations (see Section 2.9).

The obtained RTRW of Ponorogo Regency is for the year 2012-2032. It is not yet known whether a new Regional Regulation on the new RTRW has been issued or is still being prepared. Therefore, confirmation from the competent agency in Ponorogo Regency is required. If a new RTRW Regional Regulation is already in place, the obtained RTRW is no longer valid. However, if the RTRW of Ponorogo Regency has not yet been revised or is still being revised, then the obtained RTRW is still valid.

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 16. This area meets all the criteria as visualized in the previous figures.

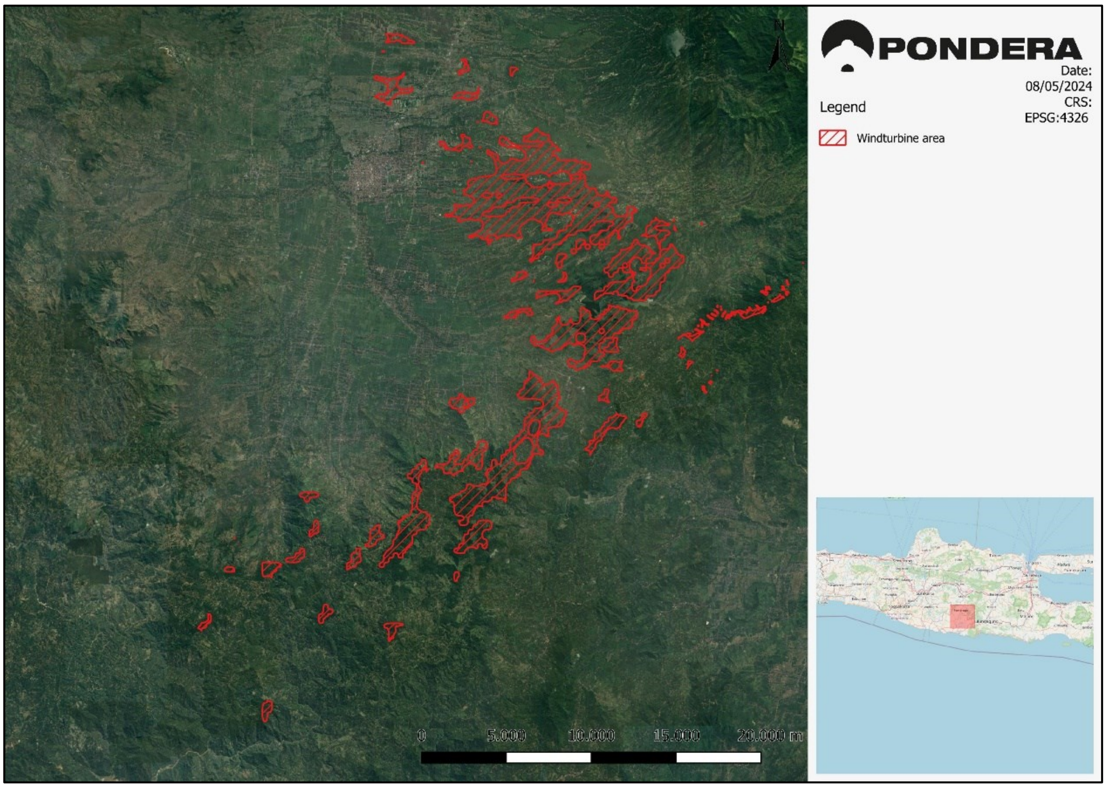

Figure 16. Final WTG-area based on the restriction criteria. Source: Google Satellite Images.

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;
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. Whereas the WTG-area is significantly scattered, 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. Therefore, we have selected this mid-southern part of the WTG-area for further analysis, also due to the more promising wind climate.

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.

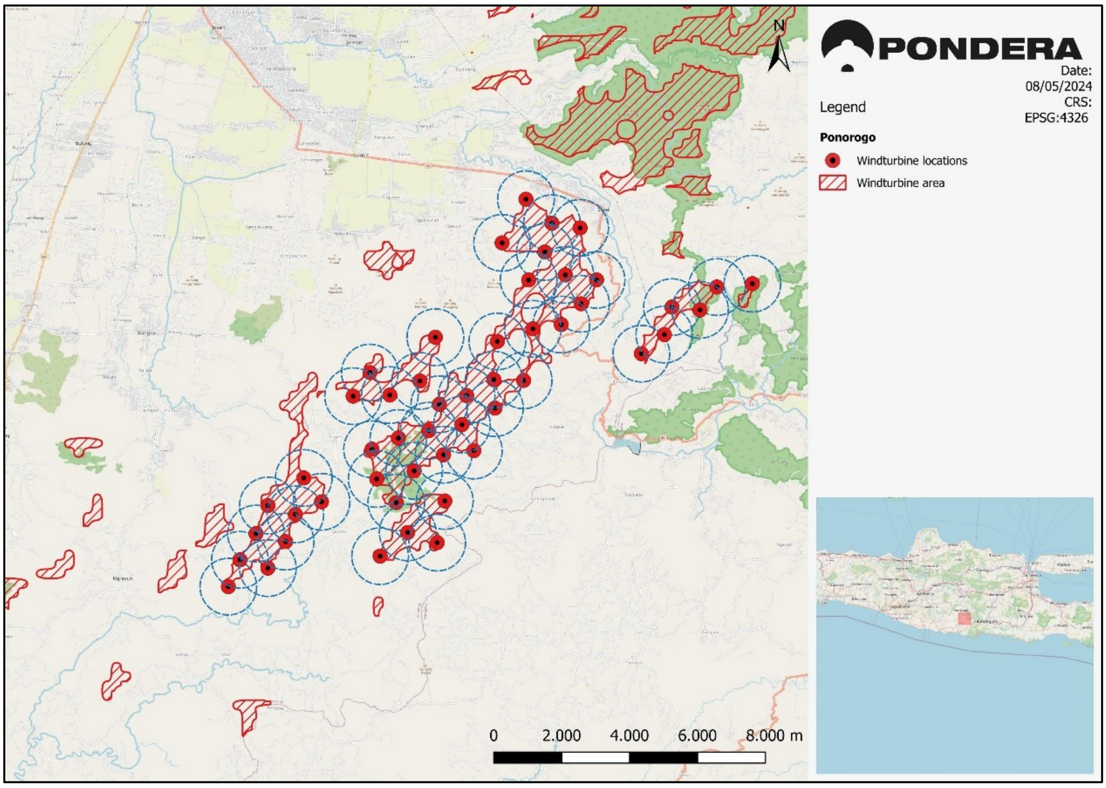

Figure 17. Preliminary wind farm layout at the final WTG-area.

Figure 17 displays an overview of the wind turbine locations in the final WTG-area. A total of 50 wind turbines were positioned into the area, amounting to an envisioned total installed capacity of 200 MW (based on 4 MW wind turbines). 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.

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 and the few available highways, regional road systems are used for almost all transportation (see Figure 18). 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 18. 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

The nearest port of the envisioned Ponorogo wind farm is Port of Surabaya (i.e. Port of Tanjung Perak), 220 km from the site. This is a major port with quay cranes serving Eastern Java (see Figure 19). Another option is the Port of Semarang (i.e. Port of Tanjung Emas), serving Central Java. However, this port is farther away (~270 km from the site). On the south coast, no major ports are present.

Figure 19. A satellite image of the Port of Surabaya.

From the Port of Surabaya to the Madiun exit of the highway (160 km from Surabaya), no problems are expected. It is assumed that bridges on the highway do not need reinforcement, and bridges crossing the highway are high enough, more than the stated clearance of 4.2 m on the bridges itself.

Based on a rather rudimentary method (see Figure 20), a height of ~6 m between road surface and bridge was derived (3.5x Toyota Innova Reborn of 1.795 m height according to its specifications, which equals to 6.3 m). While this method is not completely reliable, the height seems to be much more than the shown maximum height of 4.2 m.

Figure 20. The height of bridges above road surface seems to be more than 4.2 m. As a comparison, this Toyota Innova Reborn's height is 1.795 m according to specifications.

From the highway to the base of the mountains, the road leads through the towns of Madiun, Ponorogo, and several smaller villages (see Figure 21). As any other local and regional road in Indonesia, they are not built for heavy transport, and the available space on and around these roads is limited (see Subsection 2.4.1). No ring roads are available around these towns. However, it is expected that on the major roads from the highway to south of Ponorogo, no big improvements are necessary. Furthermore, the road crosses a railway in the north of Madiun. This railway is not electrified, and thus, no reconstruction is expected on this location.

