REPORT

Wind Energy Development Prospectus:
68 MW Project in Probolinggo – Lumajang, 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

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

UNOPS

Pondera

Headquarters Nederland

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

Mailbox 919
6800 AX Arnhem

Office South East Asia

Jl. Mampang Prapatan XV no 18
Mampang
Jakarta Selatan 12790
Indonesia

Office North East Asia

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

Office Vietnam

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

Title page

Document type

Wind Farm Prospectus

Project name

Probolinggo – Lumajang, East Java – 68 MW

Version number

V5.0

Date

31 August 2024

Client

UNOPS – ETP

Author

Pondera, Witteveen+Bos, BITA, and Quadran

Reviewed by

ETP

ENERGY TRANSITION PARTNERSHIP UNOPS PONDERA

EIK ISO 9001 : 2015 gecertificeerd

Table of Content

List of Figures

List of Tables

1 Introduction of the Wind Farm Prospectus

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

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

Section 2.1: Introduction of the location

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

Section 2.2: Wind resource availability and land use

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

Section 2.3: Design of the preliminary wind farm layout

Section 2.4: Accessibility

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

Section 2.5: Geology and seismicity conditions

Section 2.6: Biodiversity, socio-economic and environmental conditions

Section 2.7: Transmission network design

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

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

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

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

2 Analysis of Probolinggo – Lumajang Wind Farm, East Java – 68 MW

2.1 Introduction of the wind farm location

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

2.1.1 Geographic location

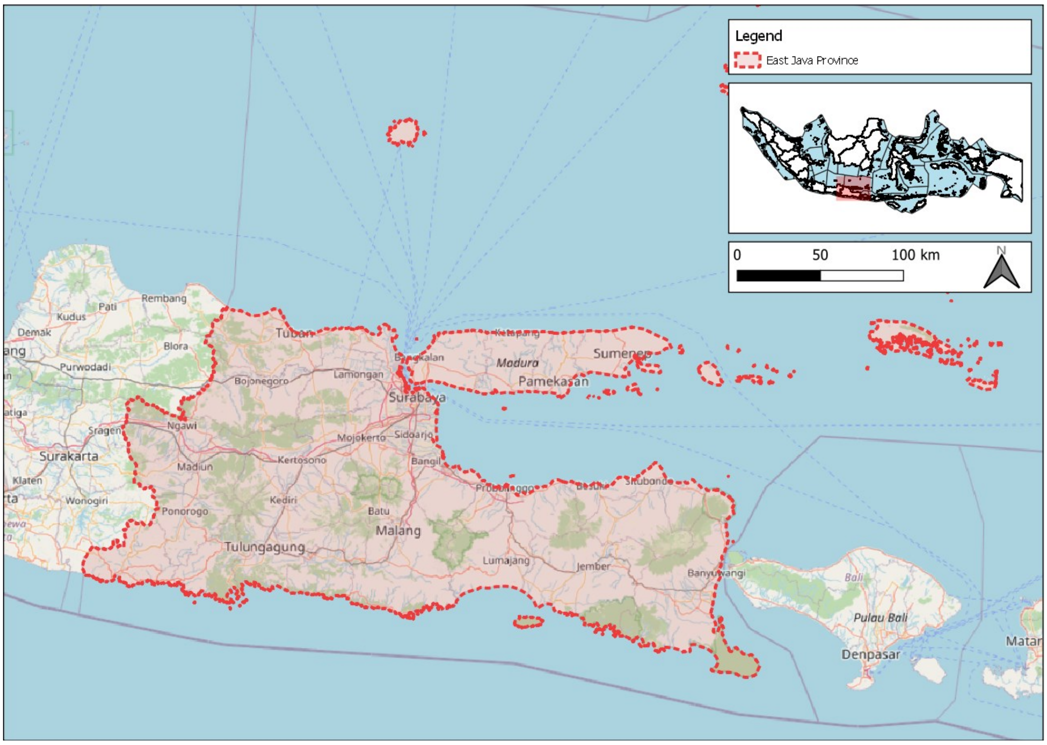

Figure 1. A map of East Java province in which the envisioned Probolinggo – Lumajang wind farm area is located

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 Probolinggo and Lumajang Regency. This site will be referred to as Probolinggo – Lumajang wind farm.

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.

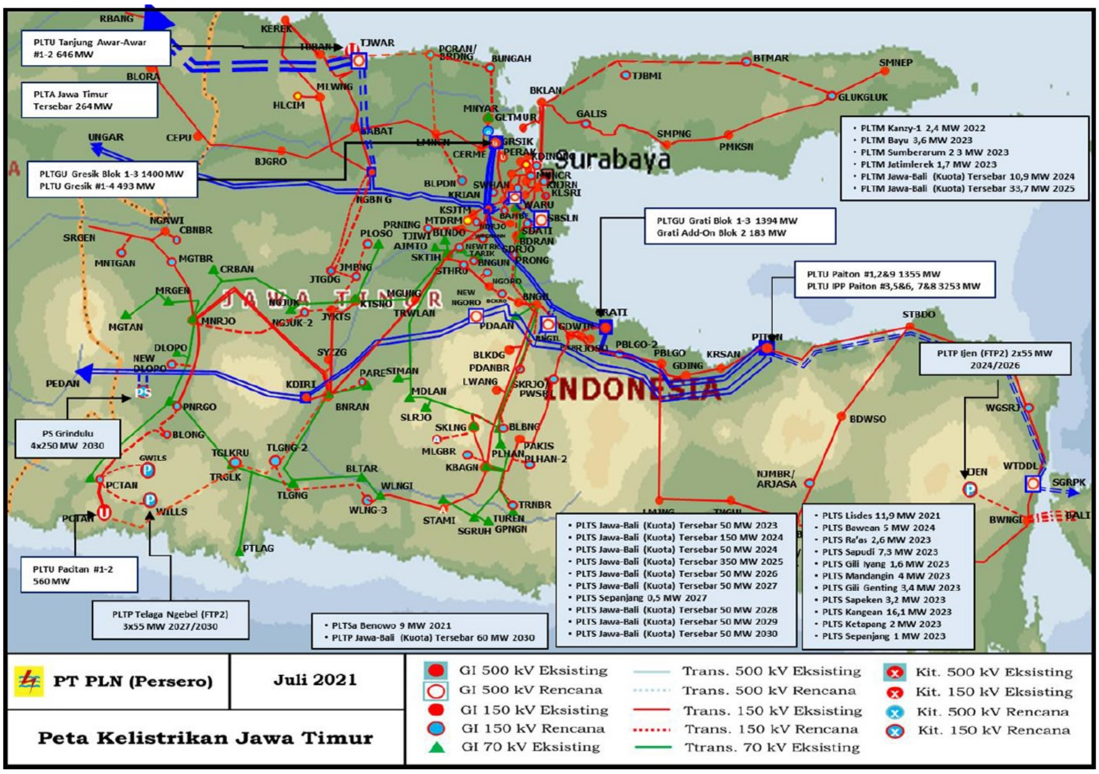

Figure 2. A map of East Java electricity system in RUPTL (Source: RUPTL PLN 2021-2030)

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

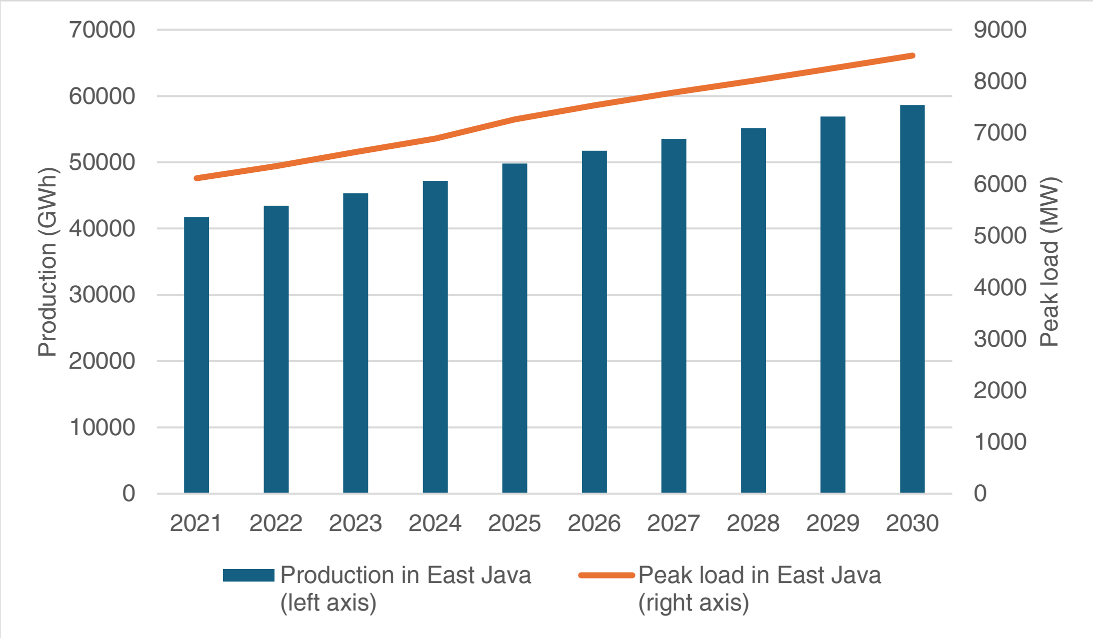

Figure 3. Projected electricity production and peak load in East Java (Source: RUPTL PLN 2021-2030)

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)

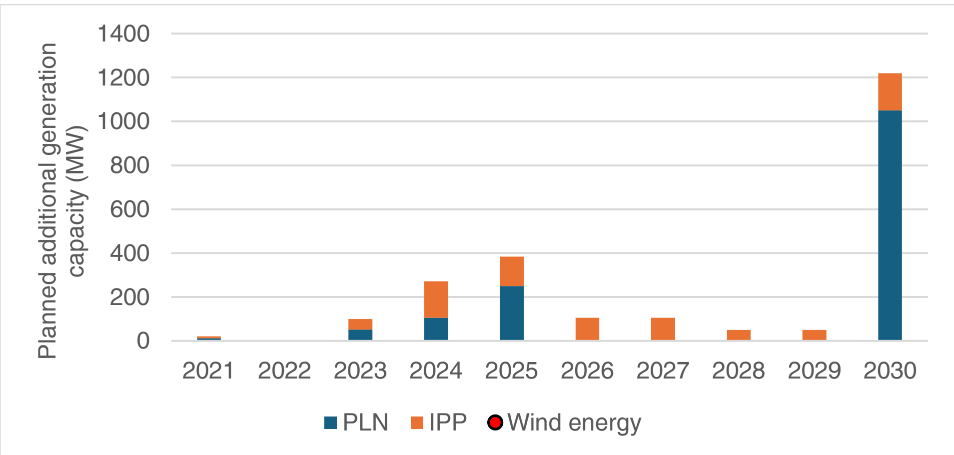

Figure 4. Additional generation capacity being planned for East Java (IPP: Independent Power Producer; Source: RUPTL PLN 2021-2030)

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 turbines 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 Probolinggo and Lumajang 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.

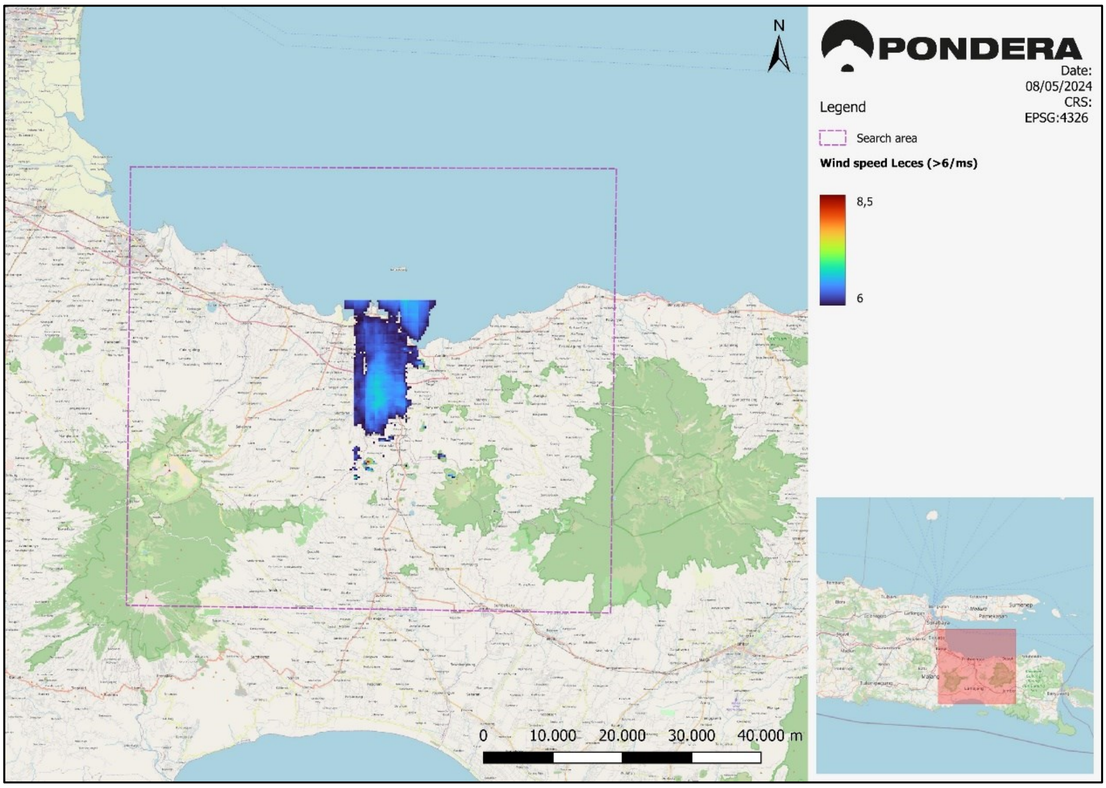

Figure 5. Probolinggo – Lumajang search area with wind speed distribution. The purple-dash bounding box shows the full search area. The color bar indicates average wind speeds which are above 6 m/s at 100 m height according to the Global Wind Atlas (GWA) climatology.

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.

