REPORT

Wind Energy Development Prospectus:
312 MW Project in North Padang Lawas – South Tapanuli, North Sumatra

2024

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

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1 Introduction of the Wind Farm Prospectus

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

Eight potential wind farm locations on Java and Sumatra have been assessed on their techno-economic viability. These locations are Aceh Besar (Aceh), Dairi (North Sumatra), Gunung Kidul (DI Yogyakarta), Kediri (East Java), North Padang Lawas – South Tapanuli (North Sumatra), Ponorogo (East Java), Probolinggo – Lumajang (East Java), and Ciracap (West Java). Findings from the study are consolidated in a wind farm prospectus per location, of which the underlying document is regarding North Padang Lawas – South Tapanuli 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 North Padang Lawas – South Tapanuli Wind Farm, North Sumatra – 312 MW

2.1 Introduction of the wind farm location

This section introduces the wind farm location, i.e. North Sumatra (North Padang Lawas – South Tapanuli) in three parts: (1) geographic location, (2) status in RUPTL, and (3) status of development.

2.1.1 Geographic location

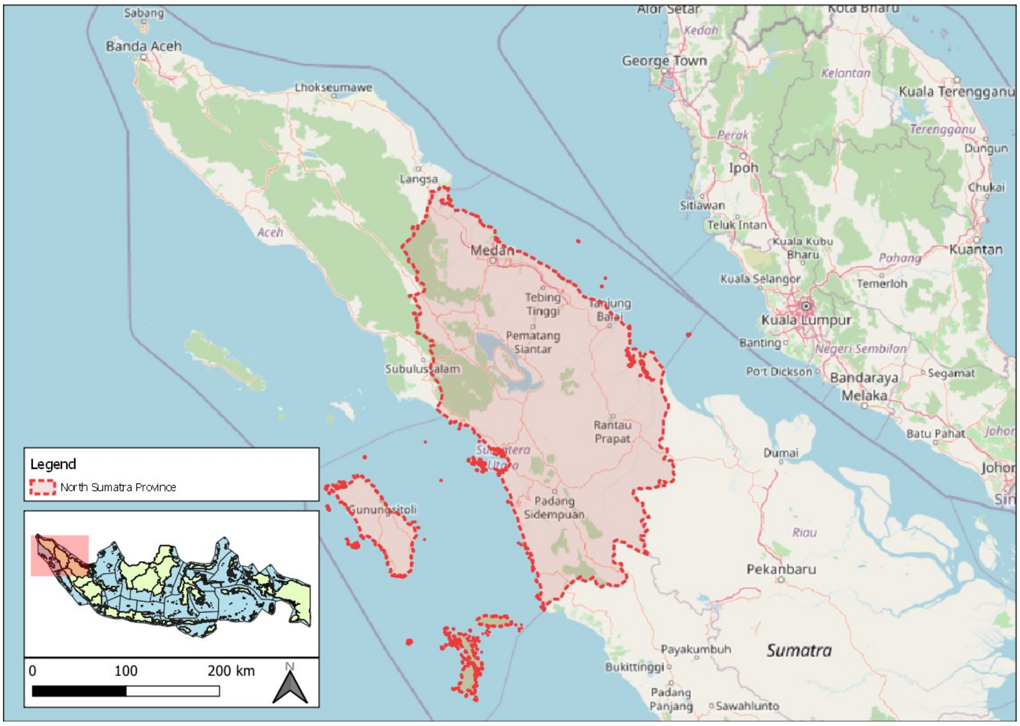

Figure 1. A map of North Sumatra province in which the envisioned North Padang Lawas – South Tapanuli wind farm area is located.

As shown in Figure 1, North Sumatra is a province situated close to northwestern tip of Sumatera Island, which is in the western part of Indonesia. There are three neighboring provinces of North Sumatra, namely, DI Aceh, Riau, and West Sumatra. Covering an area of 72,981 km^2, North Sumatra is inhabited by approximately 15.1 million people in 2022[1], making it the fourth most populous province in Indonesia. GDP per capita of this province is IDR 63.19 million, ranked 14th among all provinces in the country[2]. Furthermore, the province's economic growth is 5.01% in 2023 (c-to-c)[3]. To provide context, Indonesia's economic growth in that year is 5.05% (c-to-c)[4].

[1] https://sumut.bps.go.id/statictable/2023/03/10/2929/jumlah-penduduk-menurut-jenis-kelamin-rasio-jenis-kelamin-dan-kabupaten-kota-jiwa-2022.html
[2] https://www.statista.com/statistics/1423411/indonesia-per-capita-gdp-at-current-prices-of-provinces/
[3] https://sumut.bps.go.id/pressrelease/2024/02/05/1212/ekonomi-sumatera-utara-tahun-2023-tumbuh-sebesar-5-01-persen--c-to-c-.html
[4] https://www.bps.go.id/en/pressrelease/2024/02/05/2379/indonesias-gdp-growth-rate-in-q4-2023-was-5-04-percent--y-on-y-.html

North Sumatra is known, among others, for its ecotourism, agriculture, and industry. One of its famous tourist destinations is Lake Toba, an enormous natural crater lake with a large island (i.e. Samosir Island) within its center. Meanwhile, major agricultural products of North Sumatra include coffee, rubber, and palm oil.

There are two industrial estates in North Sumatra[5], namely, Medan Industrial Estate (1,000 ha) and Medan Star Industrial Estate (103 ha). Another industrial estate, Kuala Tanjung Industrial Estate (3,400 ha), is still in development. Strategically located in the Malacca Strait, this estate will be in the vicinity of the Kuala Tanjung Port, which was envisioned to become an international hub for the west part of Indonesia[6]. Goods to be produced on the estate include, among others, palm oil, steel, aluminum, cement, food, and rubber products.

Meanwhile, there is one special economic zone (SEZ) in the province: Sei Mangkei SEZ (2,002 ha)[5]. Located in the southeast of Medan, this SEZ was inaugurated in 2015 to facilitate industrial activities producing international-quality palm oil and rubber[7].

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

1. Sei Mangkei SEZ (23.28 MW by 2025[8])
2. Kuala Tanjung Industrial Estate (18 MVA in 2022)
3. Lake Toba Super Priority Tourism Destination (25.87 MW[9])

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

The envisioned wind farm location is spread across two neighboring regencies: North Padang Lawas Regency and South Tapanuli Regency. Thus, the name "North Padang Lawas – South Tapanuli wind farm" is used in this report.

2.1.2 Status in RUPTL PLN 2021-2030

Figure 2 portrays the electricity system of North Sumatra. The system consists of the main island (150 kV and 275 kV transmission line) and Nias Island (70 kV transmission line). According to RUPTL PLN 2021-2030, the peak load of this province in 2020 is 1,883 MW. The level of energy production and peak load in 2021-2030 is projected to increase steadily as shown in Figure 3. This projection is based on the assumption that the average demand growth rate will be 5.5% per year.

[5] https://regionalinvestment.bkpm.go.id/pir/kawasan-industri-kek/
[6] https://northsumatrainvest.id/en/investment-project/kuala-tanjung-industrial-estate
[7] https://www.seimangkeisez.com/en/
[8] https://web.pln.co.id/cms/media/siaran-pers/2022/05/siap-sambut-investor-pln-perkuat-keandalan-kelistrikan-di-kek-sei-mangkei/
[9] https://web.pln.co.id/cms/media/siaran-pers/2022/12/pakai-rec-pln-danau-toba-jadi-destinasi-pariwisata-berbasis-energi-hijau-pertama-di-indonesia/

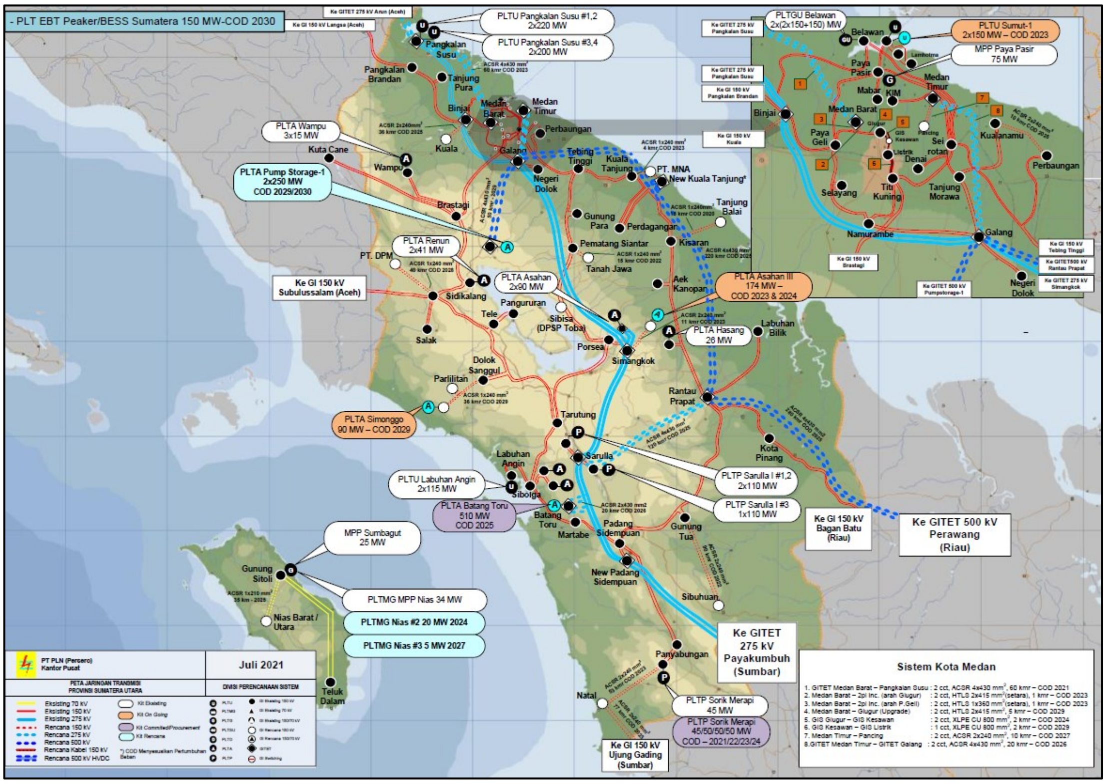

Figure 2. A map of North Sumatra electricity system in RUPTL (Source: RUPTL PLN 2021-2030)

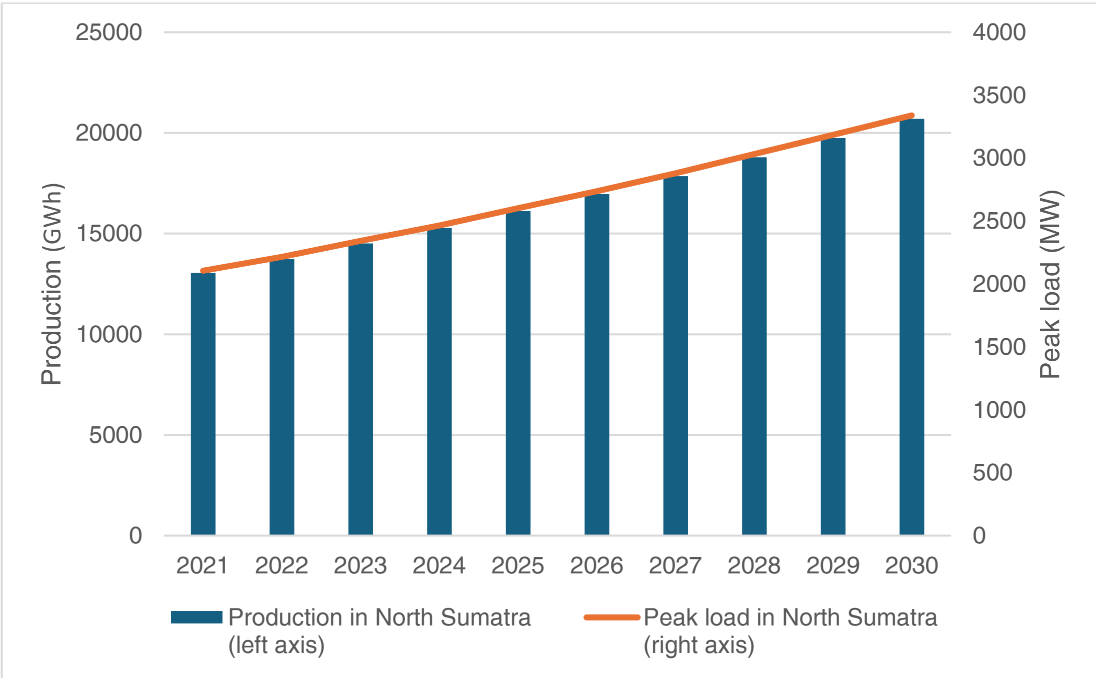

Figure 3. Projected electricity production and peak load in North Sumatra (Source: RUPTL PLN 2021-2030).

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 three sources, namely, PLN, Independent Power Producer (IPP), and *Wilayah Usaha* cooperation. Moreover, wind energy development is only allocated 55 MW each for 2024 and 2025, totaling 110 MW. It is noteworthy that the allocation is applicable for the whole Sumatra system (including other provinces). On top of this allocation, the RUPTL also identifies 88 MW of wind power potential in North Sumatra.

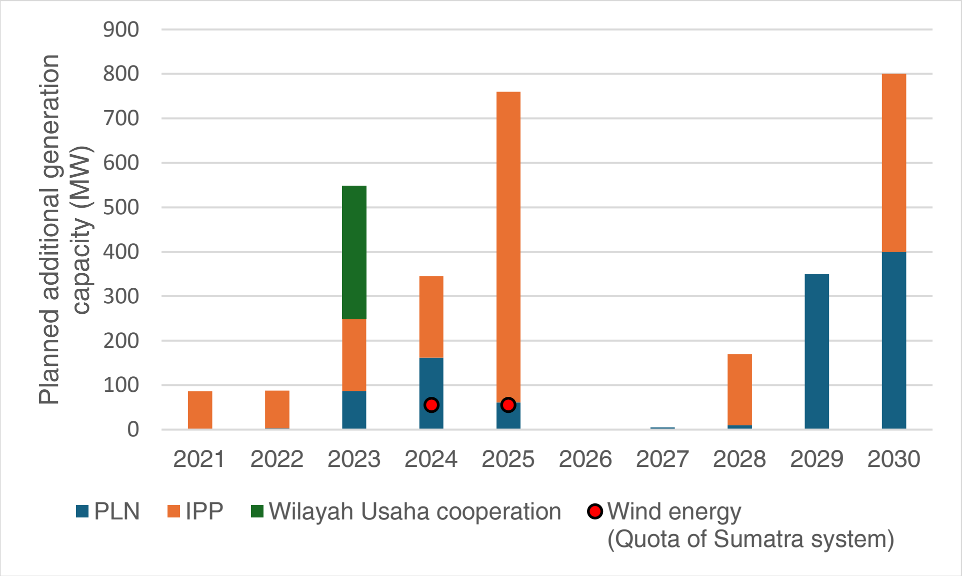

Figure 4. Additional generation capacity being planned for North Sumatra (IPP: Independent Power Producer; Source: RUPTL PLN 2021-2030).