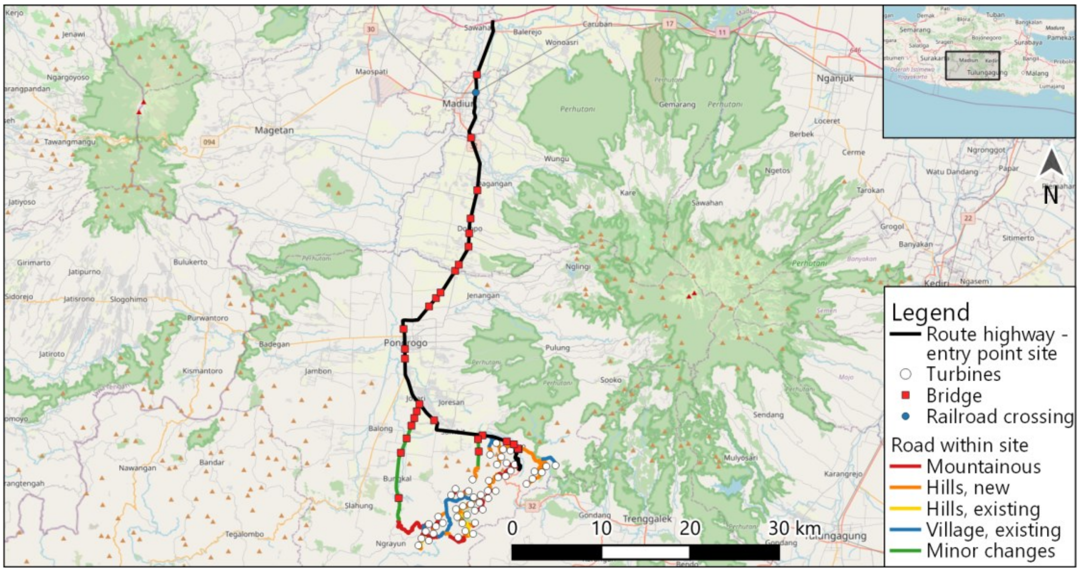

Figure 21. Route from toll road to the site in Ponorogo Regency.

The most difficult parts of this route are the junctions in the city center of Ponorogo, where transport has to take some sharper turns. The sharpest turns can be avoided when Jl. Letnan Jenderal S. Parman is taken, instead of Jl. Soekarno-Hatta (through the center). The road on Jl. Letnan Jenderal S. Parman is slightly narrower, but the turns are slightly wider, and the junctions are less busy as these are located just outside of the city center.

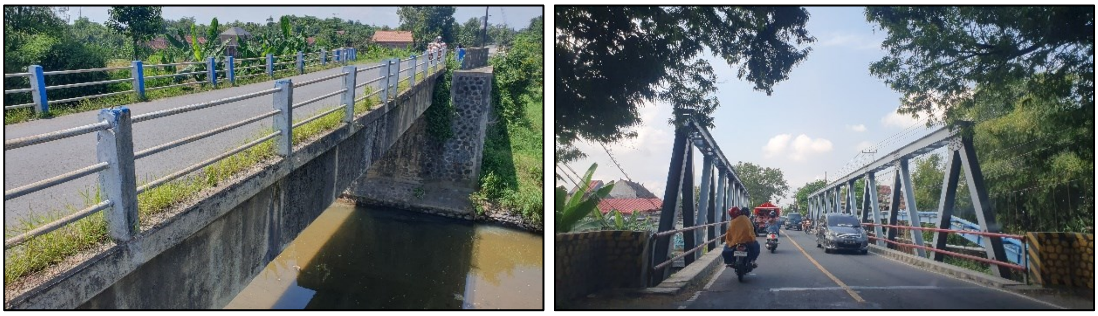

Figure 22. An example of an old concrete bridge (left; from 1970) and steel bridge (right). Both bridges are between Ponorogo city center and the site.

From the toll road to the different access roads into the site, 29 bridges have to be crossed. These are mostly smaller to medium concrete bridges (~5-20 m in length). Of the 29 bridges, 26 bridges are made from concrete, whereas 2 bridges are made of steel (see Figure 22). One of the bridges will need a complete replacement as in its existing form, this bridge is too narrow and in a poor condition (Kreteng Buntung bridge on Jl. Raya Sawoo - Sriti with a length of 75 m; see Figure 23). It is expected that a sum of $1,500,000 is sufficient to rebuild this bridge with a width of 6 m. Additionally, it is expected that most of these bridges will need reinforcement before heavy transport can take place.

Figure 23. Kreteng Buntung bridge which will need replacement.

2.4.3 Transport within the site

The terrain within the site is complex and irregular (see Subsection 2.2.3), and spans over multiple mountain ranges. This means that the road layout within the site cannot consist of solely one main access road connecting most of the turbines. Instead, from the main roads, several ‘branches’ of considerable length will have to be made to reach one or more turbines.

The preliminary road layout is shown in Figure 24. Some sections have to be built in mountainous terrain (shown as red lines, 33.4 km), which are considerably more expensive to construct as large volumes of cut and fill are expected. Cut and fill is a process where a road is cut into a slope and, if the excavated material is suitable, used to fill areas where material is needed to fill depressions or used to widen a road. Meanwhile, examples of the roads which are shown as green lines and blue lines are displayed in Figure 25 and Figure 26, respectively.

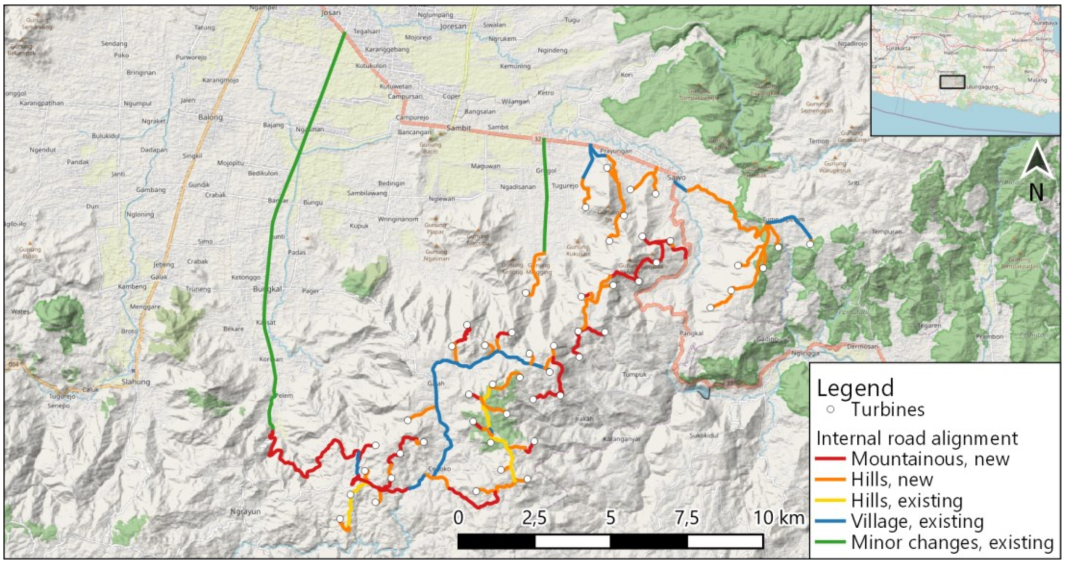

Figure 24. Preliminary road layout, based on a maximum of 10% inclination and DEMNAS height model.


Figure 25. A photo of the road between the main road and the starting point of access road (left; shown as green lines in the preliminary road layout), and an example of existing road in mountainous setting within the site area (right).


Figure 26. Existing road in valley within and between villages within the plateau (left), and existing road connecting the villages on the plateau valley (right). Both roads are shown as blue lines in the preliminary road layout.

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

- Inquire or measure accurate heights between road surface and bridges on toll roads. The height of the lowest bridge may be a limiting factor of the diameter used for the base of the turbine tower;
- The resolution of the open source height models is not precise enough for mountainous terrain to make a detailed road alignment. A LiDAR-based height model will likely show steeper slopes of hills and mountains. This may increase the total length of access road and might be a significant factor in cost calculations; and
- Some turbines are hard to reach or far away from other turbines. Relocating some turbines to more accessible locations might reduce road length that has to be improved or constructed.

2.5 Geology and seismicity conditions

The terrain within the site is part of the Southern Mountains of East Java, a mountain range south of Ponorogo. The next subsections will describe specifically the area's geology and seismicity in greater depth.

2.5.1 Geology

Within the site, the geology is mainly uplifted volcanic (mainly andesite) rocks from Miocene age (Mandalika Formation and Arjosari Formation). The uplifted area is located between the fore-arc basin (south of the site in the ocean) and the volcanic arc (north of the site). A side profile on the geology can be found in Figure 27. There is little information available about local geology or tectonic activity.