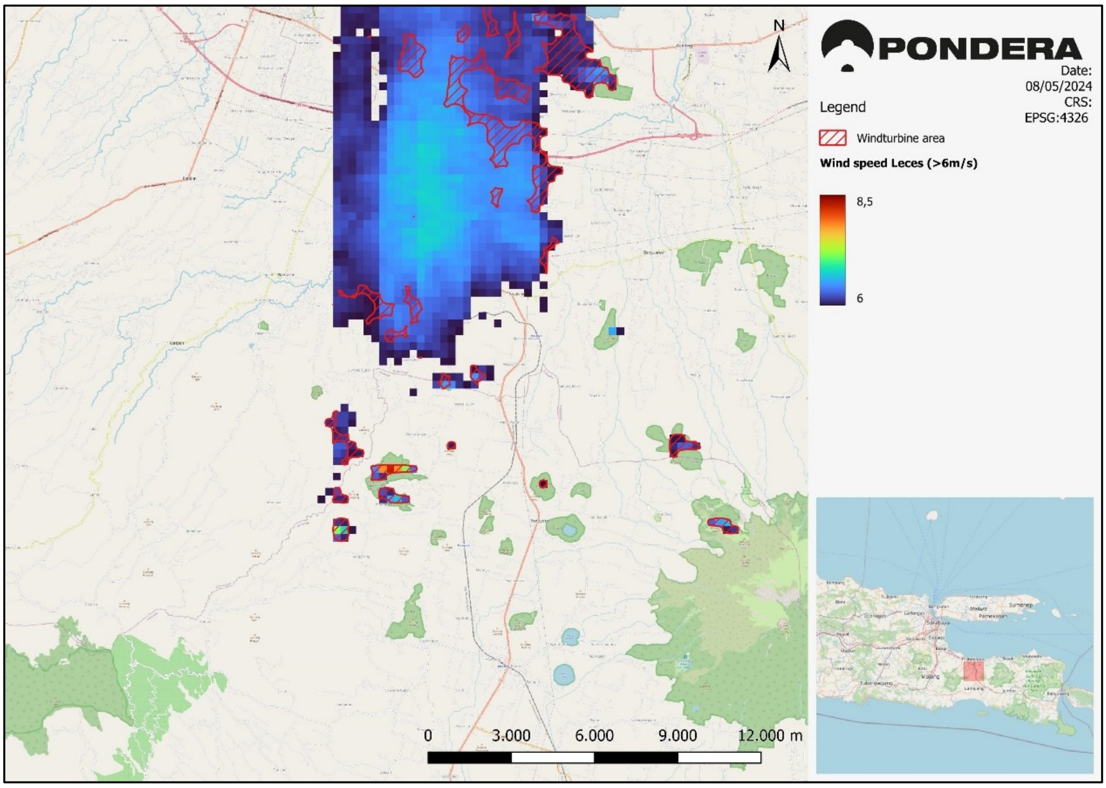

Figure 6. A zoomed-in look at the Probolinggo – Lumajang search area, along with the wind speed distribution. The red, dashed polygons represent the final WTG-area which meets all the criteria. Average wind speeds above the threshold of 6 m/s at 100 m height according to GWA are shown.

Additionally, Figure 7 visualizes the long-term average wind direction distribution for the Probolinggo – Lumajang area. As can be interpreted from this figure, the wind climate in the area primarily consists of wind from the southern 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 June 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 southern wind directions. Approximately from November until May (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.

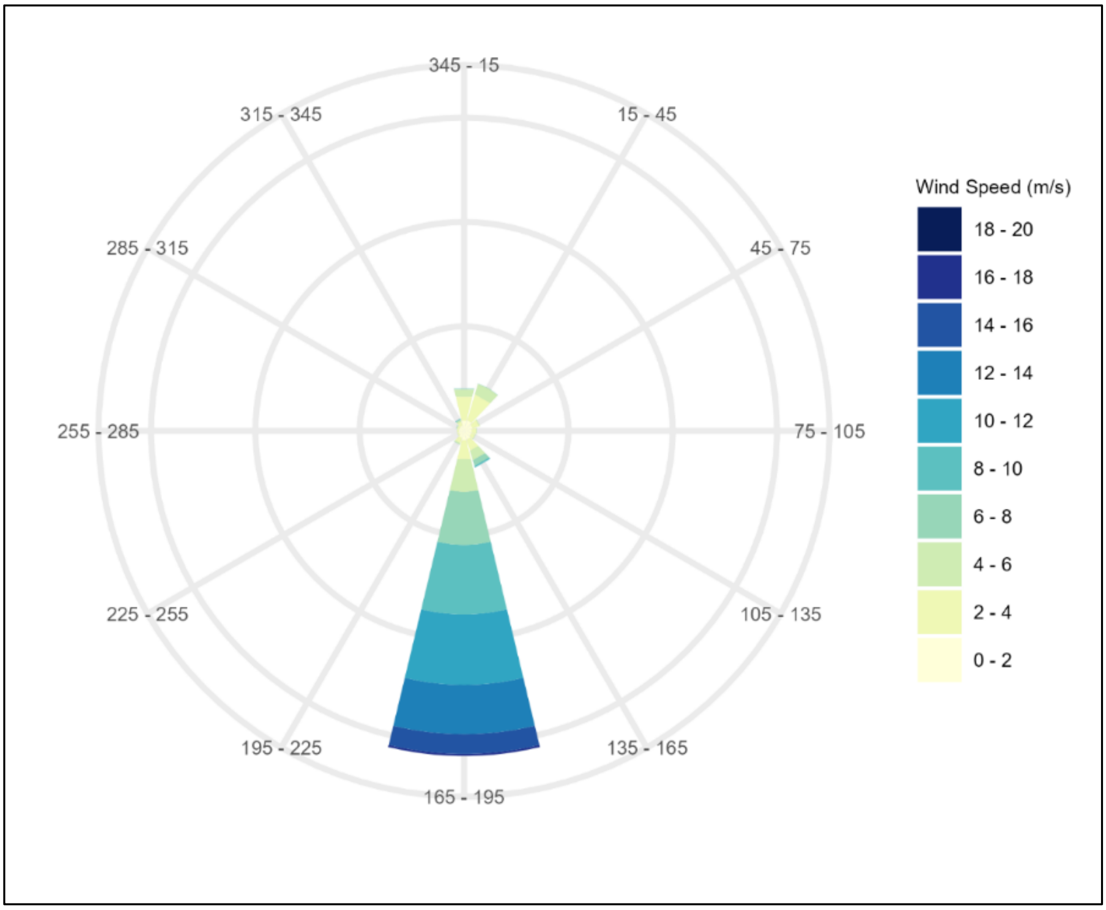

Figure 7. Wind rose diagram with wind directions and wind speed categories based on a 10-year climatology, including the 2004-2015 time series of hourly data. Source: EMD-WRF.

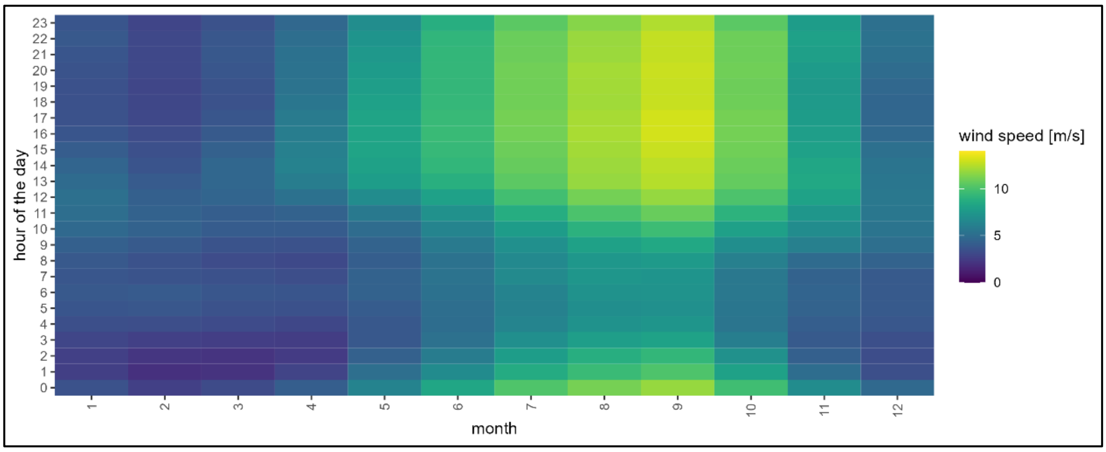

Figure 8. The wind speed distribution throughout the day, visualized per month of the year. Based on a 10-year climatology, including the 2004-2015 time series of hourly data. Source: EMD-WRF.

2.2.3 Topography

Figure 9 shows the topography of the search area in the Probolinggo – Lumajang 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.

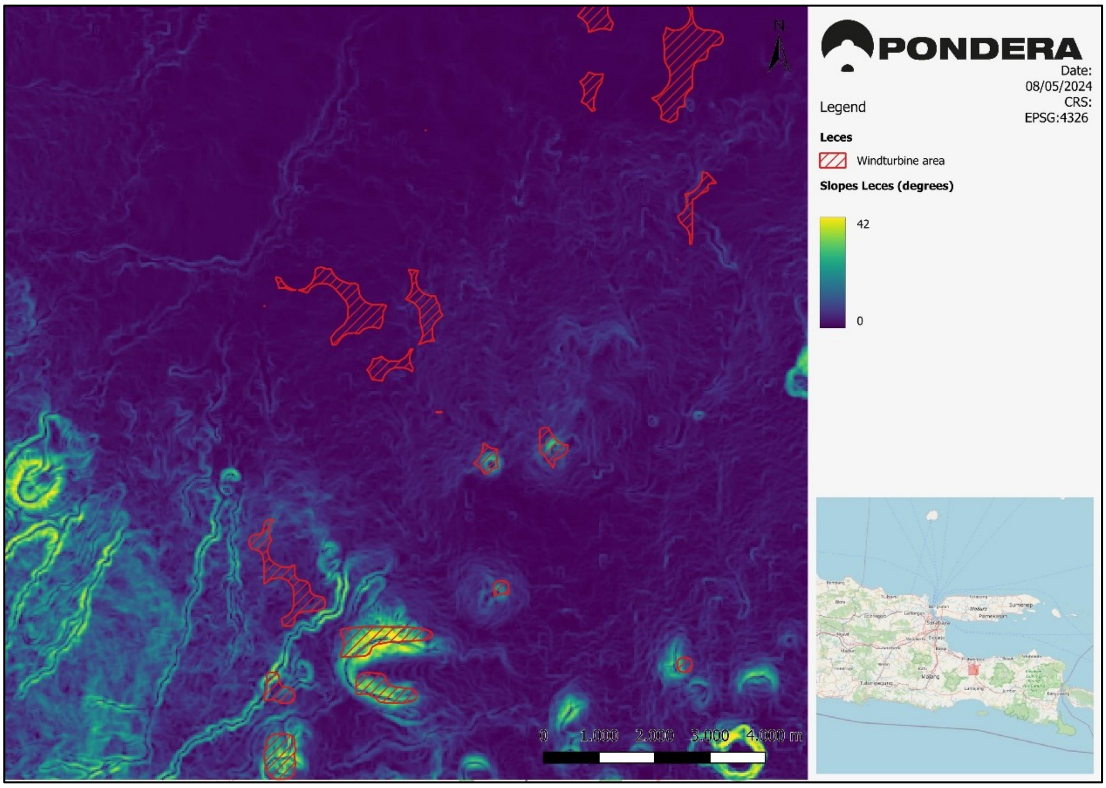

Figure 9. Topography of the Probolinggo – Lumajang WTG-area, showing the slope (in degrees; according to calculated based on FABDEM data) at the region.

2.2.4 Land use

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

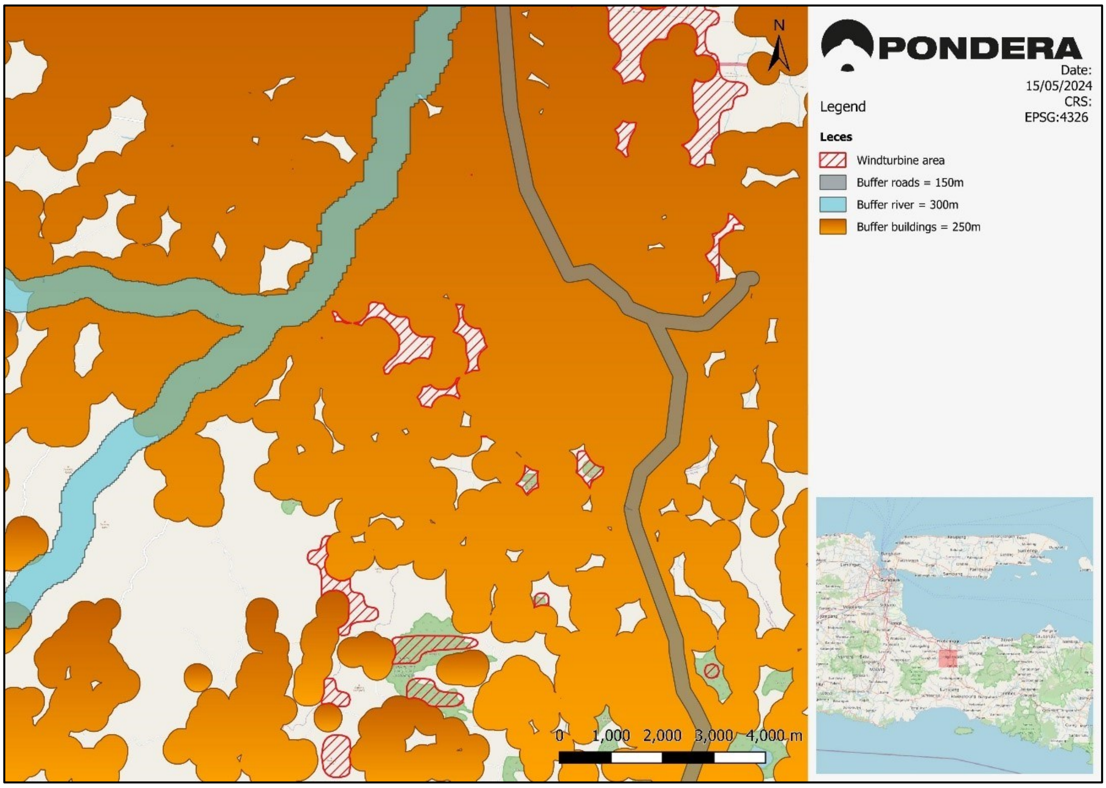

Figure 10. Exclusion zones in the Probolinggo – Lumajang area based on land use. Source: ESRI and OSM.

2.2.5 Specific permitting requirements

As mentioned, the WTG area is near the border of two regencies, i.e. Probolinggo Regency and Lumajang Regency. Therefore, the permitting requirements at these two locations are scrutinized in this subsection.