2.1.3 Status of development

To the best of our knowledge, there is no ongoing development for wind energy in North Sumatra. During the trade mission of the Kingdom of the Netherlands to North Sumatra in early 2022, a representative of the Provincial Energy and Mineral Resources Agency mentioned that the wind at the province has relatively unstable speeds with inconsistent direction as per the existing data. Hence, a feasibility study was needed to obtain deeper insights of the wind characteristics and potential.

2.2 Wind resource availability and land use

2.2.1 Approach

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

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

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

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

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

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

2.2.2 Wind resource and characteristics

Figure 5 shows the initial search area (bounded by the purple-dash box), near and within North Padang Lawas and South Tapanuli. Within the figure, areas with average wind speeds of more than 6 m/s are indicated by the "pixels" with distinct color as described by the color bar. It can be concluded that promising wind resources are located along multiple "strip-shaped" areas.

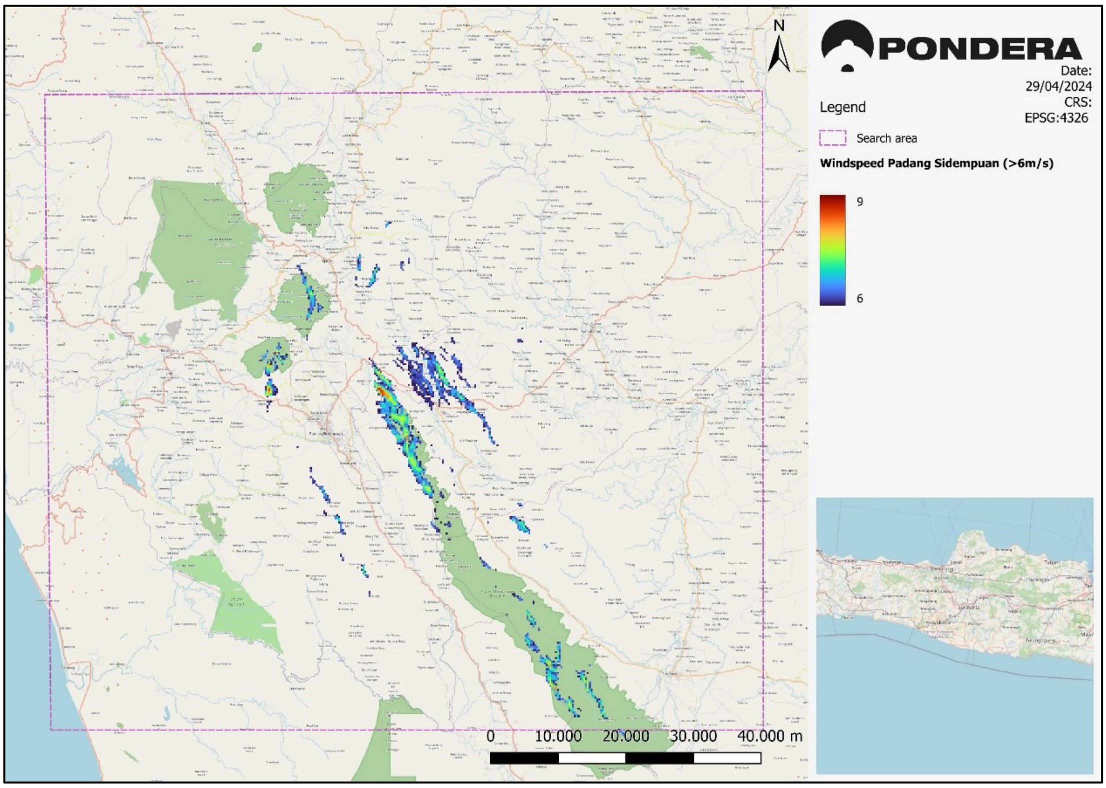

Figure 5. North Padang Lawas – South Tapanuli search area with wind speed distribution. The purple-dash bounding box shows the full search area. The color bar indicates average wind speeds which are above 6 m/s at 100 m height according to the Global Wind Atlas (GWA) climatology.

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.

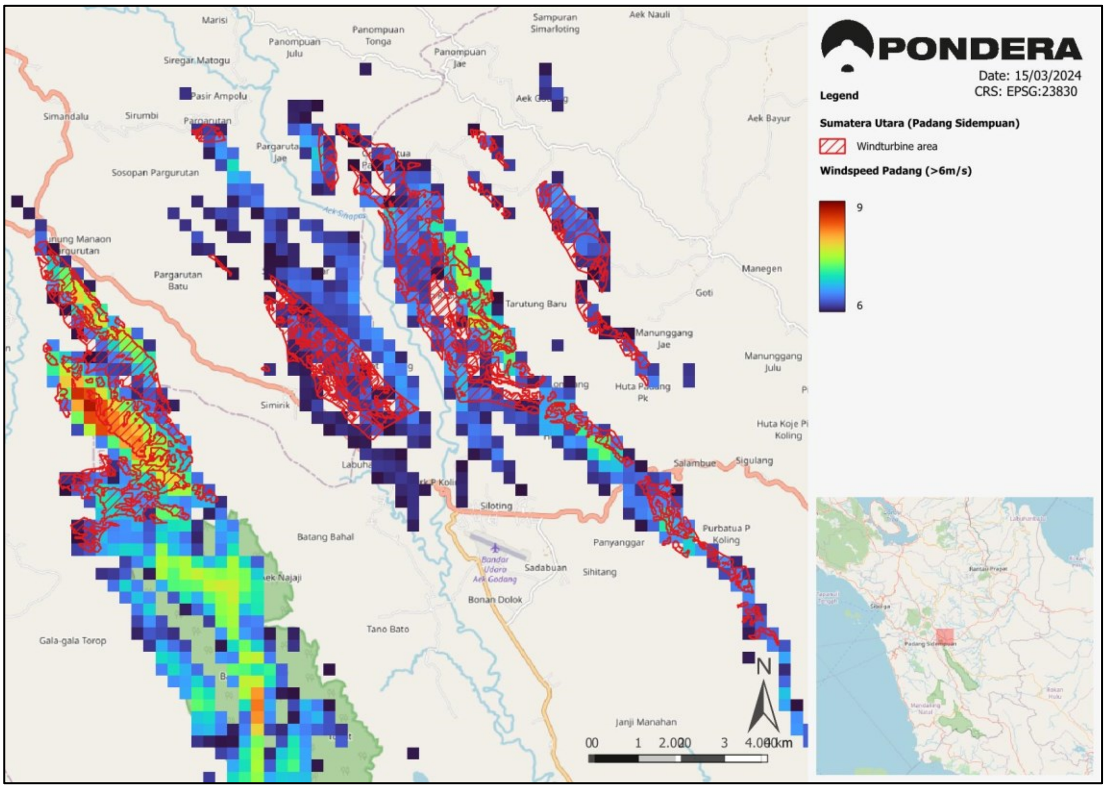

Figure 6. A zoomed-in look at the North Padang Lawas – South Tapanuli search area with the wind speed distribution. The red, dashed polygons represent the final WTG-area which meets all the criteria. Average wind speeds above the threshold of 6 m/s at 100 m height according to GWA are shown.

Additionally, Figure 7 visualizes the long-term average wind direction distribution for the North Padang Lawas – South Tapanuli area. As can be interpreted from this figure, the wind climate in the area primarily consists of wind from the western direction.

In Figure 8, the wind speed distribution throughout the day for each month per year is visualized. The highest wind speeds are observed between May and October, when the intertropical convection zone (ITCZ), is positioned north of the site. Therefore, this period can also be distinguished from the other months by the prevailing western wind directions. Approximately from November until April (though the timing can vary from year to year), when the ITCZ is passing over the site towards the south, the lowest wind speeds are observed. As expected, during these months most of the eastern and northeastern winds are observed. Besides the annual wind speed and direction patterns, which strongly depend on the positioning of the ITCZ, interannual variations are caused by the El Niño and La Niña phenomena. During a strong El Niño year, the trade winds are weaker, while during a La Niña year, they are strengthened, resulting in higher wind speeds over the area.

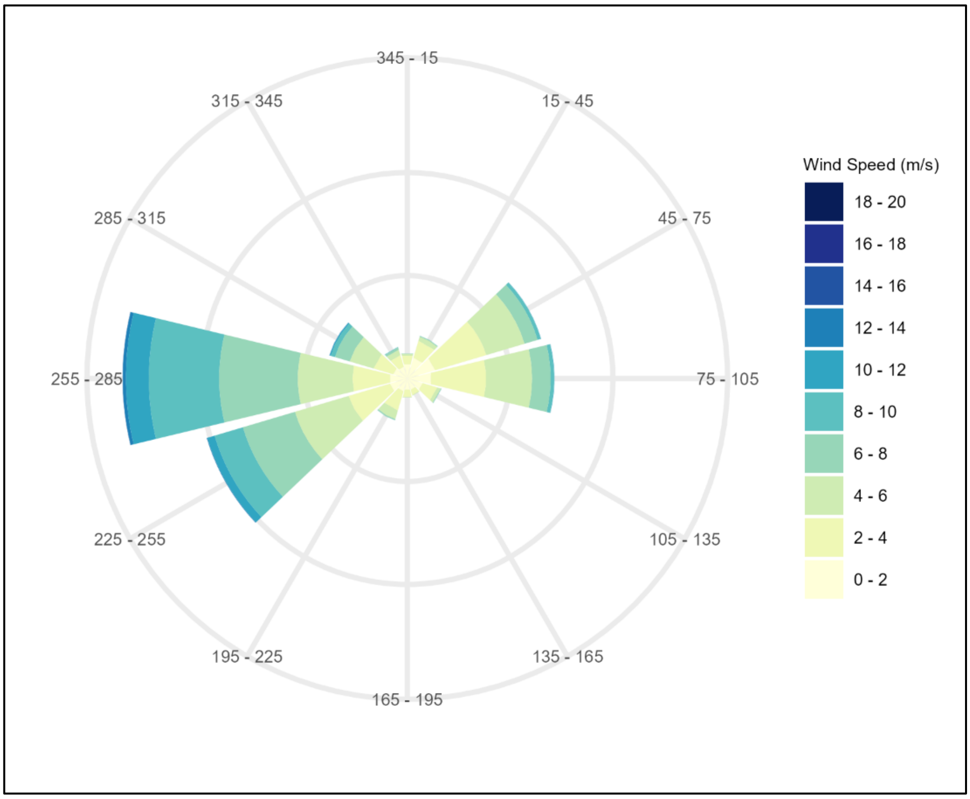

Figure 7. Wind rose diagram with wind directions and wind speed categories based on a 10-year climatology, including the 2004-2015 time series of hourly data. Source: EMD-WRF.

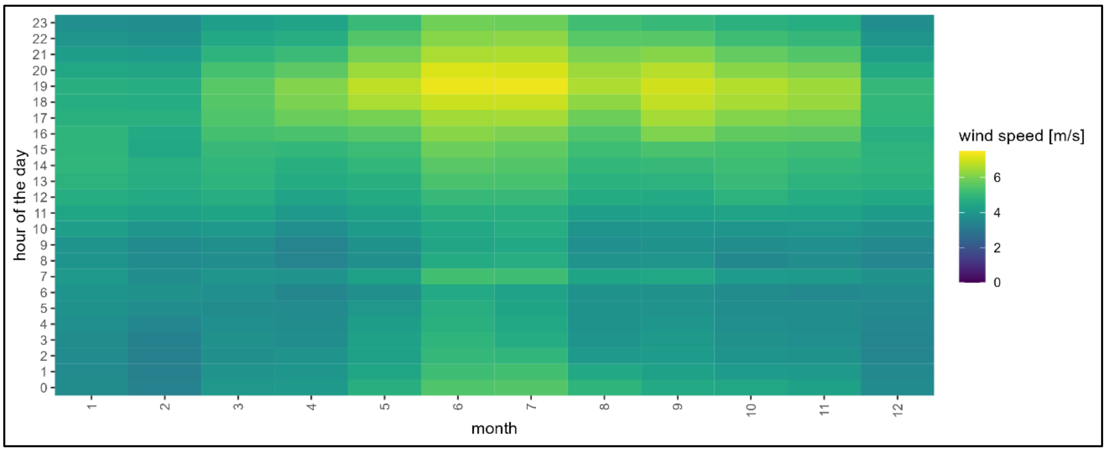

Figure 8. The wind speed distribution throughout the day, visualized per month of the year. Based on a 10-year climatology, including the 2004-2015 time series of hourly data. Source: EMD-WRF.

2.2.3 Topography

The WTG area is located 40 to 70 km from the southwest coast of Sumatra. This region is characterized by hilly terrain (400-800 m above MSL), and the hills are oriented in northwestern to southeastern direction. The topography is heavily influenced by the presence of a geological fault system (see Section 2.5) which cuts through the entire length of the island (northwest to southeast direction). Several individual faults from this system are present within the area.
Some of them can be recognized by deep valleys as this weak spot in the ground enabling the rivers to erode easily into the terrain. The geological faults in the area are also the reason that many different rock types are present on the surface. This causes a variety in topography, landscapes and land use within the site.

Figure 9 shows the topography of the search area in the North Padang Lawas – South Tapanuli 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.