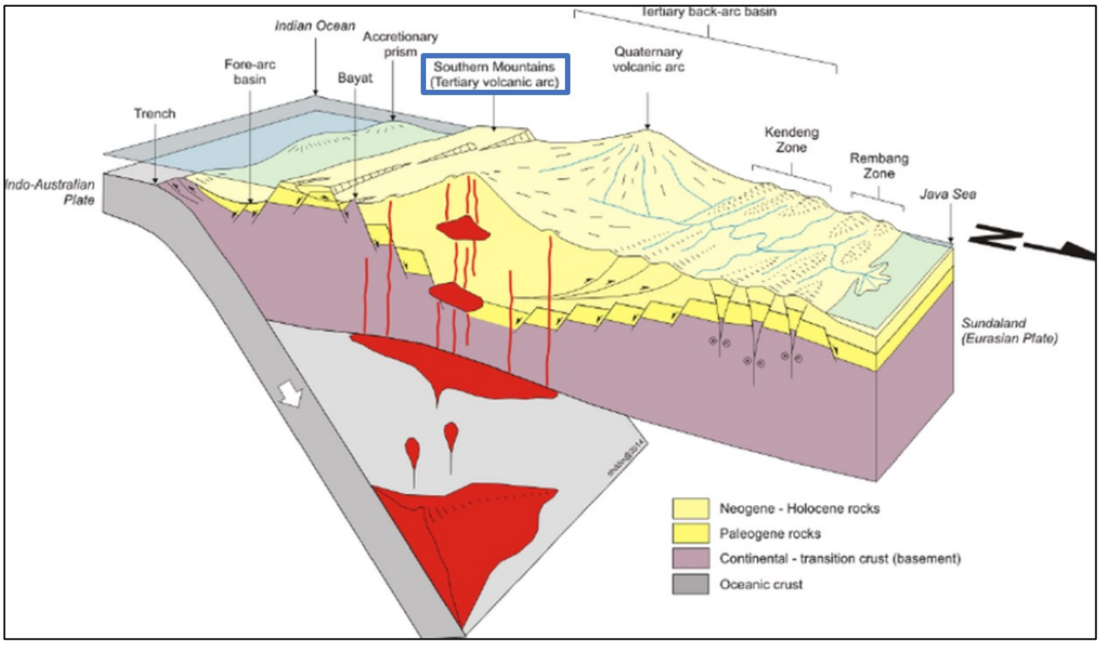

Figure 27. A side profile of Eastern Java geology. The site is located in the Southern Mountains, as marked with the blue box.

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 28 visualizes land movement vulnerability index of the soil in and around the WTG-areas. Most of the turbine locations are situated in moderate to high risk areas considering land movement. However, due to the geological history (uplifted volcanic rocks), it is expected that the hard bedrock does not lie deep beneath the surface (up to a few meters deep). In contrast to most areas on Java Island, which consists of a thick pack of volcanic ash/debris that can be susceptible to land movement on steep slopes, it is expected that the turbine foundation in this area can be anchored in the bedrock directly, lowering the risk of land movement. However, landslides higher up the mountains consisting of material on top of the bedrock can still pose a threat to the turbines.

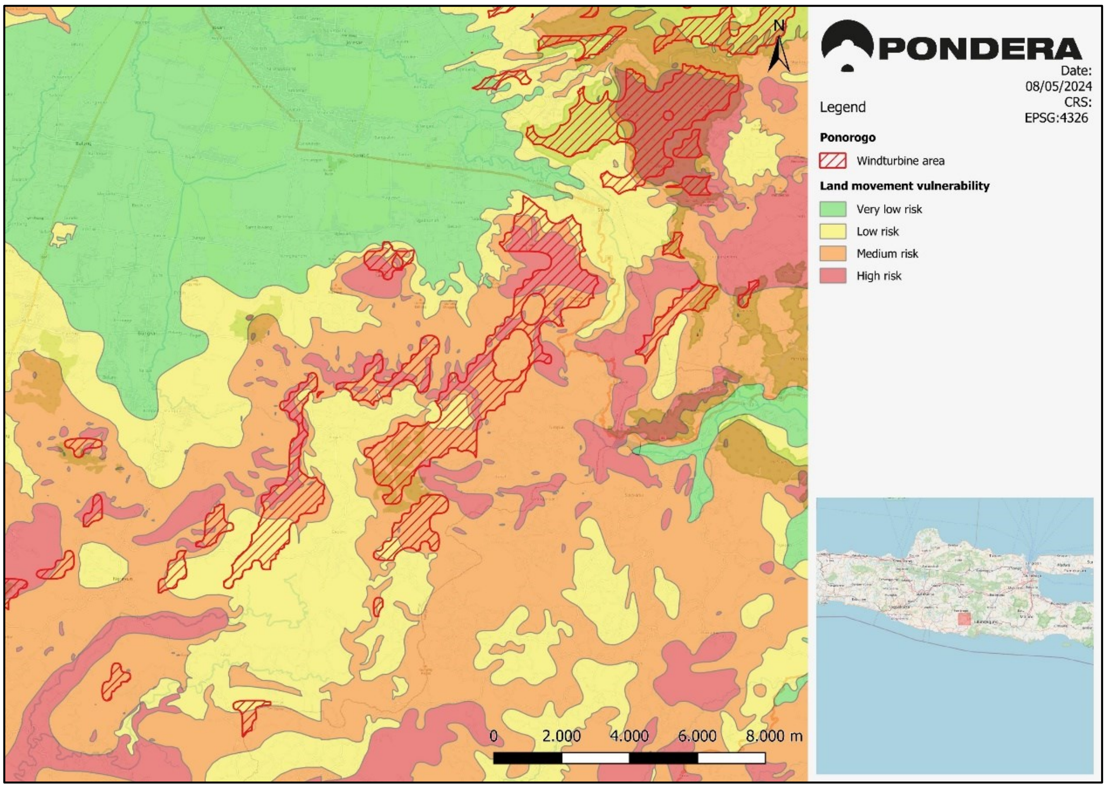

Figure 28. Land movement vulnerability index of Ponorogo.

The stability and capability of the soil on top of the bedrock surrounding wind turbines on steep slopes should be further investigated during the feasibility stage. This can be done by a geotechnical soil investigation (determining soil characteristics such as shear strength, density, permeability etc.), and a following soil stability analysis, in combination with a LiDAR-study. It is expected that the LiDAR study will result in much steeper slopes than the lower resolution elevation models. However, the risk of landslides should still be low considering the geology (volcanic rocks).

2.5.2 Seismicity

In the area, no major fault lines are present. In the southern mountains, some southwest to northeast oriented faults (sinistral) are known. No information has been found about the slip rates and/or recurrence times of earthquakes.

Apart from these faults, a large subduction zone is situated south of Java. The movement in this subduction zone is 7 cm/year, which results in regular earthquakes. Most of these are magnitude 4 to 5, and occasionally higher. According to the USGS, three large (> M7.0) earthquakes occurred south of Java (7.0, 7.7, and 7.8) since 1990.

According to the Ministry of Energy and Mineral Resources (MEMR or *Kementerian ESDM*), large portions of the area have the potential to be hit by strong earthquakes with an intensity of VII-VIII and VIII on the Modified Mercalli Intensity (MMI) scale. Figure 29 provides a visual representation of the earthquake risk level in and around the WTG-area.