Probolinggo Regency

The overlay between Probolinggo Regency Spatial Plan (*Rencana Tata Ruang Wilayah* or RTRW) 2010-2029 and the WTG area in this regency is shown in Figure 11. As inferred by the figure, the WTG area intersects with the following types of land use:

1. Plantation Area (*Kawasan Perkebunan*)
2. Production Forest Area (*Kawasan Hutan Produksi*)
3. Dryland Agriculture/Farming Area (*Kawasan Pertanian Lahan Kering*)
4. Irrigated Rice Field Area (*Kawasan Sawah Irigasi*)
5. Settlement Area (*Kawasan Permukiman*)

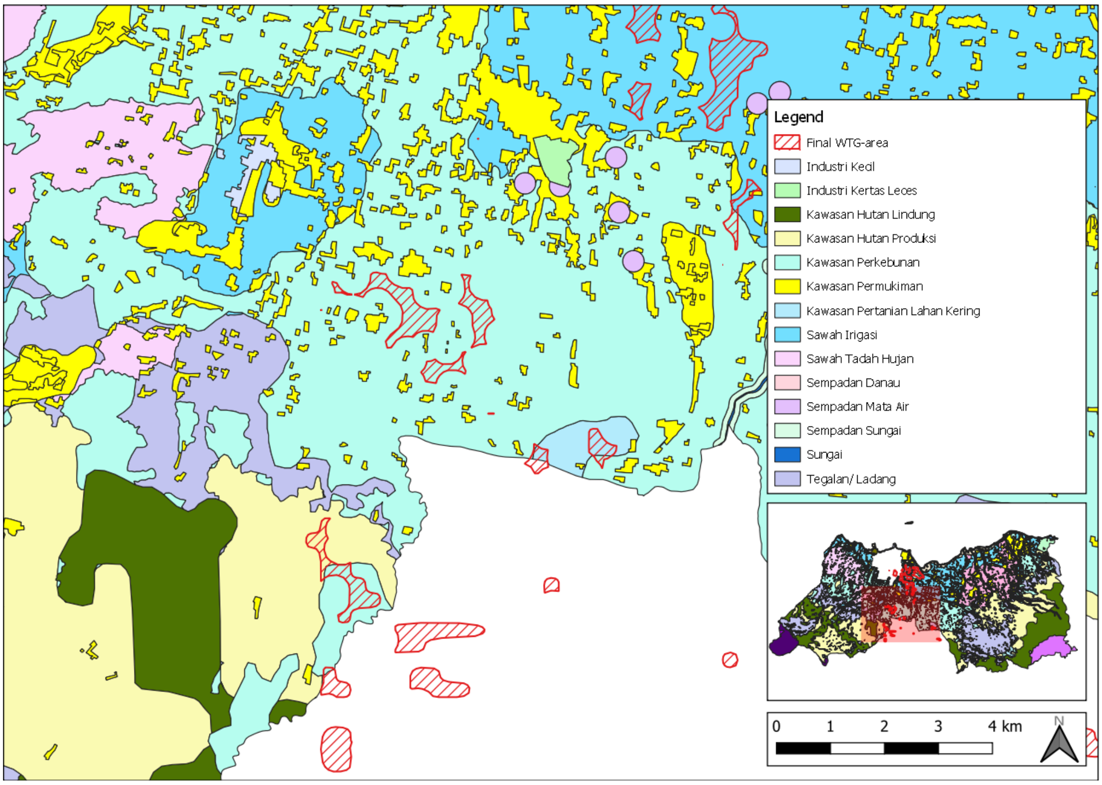

Figure 11. The map of spatial plan of Probolinggo Regency (RTRW 2010-2029) is overlaid with the final WTG-area.

In this regency, a majority of the WTG area overlaps with Plantation Area. This area is usually owned by either a (private or state-owned) company or the local community. The former case is typified by the cultivation of a single type of plant. Conversely, in the latter case, the area is usually cultivated with several types of plants. If the area is not part of the Sustainable Food Agriculture Area (*Kawasan Pertanian Pangan Berkelanjutan*/KPPB), then the Plantation Area can be used for wind farm development (and other types of power generation and transmission activities for public interest) once a purchase or lease agreement is obtained with the landowner[16].

A small part of the WTG area is situated in Production 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.

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

Parts of WTG area in Irrigated Rice Field Area are assumed to be treated similarly as Wetland Agricultural Areas. It can also be assumed that both Irrigated Rice Field Area is under the community's ownership. If the area is not a protected rice field (*Lahan Sawah Dilindungi*/LSD), then the area can be used for the construction of a wind farm (and other types of power generation and transmission activities for public interest) after going through a purchase or rental agreement with the landowner[16]. However, if the area is considered a protected rice field, then the area can only be used for wind farm development if there is a permission from the Minister of ATR/BPN, in accordance with Presidential Regulation No. 59/2019 concerning *Control of Land Conversion*.

Parts of WTG area overlapping with Dryland Agriculture/Farming Area are assumed to either be owned by the community, private companies, or state-owned companies. Wind farm development (and 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].

Finally, parts of the WTG-area that are in 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.

It is worth noting that the obtained RTRW of Probolinggo Regency is for the year 2010-2029. It is not yet known whether a new Regional Regulation has been issued regarding the new RTRW, or if the new RTRW is still being revised/prepared. Hence, confirmation from the competent agency in Probolinggo Regency is required. If there is already a new RTRW Regional Regulation, the RTRW used in this report is no longer valid. Nevertheless, if the RTRW has not yet been revised or is still being revised, then this analyzed RTRW is still valid.

Lumajang Regency

The overlay between Lumajang Regency Spatial Plan (RTRW) 2023-2043 and the WTG area in this regency is shown in Figure 12. As inferred by the figure, the WTG area intersects with the following types of land use:

1. Fixed Production Forest Area (*Kawasan Hutan Produksi Tetap*)
2. Plantation Area (*Kawasan Perkebunan*)

Wind farm development at Fixed Production Forest Area is possible under certain circumstances, as already explained above (i.e. with regard to Production Forest Area). Forest Area Use Approval shall be obtained from MoEF by the developer. Other possible consequences include payment of non-tax state income and rehabilitation planting.

As also explained above, Plantation Area can be used for wind farm development (and other types of power generation and transmission activities for public interest) as long as the area is not part of the Sustainable Food Agriculture Area (*Kawasan Pertanian Pangan Berkelanjutan*/KPPB), and a purchase or lease agreement is achieved with the landowner[16].

Since the analyzed RTRW of Lumajang was relatively recently published (compared to the other regencies as part of this study), it can be assumed that the spatial plan is still effective at the time of writing.

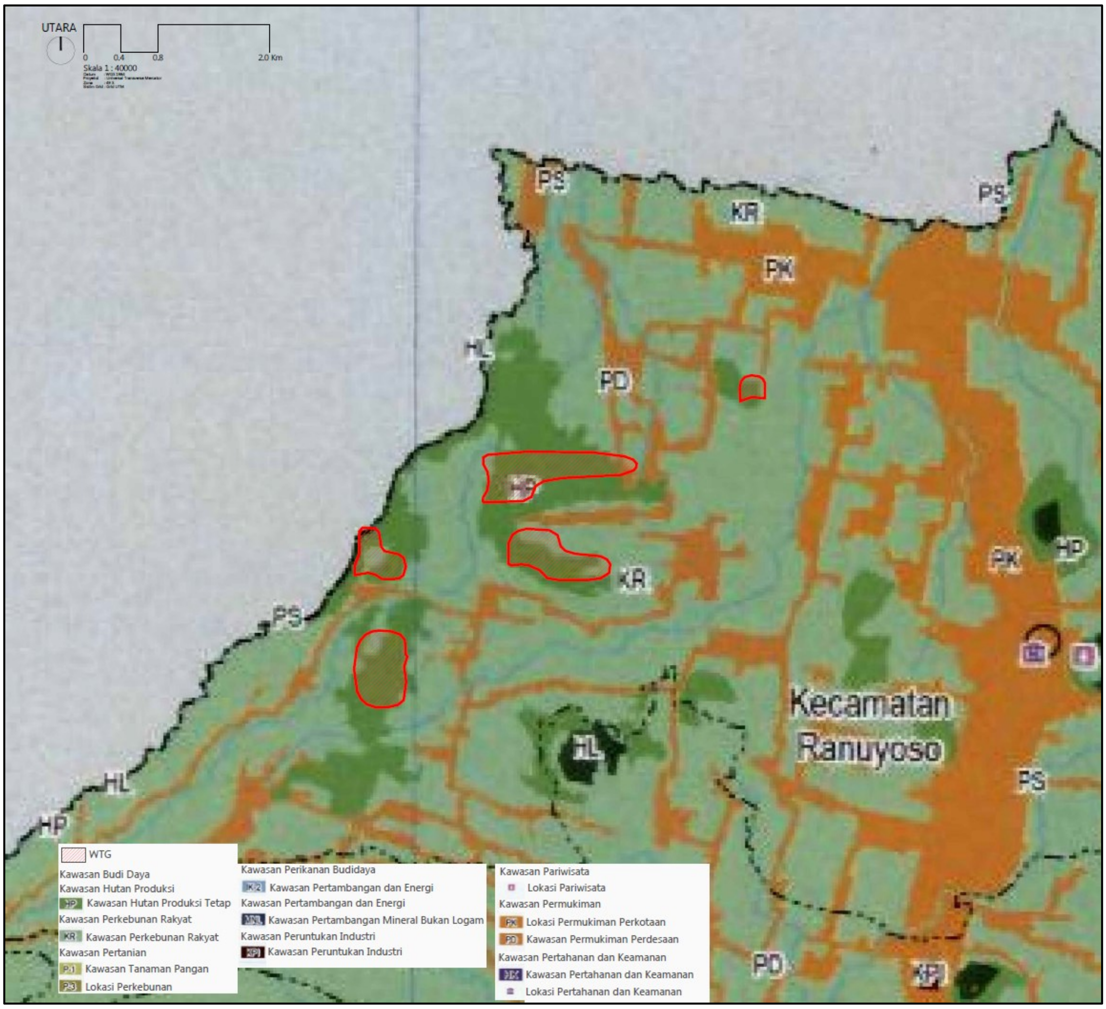

Figure 12. The map of spatial plan of Lumajang Regency (RTRW 2023-2043) is overlaid with the final WTG-area.

Later in Section 2.3, it will be shown that the envisioned wind turbines are placed in the southwestern section of the final WTG-area. Thus, the relevant land use types for Probolinggo – Lumajang wind farm are Plantation Area and (Fixed) Production Forest Area. The wind farm area is roughly split into two equal portions (50/50) to the respective land use types. The values and entailed costs of these land use types are taken into account in the business case calculations (see Section 2.9).

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

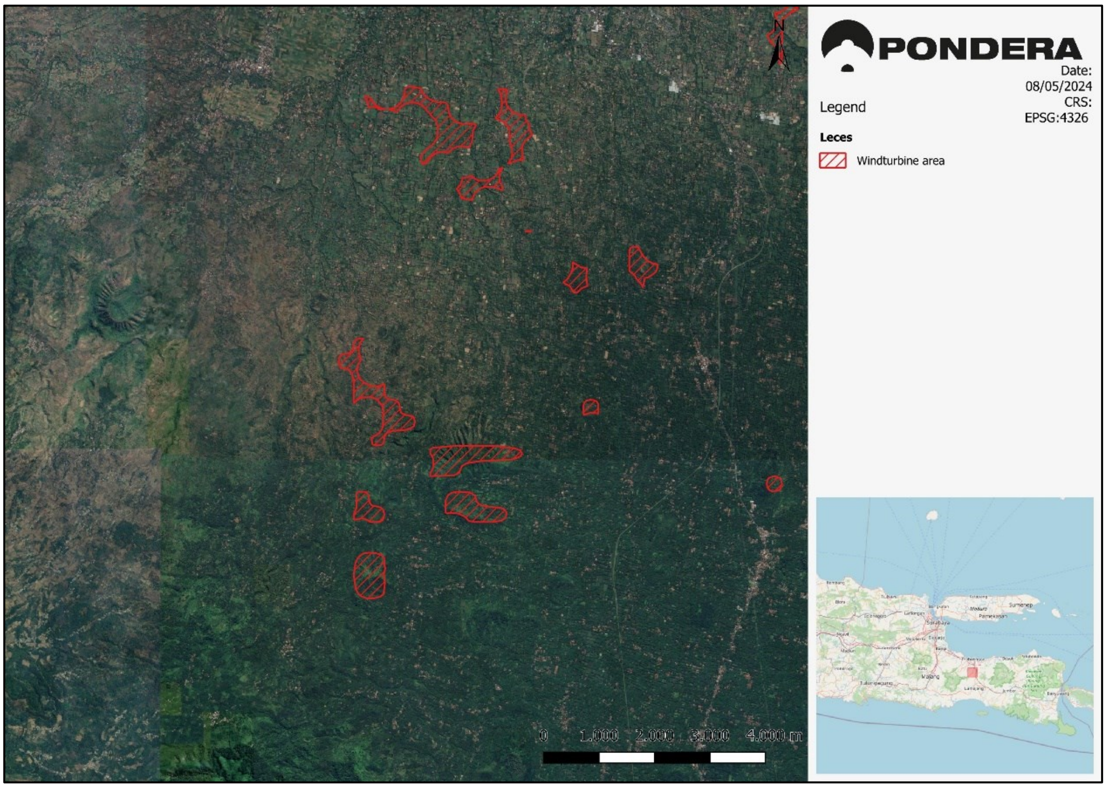

Figure 13. Final WTG-area based on the restriction criteria. Source: Google Satellite Images.

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 southern and central 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.

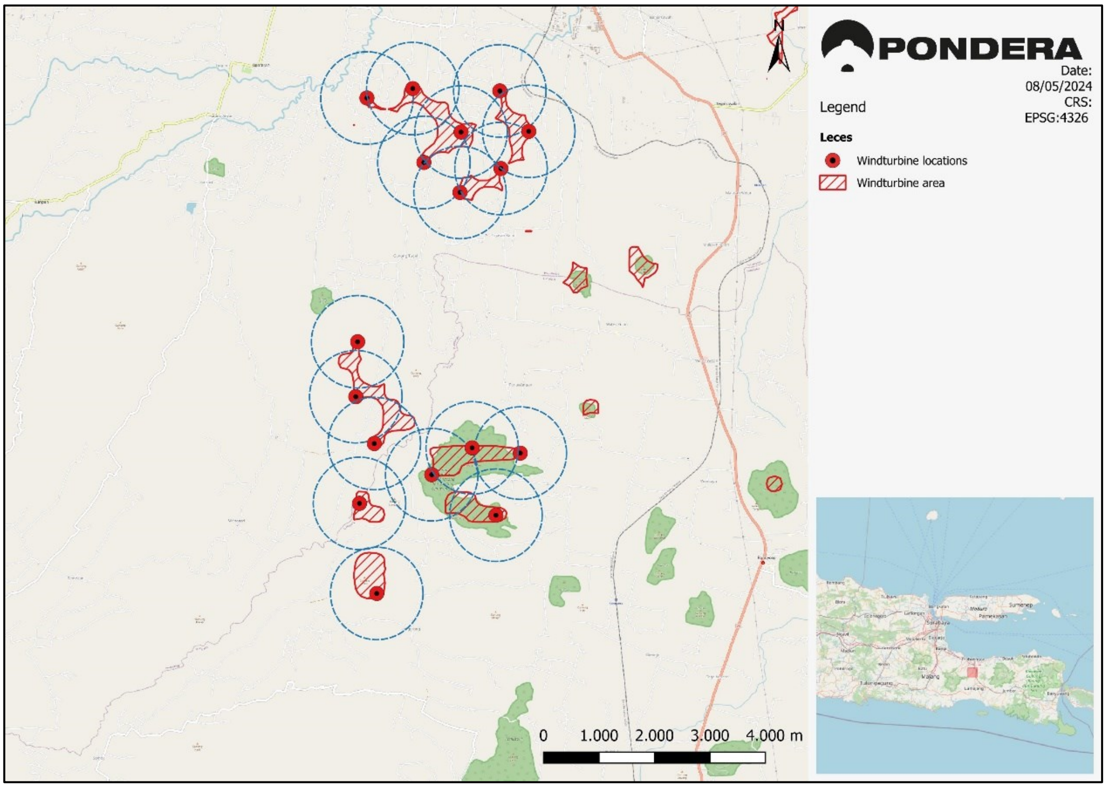

Figure 14. Preliminary wind farm layout at the final WTG-area.