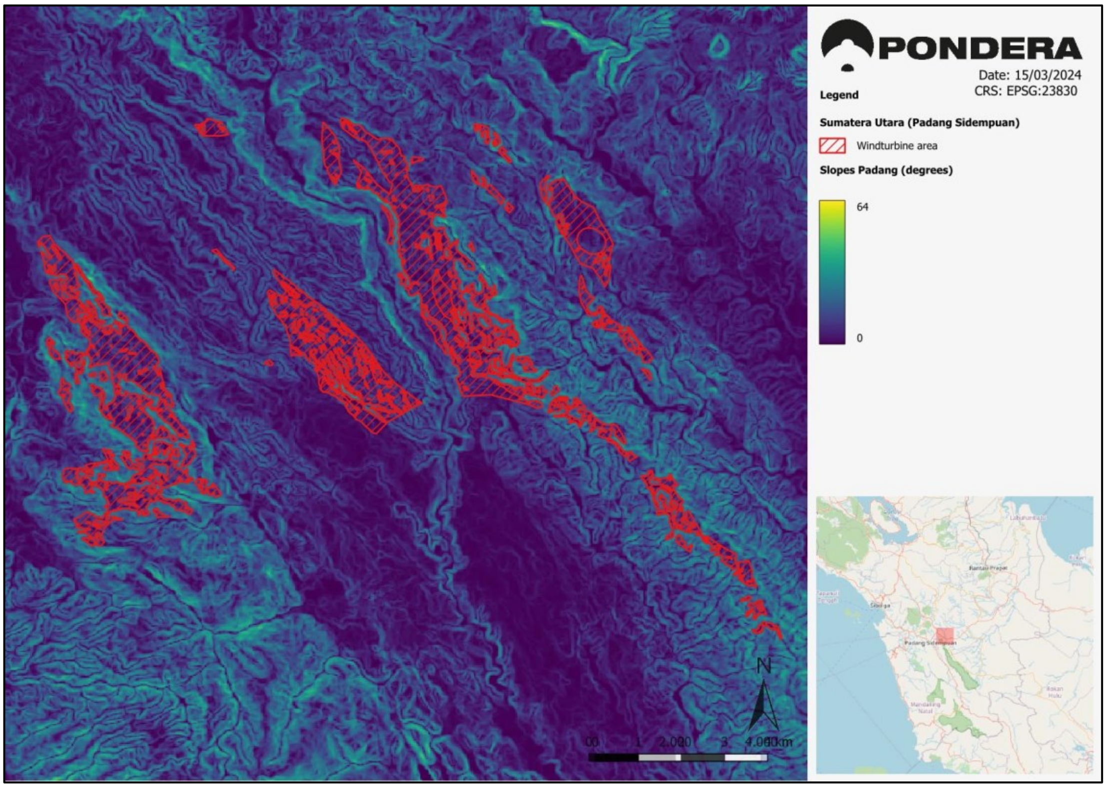

Figure 9. Topography of the North Padang Lawas – South Tapanuli WTG-area, showing the slope (in degrees; according to calculated based on FABDEM data) at the region.

2.2.4 Land use

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

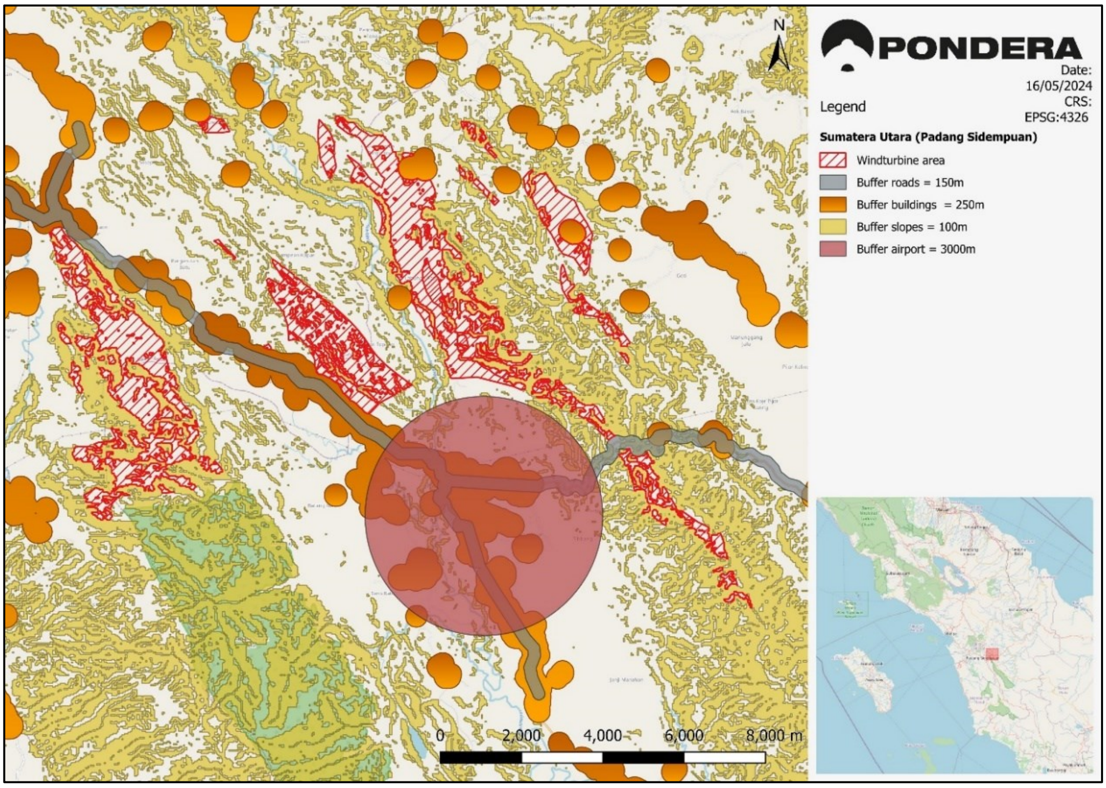

Figure 10. Exclusion zones at the North Padang Lawas – South Tapanuli area based on land use, topography, and residential areas. Source: calculation based on FABDEM elevation, ESRI, and OSM.

2.2.5 Specific permitting requirements

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

North Padang Lawas Regency

The overlay between North Padang Lawas Spatial Plan (*Rencana Tata Ruang Wilayah* or RTRW) 2015-2035 and the WTG area in this regency is shown in Figure 11. As inferred by the figure, the WTG area intersects with four types of land use, which are:

1. Fixed Production Forest Area (*Kawasan Hutan Produksi Tetap*/HTP)
2. Non-Forest Estate Area (*Area Penggunaan Lain*/APL)
3. Limited Production Forest Area (*Kawasan Hutan Produksi Terbatas*/HPT)
4. Dryland Farming/Agricultural Area (*Kawasan Peruntukan Pertanian Lahan Kering*)

Figure 11. The map of spatial plan of North Padang Lawas Regency (RTRW 2015-2035) overlaid with the final WTG-area in the regency. Due to the poor image quality of the RTRW, the analysis has been crosschecked using the regency-level and provincial-level RTRW from GISTARU portal of MoEF.

Spatial plan analysis was also done using the more recent North Sumatra Spatial Plan (RTRW) 2017-2037. According to the regulations, the regency-level RTRW should (eventually) be adjusted to ensure alignment with the province-level RTRW. Therefore, the province-level RTRW can be used as an additional reference. Overlaying the final WTG-area with the province-level RTRW shows that a majority of the WTG-area is situated in Production Forest Area (*Kawasan Hutan Produksi*), whereas a small part of the area is located in Limited Production Forest Area (*Kawasan Hutan Produksi Terbatas*).

Areas within the Production Forest Area, Fixed Production Forest Area, and the Limited Production Forest Area can be used for wind power generation according to Government Regulation 23/2021, given that the user obtains 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). This permit is issued by the Ministry of Environment and Forestry (MoEF), and thus, future wind farm developers must apply for this permit. Furthermore, 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. These costs have been taken into account in the business calculation made in Section 2.9.

On the other hand, areas within the Non-Forest Estate Area and Dryland Farming/Agricultural Area[10] can be utilized for wind power generation (and other types of power generation and transmission activities for public interest) if a purchase or lease agreement is obtained. In this study, it was not possible to determine the owner of WTG area within these two categories. It could be the case that a Non-Forest Estate Area is owned by the community if the commodity consists of several types of plants. Conversely, the area may be owned by a private or state-owned company if there is only a single type of plant cultivated in the area. Meanwhile, Dryland Farming/Agricultural Area is typically owned by the community.

As will be shown later in Section 2.3 (wind farm layout), the envisioned wind turbine location within the final WTG-area is mostly situated in Production Forest Area and Limited Production Forest Area. Therefore, these two land use categories will be considered in the business case calculation (see Section 2.9).

It is important to note that the obtained RTRW of North Padang Lawas Regency is for the year 2015-2035 and sourced from GISTARU website. 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 North Padang Lawas 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 RTRW is still valid.

North Padang Lawas Regency also hosts Aek Godang Airport, which is categorized as a Class III Airport. According to the air transport authorities, this airport serves one domestic flight per day (using a short-haul regional airliner) from Kualanamu Airport[11]. The airport's location is around 3-5 km away from the WTG area. Given this proximity, a thorough check with the airport authority will be needed on whether flight navigation at the airport could be disrupted by the presence of the envisioned wind farm.

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

[11] https://lpse.dephub.go.id/eproc4/dl/bbd4a96037a2f85a77ca213a282fb7bcf8ac78cb378a682d0fda0512c2037ccc4ad9b1601c84a24bb9d252c6c27d23d6d33fbc9bd4d3f4466185e5897ec71def81ccaa421a6f971b3e55950463395cd249d7042d8d05d30aed0f26b8777f887e#:~:text=Kantor%20Unit%20Penyelenggara%20Bandar%20Udara,Sumber%20Daya%20Manusia%20Kantor%20Unit

South Tapanuli Regency

Analysis of permitting requirements for this regency was done based on South Tapanuli Regency Spatial Plan (RTRW) 2017-2037. Overlaying the spatial plan against the WTG area results in the map shown in Figure 12. This figure suggests that the WTG area is located in:

1. Dryland Farming/Agricultural Area (*Kawasan Peruntukan Pertanian Lahan Kering*)
2. Small River Border Area (*Kawasan Sempadan Sungai Kecil*)
3. Fixed Production Forest Area (*Kawasan Hutan Produksi Tetap*/HTP)
4. Wetland Farming/Agricultural Area (*Kawasan Peruntukan Pertanian Lahan Basah*)

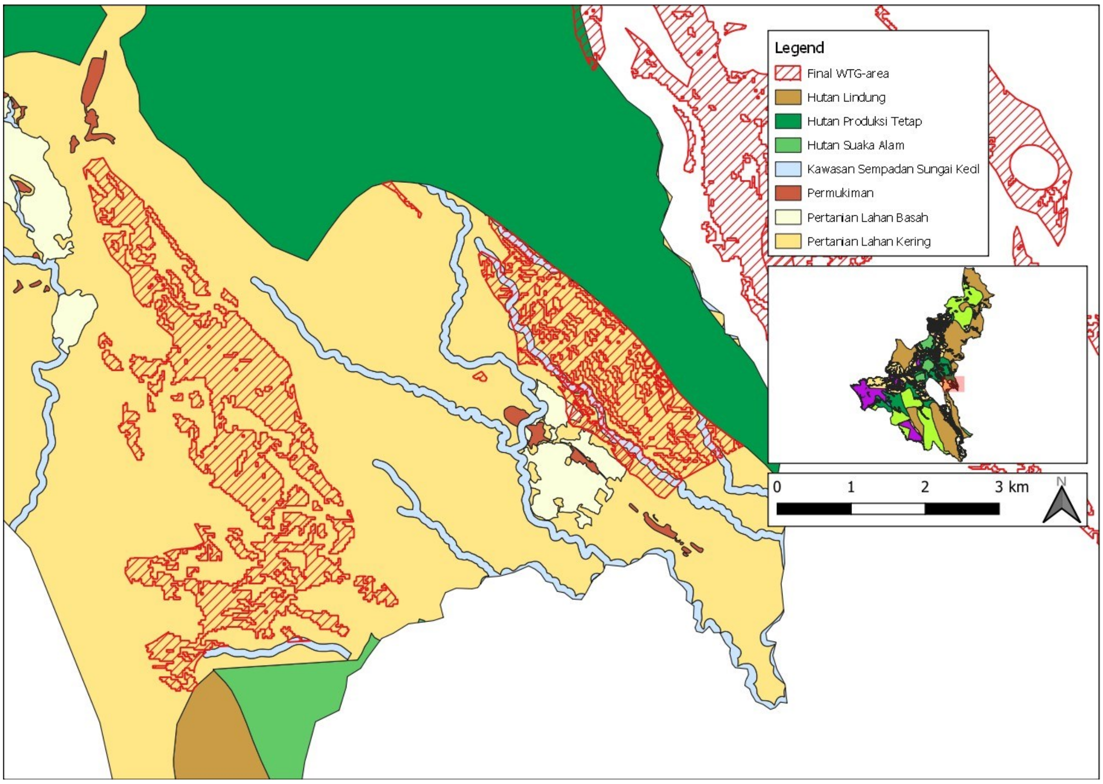

Figure 12. The map of spatial plan of South Tapanuli Regency (RTRW 2017-2037) overlaid with the final WTG-area in the regency.

In this regency, a majority of the WTG area overlaps with Dryland Farming/Agricultural Area, which can be used for wind power generation (and other types of power generation and transmission activities for public interest) if a purchase or lease agreement is obtained[10]. Ownership of this piece of land is also not yet known for this study. Therefore, it is reasonable to assume that the land is either owned by the community, private companies, or state-owned companies. An agreement shall be struck with these parties to enable wind farm development in the area. A similar agreement can be expected for the area overlapping with Wetland Farming/Agricultural Area[10].

The final WTG-area also coincides with the Small River Border Area, and therefore, the placement of individual wind turbines should consider this land use area. Moreover, as mentioned above, final WTG-area located in Fixed Production Forest Area can be utilized for wind power generation given that the user obtains 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), according to Government Regulation 23/2021. Hence, the same set of consequences (e.g. payment of compensation non-tax state income and rehabilitation planting) will apply.

As will be shown later in Section 2.3, locations of the envisioned wind turbines within the final WTG-area are mostly located in Dryland Farming/Agricultural Area. Consequently, this land use, in addition to the two found in North Padang Lawas Regency, will be incorporated in the business case calculation (see Section 2.9). Moreover, as with the previous regency, the RTRW analyzed here needs to be validated and confirmed with the competent agency in South Tapanuli Regency.

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.