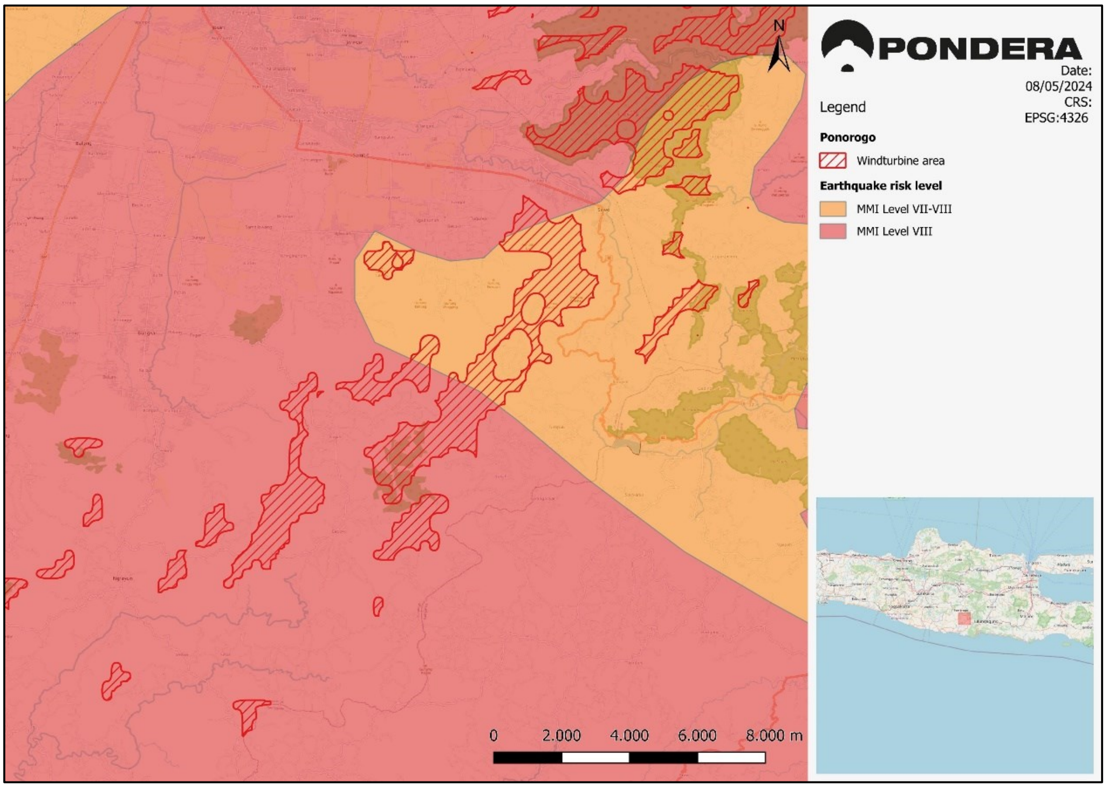

Figure 29. Earthquake hazard and risk level at Ponorogo.

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

> VII: *"Damage is negligible in buildings of good design and construction; but slight to moderate in well-built ordinary structures; damage is considerable in poorly built or badly designed structures; some chimneys are broken. Noticed by motorists."*

VIII: *"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."*

This data gives just a general impression of the magnitude of earthquakes that can be expected. During the feasibility study, the maximum expected peak ground acceleration in the bedrock and soils on top of the bedrock should be calculated for more precise hazard assessment due to earthquakes.

2.6 Biodiversity, socio-economic and environmental conditions

2.6.1 General impression

As shown in Figure 30, the area can be divided into several sections:

- Mountains surrounding the plateau;
- Plateau valley;
- Hills at base of the plateau; and
- Eastern hills.

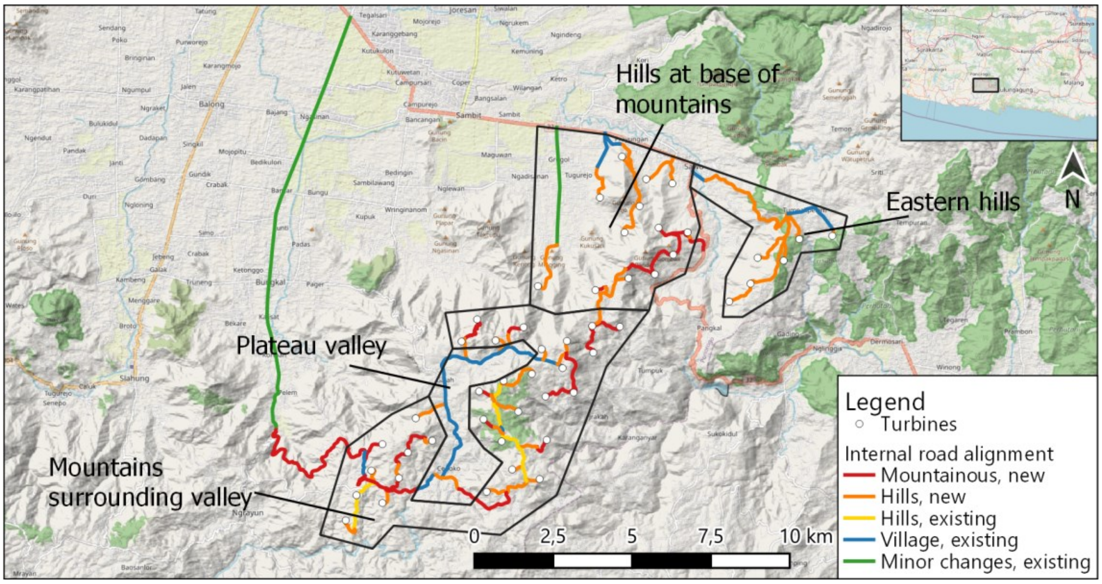

Figure 30. Division of the area into several regions based on land use and topography.

The mountains surrounding the plateau (see Figure 31) are primarily used for forestry and agroforestry. Some sections are too steep to be exploited and covered by bushes and/or grass. Closer to the villages, small scale terraces are made for cultivation of crops. The hills are not populated.

Figure 31. Impression of mountains surrounding the valley.

The valley or base of the plateau is used for crops, mainly rice and corn (see Figure 32). At the base of the slopes leading up to the surrounding mountains, terraces are used to cultivate crops. Throughout the valley, smaller villages and houses are built. The houses are not clearly clustered into separate villages, but more spread out over the valley. No wind turbines are envisioned in this valley, but the access roads will need to pass through this area.

Figure 32. Impression of the valley on the plateau.

At the base of the hills, near the Ponorogo plain, slopes are terraced, and in use for farming (mainly corn and rice; see Figure 33). Forests cover the higher elevated parts, where slopes were steeper. In some parts, clustered houses or small villages are built on the ridges on top of the hills.

Figure 33. Impression of hills at the base of the mountains.

As illustrated in Figure 34, the land use of the eastern part is diverse. The area consists of villages, scattered houses with forestry, agroforestry, small fields with crops, and some terraced rice fields.

Figure 34. Impression of land use on the eastern hills

2.6.2 Biodiversity and environmental impact

As most of the site is in use by humans (villages, forestry, crops, rice paddies etc.), it is expected that biodiversity is not as high as in a primary forest (see Table 1). No protected forests are located within the site. However, some areas are remote. Construction of a wind farm can open up an area further which will have an impact on the local biodiversity and environment. The main impacts are:

Biodiversity impact:

- Habitat fragmentation (mainly roads and transmission lines)
- Opening of area: encroachment, illegal logging, squatting, hunting, farming
- 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

Due to the presence of humans, habitat fragmentation has already taken place in large parts of the site. Further fragmentation can be minimized by using the existing roads as much as possible.

Observed flora and fauna:

According to the online biodiversity database of Global Biodiversity Information Facility (GBIF), no animal species were observed in the area (see Figure 35) 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[17]. 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). One plant species has been observed; however, this is based on a preserved specimen from 1897. It is unknown whether this species still occurs in the area. In the following tables, the observed flora and fauna that are categorized as at least 'near threatened' are listed.

Table 1. List of observed fauna (source: GBIF) which are at least near threatened according to the IUCN global red list category

Animals	English Name	Status
-	-	-

Table 2. List of observed flora (source: GBIF) which are at least near threatened according to the IUCN global red list category

Plants	English Name	Status
Myristica teysmannii	-	Endangered (EN)

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

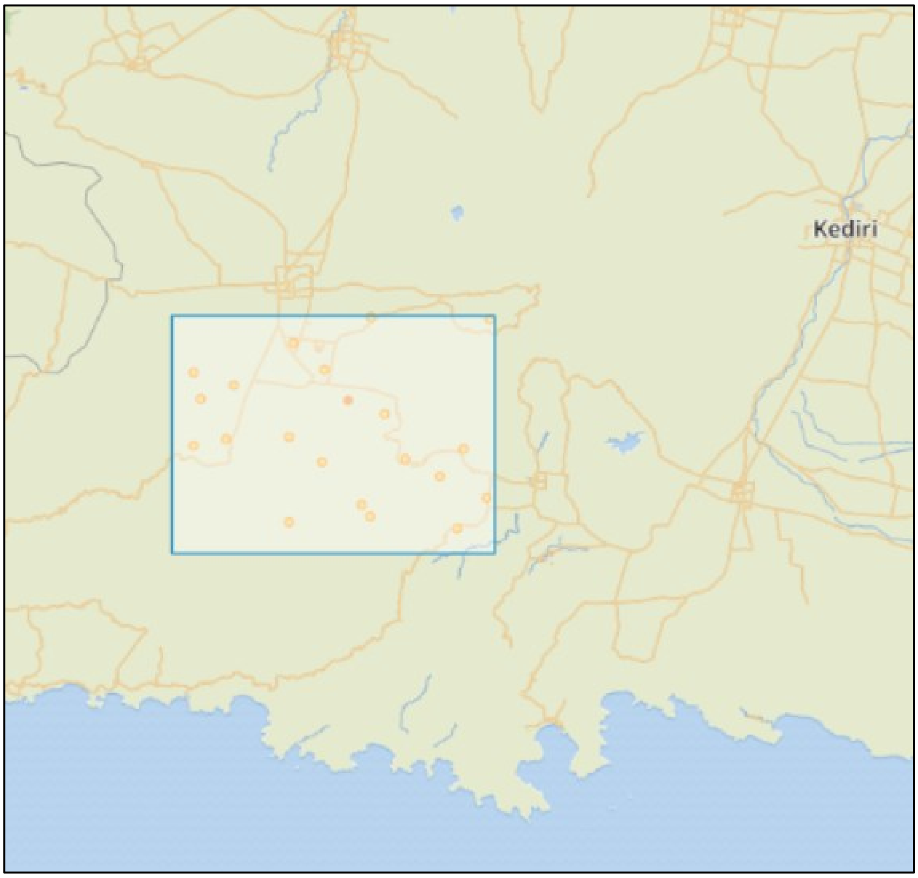

Figure 35. The area in which the abovementioned flora and fauna has been observed (covering the envisioned wind farm location)