Figure 14 displays an overview of the wind turbine locations in the final WTG-area. A total of 17 wind turbines were positioned into the area, amounting to an envisioned total installed capacity of 68 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 15). 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.

Figure 15. 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.

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.

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.

However, for this particular site, transport might be less of an issue as a highway exit is planned right at the base of the envisioned wind farm. The transport might be considerably easier at this site compared to other sites on Java and Sumatra.

2.4.2 Port-to-site transportation

All major ports of Java are located on the north coast, bordering the calmer Java Sea compared to the Indian Ocean on the south coast. Most of the long-distance transport of goods is done via the northern part of the island. Port of Surabaya (i.e. Port of Tanjung Perak) is the nearest major port, at a distance of about 100 km from the site (see Figure 16). From Port of Surabaya, an access point of the highway is located right at the entrance/exit of the port. The Port of Probolinggo could be considered too at a later stage. However, that port currently lacks the facilities for the import of major wind turbine components (e.g. suitable cranes, sufficient storage area) and the exit route from the port to the highway comes with logistical challenges.

When one or more of the envisioned wind farms in East Java are constructed, transport for all sites via one access point (Surabaya) may have advantages (i.e. contacts with port and authorities, contracts, port investigation, temporary storage which can be reused, etc.).

Figure 16. A satellite image of the Port of Surabaya. Entry/exit road at the western part of the port and entry of the highway are in line, which makes this port suitable for transportation of long wind turbine components.

The access from the Port of Surabaya to the site is depicted in Figure 17. Probolinggo (Leces area) can be reached via the highway with an exit ~5 km north of the northern edge of the site. From there, a wide regional road runs south to Lumajang Regency. Expansion of the highway in the southern direction is planned, at the east of the existing regional road (while the site lies on the western side). News articles mention that the construction will be done in 2025-2029, but no further information has been found.

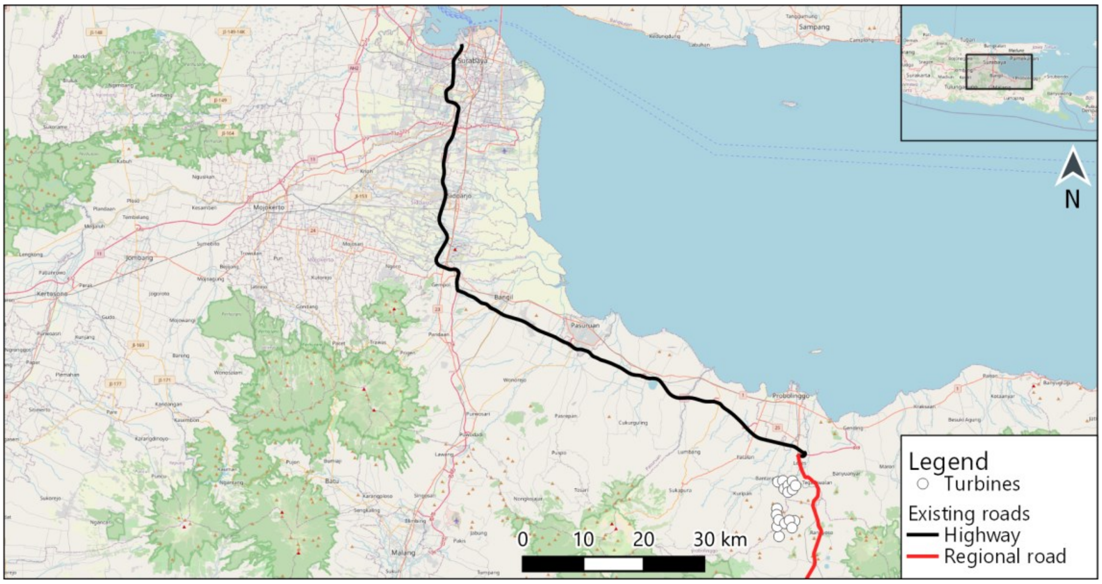

Figure 17. The largest roads from the Port of Surabaya to site.

The regional road is sufficient in width and quality, and is closer to the site (see Figure 18). Thus, an additional available highway from Probolinggo to the south will probably have little impact on the financial feasibility of the project.

Figure 18. Regional road between highway and site (Probolinggo-Lumajang). This road is very wide compared to most regional roads on Java Island.

On the highway/toll road, no road upgrades are expected as the toll roads and access roads are wide in all sections. However, a limiting factor may be the height of the numerous bridges over the toll roads. The available signs are unclear about the clearance as both signs of 4.2 m (on the bridge) and 5.1 m (side of the road) are being shown. This height is particularly important for the diameter of the base of the turbine tower, as this height can limit the diameter of the base that can be used. The base is normally transported horizontally, and manufactured as one piece.

Based on a rather rudimentary method (see Figure 19), 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 19. 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.

Between the highway and the site, 6 bridges have to be crossed on the regional road. Most of these are made of concrete (between 37 and 7 m in length) and one steel bridge (45 m long). The steel bridge is closed at the top. It is expected that some bridges might need strengthening before heavy transport can take place. Figure 20 displays an example of the steel bridge and the concrete bridge.

Figure 20. An illustration of a steel bridge (left) and a wide concrete bridge (right)

2.4.3 Transport within the site

Within the site, only narrow and windy roads connect the different villages and/or isolated houses. In the northern part of the site (see Figure 21), the road network is denser than the southern part. Most of these roads are mainly built for motorbikes and occasionally used by cars or small trucks. Especially in the southern part of the site (see Figure 22), these narrow roads will have to be upgraded significantly. However, reusing these roads is still cheaper compared to building roads from scratch, mainly due to the amount of land that will not have to be bought if the existing public roads are upgraded.

Figure 21. Impressions of roads/paths on the northern part of the site. Some larger asphalted roads are present, but most of them need widening.

Figure 22. Impressions of roads/paths on southern part of the site. These roads are mainly built for motorbikes and occasional use by cars or small trucks.

On the southern part of the site, a deep gorge runs in between the turbine locations. No roads lead from one side to the other. It is probably not cost effective to build a new road through this gorge, including a small bridge to pass the stream at the bottom.

Especially in the southern part of the site, there are a few small bridges over several small streams. It is expected that no bridge has to been constructed, but can also be replaced by big culverts. The cost for these crossings is expected to lie within the given -20 to +50% cost range of the road construction and are not separately accounted for.

A total of 15.1 km of new road will have to be constructed, and 19.7 km of existing road has to be upgraded (depicted as blue lines in Figure 23). 3.5 km of the new road leads through steep terrain (depicted as red lines in Figure 23), whereas the remaining 11.6 km is through flat to hilly terrain. In the steep terrain, the road will have to be cut into the side of the hills, which results in higher amounts of cut & fill and cost.

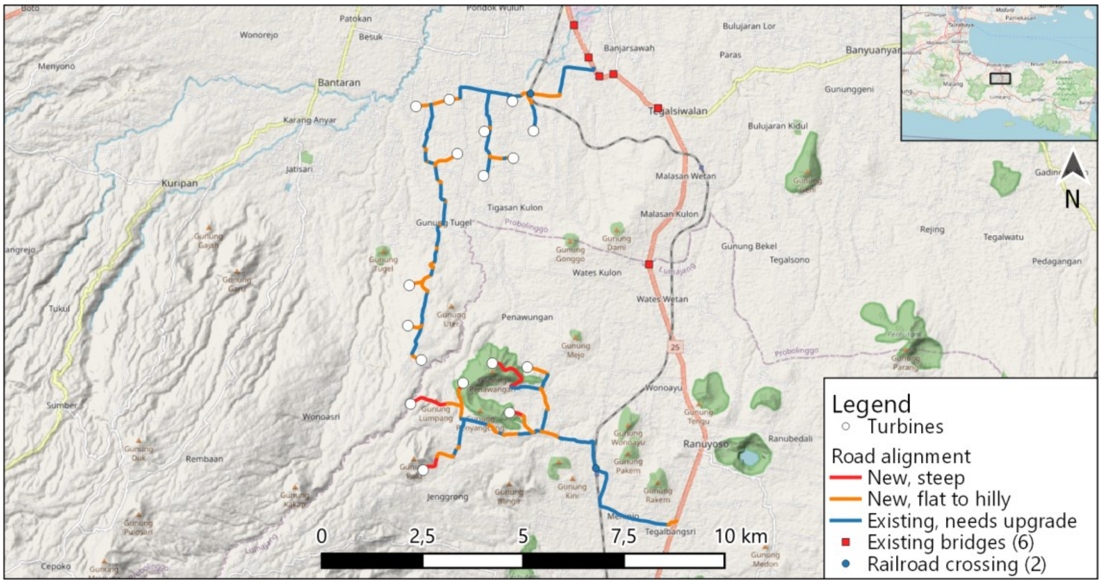

Figure 23. Road layout within site. The southern part of the site is divided by a gorge. Some turbines in the southern part are connected to the northern part of the site.

In between the site and the major road, runs a single, non-electrified railroad track. This railroad needs to be crossed in two places. One of these places is over an (narrow) existing crossing. An amount of USD 100,000 is reserved for extra costs on construction and permission from KAI (Indonesian Railway Company).

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; and
- Consult KAI about possible regulations for upgrading or building a new railroad crossing.

2.5 Geology and seismicity conditions

The envisioned wind farm is located on the lower end of the eastern slopes of the active Mount Bromo/Mount Semeru complex. The nearest active crater (Mount Bromo) is located at a distance of 26.6 km from the nearest turbine.

2.5.1 Geology

Little specific information is found about the local geology around the wind farm. The geological map of the site is shown in Figure 24. As the turbines are located on the lower end of the slopes of the Bromo (west) and Lemongan (east) volcanoes, the subsurface mostly consists of volcanic debris and ash because of past eruptions of Bromo and Lemongan volcanoes. Lava flows (hard rock) from these craters will probably not have reached the site. The deep gorge in the site indicates that the material is easily erodible and probably easy to excavate during road construction and/or platform levelling.

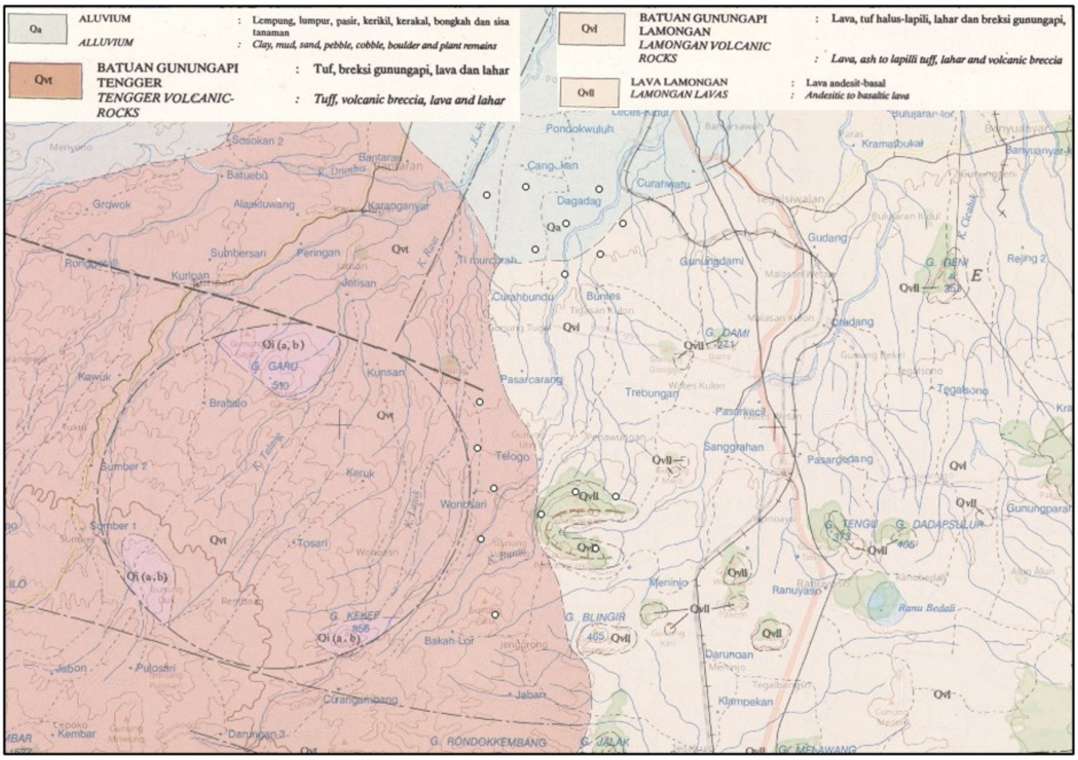

Figure 24. Geological map of the site. Turbines are represented by white dots with black outlines. The colors indicate the geological formations at the surface. The most northern turbines are located in sediment (clay, sand and pebbles, Qa), the others in volcanic debris (Qvt and Qvl) or possibly in harder extrusive rocks (lava flows, Qvll).

Within and around the southern part of the site, many small circular hills can be seen on topographic maps. These are likely intrusions, formed by small vertical vents (dikes) originating from a deeper magma chamber which is or was once connected to Lemongan volcano. Closer to Mount Lemongan, more of these structures can be found. It is likely that these hills consist of significantly harder material (lava flows) than the surroundings (volcanic debris). If existing lava flows around Mount Penyangcang must be cut away for road construction, this will increase the cost significantly of that section.

Figure 25 visualizes Land Movement Vulnerability Index of the soil in and around the WTG-areas. Most turbines are envisioned to be in very low, low, and medium vulnerability areas. Meanwhile, one turbine is located in a high risk area.