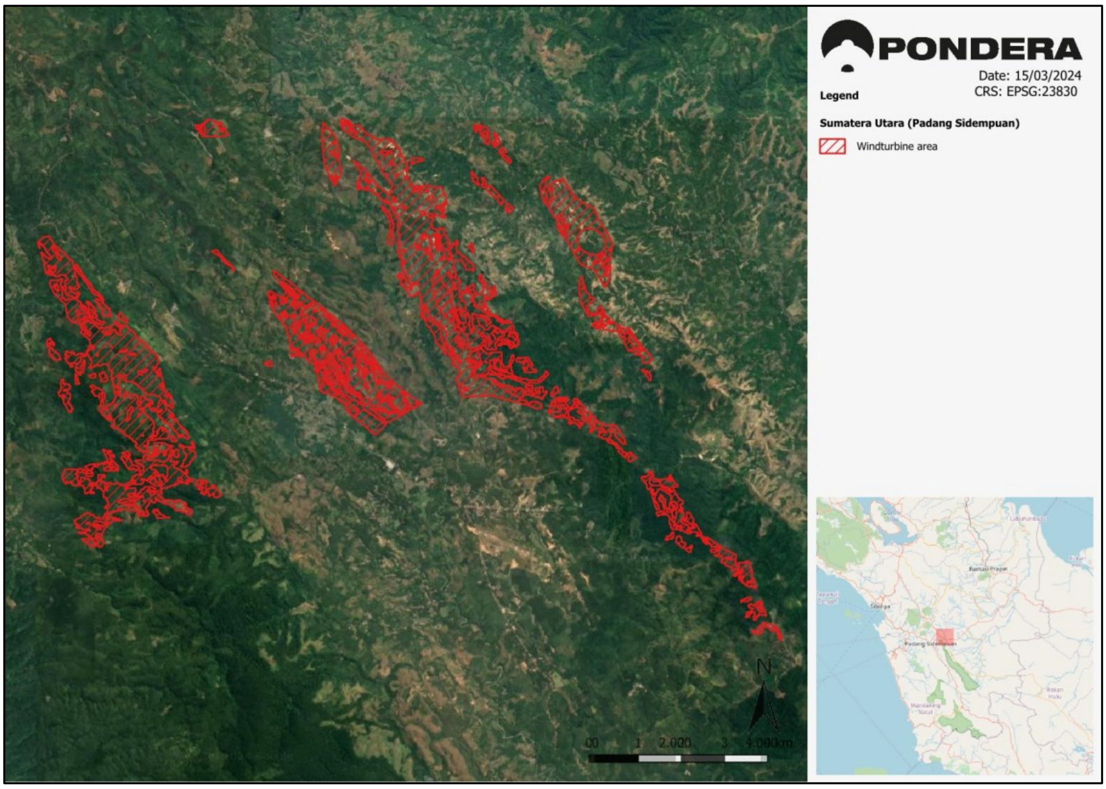

Figure 13. Final WTG-area based on the restriction criteria. Source: Google Satellite Images.

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

As the Indonesian wind climate generally consists of areas with lower to medium wind speeds, a wind turbine type that suits these wind conditions should be selected. For a provisional wind farm layout, a 4 MW reference wind turbine with a rotor diameter of almost 170 m and a hub height of 140 m has been used. This makes the total tip height around 220-225 m. To reduce the wake losses and possible negative turbulence influences, a standard distance of five times the rotor diameter was used in the preliminary wind farm layout.

During the positioning of the turbines, additional visual checks were performed based on satellite images, taking into account: 1) power lines, 2) buildings, 3) size of the area, with a minimum of three turbines in proximity, 4) accessibility of the area relative to other parts of the WTG-area, 5) minimization of the restriction criteria, 6) selection of the highest wind speed areas and 7) fulfillment of the installed capacity goals as stipulated in RUPTL PLN 2021-2030.

Figure 14 displays an overview of the wind turbine locations in the final WTG-area. A total of 78 wind turbines were positioned into the area, amounting to an envisioned total installed capacity of 312 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.

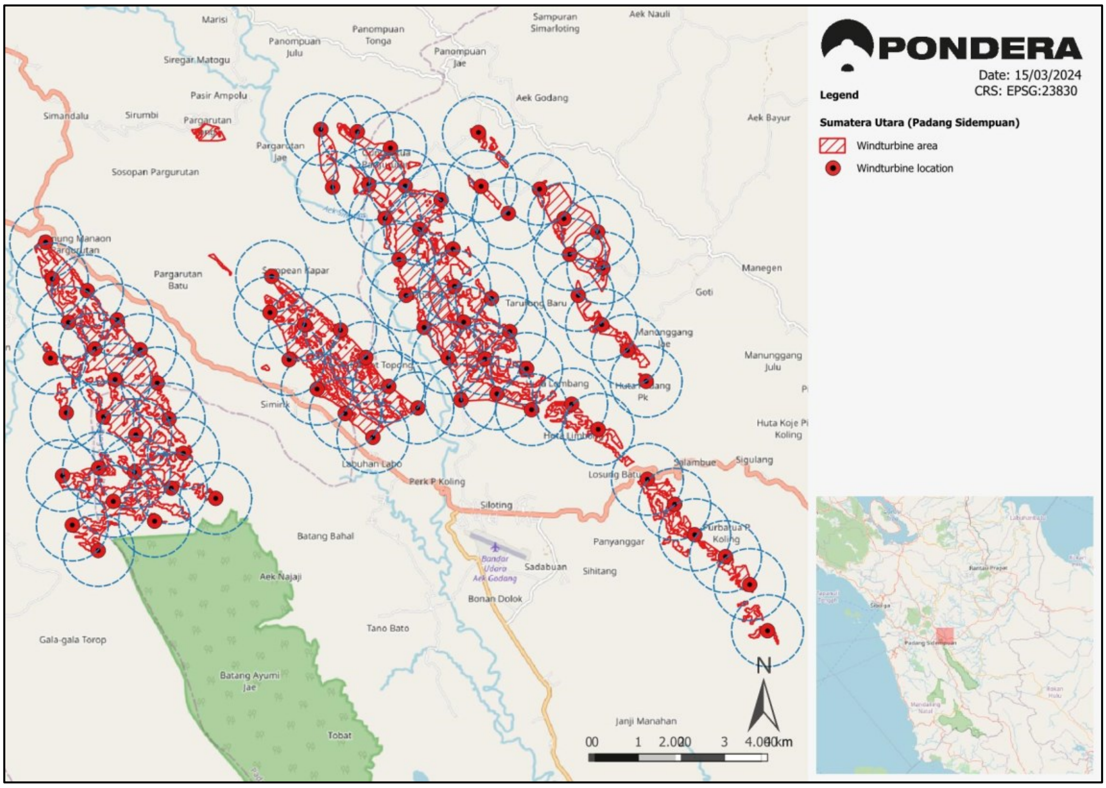

Figure 14. Preliminary wind farm layout at the final WTG-area.

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. 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 a more densely populated and flatter terrain.


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.

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

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

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

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

2.4.2 Port-to-site transportation

There are two ports being considered to facilitate the transport of wind turbines to the North Padang Lawas – South Tapanuli WTG-area. Port of Sibolga is the nearest medium-sized port in the area, at a distance of ~100 km from the WTG-area in the northwest direction. Meanwhile, the largest available port is situated in Dumai (Riau Province), 300 km from the WTG-area in the northeast direction.

Figure 16. Location and access from the Port of Sibolga (northwest of WTG-area/turbines) and the Port of Dumai (northeast of WTG-area/turbines) to the North Padang Lawas – South Tapanuli WTG-area

Port of Sibolga to site

During the desk study, it was assumed that the closer-located Port of Sibolga could be used. However, during the site visit, numerous smaller and bigger obstacles were observed near the port and on the road to the site.

Four locations are in particular problematic:

1. <u>Exit from Port of Sibolga to the main road</u>
   The port itself is probably sufficient for wind turbine transport. The port has a water depth of about 7 m (according to officials), an offloading platform of 150 x 30 m and one fixed crane. However, no special access roads are available to and from the port. All transport is done through the neighbouring residential area (see Figure 17 and Figure 18). Moreover, two 90-degree turns have to be taken within this area, with houses in close proximity.

Figure 17. A satellite image of Port of Sibolga showing the port being surrounded by a residential area, and two 90-degree turns must be made to enter the main road in southeastern direction.

Figure 18. Residential road just outside of the Port of Sibolga.

2. <u>Bridge of Batangoru (Jl. Merdeka / Jl. Balige intersection)</u>
This bridge has a ‘cage’ design (i.e. steel beams linking both sides on the top). Normally, this would not be a problem if the top is high enough and the road leading to the bridge are straight. However, on the Jl. Merdeka/Jl. Balige crossing, a 90-degree turn must be made directly after exiting the bridge (see Figure 19). This is probably not possible without changing the road layout and relocating buildings directly around this intersection.

Figure 19. The intersection directly after the Bridge of Batangoru will need to be redesigned as wind turbines will need to pass the bridge before they are able to turn

3. <u>Hairpins in Sialogo, South Tapanuli</u>
At the village of Sialogo in South Tapanuli Regency (see Figure 20), there is a steep drop in elevation. In the road, five hairpins (diameter 30-35 m) are constructed. As these turns are situated within a village, buildings are near the road and numerous electricity and telecommunication poles and cables are present.

Figure 20. Hairpins in a road in Sialogo, South Tapanuli due to the steep elevation drop

4. <u>General road layout</u>
   The route from Sibolga to the WTG-area leads through hilly and mountainous terrain. Numerous turns will have to be inspected if they are wide enough for wind turbine transport. It is expected that for large portions of these turns, at least the electricity and telecommunications poles will have to be temporarily removed or placed elsewhere. Because of the hilly terrain, numerous bridges are present over streams and some larger rivers. During the site visit, 63 bridges were counted between Sibolga and Aek Godang Airport, which is approximately 3.5-6.5 km from the WTG-area. Most of these bridges are between 5-15 m long and made from concrete. There are also a few steel bridges with a length between 20 to >100 m. At this stage, it is not yet known whether all these bridges can accommodate wind turbine transport.

According to local stakeholders, because of these reasons, all heavy transport in the region is done via the Port of Dumai. This port lies significantly further away from the WTG-area but leads mostly through flat terrain with straight roads. Therefore, the port of Sibolga has been excluded from further analysis for the transport of components of the wind farm.

Port of Dumai to site

As most of the heavy transport in the area uses the Port of Dumai, the road from the site to the lowland east of the search area (Sipoepoes, Padang Bujur Village) has been examined as well. Due to time constraints, the remaining road to Dumai has not been surveyed, but a desk study shows that the roads from Sipoepoes to Dumai feature significantly more straight sections and the road is of a more constant quality and width.

The road from Kota Pinang to the site passes several towns. In Gunung Tua, the road leads through the center of the town (see Figure 21). The main road takes a 90-degree turn. In this section, a redesign of the road might be necessary, as exemplified in Figure 21.

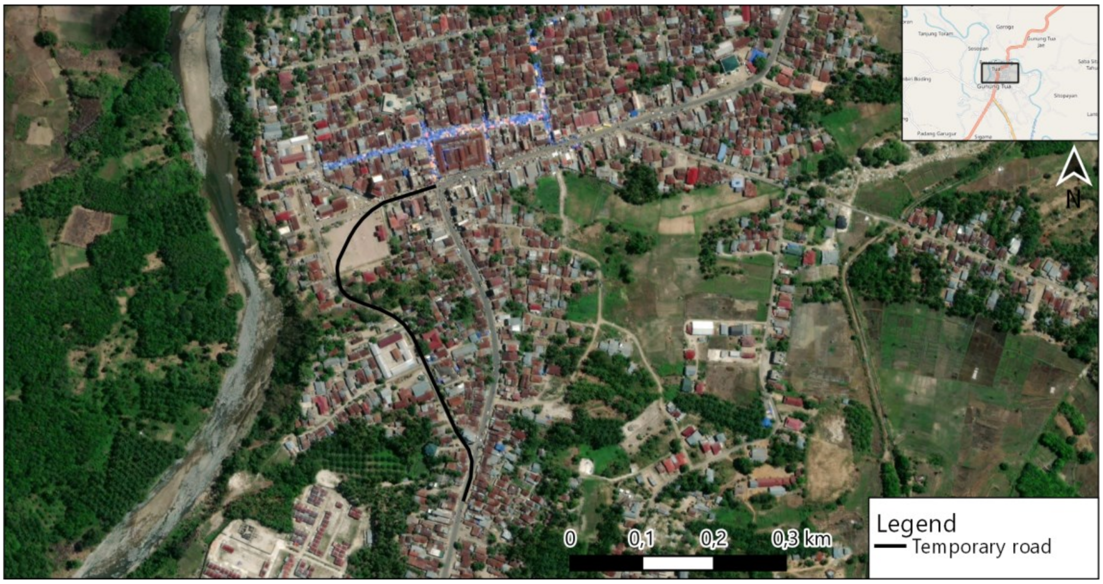

Figure 21. The black line represents a diversion from the main road; this uses mainly existing roads (~350 m), and 200 m of new temporary road over a square/parking lot.

From Dumai to Kota Pinang, several large bridges will have to be passed. The longest of these bridges (75- and 230-m length) are built in 2017-2019 right next to the old bridges and might not need strengthening. The main bridge close to Kota Pinang (Barumun, 180 m) was also built next to an old bridge, but it is unknown in which year the bridge was built. Other than these bridges, one concrete bridge on Jl. Soekarno Hatta, 3-km south of Dumai, is expected to need strengthening.

From Kota Pinang to the site, four bridges (three smaller concrete and one longer steel bridge) are present that might need strengthening. Figure 22 shows an example of concrete and steel bridge, respectively.

Figure 22. An example of a concrete bridge (left) and a steel bridge (right).

In terms of terrain, one larger obstacle has been observed, which is the elevation from west of Sipoepoes to the eastern access point of the envisioned WTG-area (see Figure 23). The road is in good condition, and based on satellite imagery, the radius of the two sharp turns is roughly 25 and 30 m (measured from middle of road). This is more than the minimum radius of 20 m, and thus, no major road reconstruction is expected. However, for a short section on the northern hairpin, a rock wall is present on both sides of the roads which may limit the amount of space (see Figure 24). The smaller outcrop may have to be removed.

Figure 23. The elevation from the west of Sipoepoes to the eastern access point of the envisioned WTG-area

Figure 24. Part of the northern hairpin features a rock wall on both sides; the smaller rock outcrop is estimated to be about 8 m high.

It is worth noting that a large-scale toll road construction program is currently underway (JTTS, *Jalan Tol Trans Sumatera*) in Sumatra. In 2024, the focus lies on the completion of Phase I and II (see Figure 25). Planning of later phases, including Section 8 Rantauprapat-Dumai, is not yet clear. This section is expected to be an important path from Port of Dumai to the WTG-area.