Even when no or little species from the IUCN global red list are present in the area, the construction of a wind farm can have an impact on biodiversity and the environment. This 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

As shown in Figure 36, most of the turbines are envisioned on the mountains surrounding the plateau and the hills at the foot of the mountains, which are sparsely populated areas. The largest social impact in this area will be during construction (limited accessibility during transport, road construction, noise) and visual impact of the turbines.

The villages in the lower elevated areas are mostly small scale farmers and small shop owners. Roads from these villages to Ponorogo city are busy during peak hours indicating large numbers of commuters to and from Ponorogo. The plateau in the mountains is less populated are consists mostly of farmers.

The existing roads within the valley and surrounding mountains and down to the Ponorogo plain are in bad condition. Getting around in the area takes considerable time and is mostly done with motorbikes. An improved road within the valley and down to Ponorogo plain will substantially decrease travel time within the valley and to Ponorogo.

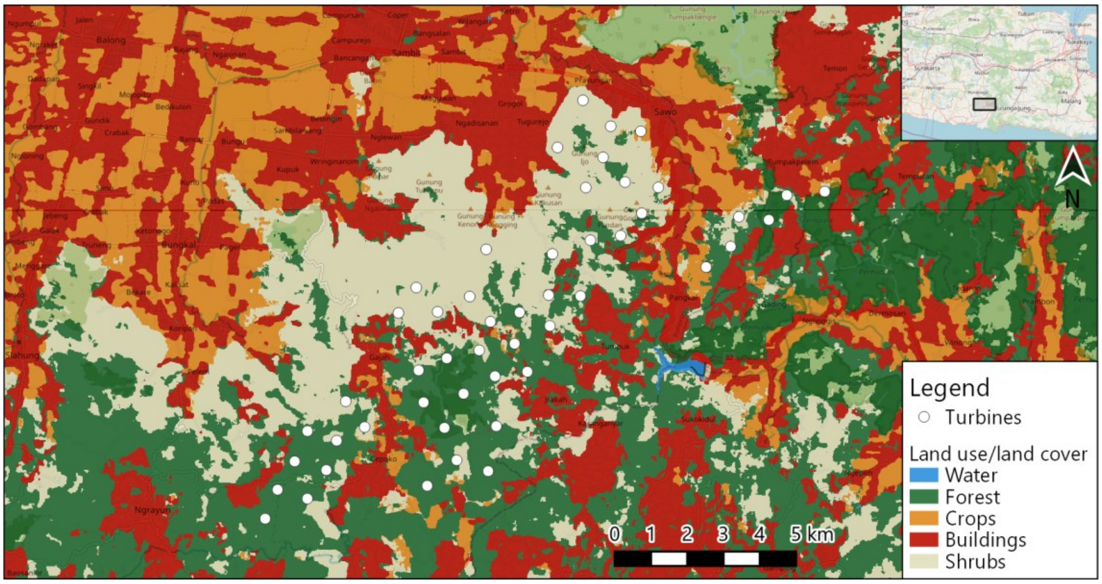

Figure 36. Land use map based on satellite imagery (ESRI/Sentinel 2, 2022). The area directly around the wind farm is primarily covered by forest and shrubs.

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; and
- Increased mobility within the villages in the valley and down to Ponorogo when access roads are made public.

As the turbines are mostly built further away from the villages in this region, the social impact is mainly limited to the loss of agricultural land, reduced accessibility during road construction and transport, and visual impact. Road construction, however, might greatly improve accessibility to the whole valley on the plateau (see Subsection 2.6.1), which may have a positive impact on the local economy.

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 37. The annual population growth rate in Ponorogo declined from 0.69% in 2021 to 0.6% in 2023. However, the population slightly increased from 955,840 people in 2021 to 959,500 people in 2023.

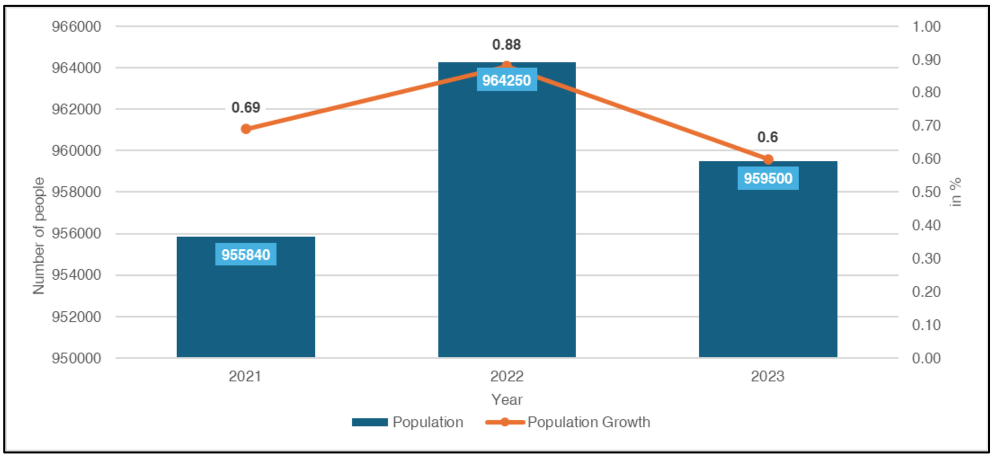

Figure 37. Population and annual population growth rate in Ponorogo Regency in 2021-2023 (Source: [BPS Ponorogo](#)).

The regency's population pyramid is shown in Figure 38. Moreover, the gender ratio in the regency is 0.9976 in 2022.

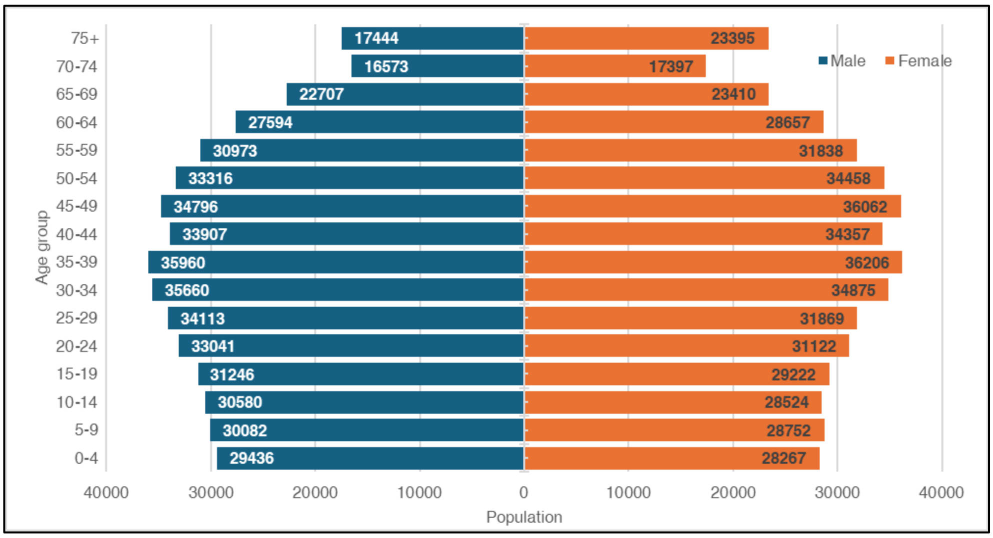

Figure 38. Population pyramid in Ponorogo Regency in 2020 (Source: [BPS Ponorogo](#)).

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. The labor force participation rate in 2023 was 75.88%, increased from the two previous years. Meanwhile, there is a slight overall increase in the unemployment rate from 2021 to 2023.

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

Metric (in %)	**Year**		
	2021	**2022**	**2023**
Labor force participation rate	72.63	72.92	75.88
Unemployment rate	4.38	5.51	4.66

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 Ponorogo Regency from 2023 (Source: BPS Ponorogo).