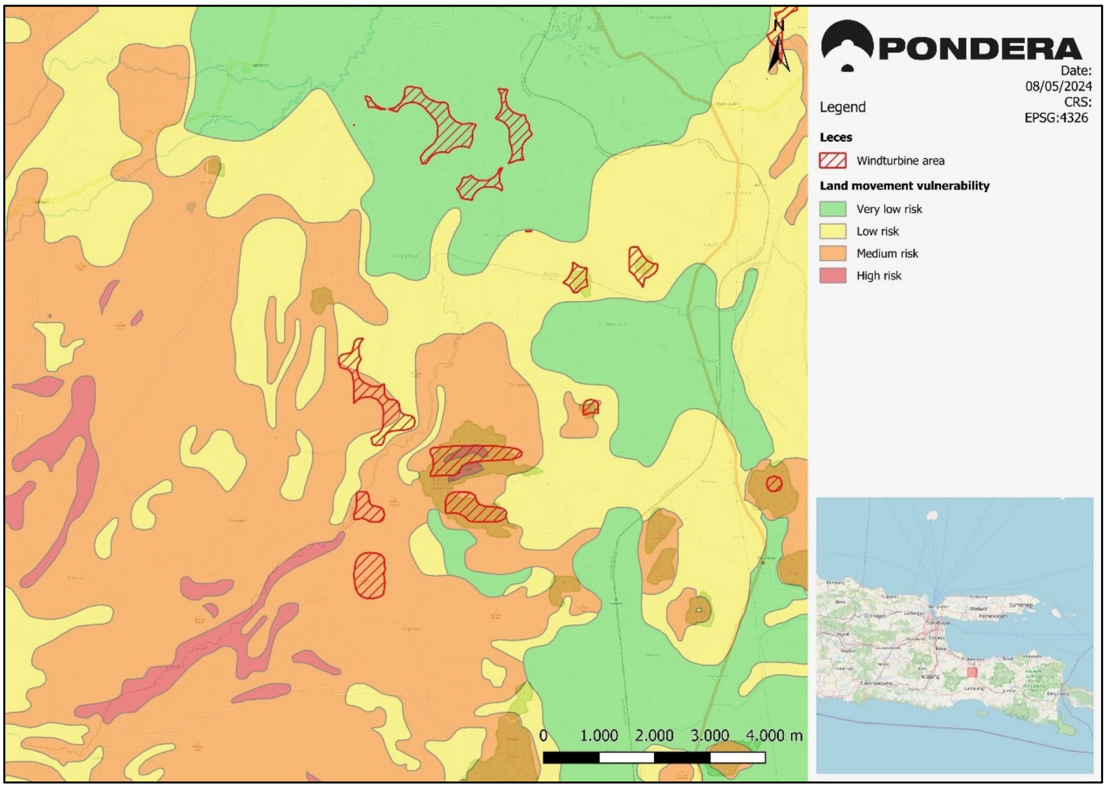

Figure 25. Land movement vulnerability index for Probolinggo – Lumajang.

The deep gorge in the area suggests that the material of the soil can easily erode and lacks cohesion. Especially for the turbines built near the gorge and on steeper slopes, the stability and capability of the soil to carry wind turbines 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.

Another type of land movement is liquefaction, but this is more related to seismic activity and included in Subsection 2.5.2.

2.5.2 Seismicity

According to the geological map (see Figure 24), some faults are observed in the nearby area. These are likely to be related to volcanic activity. As these volcanoes are still active, earthquakes can still be expected. However, according to the USGS database, no crustal earthquakes (< 40 km depth) were recorded in the area near (50 x 50 km) the site since the start of accurate measurements in the 1960s.

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

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 earthquakes with an intensity of VII to VIII on the Modified Mercalli Intensity (MMI) scale. Figure 26 provides a visual representation of the earthquake risk level in and around the WTG-area.

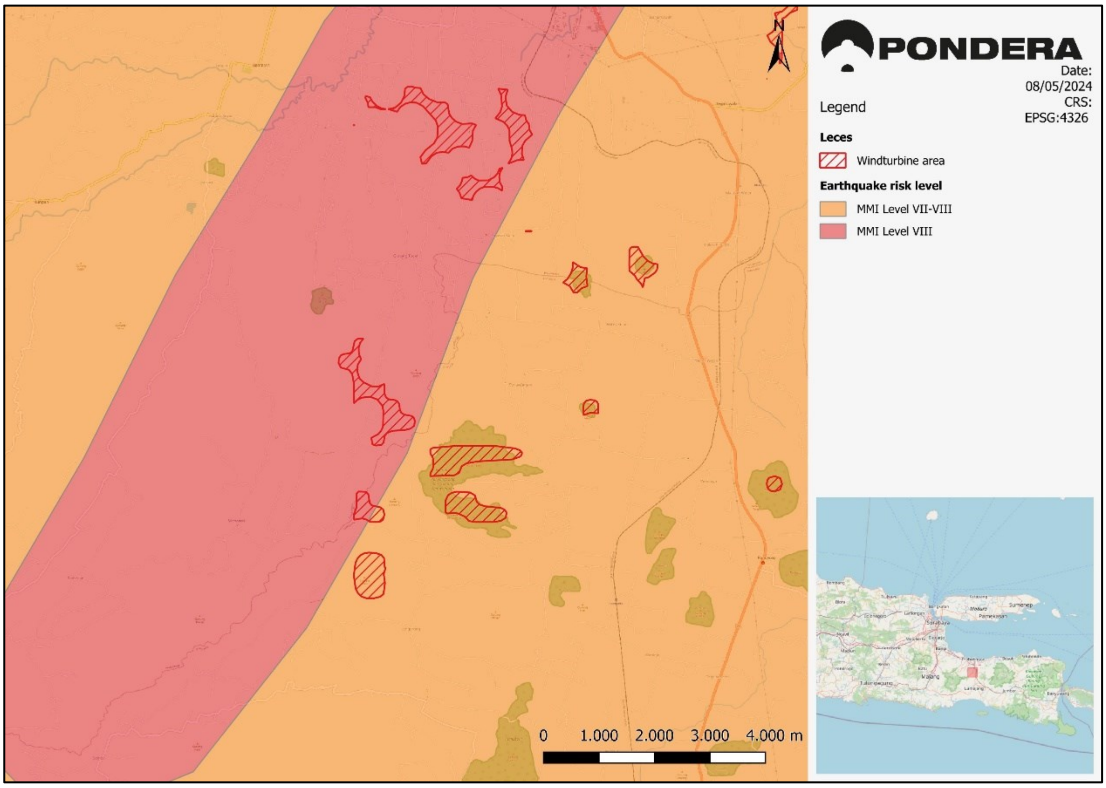

Figure 26. Earthquake hazard and risk level at Probolinggo – Lumajang

The MMI scale classifies earthquakes based on the impact on the surface rather than the energy released (like Richter's scale). The area in classified as potential intensity of VII-VIII and VIII which are 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 should be calculated for more precise hazard assessment due to earthquakes.

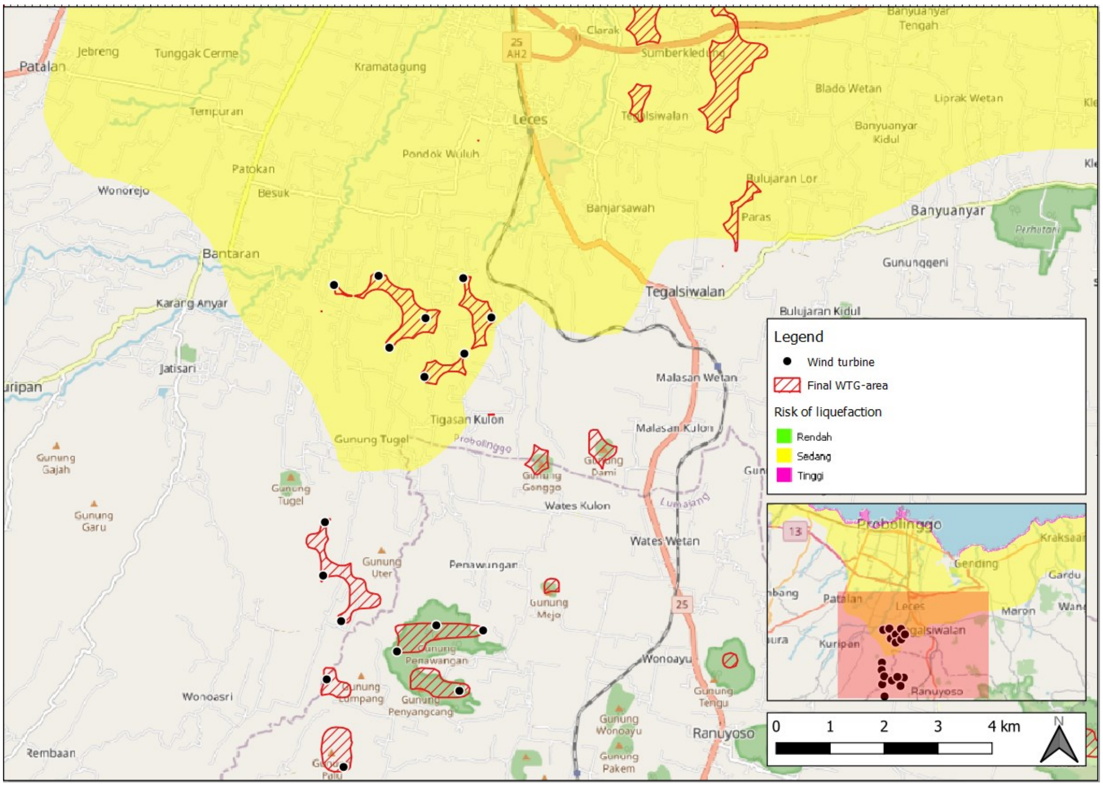

Figure 27. Risk of liquefaction (MEMR). Yellow areas (*Sedang*) are at medium risk of liquefaction, whereas bright pink and bright green areas are at high (*Tinggi*) and low (*Rendah*) risk of liquefaction, respectively.

According to MEMR (see Figure 27), the northern part of the site (eight out of the seventeen wind turbine locations) lies in an area with 'medium' risk of liquefaction. This is a phenomenon where the soil/sediment after an earthquake can behave as a liquid/sludge and flow to lower elevations (10s to 100s of meters). During the feasibility stage, the risk of liquefaction should be looked into in further detail by examining the soil characteristics and local hydrogeology.

2.6 Biodiversity, socio-economic and environmental conditions

2.6.1 General impression

The northern part and southern part of the site differ from each other both in topography, land use, and population density. While still elevated 80 to 100 m above sea level, the northern part lies in an area that can be counted as coastal plains. The southern part is located at the foot of Mount Bromo. Both areas are displayed in Figure 28.

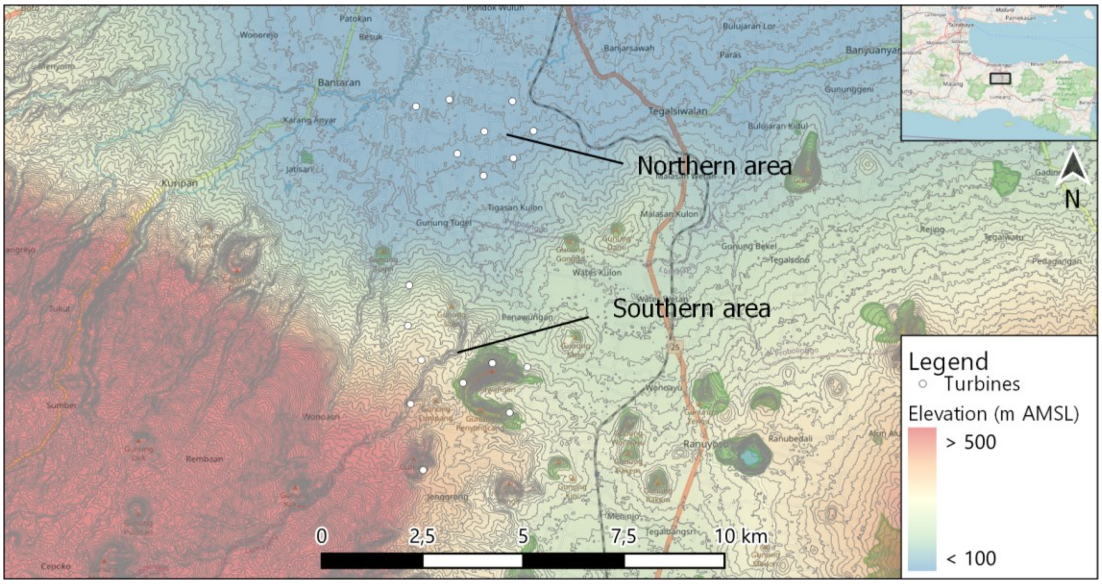

Figure 28. Elevation around the site. The northern area is located in coastal plains, while the southern area is located at the foot of Mount Bromo.

Northern part of the site

This area is covered by small agricultural fields, mostly corn/maize and sugarcane, separated from each other by rows of bushes and trees (see Figure 29 and Figure 30). Small villages (ranging from ~5 to ~100 houses) and some isolated buildings are scattered throughout the area. The topography is flat, with an occasional shallow stream. These streams seem to be almost dry, and are mostly draining during and after rainfall.

Figure 29. An impression of the northern part of the site. Small fields are separated by bushes and trees. Groups of houses and villages are scattered throughout the area.

Figure 30. Another impression of the northern part of the site. Small fields are separated by bushes and trees.

Southern part of the site

The southern part is more heavily vegetated compared to the northern area. More than 50% of this area is covered by patches of forest or groups of trees and bushes. Agricultural fields (mostly corn/maize, sugarcane, and various crops) lie between patches forests and villages. The forests are used for small scale forestry and possibly for hunting and bird catching, as hunting rifles and bird traps were observed during the site visit.

The topography is hilly, with some deeper incised streams, up to 10 m deep. A deeper gorge cuts through the area from southwest to northeast direction, separating the three western turbines from the others. No road connects both sides of this gorge. As can be seen in Subsection 2.4.3, the access road of these western turbines is connected to the northern part of the site because of this topography. Including land acquisition, the upgrading of an existing road is cheaper compared to constructing a new mountain road up and down the gorge and a bridge.

Within the site, a remnant of a small volcano rises 150 to 250 meters above the surrounding terrain. The area is slightly less densely populated compared to the northern area. Moreover, illustrations of the southern part of the site are presented in Figure 31, Figure 32, Figure 33, and Figure 34.

Figure 31. An impression of the southern area. It consists of aa more heavily forested area with small fields and villages. This viewpoint is looking at the base of Mount Bromo.

Figure 32. Another impression of the southern area. This viewpoint looks at Mount Penawangan, with coastal plains in the background.

Figure 33. Gorge with steep slopes. Three turbines are envisioned on the left side of the gorge. This viewpoint looks at the coastal plains (the northern part of the site) in the background.

Figure 34. An impression of the southern area, which consists of forests, fields, and small villages

2.6.2 Biodiversity and environmental impact

While humans are present throughout the area, and no continuous forest is located within the site, large parts of the area are still heavily vegetated. Especially in the southern part of the site, biodiversity may still be high, as nearby the small mountains and the gorge are fully covered with forest. The forest in the gorge is marked as a protected forest (*Hutan Lindung*). The main impacts of wind farm development are:

Biodiversity impact:

- Bird & bat strikes (turbines)
- Opening of area: encroachment, illegal logging, squatting, hunting, farming
- Further habitat fragmentation (mainly by new roads and transmission lines)

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 large scale human presence and influence in the region, the opening of the area has already taken place in almost all parts of the area.

Observed flora and fauna:

According to the online biodiversity database of Global Biodiversity Information Facility (GBIF), several animal and plant species were observed in the area (see Figure 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).