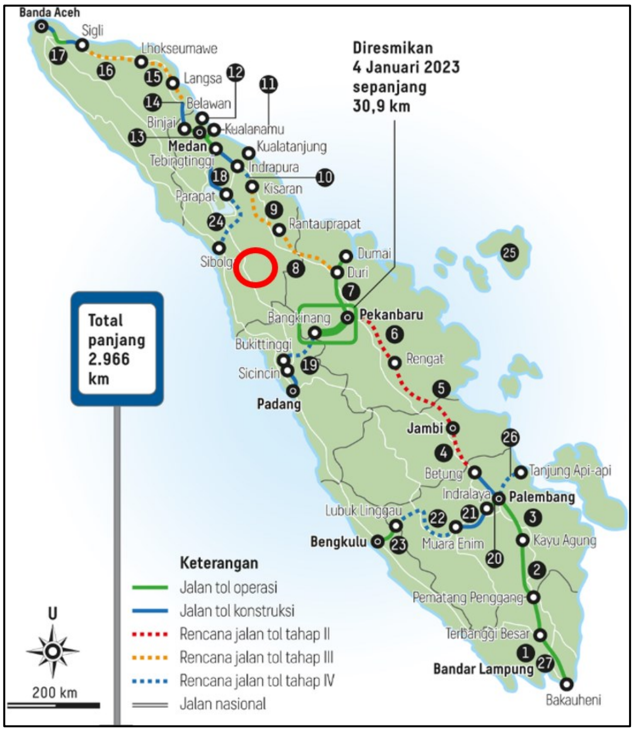

Figure 25. Status of highway construction on Sumatra. Dashed lines represent planned highways, with construction yet to be started. Section 8 could be used when it is finished before the envisioned wind farm construction starts at the WTG-area (red circle). Source: Kompas.com, published 5 April 2023.

Since the toll road construction started in 2014, a length of 884 km has already been completed as per February 2024. If construction of Section 8 is finished before the envisioned transport of wind turbines to the WTG-area, then the cost of transport may significantly be reduced as bridge strengthening or local changes in road layout between the port and site will not be necessary.

Assuming that the future construction of North Padang Lawas – South Tapanuli wind farm starts in 2028 with new access roads and foundations, transporting large turbine components will probably not start before 2029. It can be assumed that the toll road between Dumai and Kota Pinang/Rantauprapat will have been finished by then. Consequently, major bridge strengthening between Dumai and Kota Pinang are not taken into account in cost of EPC (engineering, procurement and construction).

2.4.3 Transport within the site

Within the site (WTG-area), a main road is available, linking the different sections of the wind farm over a length of 20 km. It is expected that no major reconstruction of this road is necessary. The exception to this might be the bridge over Aek Sihapas river, in the central part of the site. This river is located in a deep valley, 50 m below surrounding terrain. When wind turbines are placed on both sides of this valley, the individual parts will have to be transported through this valley regardless of whether the transport will happen from the Port of Sibolga or the Port of Dumai.

One crossing on the main road (about 1.5 km northwest of Aek Godang Airport) has both an old concrete bridge and a new steel bridge right next to each other (see Figure 26). The new steel bridge can probably take a heavier load but features steel beams on the sides and at the top.

Figure 26. A crossing near Aek Godang Airport features an old concrete bridge and a new steel bridge.

On both sides of the river, a 90-degree turn is present directly in front and after of the bridge (see Figure 27 and Figure 28), which makes crossing through the new bridge with long turbine components impossible, as the steel beams restrict any movement outside of the road profile. Aerial drone imagery of this location is not available as it is located within the no-fly zone of Aek Godang Airport.

Figure 27. Sharp turns on both sides of the river (photos taken with wide angle lens, which makes the situation more spacious than in reality).

Figure 28. Concrete and steel bridge over Aek Sihapas river, with sharp turns on both sides.

The terrain within the site is irregular (Subsection 2.2.3): some areas are mountainous and some hilly. For the internal road layout (see Figure 29), a distinction was made between new and upgradable roads in both mountainous and hilly terrain as shown in Figure 30. A total of 95 km of new and upgraded road is expected for this wind farm layout.

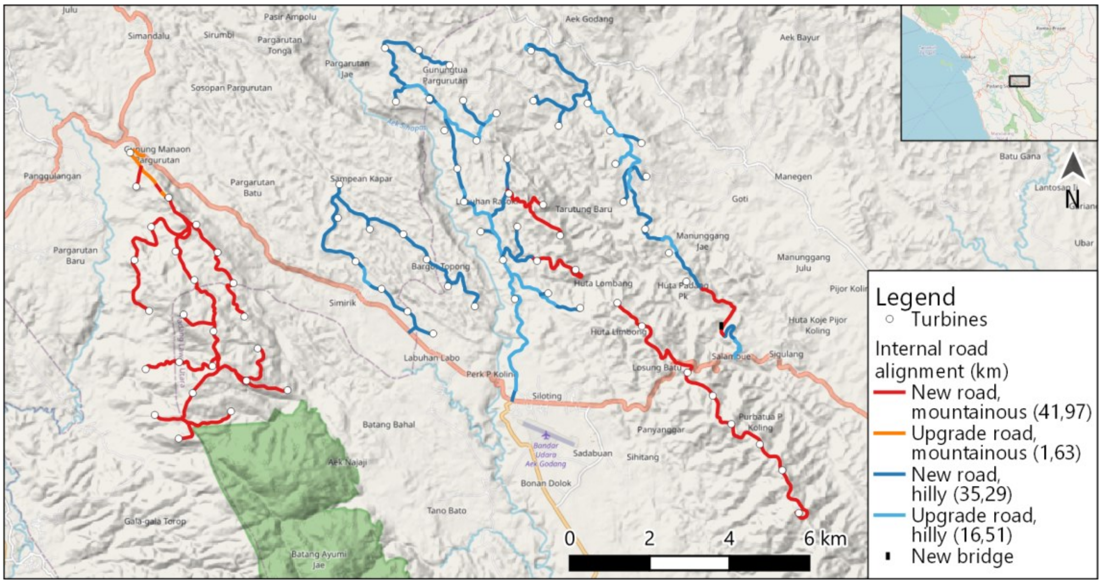

Figure 29. Internal road layout for the WTG-area.

Figure 30. A part of the upgradable internal road in hilly area (left); some parts are asphalted and mostly ~4 m wide (right). The road has to be widened, especially in the curved sections.

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

- Inquire about the planning of toll road construction between Dumai and Rantauprapat. When the toll road is available during wind turbine transport, transport to the site may be made considerably easier and less bridges will have to be strengthened.
- Check whether the use of the old bridge in combination with the nearby existing hairpin roads over Aek Sihapas is possible (~1.5 km northwest of Aek Godang Airport).

2.5 Geology and seismicity conditions

Near the site, the main faults from the ‘Great Sumatran Fault System’ divert in a set of smaller faults (see Subsection 2.5.2). Movement between these faults resulted in a high variety in rock formations on the surface within the site. This geology means that the terrain within the site varies from mountainous to hilly terrain. A deep valley cuts through the terrain, probably where one of the smaller faults is located as this is a weak spot in subsurface.

From a geology and therefore terrain perspective, the central hilly area is the most suitable for wind turbine construction. The steeper hills in the western and southeastern parts of the site are more challenging in terms of road construction and wind turbine transport. In these parts, special attention is necessary to find the most optimal road alignment, as the current road alignment is based on a publicly available height model (not high-resolution LiDAR data).

The next subsections will describe specifically the area’s geology and seismicity.

2.5.1 Geology

As shown in Figure 31, the subsurface consists of older formations from the Alas and Kuantan formations of (pre-)Trias age, surrounded by younger sediments and volcanics. The Kuantan formation mainly consists of black slates in varying grades of metamorphism in which sandstone and quartzite beds can occur. Within the Kuantan formation, a limestone member is present within the site area.

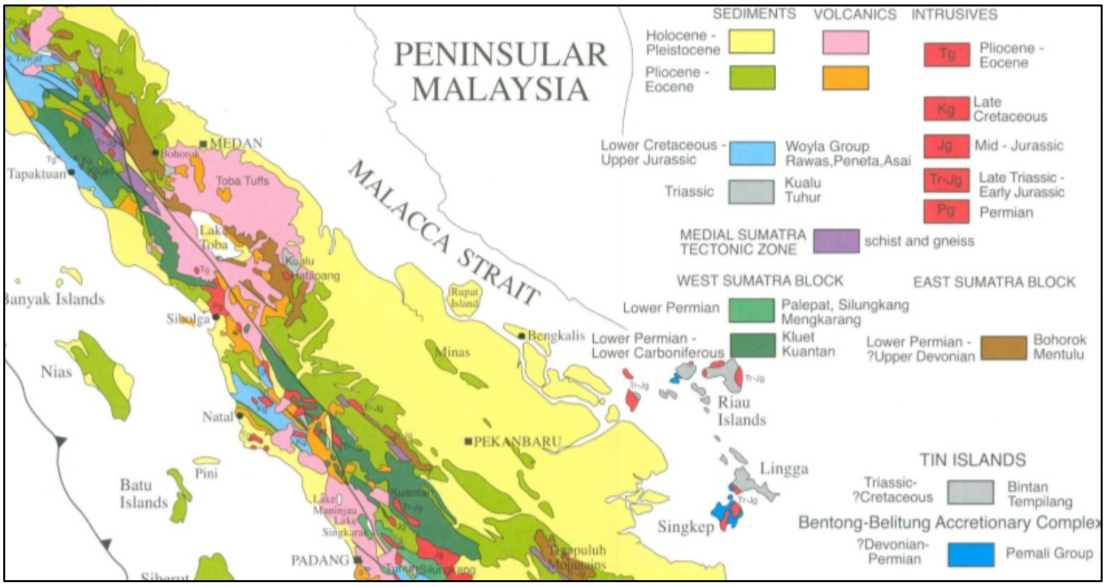

Figure 31. Geological map of the region, site in red (Barber, 2005).

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

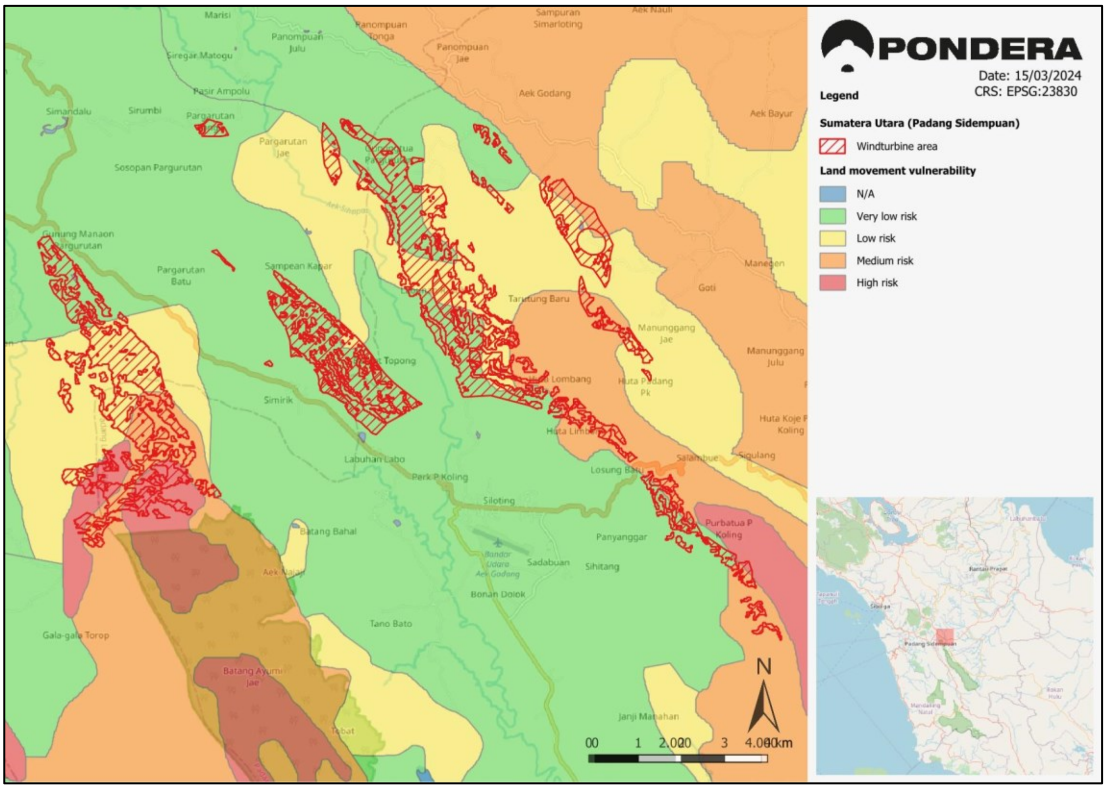

Figure 32. Land Movement Vulnerability Index for North Padang Lawas – South Tapanuli WTG-area (Source: Geological Disaster Mitigation Portal of the Ministry of Energy and Mineral Resources).

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

2.5.2 Seismicity

The site lies relatively close to the Great Sumatran Fault (see Figure 33). This is a collection of dextral faults running over the length of the island with a total length of ~1,900 km. The fault accommodates the movement between the oblique plate convergence between the Indo-Australian oceanic plate and overriding Sumatran-Eurasian continental plate. The slip rate (movement) is estimated to be 14-15 mm/year. This movement is not constant but happens intermittently during earthquakes. On average, a major earthquake occurs once along the 1,900 km long fault system every 5 years (Natawidjaja*,* 2018). The site is situated in a location where the Great Sumatran Fault systems diverge into a wider system of faults. This means that within the site, a larger number of smaller faults are present.