Educational attainment	**Working**	**Unemployed**	**Economically Active**	**Percentage of Working to Economically Active (%)**
Primary school (SD)	242,997	4,980	247,977	97.99
Middle school (SMP)	130,228	8,292	138,520	94.01
High school (SMA)	139,560	12,187	151,747	91.97
University	52,926	2,200	55,126	96.01
Total	**565,711**	**27,659**	**593,370**	**95.34**

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 Ponorogo Regency in 2022-2023 (Source: BPS Ponorogo).

Pure participation rate	**Year**	
Educational level	**2022**	**2023**
Primary school	98.91	98.72
Middle school	85.99	88.15
High school	68.37	69.36

Table 6 shows the number of educational facilities in Ponorogo 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 Ponorogo Regency in 2023 (Source: BPS Ponorogo).

Type of school	Number of facilities
Kindergarten	456
Raudatul Athfal (Islamic Kindergarten)	274
Primary school	573
Madrasah Ibtidaiyah (Islamic Primary School)	124
Middle School	90
Madrasah Tsanawiyah (Islamic Middle School)	97
High School	26
Vocational High School	39
Madrasah Aliyah (Islamic High School)	73
University	11

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 Ponorogo 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 Ponorogo Regency in 2021-2023 (Source: BPS Ponorogo).

Metric	Year		
	2021	2022	2023
Human Development Index	71.81	72.61	73.18
Gender Empowerment Index	67.63	67.69	68.52
Gender Development Index	93.65	93.96	94.40

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 also 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 Ponorogo 150 kV PLN substation is selected for this, located in the east of the village of Kauman. The aerial photo of this substation is included in Figure 39. 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.

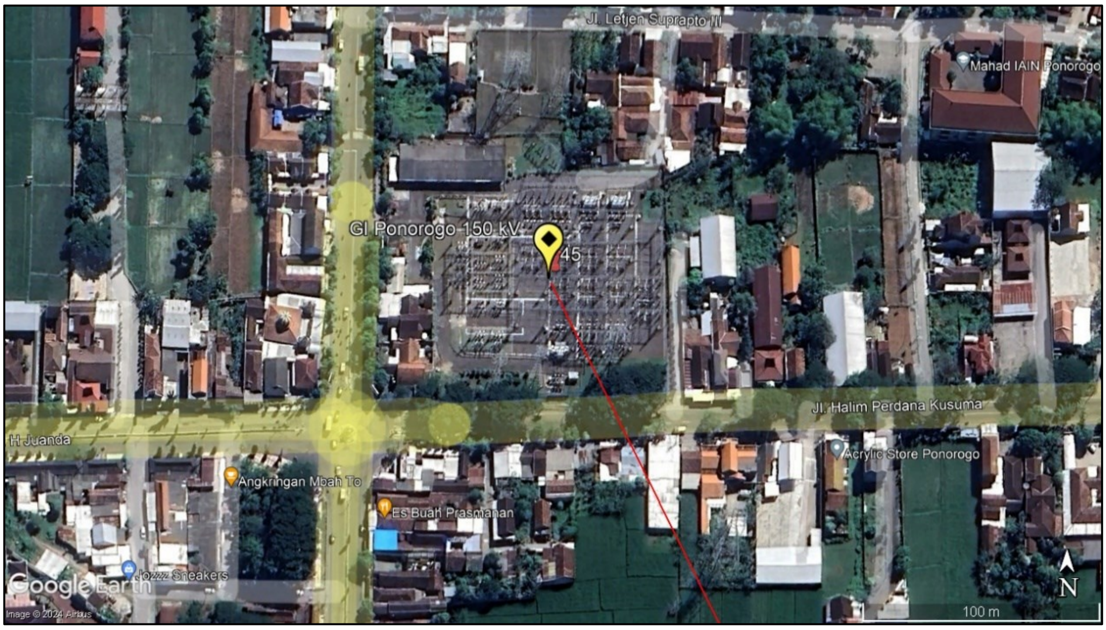

Figure 39. Location of the Ponorogo 150 kV PLN substation. Source: Google Maps.

2.7.2 Schematic design transmission and distribution network

In Figure 40, the schematic design of the transmission and distribution network is illustrated. The 50 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 five 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 Ponorogo substation.

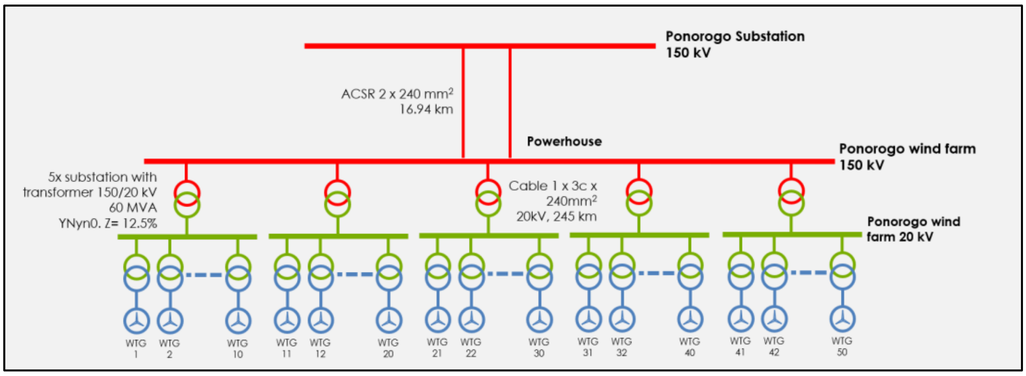

Figure 40. A schematic design of the transmission and distribution network at the envisioned Ponorogo wind farm.

The overhead transmission line between the powerhouse and the PLN substation is assumed to be a straight line between both locations, covering 17 km as visualized in Figure 41. A total of 46 towers are planned with an intermediating distance between the towers of 340-450 m.

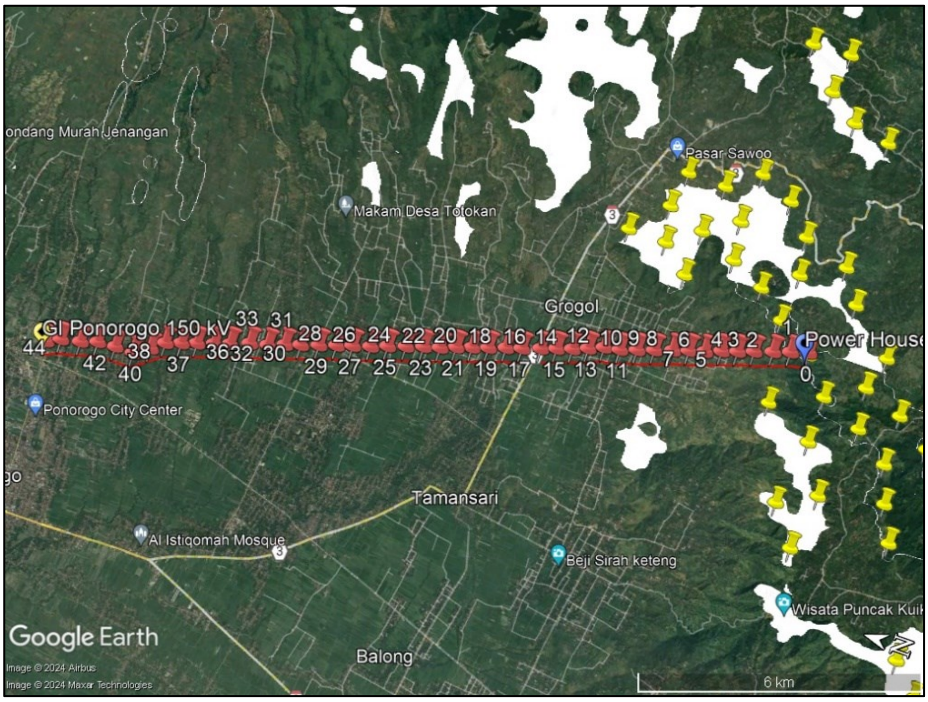

Figure 41. A schematic representation of the position of overhead transmission line between the powerhouse and the Ponorogo substation.

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 Ponorogo site, the long-term wind speeds are determined based on the Large-Eddy Simulations (LES) with the model ASPIRE from Whiffle. The key strength of this large eddy simulation (LES) model is its ability to provide a detailed representation of complex flow patterns. This is important since the WTGs under consideration are placed in (very) complex terrain with high turbulence intensity.

The horizontal resolution of the LES is 100 m and the resolution in vertical direction is 40 m. The climatology is based on a selection of 50 representative days selected between the years 2002 and 2024. The selection was made based on the wind speed data of the nearest ERA5 grid point at 100 m height and accounts for variations in the wind climate due to El Niño and La Niña.