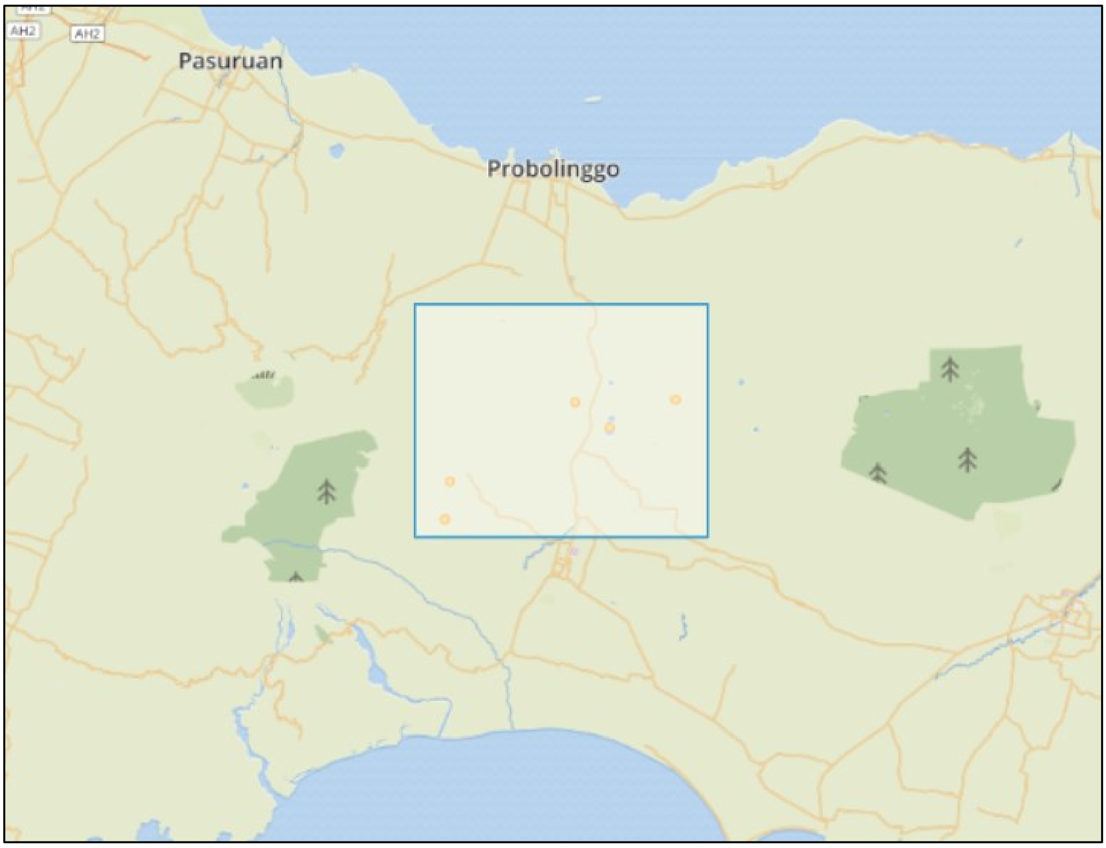

Figure 35. The area in which the abovementioned flora and fauna has been observed (covering the envisioned wind farm location). All of these observations are categorized as at least 'least concern.'

In the following tables, the observed flora and fauna that are categorized as at least 'near threatened' are listed. The species in grey are either historic sightings (1920-1930) or unknown date. It is unknown whether these are still present in the area, but are not in the database as an observed species in more recent times.

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

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
Macaca fascicularis	Con Song Long-tailed Macaque	Endangered (EN)
Gonocephalus kuhlii	- (lizard species)	Vulnerable (VU)
Trachypithecus auratus	East Javan Langur	Vulnerable (VU)
Rasbora lateristriata	Sidestrap rasbora	Vulnerable (VU)
Calidris ruficollis	Red-Necked Stint	Near Threatened (NT)

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

Plants	English Name	Status
Dipterocarpus retusus	Hollong	Endangered (EN)
Pandanus faviger	-	Near Threatened (NT)

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

- Reuse as much of the existing infrastructure as possible or feasible, such as the existing access roads within the area;
- 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; 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 conducted during the feasibility phase.

2.6.3 Social impact

As depicted in Figure 36, numerous small villages are located in the area. The envisioned turbines are placed in between these villages. Some existing buildings are located near (< 300 m) the current envisioned turbine locations, but these turbines can be shifted during the feasibility study to ensure sufficient distance. The villages within the wind farm area (both northern and southern area) consists mainly of small scale farmers. No other major activity has been observed during the site visit.

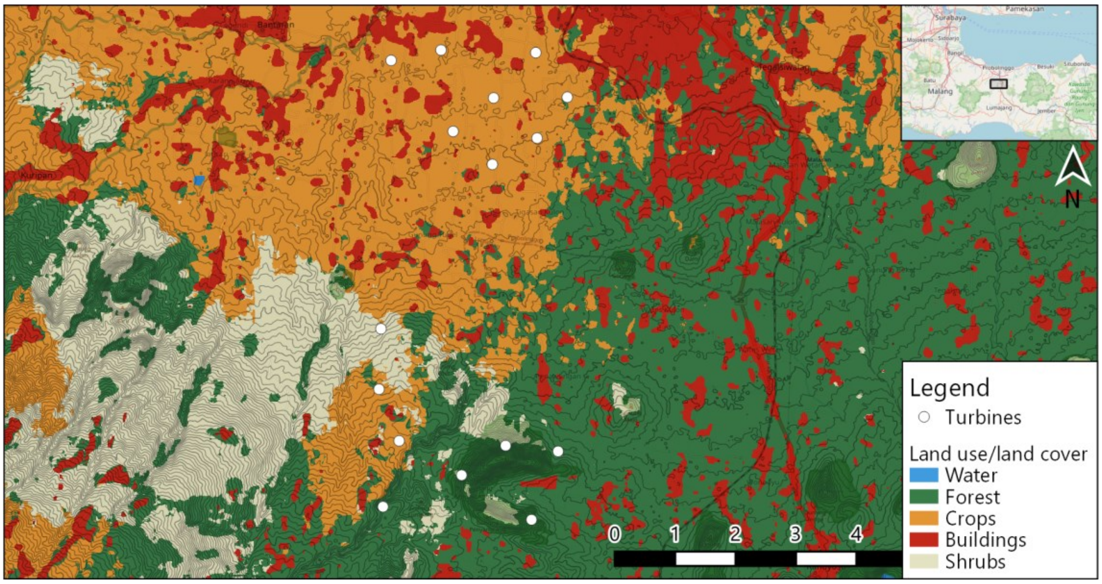

Figure 36. Land use map based on satellite imagery (ESRI/Sentinel 2, 2023).

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 after public road upgrades.

With the current land use, the visual impact in the southern part (east of the gorge) of the site may be quite limited. During the site visit, only a few open views were observed, and visibility range was almost always less than 50 meters due to high and thick vegetation.

Most of the southern area is hard to reach by other transport than by foot or motorbikes. The mobility of the population nearby is likely to be increased when public roads are upgraded, cutting down travel times between the southern area and the main road to Probolinggo – Lumajang.

The next paragraphs provide an overview of the population and employment statistics of Probolinggo and Lumajang Regency.

Population

Probolinggo

The graph of population and annual population growth rate is shown in Figure 37. It can be seen that the annual population growth rate in the regency rose from 0.22% in 2021 to 0.34% in 2023. The total number of inhabitants increased from 1,155,894 people in 2021 to 1,163,859 people in 2023.

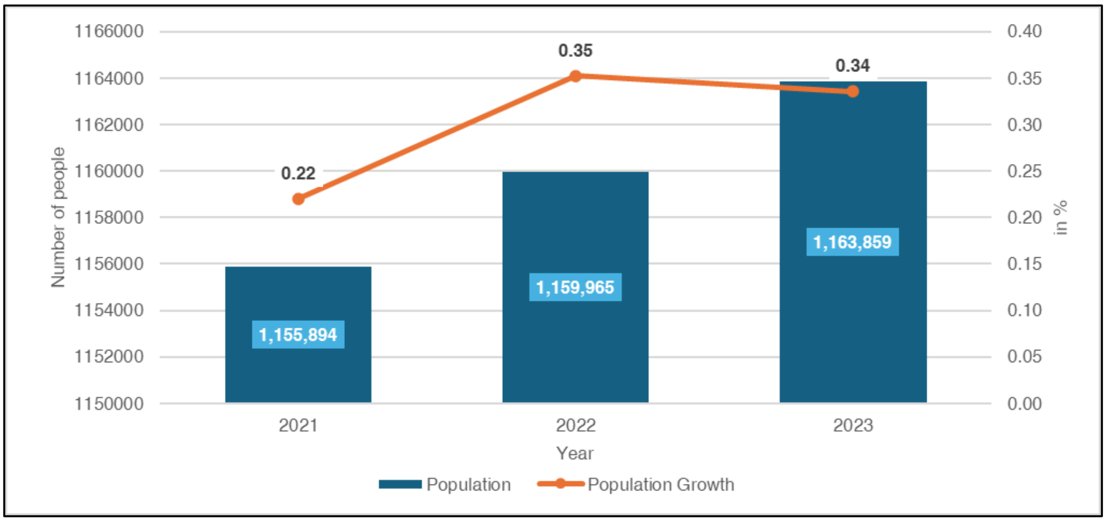

Figure 37. Population and annual population growth rate in Probolinggo Regency in 2021-2023 (Source: [Statistics of Probolinggo Regency (bps.go.id)]).

The regency's population pyramid is shown in Figure 38. It is worth noting that the gender ratio was 0.97 in 2022.

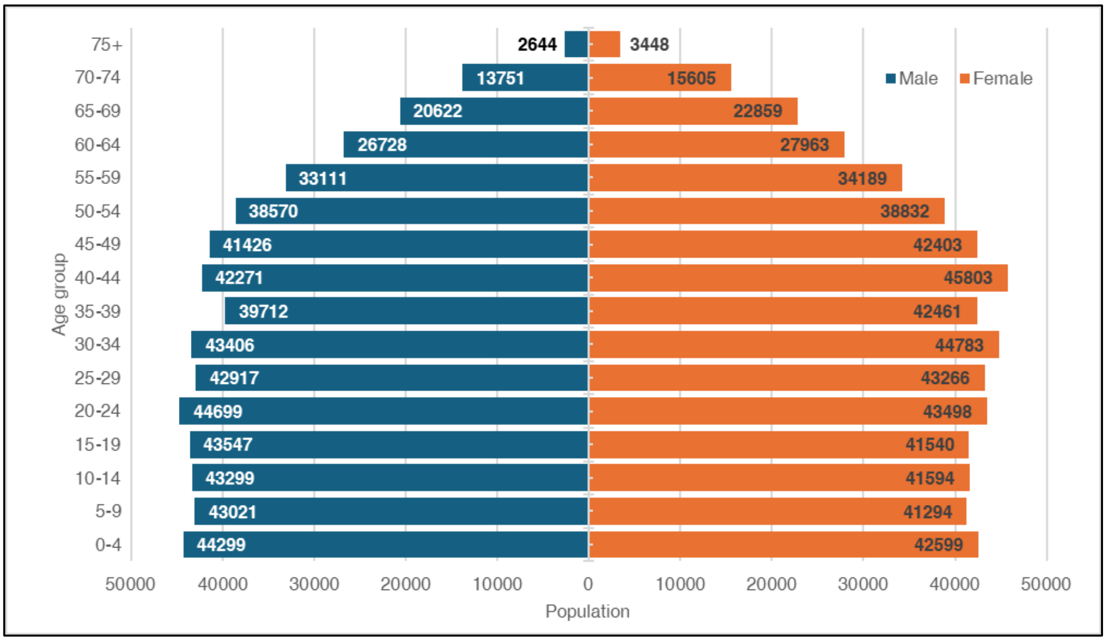

Figure 38. Population pyramid in Probolinggo Regency in 2022 (Source: [Statistics of Probolinggo Regency (bps.go.id)]).

Lumajang

The graph of population and annual population growth rate is shown in Figure 39. It can be seen that the annual population growth rate in the regency declined from 0.67% in 2021 to 0.62% in 2023. Meanwhile, the total number of inhabitants increased from 1,125,000 people in 2021 to 1,139,000 people in 2023.

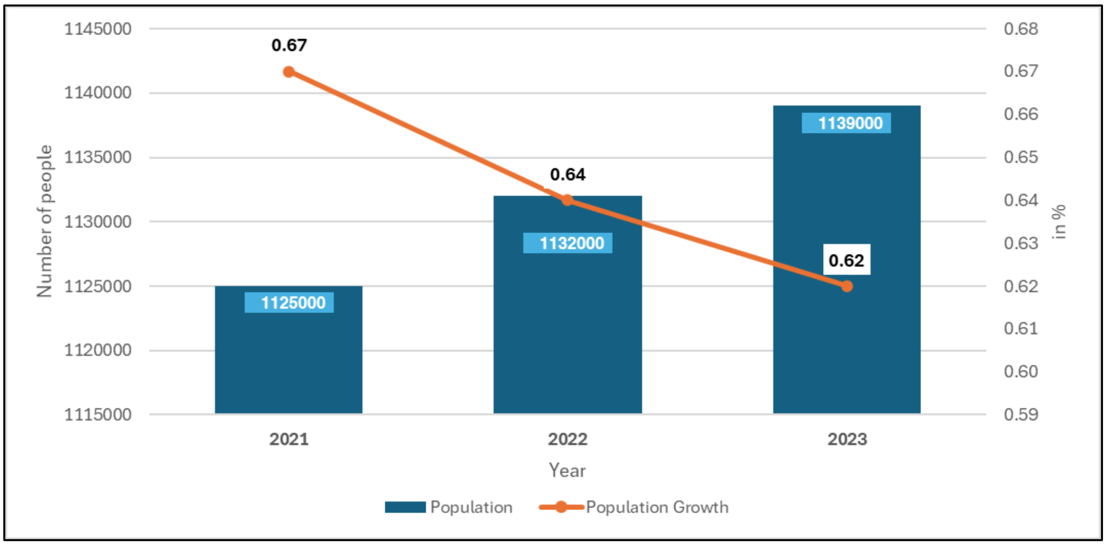

Figure 39. Population and annual population growth rate in Lumajang Regency in 2021-2023 (Source: [Statistics of Lumajang Regency (bps.go.id)]).

The regency's population pyramid is displayed in Figure 40. It is worth noting that the gender ratio was 0.9779 in 2022.