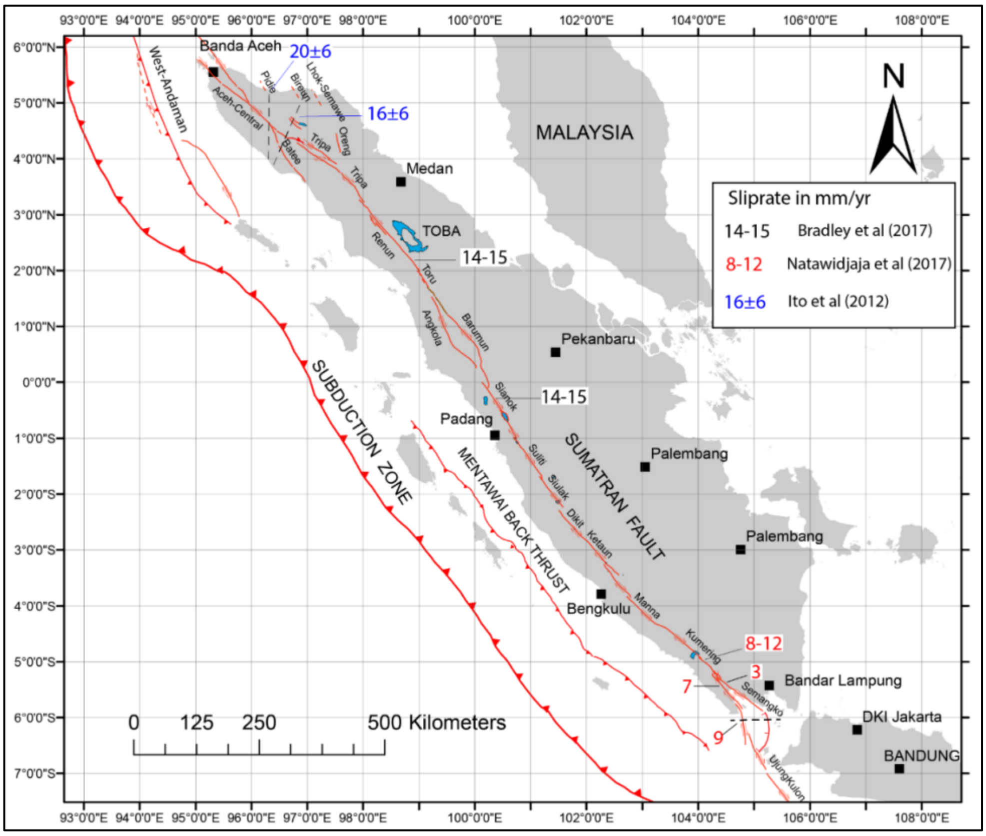

Figure 33. Generalized location of Great Sumatran Fault system, running along the entire length of the island.

According to the Ministry of Energy and Mineral Resources (MEMR or *Kementerian ESDM*), large portions of the area have the potential to be hit by strong earthquakes with an intensity larger than VIII on the Modified Mercalli Intensity (MMI) scale. Figure 34 provides a visual representation of the earthquake risk level in and around the WTG-area.

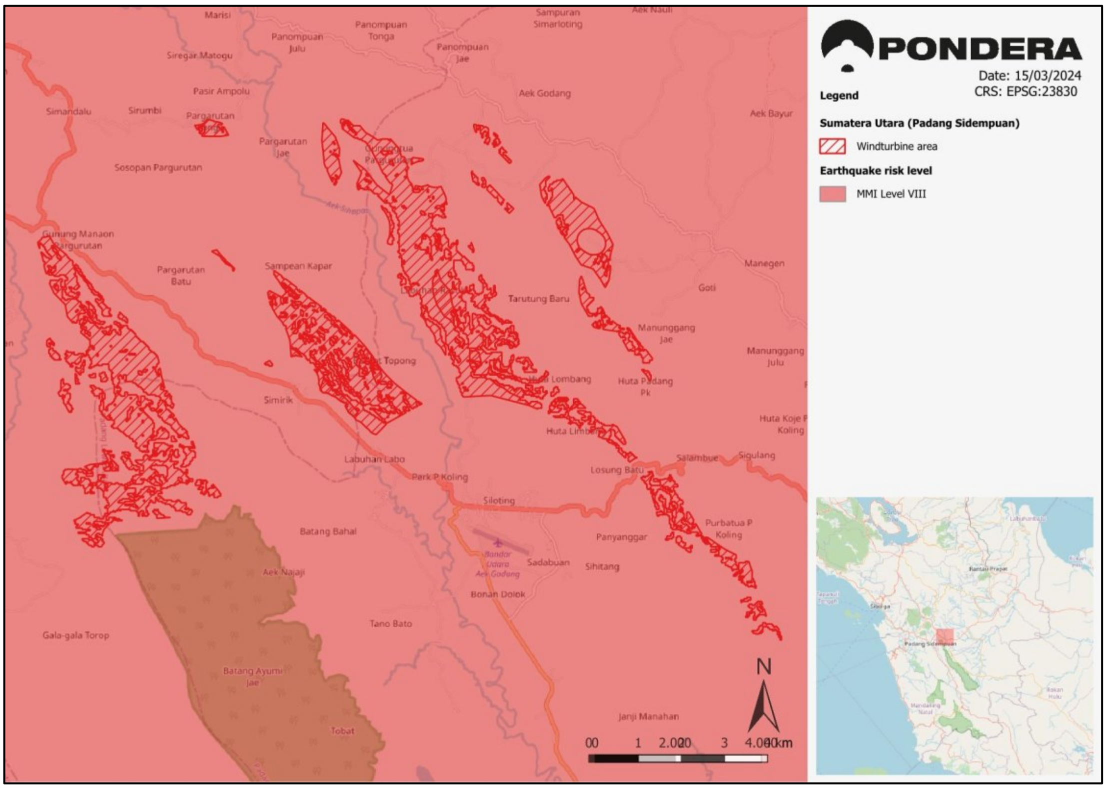

Figure 34. Earthquake hazard and risk level at North Padang Lawas – South Tapanuli WTG-area.

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

> *"Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage is great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned."*[12]

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

[12] https://pubs.usgs.gov/gip/earthq4/severity_text.html

2.6 Biodiversity, socio-economic and environmental conditions

2.6.1 General impression

The North Padang Lawas – South Tapanuli WTG-area can be divided into three sections as shown in Figure 35, both in terms of topography and land use. Roughly three types of landscape can be distinguished:

1. Western mountain range (see Figure 36). Slopes are long and not interrupted by smaller valleys. This landscape type is fully used by plantations (mainly palm oil, some rubber trees).
2. Central hilly area (see Figure 37). This landscape type has a deep gorge, and is used for agroforestry, various crops, and plantations. As shown in Figure 38, there are also deep valleys cutting into the terrain in this area.
3. Eastern mountain range (see Figure 39). In this area, there are steeper slopes and numerous smaller valleys. Large parts are covered by primary forest with some small farmers' fields.

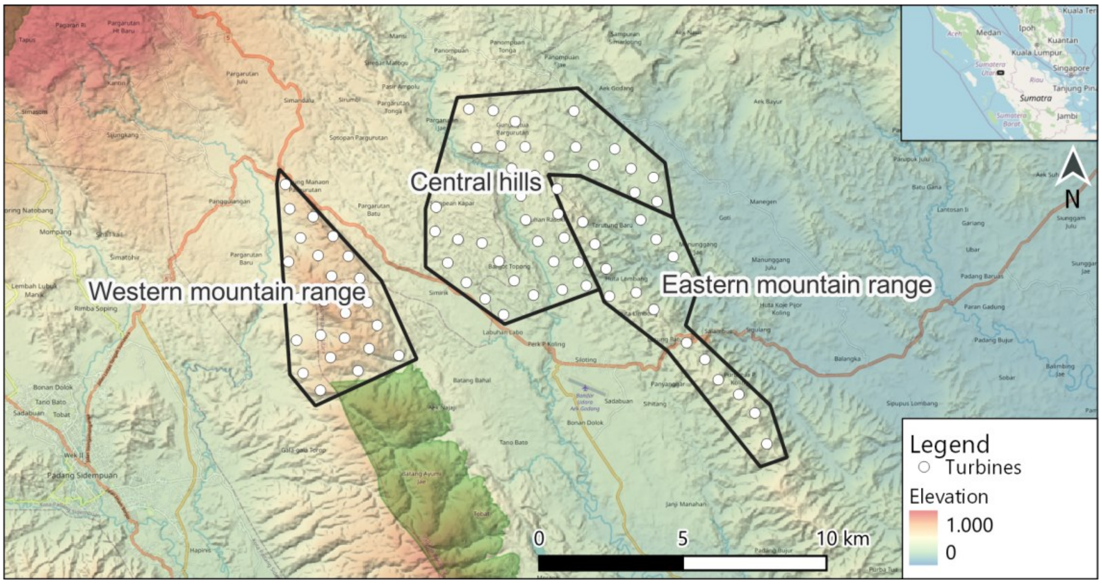

Figure 35. Site divided into three sections with similar topography and land use.

Figure 36. An impression of the western mountain range.

Figure 37. An impression of the central hilly area.

Figure 38. An impression of the valley within the central hilly area.

Figure 39. An impression of the eastern mountain range.

2.6.2 Biodiversity and environmental impact

Most of the WTG-area has already been developed for plantations or agricultural use. It is expected that these areas are not the highest ranked location in terms of biodiversity. However, in the southeastern part, some primary forests are still present. These forests are not situated in a protected area. Development in the forest area will likely have an impact on biodiversity and the environment. The main impacts are as follows:

Biodiversity impact

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

Environmental impact

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

Due to the large scale of human presence in the region, it is expected that extra impact due to wind farm construction are mostly limited to the southeastern part where primary forest is still present.

Observed flora and fauna

According to the online biodiversity database of Global Biodiversity Information Facility (GBIF), no endangered animal or plant species were observed in the area in recent times (see Figure 40) 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[13]. 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).

There is no fauna registered with at least ‘near threatened’ status according to the IUCN list. Moreover, there is only one type of flora registered in the IUCN list, as presented in Table 1. The observed *Orania sylvicola* (a type of palm) was observed in the 1930’s and based on a preserved specimen. It is unknown whether this type of palm is still present in the area.

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

Plants	English Name	Status
Orania sylvicola	-	Near threatened (NT)

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

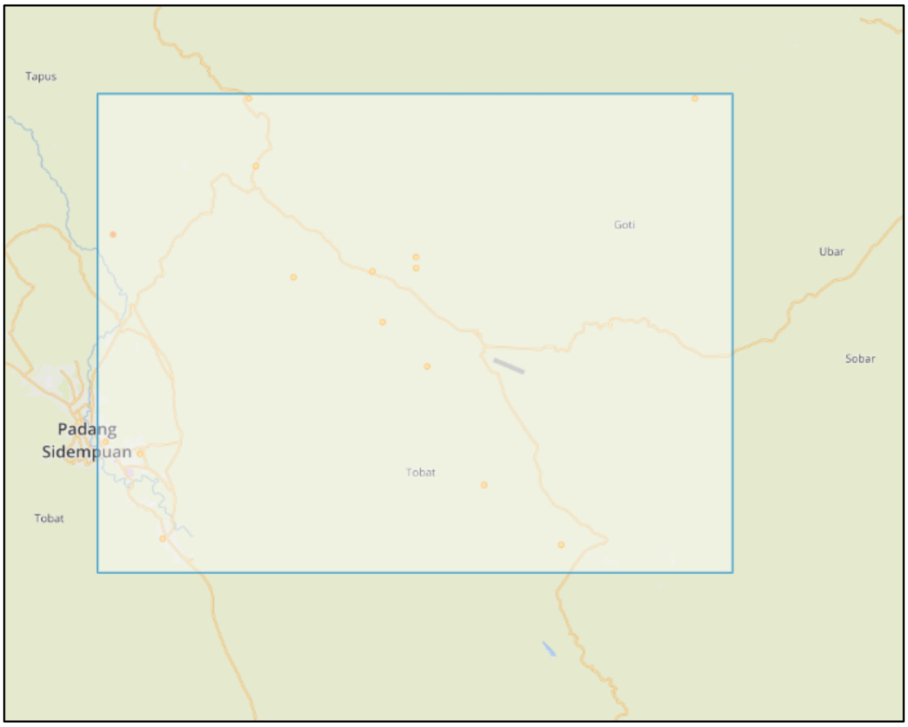

Figure 40. The area in which the abovementioned flora and fauna has been observed (covering the envisioned wind farm location). All of these observations are categorized as 'least concern' or 'not evaluated.'

Even when no endangered species are observed in the primary forest, development will still have an effect on biodiversity. Also, international funding for development within primary forests is not granted easily. Influence on the environment and biodiversity should be limited as much as possible and any loss must be compensated.

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

- Reuse as much of the existing infrastructure as possible, such as the existing 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;
- Ideally only one access point should be made to enter a particular section of the wind farm to limit the opening of the area for other activities such as illegal logging and hunting/poaching; and
- Limiting the amount of forest cleared around each wind turbine (generally between 50 to 100 x 100 m area). This space is used for the crane and storage. By using self-climbing cranes instead of traditional cranes, this space can be minimized. With careful planning, temporary storage of wind blades next to the road instead of next to the turbine might also reduce the required area around the wind turbines.

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

2.6.3 Social impact

Apart from the villages near the main road, the area is sparsely populated. Spread out over the site, a number of smaller villages (about 20-50 houses per village) are present (see Figure 41). Near the main road, the population consists mainly of small shop and restaurant owners. The road is an important connection between areas on the southwest and northeastern coast, and thus, the traffic is a source of income for the villagers. Farther away from the main road, the population mainly consists of small-scale farmers and plantation workers. The potential turbines are placed at a distance of at least 300 meters from these dwellings.

The social impact can be divided into several aspects:

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

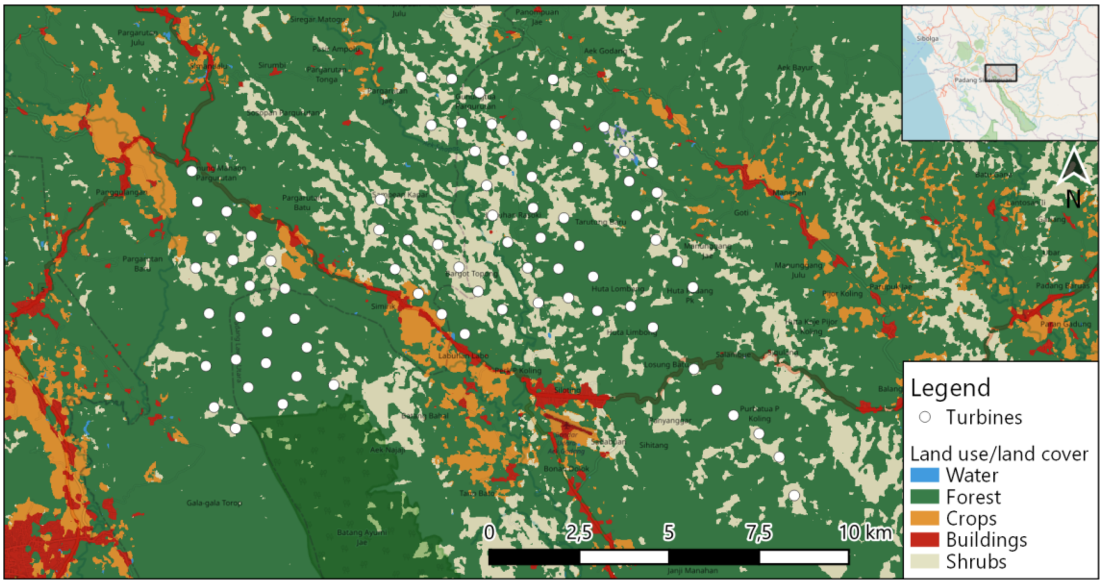

Figure 41. Land use map based on satellite imagery (ESRI/Sentinel 2, 2022). The area directly around the wind turbines is primarily covered by forest (plantations, agroforestry), crops and shrubs.