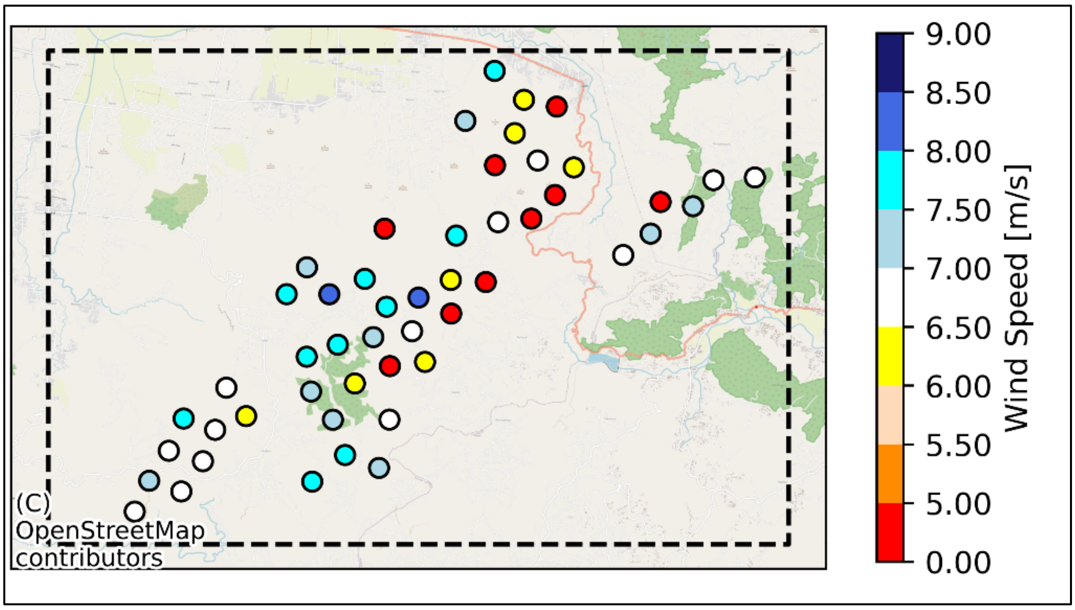

Figure 42. Long-term average wind speed results with the ASPIRE model at a height of 140 m at the turbine locations. The black-bordered circles represent the wind turbines, whereas the colors within the circle indicate the respective long-term average wind speed.

Figure 42 shows the resulting climatology at the locations of the WTGs. The modeled long-term wind speed, which is averaged over all 50 WTGs at the planned hub height of 140 m, is 6.8 m/s. The mean wind speed in the Global Wind Atlas (GWA), is similar. There is a large variability in wind speeds over the area, which is likely driven by the orography. A total of 9 out of 50 turbines have a wind speed below the threshold value and their positions could be reconsidered. The southwestern part of the area has the highest wind speeds, up to 8.2 m/s. Nevertheless, verification of the numerical models through measurements is essential, and here, the more intricate LES model is employed for further analysis.

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.

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 [%]	8.6%	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 8.6%.
	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)[18] with linear parametrization is used to calculate blockage. 0% blockage is expected for the layout at Ponorogo.
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 a grid non-availability from grid operator.

[18] 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
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.
	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.

Category	Types of energy loss	Amount	Explanation
	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 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 on 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 [%]		**20.5%**	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 9.

Table 9. Energy yield for all 23 WTGs at the Ponorogo wind farm

Parameter [Unit]	**Amount**
Number of new WTGs	50
Rated Power per WTG [MW]	4.0
Total rated Power [MW]	92.0
Rotor diameter [m]	~170
Hub height [m]	140
Air density [kg/m3]	1.150
Wind speed [m/s]	6.8
Gross result [MWh/yr]	709,922
Gross results including wake effects [MWh/yr]	655,968
P50 [MWh/yr] [19]	**564,393**
P90 (25 yr) [MWh/yr]	**419,733**
P50 [hrs/yr]	2,940
P90 (25 yr) [hrs/yr]	2,186

2.8.3 Power output variation

In Subsection 2.8.2, we have provided an estimate of the P50 annual production, equal to 564,393 MWh per year. Previously, during the first wind resource assessment in Subsection 2.2.2, 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.

[19] Note that the P50 value is based on the LES calculation. The uncertainty in the AEP will be reduced, once on-site measurements are performed. Until that time, the results of this study shall be interpreted with careful discretion.

Figure 43 shows the average wind farm power output for each month, subdivided in the hours over a full day. The input data for this figure is derived from the ASPIRE modelling 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.

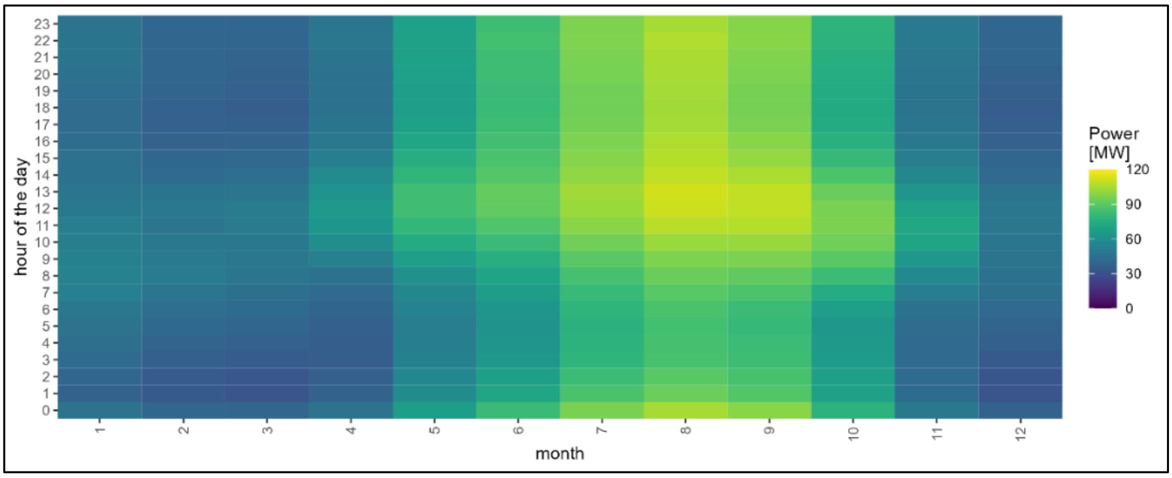

Figure 43. Overview of the monthly variation in wind farm average power output per hour of the day based on the P50 values from Subsection 2.8.2 in combination with the monthly and hourly variation in wind speed from EMD-WRF

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 (8 met masts for 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 50 wind turbines at the wind farm are shown in Table 10.

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

Main component	Quantity
Nacelle incl. generator (4 MW)	50 pcs
Blade (85 m)	150 pcs
Tower segments (total 140 m height)	300 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 Surabaya and via road transport brought the wind farm site;
- Import duty of 5% apply for the generator and blades, and 15% for tower parts are assumed[20];
- The cost includes transport, crane rental, installation and commissioning.

[20] 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 50 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	74 km
	Upgrading existing road	13 km
Strengthening bridges (incl. design, materials, transport, labor)	Concrete bridge strengthening	26 bridges
	Steel bridge strengthening	2 bridges
	New bridge	1 bridge
Foundations (incl. design, materials, transport, labor)	Anchors (72 per foundation)	3,600 pcs
	Anchor cages	50 pcs
	Concrete (230 m^3 per foundation)	11,500 m^3
	Steel (35 tons per foundation)	1,750 tons
Crane hardstands (incl. design, materials, transport, labor)	Crane hardstands (50 x 100 m) using gravel	50 hardstands

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

- Civil works are including design, materials, transport, and labor;
- 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 (19 km, 48 towers)	Transmission towers	46 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