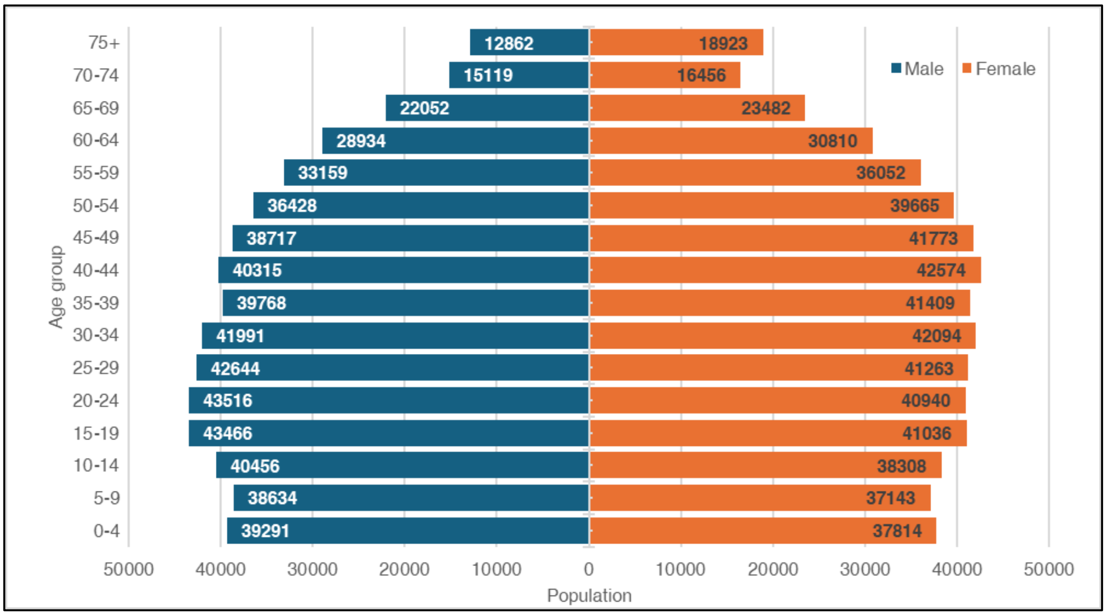

Figure 40. Population pyramid in Lumajang Regency in 2021 (Source: [Statistics of Lumajang Regency (bps.go.id)]).

Employment, education, and development

Probolinggo

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. During 2021-2023, both the labor force participation rate and the unemployment rate declined.

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

Metric (in %)	Year		
	2021	2022	2023
Labor force participation rate	73.24	71.56	69.48
Unemployment rate	4.55	3.25	3.24

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 Probolinggo Regency from 2023 (Source: Statistics of Probolinggo Regency (bps.go.id)).

Educational attainment	Working	Unemployed	Total of Economically Active	Percentage of Working to Economically Active
Primary school (SD)	355,505	1,975	358,480	99.17
Middle school (SMP)	97,522	5,109	102,631	95.02
High school (SMA)	130,601	11,103	142,704	91.52
University	33,775	460	34,235	98.66
Total	**617,403**	**20,647**	**638,050**	**96.76**

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 Probolinggo Regency in 2021-2023 (Source: BPS Kabupaten Probolinggo)

Pure participation rate	Year		
Educational level	**2021**	**2022**	**2023**
Primary school (SD)	97.55	99.91	99.67
Middle school (SMP)	70.39	70.83	77.30
High school (SMA)	38.45	42.05	52.39

The number of educational facilities in the regency, according to the different education levels, in 2023 is shown in Table 6.

Table 6. Educational facilities in Probolinggo Regency in 2023 (Source: [Statistics of Probolinggo Regency (bps.go.id)]).

Type of school	Number of facilities
Kindergarten (TK)	505
Raudatul Athfal (Islamic Kindergarten)	410
Primary school (SD)	626
Madrasah Ibtidaiyah (Islamic Primary School)	414
Middle School (SMP)	218
Madrasah Tsanawiyah (Islamic Middle School)	222
High School (SMA)	76
Vocational High School (SMK)	58
Madrasah Aliyah (Islamic High School)	133
University	8

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

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

Human Development Index in the regency from 2021 to 2023 shows a generally increasing trend, as shown in Table 7.

Table 7. Human Development Index, Gender Empowerment Index, and Gender Development Index in Probolinggo Regency in 2021-2023 (Source: [Statistics of Probolinggo Regency (bps.go.id)]).

Metric	Year		
	2021	2022	2023
Human Development Index	68.94	69.56	70.36
Gender Empowerment Index	68.22	68.69	68.75
Gender Development Index	85.63	86.33	86.76

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 in the regency from 2021 to 2023 shows an overall increasing trend, 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 in the regency from 2021 to 2023 shows a generally increasing trend, as shown in Table 7.

Lumajang

The labor force participation rate (TPAK) and the unemployment rate (TPT) are displayed in Table 8. During 2021-2023, the labor force participation rate experienced an increase, whereas the unemployment rate fluctuated.

Table 8. Labor force participation rate and unemployment rate in Lumajang Regency in 2021-2023 (Source: Statistics of Lumajang Regency (bps.go.id)).

Metric (in %)	Year		
	2021	2022	2023
Labor force participation rate	66.2	66.8	68.5
Unemployment rate	3.51	4.91	3.67

The number of workers according to highest education from in 2023 is presented in Table 9. 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 9. Workers according to highest education (people) in Lumajang Regency from 2023 (Source: BPS Kabupaten Lumajang).

Educational attainment	Working	Unemployed	Total of Economically Active	Percentage of Working to Economically Active
Primary school (SD)	329,416	7,400	336,816	97.80
Middle school (SMP)	102,018	3,605	105,623	96.59
High school (SMA)	127,070	9,706	136,776	92.90
University	41,043	2,115	43,158	95.10
Total	**599,547**	**22,826**	**622,373**	**96.33**

The pure participation rate of the regency is shown in Table 10.

Table 10. Pure participation rate in Lumajang Regency in 2019-2023 (Source: BPS Kabupaten Probolinggo)

Pure participation rate	**Year**		
Educational level	**2019**	**2022**	**2023**
Primary school	97.06	99.95	99.41
Middle school	76.9	79.05	84.21
High school	44.42	46.10	49.18

The number of educational facilities in the regency, according to the different education levels, in 2023 is shown in Table 11.

Table 11. Educational facilities in Lumajang Regency in 2023 (Source: BPS Kabupaten Lumajang).

Type of school	**Number of facilities**
Kindergarten (TK)	454
Raudatul Athfal (Islamic Kindergarten)	190
Primary school (SD)	557
Madrasah Ibtidaiyah (Islamic Primary School)	207
Middle School (SMP)	143
Madrasah Tsanawiyah (Islamic Middle School)	139
High School (SMA)	30
Vocational High School (SMK)	40
Madrasah Aliyah (Islamic High School)	88
University (*in 2021*)	10

The Human Development Index in Lumajang Regency from 2021 to 2023 rose from 67.65 to 69.37, as shown in Table 12. The table also shows that both GEI and GDI increased over the same period.

Table 12. Human Development Index, Gender Empowerment Index, and Gender Development Index in Lumajang Regency in 2021-2023 (Source: Statistics of Lumajang Regency (bps.go.id)).

Metric	**Year**		
	2021	**2022**	**2023**
Human Development Index	67.65	68.48	69.37
Gender Empowerment Index	59.38	59.61	59.88
Gender Development Index	88.39	88.77	89.06

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 Probolinggo 150 kV PLN substation is selected for this, located in the south of the center of the city of Probolinggo. The aerial photo of this substation is included in Figure 41. 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 41. Location of the Probolinggo 150 kV PLN substation. Source: Google Maps.

2.7.2 Schematic design transmission and distribution network

In Figure 42, the schematic design of the transmission and distribution network is illustrated. The 17 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 two 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 Probolinggo substation.

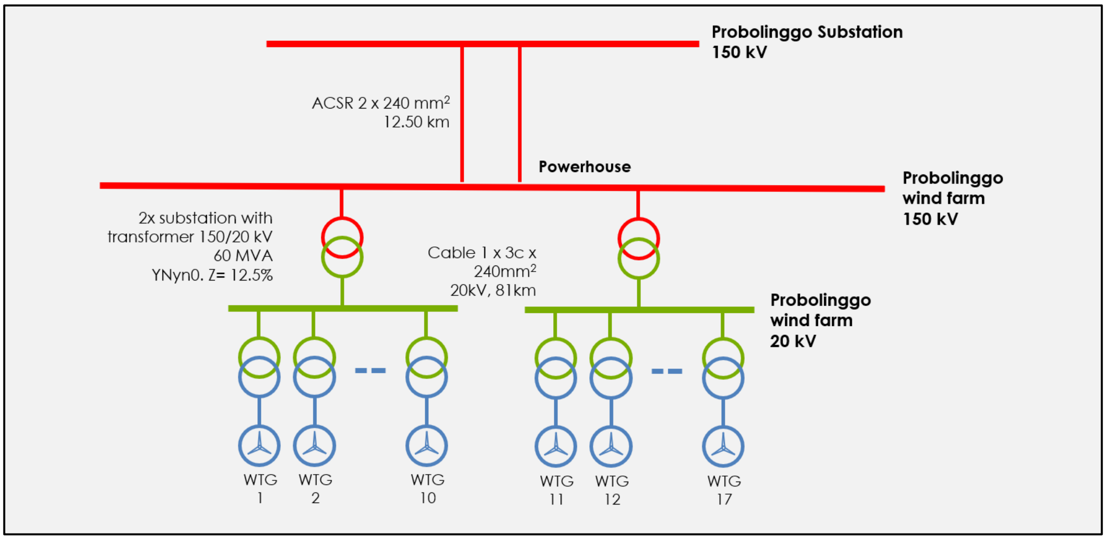

Figure 42. A schematic design of the transmission and distribution network at the envisioned Probolinggo – Lumajang wind farm.

The overhead transmission line between the powerhouse and the PLN substation is assumed to be a straight line between both locations, covering 12.5 km as visualized in Figure 43. A total of 34 towers are planned with an intermediating distance between the towers of 340-450 m.

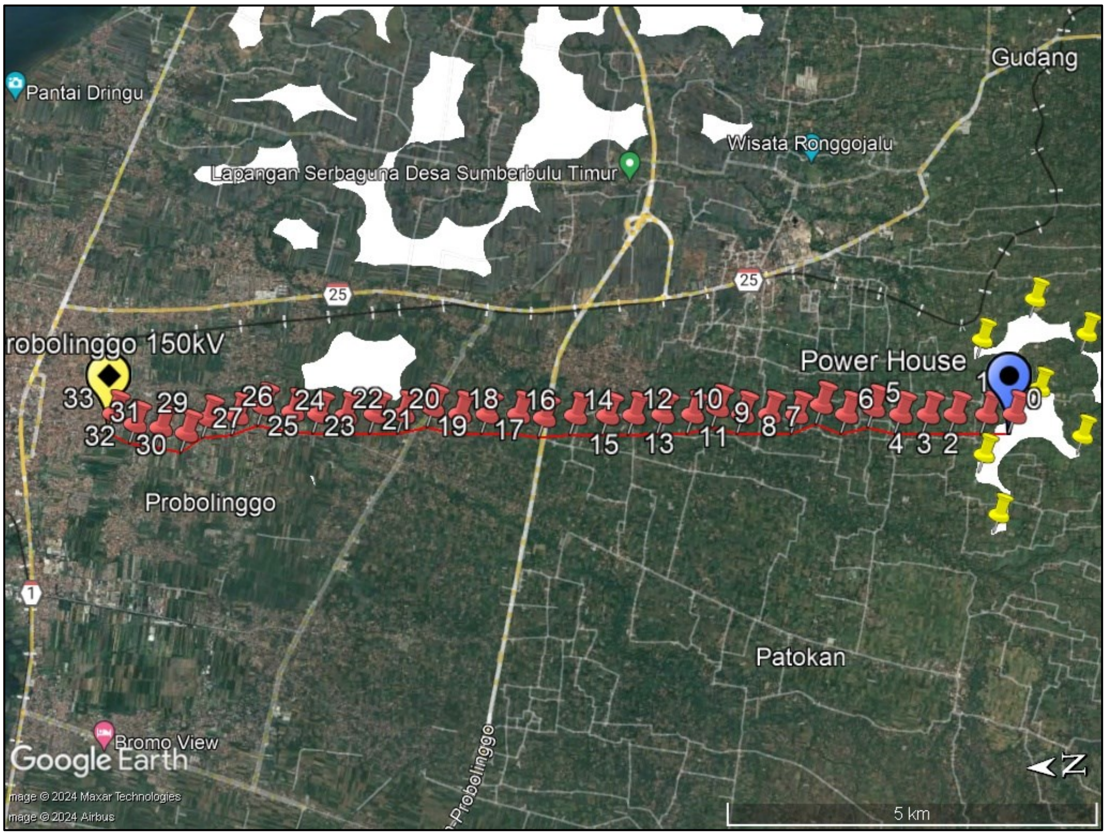

Figure 43. A schematic representation of the position of overhead transmission line between the powerhouse and the Probolinggo substation.

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

Figure 44 shows the resulting climatology at the locations of the WTGs. The modeled long-term wind speed, which is averaged over all 17 WTGs at the planned hub height of 140 m, is 7.2 m/s. The AEP is subsequently calculated based on the power curve of a 4 MW reference WTG with a rotor diameter of nearly 170 m and a hub height of 140 m.

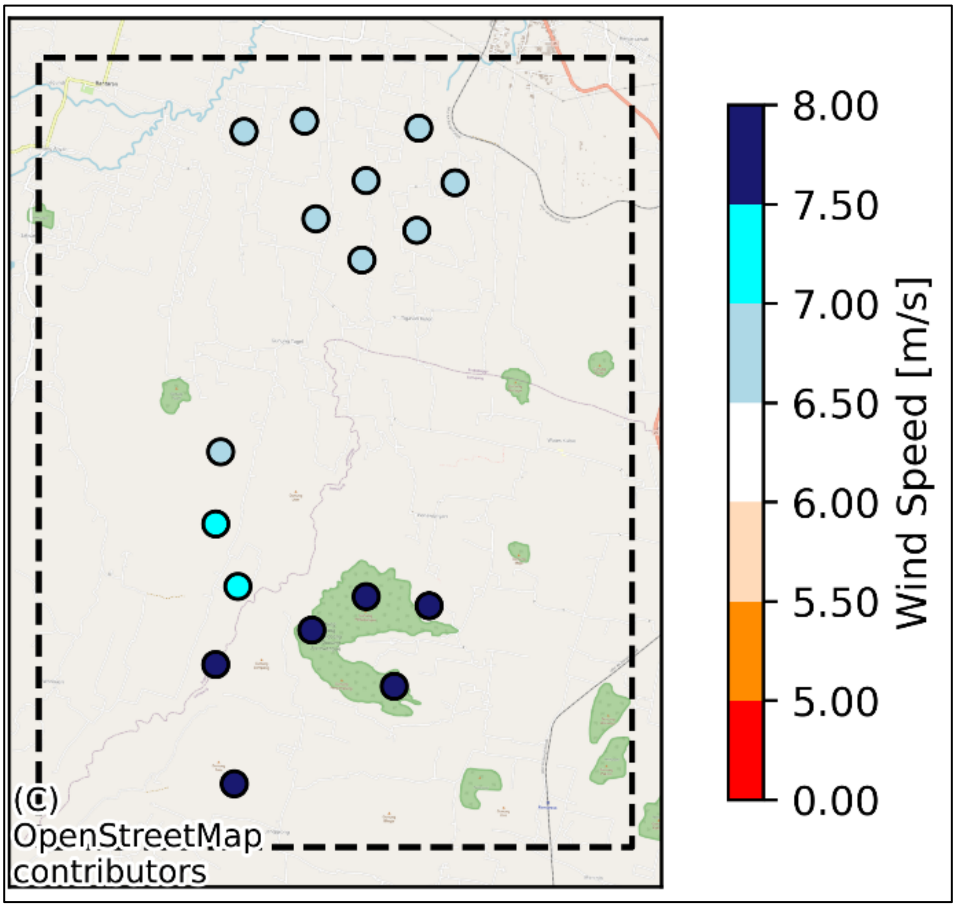

Figure 44. Long-term average wind speed results with the windPRO model at a height of 140 m at the turbine locations. The black-bordered circles represent the wind turbines, whereas the colors within the circle indicate the respective long-term average wind speed.