As the turbines are mostly built in sparsely populated areas, the social impact is mainly limited to the loss of agricultural land, reduced accessibility during road construction and transport and visual impact.

The next paragraphs provide an overview of the population and employment statistics of North Padang Lawas and South Tapanuli Regency.

Population

North Padang Lawas

The graph of population and annual population growth rate is shown in Figure 42. It can be seen that the annual population growth rate in the regency declined from 2.07% in 2021 to 2.00% in 2023. Meanwhile, the total number of inhabitants increased from 264,940 people in 2021 to 275,490 people in 2023.

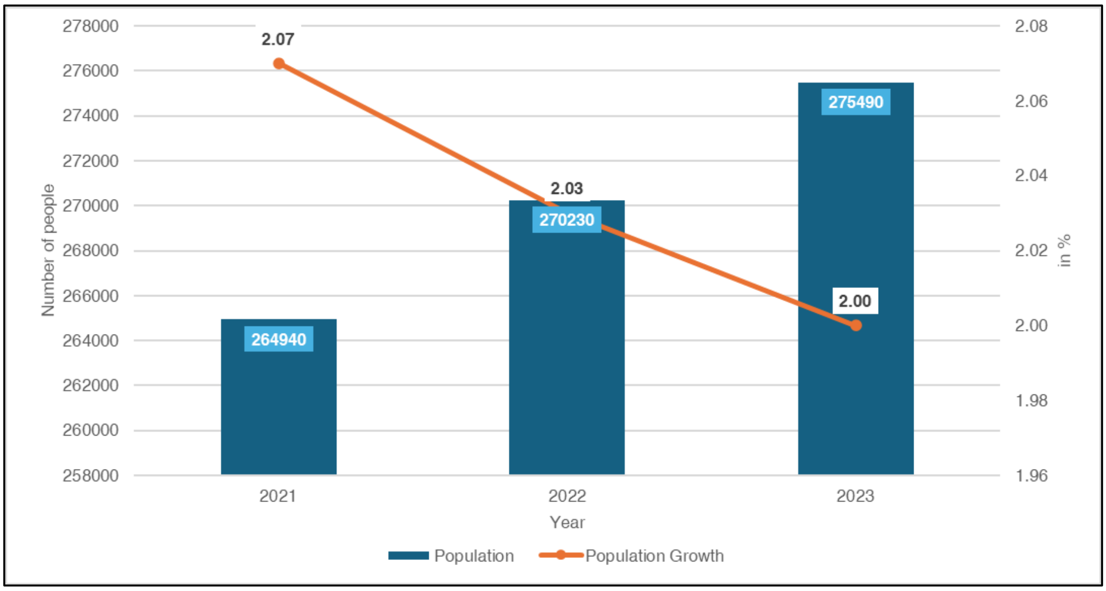

Figure 42. Population and annual population growth rate in North Padang Lawas Regency in 2021-2023 (Source: [Statistics Board of North Padang Lawas Regency (bps.go.id)](bps.go.id)).

The regency's population pyramid is shown in Figure 43. It is worth noting that the gender ratio was 1.01 in 2023.

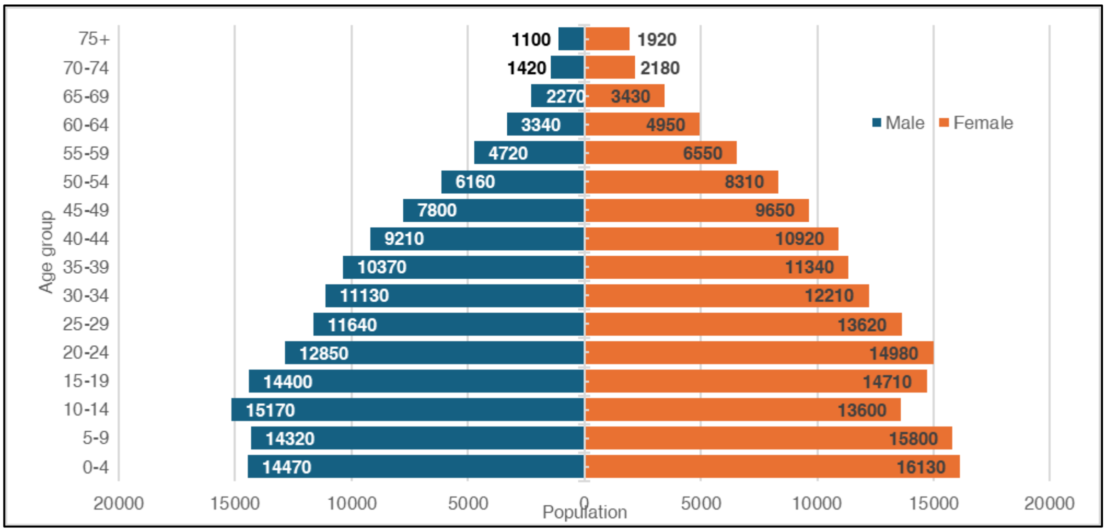

Figure 43. Population pyramid in North Padang Lawas Regency in 2023 (Source: [Statistics Board of North Padang Lawas Regency (bps.go.id)](bps.go.id)).

South Tapanuli

The graph of population and annual population growth rate is shown in Figure 44. It can be seen that the annual population growth rate in the regency increased then declined in 2021-2023. Meanwhile, the total number of inhabitants steadily increased within that period.

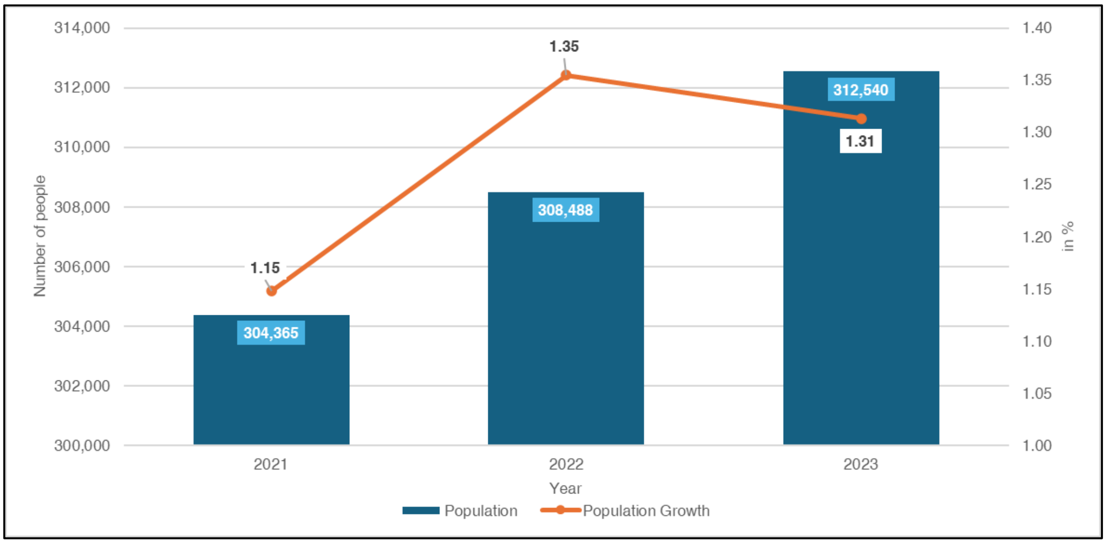

Figure 44. Population and annual population growth rate in South Tapanuli Regency in 2021-2023 (Source: [Statistics of Tapanuli Selatan Regency (bps.go.id)]).

The regency's population pyramid is displayed in Figure 45. It is worth noting that the gender ratio was 101.38 in 2023.

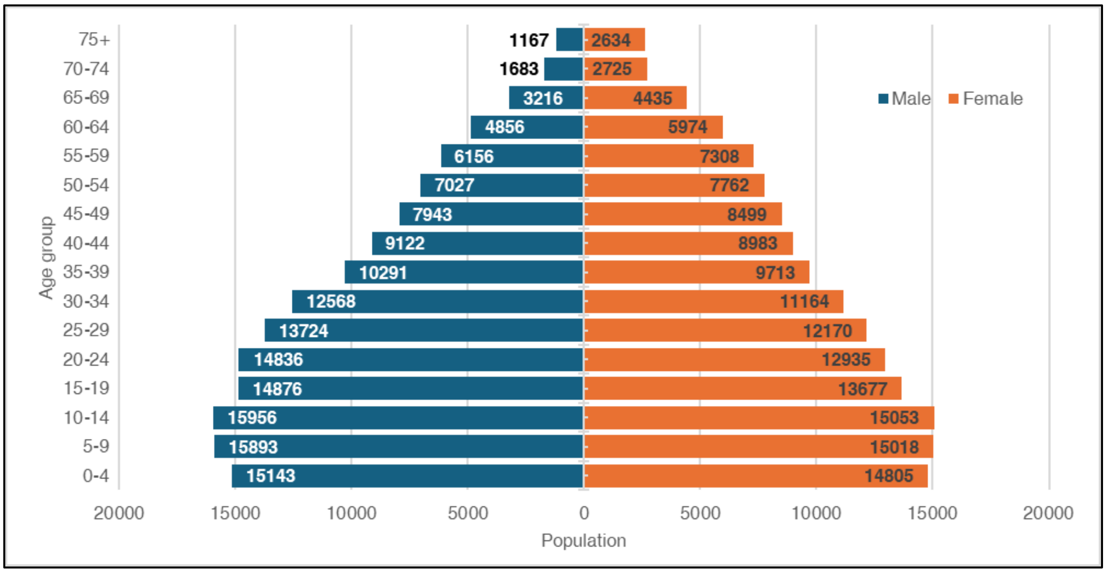

Figure 45. Population pyramid in South Tapanuli Regency in 2022 (Source: [Statistics of Tapanuli Selatan Regency (bps.go.id)]).

Employment, education, and development

North Padang Lawas

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 2. During 2021-2023, the labor force participation rate dropped followed by an increase, whereas the unemployment rate increased.

Table 2. Labor force participation rate and unemployment rate in North Padang Lawas Regency in 2021-2023 (Source: BPS Kota Medan).

Metric (in %)	Year		
	2021	2022	2023
Labor force participation rate	76.82	70.33	73.41
Unemployment rate	3.19	4.31	4.42

The number of workers according to highest education from is presented in Table 3. Overall, the workforce was dominated by graduates of primary school, followed by high school and middle school.

Table 3. Workers according to highest education (people) in North Padang Lawas Regency in 2023 (Source: BPS Kabupaten Padang Lawas Utara).

Educational attainment	Working	Unemployed	Total of Economically Active	Percentage of Working to Economically Active
Primary school (SD)	31,510	277	31,787	99.13
Middle school (SMP)	31,383	324	31,707	98.98
High school (SMA)	55,656	4,947	60,603	91.84
University	14,671	607	15,278	96.03
Total	**133,220**	**6,155**	**139,375**	**95.58**

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 4.

Table 4. Pure participation rate in North Padang Lawas Regency in 2021-2023 (Source: BPS Sumatera Utara).

Pure participation rate	Year		
Educational level	2021	2022	2023
Primary school	98.80	100.65	99.85
Middle school	83.89	87.34	92.24
High school	69.33	77.08	82.89
University	10.32	15.66	11.76

Table 5 shows the number of educational facilities in the regency. Among the different education levels. The largest number of educational facilities is that of primary school, followed by middle school (SMP), senior high school (SMA), vocational high school (SMK), and university.

Table 5. Educational facilities in North Padang Lawas Regency in 2021 (Source: Statistics Board of North Padang Lawas Regency (bps.go.id)).

Educational level	Number of units
Primary School	206
Middle School	79
Senior High School	42
Vocational High School	10
University	3

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

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

Human Development Index in the regency from 2021 to 2023 has an increasing trend, as shown in Table 6.

Table 6. Human Development Index, Gender Empowerment Index, and Gender Development Index in North Padang Lawas Regency in 2021-2023 (Source: Statistics Board of North Padang Lawas Regency (bps.go.id)).

Metric	Year		
	2021	2022	2023
Human Development Index	70.11	70.93	71.63
Gender Empowerment Index	68.14	68.98	67.41
Gender Development Index	88.06	88.10	88.26

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 fluctuated, as shown in Table 6.

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 an increasing trend, as shown in Table 6.

South Tapanuli

The labor force participation rate (TPAK) and the unemployment rate (TPT) are displayed in Table 2. During 2021-2023, the labor force participation rate experienced an increase, whereas the unemployment rate had a decreasing trend.

Table 7. Labor force participation rate and unemployment rate in South Tapanuli Regency in 2021-2023 (Source: BPS Kota Medan).

Metric (in %)	Year		
	2021	2022	2023
Labor force participation rate	74.38	74.53	75.64
Unemployment rate	4.00	3.65	3.49

The number of workers according to highest education from is presented in Table 8. Overall, the workforce was dominated by graduates of high school, followed by primary school and middle school.

Table 8. Workers according to highest education (people) in South Tapanuli Regency in 2023 (Source: BPS Kabupaten Tapanuli Selatan)

Educational attainment	Working	Unemployed	Total of Economically Active
Primary school (SD)	46,512	506	46,658
Middle school (SMP)	39,878	732	40,610
High school (SMA)	43,729	3,955	47,684
Vocational high school (SMK)	15,189	-	15,189
Diploma I/II/III	3,165	-	3,165
University	13,659	660	14,319
Total	**161,772**	**5,853**	**167,625**

The pure participation rate of the regency is shown in Table 9.

Table 9. Pure participation rate in South Tapanuli Regency in 2021-2023 (Source: BPS North Sumatra).

Pure participation rate	Year		
Educational level	**2021**	**2022**	**2023**
Primary school	98.14	99.62	99.02
Middle school	80.80	73.48	89.83
High school	68.89	57.67	67.98
University	17.61	19.44	21.19

The number of educational facilities in South Tapanuli Regency is shown in Table 10.