Main component	Sub-component	Quantity
Powerhouse (1 for the entire wind farm)	Incoming MV switchgear	50 pcs
	LV switchgear	1 pc
	DC Supplies	1 pc
	Lightning protection	1 pc
	2x3C 300mm cable	567 m
Wind farm electrical works (between the powerhouse, substations, and wind turbines)	Transformers 20kV (5MVA)	50 pcs
	Switchgear	50 pcs
	MVAC Cable (1 x 3c x 240) 50 and 300 meters	245 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 (five for the entire wind farm)	Transformer 150/20kV 30 MVA	5 pcs
	Neutral Grounding Resistor	5 pcs
	Switchyard	1 pc
	In/outgoing bays, coupler, busbars, Panel RCP	5 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 depends 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 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[21]) 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 4,785,000	DEVEX: Prior to Financial Close	90% - baseline -120%
Project management	USD 15,477,000	DEVEX: Until CoD	Baseline
Wind turbines	USD 139,364,000	CAPEX: Including transport and installation	90% - baseline -120%
Civil works: foundations	USD 20,036,000	CAPEX	80% - baseline -150%
Civil works: roads	USD 53,298,000	CAPEX	80% - baseline -150%
Civil works: crane hardstands	USD 9,475,000	CAPEX	80% - baseline -150%
Electrical works	USD 44,913,000	CAPEX	90% - baseline -120%
Land acquisition	USD 37,673,000	CAPEX	90% - baseline -150%
Risk contingencies	USD 24,763,000	DEVEX + CAPEX	Baseline
Lower bound total investment cost (DEVEX + CAPEX)	**USD 310,548,000**	**Investment cost per MW: USD 1,553,000**	
Baseline total investment cost (DEVEX + CAPEX)	**USD 349,783,000**	**Investment cost per MW: USD 1,749,000**	
Upper bound total investment cost (DEVEX + CAPEX)	**USD 447,836,000**	**Investment cost per MW: USD 2,239,000**	
Baseline operational expenditure (OPEX)	**USD 5,951,000 / year**	**Operational cost per MW / year: USD 30,000**	

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

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	10.39%	8.38%	4.72%
Average Debt Service Coverage Ratio (DSCR) at P90	0.85	0.77	0.61
Net profit at P50 over 25 years	USD 206,311,000	USD 163,811,000	USD 66,725,000

3 Conclusion and Recommendations

Based on the conducted analysis, it is concluded that the overall techno-economic viability of a wind farm in Ponorogo requires improvement. The main cause for this result is the lower wind speeds than expected at specific wind turbine locations. Although the initial wind resource assessment only included areas with annual average wind speeds above 6 m/s, during the wind modelling stage, the long-term wind speed at ten wind turbine locations turned out to be below this number (see Figure 42). This is caused by the effect of the site's topography on the wind characteristics, which is to a lesser extent notable when creating a wind speed map based on Global Wind Atlas.

Based on the wind modelling, it seems that less promising wind speeds are present at nine out of the fifty chosen wind turbine locations. Therefore, we recommend reconsidering the site layout during a follow up study. The business case could be improved by potentially excluding the nine turbine locations for future development, and validating the wind speed (by wind measurements). Exclusion of the nine wind turbine locations could still lead to a wind farm size of approximately 150-170 MW.

Furthermore, specific components drive up the investment cost significantly. The strengthening of 28 bridges is a major cost factor (+/- 3% of the investment cost) for this wind farm. Also, the cost for constructing new roads and road upgrades is significant (+/- 11% of the investment cost). In a follow up study, the aim should be to find cost savings for this particular cost (see specific recommendations under *Transport*).

Aside from the lack of wind resources at several wind turbine locations and some high cost factors, the envisioned wind farm entails 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. Hence, we recommend placing at least eight met masts for data gathering for at least one year (see Figure 44). The background of the figure is the wind speed from the Global Wind Atlas (GWA). The elevation is shown with contour lines. The red dots indicate the wind turbine locations. Meanwhile, the yellow icons show the global positioning of recommended met mast locations.

  A total of 50 turbines are spread over a large area with different elevations. In the north, the lowest turbines are positioned at around 200 m; while on the southeastern mountain, the turbines are positioned up to almost 1,000 m. In the southwestern part, the turbines are slightly lower. In order to capture the average site conditions with met masts, we recommend installing at least eight met masts. The met masts are spread over the site in order to capture the spatial variability. Especially on the mountain and ridges, it is recommended to additionally measure with an ultrasonic 3D anemometer. This is because turbines on the ridge will most likely experience up- and downdrafts. Using the ultrasonic 3D anemometer, the horizontal velocity and vertical velocity of wind will be measured. The ultrasonic 3D anemometer should also be considered in the northern area.

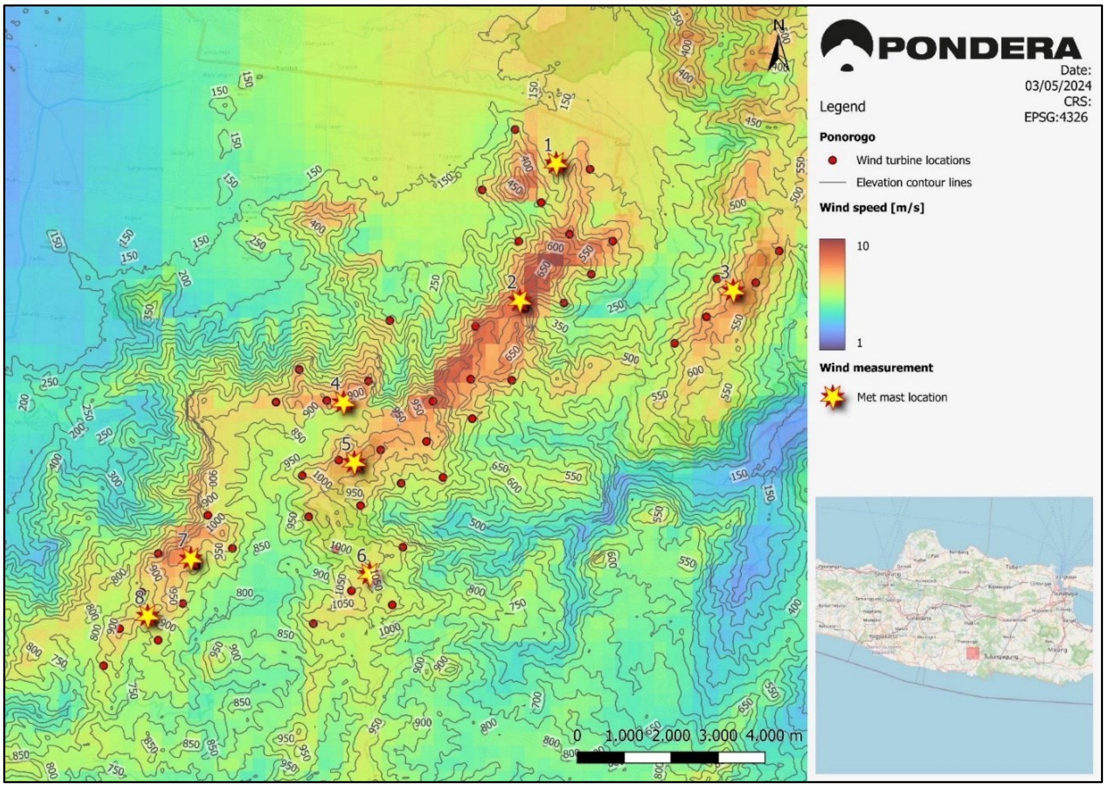

Figure 44. Recommended met mast locations.

- **Land use and permitting:** As can be derived from Figure 36 and Subsection 2.2.5, the wind farm is planned in a mix of plantation, agriculture, settlement, river border, and shrubs area. It will be mandatory for the future developer to obtain specific approvals and permits from the authorities. Considering these required actions, it is also 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 these 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 Port of Surabaya is the most suitable starting point for the transport over land. To ensure that the port in Surabaya 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. Large parts of the road to the site are in good condition and are in daily use by heavy traffic. However, it will be important to inquire or measure accurate heights between road surface and bridges on toll roads. The height of the lowest bridge may be a limiting factor of the diameter used for the base of the turbine tower. Furthermore, the resolution of the open-source height models is not precise enough for mountainous terrain to make a detailed road alignment. A LiDAR-based height model will likely show steeper slopes of hills and mountains. This may increase the total length of access road and might be a significant factor in cost calculations. Some turbines are hard to reach or far away from other turbines. Relocating some turbines to more accessible locations might reduce the road length that has to be improved or constructed.

Finally, optimization should be sought to lower the cost of strengthening of the 28 bridges. Further analysis is required to determine the current strength of these bridges and the necessity to strengthen them. In case strengthening of bridges is required, it is worth investigating if Government infrastructure funds are available to cover a part of the strengthening cost.

- **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. This need to be determined through 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.

- **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:** Although the wind farm location is not a densely populated area, there will be visual impact on the area because of the use of wind turbines with a tip height of 200 m. 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 one endangered fauna species is present in the envisioned wind farm area. The wind farm development can have an effect on the biodiversity at the area. Consequently, it is advised that during the feasibility study, a biodiversity baseline study, and risk assessment and mitigation measures are conducted as part of the Environmental and Social Impact Assessment.

- **Grid connection and PPA:** The wind farm is designed to be connected to the PLN grid. This assumes that the grid can integrate 200 MW of wind energy (with variable output), and that the substation in Ponorogo 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.

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