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 13 presents the estimated losses on the wind farm level.

Table 13. Expected losses on the wind farm level.

Category	Types of energy loss	Amount	Explanation
Interaction	Wake losses [%]	2.9%	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 2.9%.
	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 Probolinggo – Lumajang.
Availability	Non-availability [%]	4.0%	This production loss concerns the periods of a wind turbine that it is not in operation due to maintenance, malfunctioning and re-orientation of the nacelle. For onshore wind farms with more than 5 WTGs, 4.0% loss is considered.
	Balance of Plant [%]	0.1%	Balance of Plant losses occur due to the unavailability of the transformer station or access roads and therefore hinder normal wind farm operation.
	Grid downtime [%]	0.5%	Grid downtime losses are caused by grid non-availability from grid operator.

[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.
	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.

Category	Types of energy loss	Amount	Explanation
	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 of the potential habitats of protected birds and/or bats is to be conducted in the feasibility study. At this moment, the losses are assumed to be 0.0%.
	Wind sector management [%]	0.0%	To safeguard the expected WTG lifetime a so-called Site Assessment study is undertaken by the WTG manufacturer. When this Site Assessment shows exceeding loads on WTG components, based on certain climatic conditions, there is a need to change the WTG's normal operation mode to an alternative program. This often includes the application of reduced power modes which often results in production losses. At this moment it is assumed to be 0.0%.
Sub-total non-interaction losses [%]		**13.0%**	The accumulation of all of the above-mentioned losses, excluding wake losses. Based on 1-(1-loss A)*(1-loss B)*(1-loss C)*…etc.
Total losses [%]		**15.6%**	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 14.

Table 14. Energy yield for all 17 WTGs at the Probolinggo – Lumajang wind farm.

Parameter [Unit]	**Amount**
Number of new WTGs	17
Rated Power per WTG [MW]	4.0
Total rated Power [MW]	68.0
Rotor diameter [m]	~170
Hub height [m]	140
Air density [kg/m^3]	1.136
Wind speed [m/s]	7.2
Gross result [MWh/yr]	309,857
Gross results including wake effects [MWh/yr]	301,056
P50 [MWh/yr]	**261,831**
P90 (25 yr) [MWh/yr]	**194,721**
P50 [hrs/yr]	3,850
P90 (25 yr) [hrs/yr]	2,864

2.8.3 Power output variation

In Subsection 2.8.2, we have provided an estimate of the P50 annual production, equal to 261,831 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.

Figure 45 shows the average wind farm power output for each month, subdivided into the hours over a full day. The input data for this figure is derived from the windPRO results combined with the EMD-WRF average variability in wind speeds throughout the year. This graphic illustration is relevant to take into account for a grid impact study in subsequent studies for this project location.

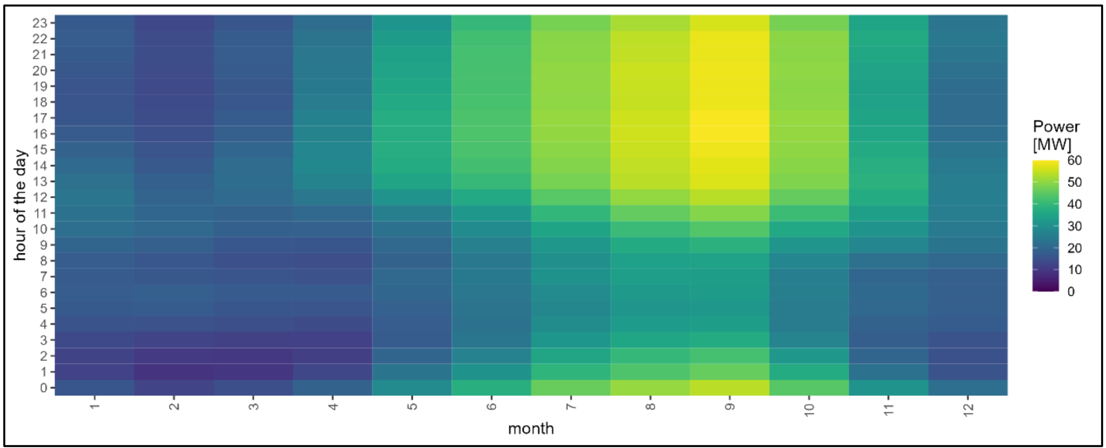

Figure 45. Overview of the monthly variation of wind farm average power output per hour of the day based on the P50 values from Subsection 2.8.2 in combination with the monthly and hourly variation in wind speed from EMD-WRF.

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 (2 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 17 wind turbines at the wind farm are shown in Table 15.

Table 15. Wind turbine quantities relevant for the envisioned Probolinggo – Lumajang wind farm.

Main component	Quantity
Nacelle incl. generator (4 MW)	17 pcs
Blade (85 m)	51 pcs
Tower segments (total 140 m height)	102 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[19];
- The cost includes transport, crane rental, installation and commissioning.

[19] 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 17 wind turbines at the wind farm are shown in Table 16.

Table 16. 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	14 km
	Upgrading existing road	20 km
Strengthening bridges (incl. design, materials, transport, labor)	Concrete bridge strengthening	5 bridges
	Steel bridge strengthening	1 bridge
Foundations (incl. design, materials, transport, labor)	Anchors (72 per foundation)	1,224 pcs
	Anchor cages	17 pcs
	Concrete (230 m^3 per foundation)	3,910 m^3
	Steel (35 tons per foundation)	595 tons
Crane hardstands (incl. design, materials, transport, labor)	Crane hardstands (50 x 100 m) using gravel	17 hardstands

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

- Civil works are including design, materials, transport, and labor;
- A highway connects the Port of Surabaya to Probolinggo, and a wide region road connects Probolinggo to an area ~3 km east of the site. No road upgrades are expected on these roads, except for strengthening some bridges on the regional road;
- Within the site, the roads are very narrow and lead through small villages. Most of these roads are primarily for motorbikes and the occasional car or truck. Almost all of these roads from the main regional road to the site have to be widened and curves reconstructed;
- 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 17.

Table 17. A list of assumptions on the electrical works components

Main component	Sub-component	Quantity
Transmission line (19 km, 48 towers)	Transmission towers	34 pcs
	Conductor	1 set
	Insulator and Fitting; Type Normal	1 set
	ACSR Hawk 240 mm^2 cable	1 set
	GSW 70 mm^2 cable	1 set
	OPGW 70 mm^2 cable	1 set
Powerhouse (1 for the entire wind farm)	Incoming MV switchgear	17 pcs
	LV switchgear	1 pc
	DC Supplies	1 pc
	Lightning protection	1 pc
	2x3C 300 mm cable	567 m
Wind farm electrical works (between the powerhouse, substations, and wind turbines)	Transformers 20 kV (5 MVA)	17 pcs
	Switchgear	17 pcs
	MVAC Cable (1 x 3c x 240) 50 and 300 meters	81 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 (two for the entire wind farm)	Transformer 150/20 kV 30 MVA	2 pcs
	Neutral Grounding Resistor	2 pcs
	Switchyard	1 pc
	In/outgoing bays, coupler, busbars, Panel RCP	2 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.
- Compensation for the use of forest, assuming IDR 2 million /ha/year
- Insurances (e.g. machine breakdown insurance, third party liability)

2.9.2 Cost assumptions

In Table 18, 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 of this particular wind farm is compared to the global average (being in 2024 USD 1.3M / MW[20]) and to the other 7 locations.

Table 18. Cost assumptions per cost component.

Cost component	Baseline cost including VAT	Comment	Cost range
Preparation works	USD 2,525,000	DEVEX: Prior to Financial Close	90% - baseline -120%
Project management	USD 5,383,000	DEVEX: Until CoD	Baseline
Wind turbines	USD 47,384,000	CAPEX: Including transport and installation	90% - baseline -120%
Civil works: foundations	USD 6,812,000	CAPEX	80% - baseline -150%

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

Cost component	Baseline cost including VAT	Comment	Cost range
Civil works: roads	USD 12,945,000	CAPEX	80% - baseline -150%
Civil works: crane hardstands	USD 1,885,000	CAPEX	80% - baseline -150%
Electrical works	USD 21,021,000	CAPEX	90% - baseline -120%
Land acquisition	USD 15,095,000	CAPEX	90% - baseline -150%
Risk contingencies	USD 8,613,000	DEVEX + CAPEX	Baseline
Lower bound total investment cost (DEVEX + CAPEX)	**USD 108,732,000**	**Investment cost per MW: USD 1,599,000**	
Baseline total investment cost (DEVEX + CAPEX)	**USD 121,663,000**	**Investment cost per MW: USD 1,789,000**	
Upper bound total investment cost (DEVEX + CAPEX)	**USD 154,218,000**	**Investment cost per MW: USD 2,268,000**	
Baseline operational expenditure (OPEX)	**USD 2,093,000 / year**	**Operational cost per MW / year: USD 31,000**	

2.9.3 Financial parameters

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

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

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

- In the PPA, no Annual Contracted Energy (ACE) applies.

2.9.4 Results of business case assessment

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

Table 19. 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	16.08%	13.75%	9.48%
Average Debt Service Coverage Ratio (DSCR) at P90	1.09	0.99	0.81
Net profit at P50 over 25 years	USD 150,155,000	USD 134,675,000	USD 95,760,000

3 Conclusion and Recommendations

Based on the conducted analyses and available data, it is concluded that the overall techno-economic viability of a wind farm in Probolinggo – Lumajang could be promising based on the IRR and DSCR outcome. The average wind speed of 7.2 m/s (although to be validated with wind measurements) is a significant contributor to the potentially promising business case. However, optimizations can be sought to further enhance the business case for this project. Specific components drive up the investment cost significantly. The strengthening of 6 bridges is a major cost factor (+/- 3.5% of the investment cost) for this wind farm. Also, the cost for constructing new roads, road upgrades, and railway tracks are significant (+/- 8% of the investment cost). In a follow up study, the aim should be to find cost savings for this cost (see specific recommendations under *Transport*).

Aside from potential cost optimization, the envisioned wind farm also entails risks that should be considered by the developer and investor. This can be summarized in the following non-limitative risk list, including the respective recommendation of mitigating measures:

- **Wind resource:** There is still significant uncertainty on the wind resource in the area as determined by this study. The variety in outcome between the different models shows that validation of the wind resource early in the development process is vital. We recommend placing at least two met masts for data gathering for at least one year to cover both the northern and southern part of the wind farm (see Figure 46). The background of the figure is the wind speeds 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.

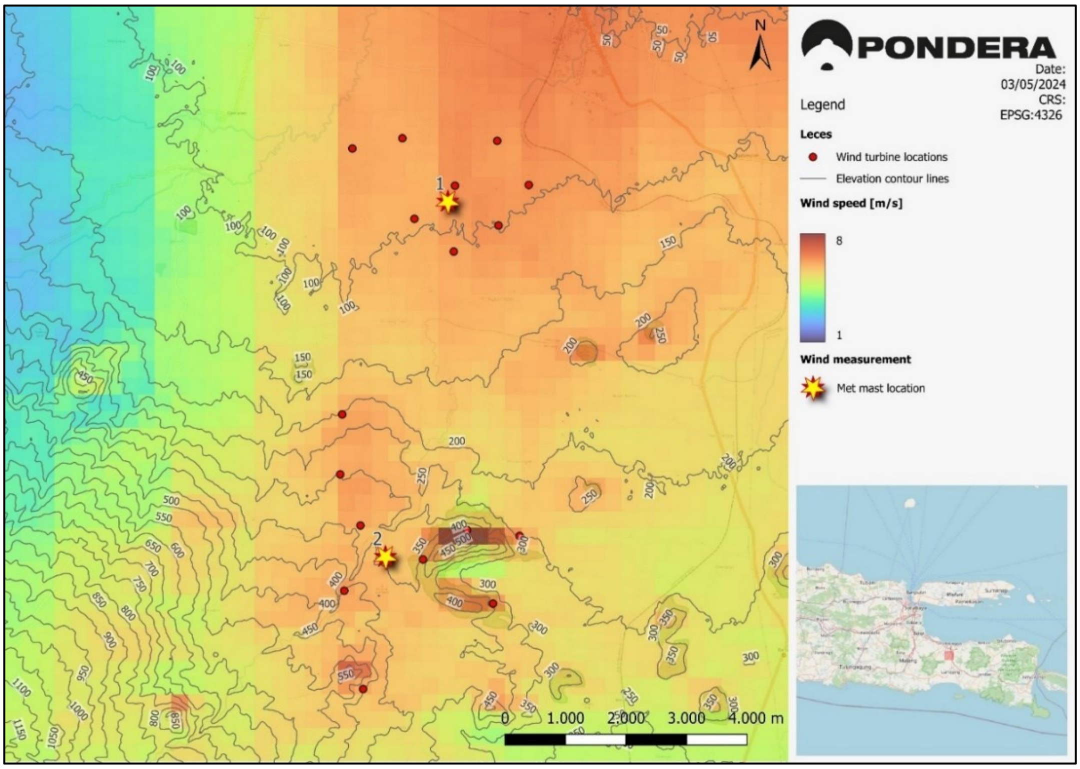

Figure 46. Recommended met mast and LIDAR locations.

- **Land use and permitting:** As can be derived from Figure 36 and Subsection 2.2.5, the wind farm is planned in a 50/50 mix of production forest area and plantation 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 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. Also, the crossing of the railway track on two locations requires further investigation on the required adjustments and alignment with KAI (Indonesian Railway Company). Finally, optimization should be sought to lower the cost for strengthening of the 8 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.
  Also, during the feasibility stage, the risk of liquefaction should be looked into in further detail by examining the soil characteristics and local hydrogeology.

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

- **Grid connection and PPA:** The wind farm is designed to be connected to the PLN grid. This assumes that the grid can integrate 68 MW of wind energy (with variable output), and that the substation in Probolinggo is suitable to facilitate the wind farm's grid connection. These assumptions should be verified during the feasibility study. Additionally, the current result of business case assessment is based on the assumption that the PPA uses the ceiling electricity tariff as stipulated in Presidential Regulation 112/2022, and that no Annual Contracted Energy (ACE) is applied. The actual PPA conditions depend on PLN and on how the tender process is set-up. An early alignment with PLN on these PPA conditions and tender process set-up is recommended.

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

4 Disclaimer

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

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

UNOPS

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