Table 10. Educational facilities in South Tapanuli Regency in 2023 (Source: Statistics of Tapanuli Selatan Regency (bps.go.id)).

Educational level	Number of units
Kindergarten (TK)	157
Diniyah Awaliyah (MDA)	191
Primary School (SD)	271
Madrasah Ibtidaiyah (MI)	12
Middle School (SMP)	47
Madrasah Tsanawiyah (MTs)	33
High School (SMA)	12
Vocational High School (SMK)	13
Madrasah Aliyah (MA)	27

As shown in Table 11, the Human Development Index of South Tapanuli Regency from 2021 to 2023 rose from 73.37 to 74.58. Additionally, GEI in the regency shows a steady increase. Over the same period, the GDI fluctuated.

Table 11. Human Development Index, Gender Empowerment Index, and Gender Development Index in South Tapanuli Regency in 2021-2023 (Source: Statistics of Tapanuli Selatan Regency (bps.go.id)).

Metric	Year		
	2021	2022	2023
Human Development Index	73.37	73.96	74.58
Gender Empowerment Index	69.25	70.95	71.61
Gender Development Index	90.74	90.99	90.63

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 Padang Sidempuan 150 kV PLN substation (ULTG) was selected for this, located in the east of the village of Sidikalang. The aerial photo of this substation is included in Figure 46. 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 46. Location of the Padang Sidempuan 150 kV PLN substation (ULTG). Source: Google Maps.

2.7.2 Schematic design transmission and distribution network

In Figure 47, the schematic design of the transmission and distribution network is illustrated. The 78 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 eight 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 Padang Sidempuan substation.

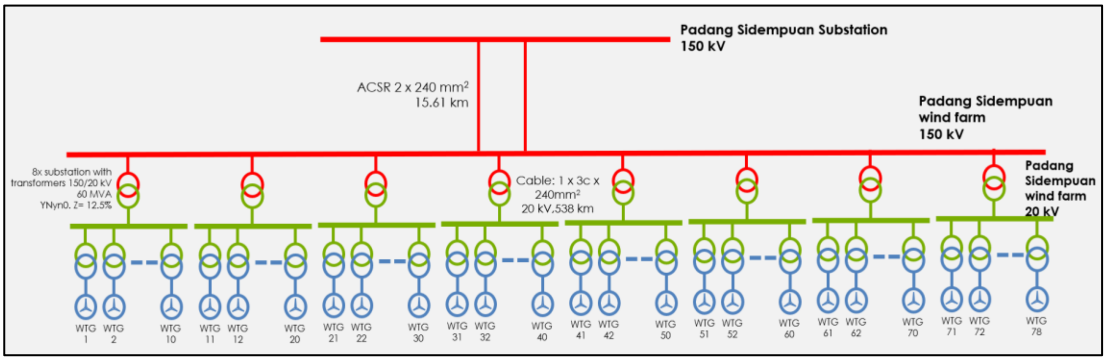

Figure 47. A schematic design of the transmission and distribution network at the envisioned wind farm.

The overhead transmission line between the powerhouse and the PLN substation is assumed to be a straight line between both locations, covering 15 km as visualized in Figure 48. A total of 44 towers are planned with an intermediating distance between the towers of 340-450 m.

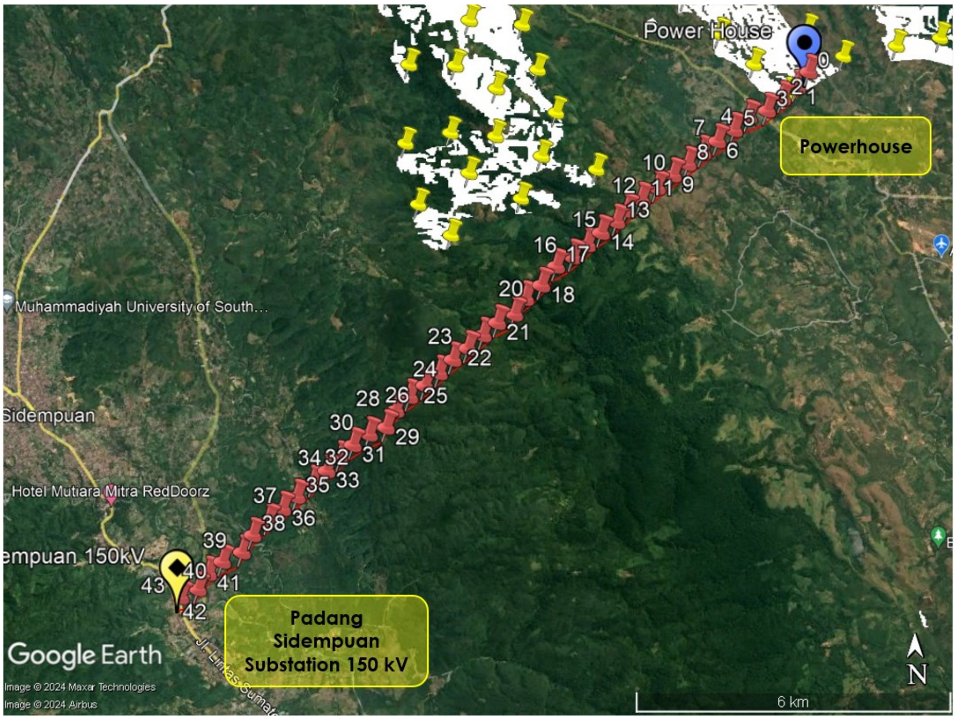

Figure 48. A schematic representation of the position of overhead transmission line between the powerhouse and the Padang Sidempuan substation.

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

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

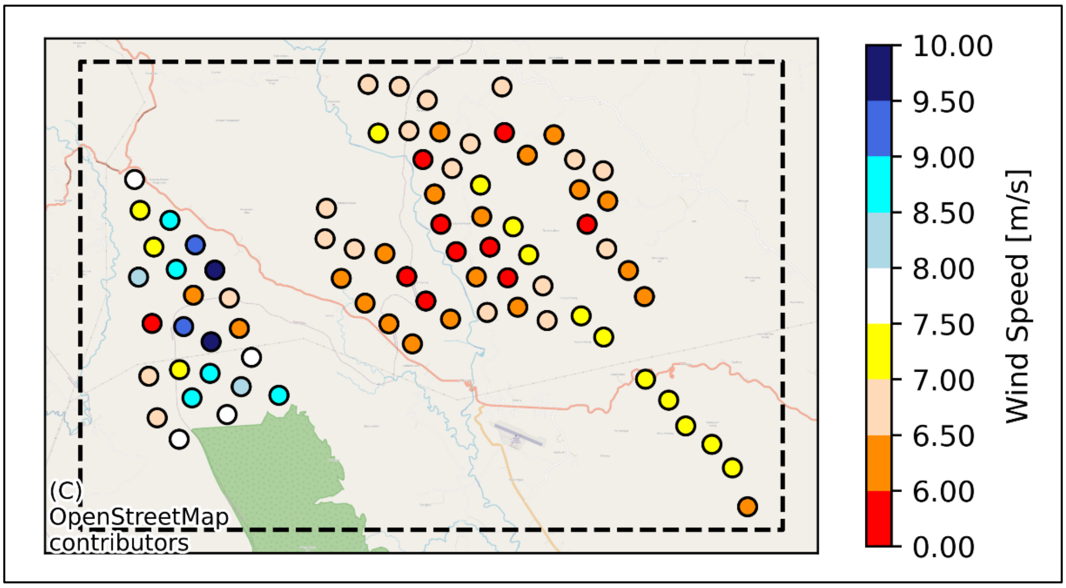

Figure 49. Long-term average wind speed results with the ASPIRE model at a height of 140 m at the turbine locations. The black-bordered circles represent the wind turbines, whereas the color within the circles indicate the respective long-term average wind speed.

Figure 49 shows the resulting climatology at the locations of the WTGs. The modeled long-term wind speed, which is averaged over all 78 WTGs at the planned hub height of 140 m, is 6.9 m/s. The locations that are marked in red indicate wind speeds below 6 m/s. It must be noted that the mean wind speed in the Global Wind Atlas (GWA), is notably lower (see Figure 6). Nevertheless, verification of the numerical models through measurements is essential, and here, the more intricate LES model is employed for further analysis. The trends in wind speed are consistent between the long-term data and the Global Wind Atlas.

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

2.8.1 Energy losses

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

In this report, the net AEP is displayed as the P50 AEP. The P50 value is a statistical level of confidence suggesting a value for AEP that may be exceeded with 50% probability. In other words, the P50 AEP is the average annual energy production that is expected over the wind farm's lifetime. Table 12 presents the estimated losses on the wind farm level.

Table 12. Expected losses on the wind farm level

Category	Types of energy loss	Amount	Explanation
Interaction	Wake losses [%]	10.8%	The wake effect is the aggregated influence on the energy production of the wind farm, which results from the changes in wind speed caused by the downwind impact of the wind turbines on each other. The wake losses are modelled using the standard NO Jensen (RISØ/EMD) model (PARK2 – 2018 version) in windPRO, resulting in an overall wake loss of 10.8%.
	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)[14] with linear parametrization is used to calculate blockage. 0% blockage is expected for the layout.
Availability	Non-availability [%]	4.0%	This production loss concerns the periods of a wind turbine that it is not in operation due to maintenance, malfunctioning and re-orientation of the nacelle. For onshore wind farms with more than 5 WTGs, 4.0% loss is considered.
	Balance of Plant [%]	0.1%	Balance of Plant losses occur due to the unavailability of the transformer station or access roads and therefore hinder normal wind farm operation.
	Grid downtime [%]	0.5%	Grid downtime losses are caused by grid non-availability from grid operator.

[14] 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%.
Subtotal non-interaction losses [%]		**13.0%**	The accumulation of all of the above-mentioned losses, excluding wake losses. Based on 1-(1-loss A)*(1-loss B)*(1-loss C)*…etc.
Total losses [%]		**22.4%**	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 P90 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 13.

Table 13. Energy yield for all 78 WTGs at North Padang Lawas – South Tapanuli wind farm.

Parameter [Unit]	Amount
Number of new WTGs	78
Rated Power per WTG [MW]	4.0
Total rated Power [MW]	312.0
Rotor diameter [m]	~170
Hub height [m]	140
Air density [kg/m3]	1.129
Wind speed [m/s]	6.9
Gross result [MWh/yr]	1,183,369
Gross results including wake effects [MWh/yr]	1,055,565
P50 [MWh/yr] [15]	**918,143**
P90 (25 yr) [MWh/yr]	**682,813**
P50 [hrs/yr]	2,943
P90 (25 yr) [hrs/yr]	2,189

2.8.3 Power output variation

In Subsection 2.8.2 we have provided an estimate of the P50 annual production, equal to 918,143 MWh per year. 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.

[15] Note that the P50 value is based on the LES calculation with a mean wind speed higher than the Global Wind Atlas. Both models are based on the underlying ERA5 model data. The uncertainty in the AEP will be reduced once on-site measurements are performed. Until that time, the results of this study shall be interpreted with careful discretion.

Figure 50 shows the average wind farm power output for each month, subdivided in the hours over a full day. The input data for this figure is derived from the ASPIRE modelling combined with the EMD-WRF average variability in wind speeds throughout the year.

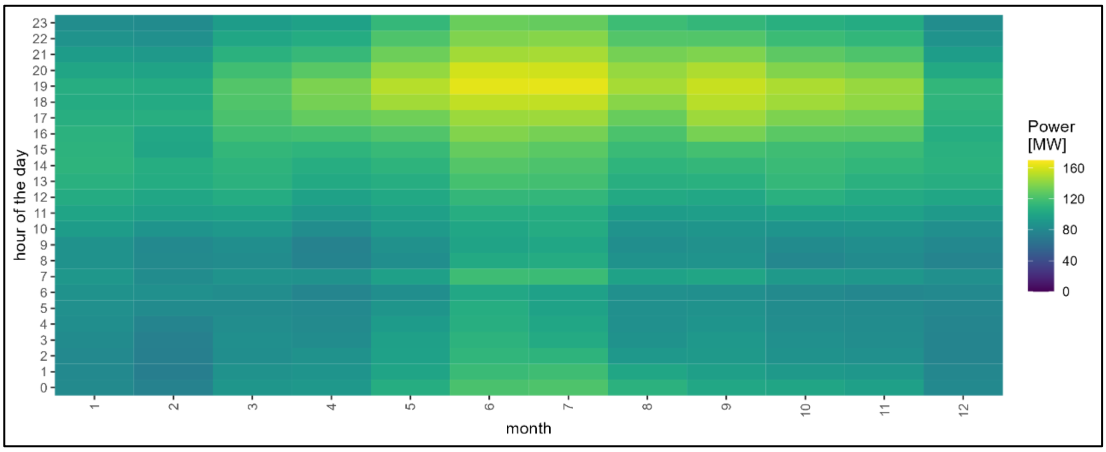

Figure 50. Overview of the monthly variation of wind farm average power output per hour of the day based on the P50 values from Subsection 2.8.2 in combination with the monthly and hourly variation in wind speed from EMD-WRF (see also Figure 8).

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: 7 met masts, duration 1 year.
- Land acquisition, assuming IDR 200,000 /m^2 + 5% tax for low-quality soils, IDR 520,000 /m^2 + 5% for moderate fertile areas, to be used for:
    - New road surface
    - Rotor diameter surface
    - Road upgrade surface
    - Powerhouse and substation surface
    - Transmission tower surface

Wind turbines

The quantities which are relevant for the installation of 78 wind turbines at the wind farm are shown in Table 14.

Table 14. Wind turbine quantities relevant for the envisioned wind farm.

Main component	Quantity
Nacelle incl. generator (4 MW)	78 pcs
Blade (85 m)	234 pcs
Tower segments (total 140 m height)	468 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 Dumai 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[16];
- The cost includes transport, crane rental, installation, and commissioning.

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

Civil works

The quantities which are relevant for the civil works necessary for the installation of 78 wind turbines at the wind farm are shown in Table 15.

Table 15. 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	77 km
	Upgrading existing road	18 km
Strengthening bridges (incl. design, materials, transport, labor)	Concrete bridge strengthening	7 bridges
	Steel bridge strengthening	1 bridge
Foundations (incl. design, materials, transport, labor)	Anchors (72 per foundation)	5,616 pcs
	Anchor cages	78 pcs
	Concrete (230 m^3 per foundation)	17,940 m^3
	Steel (35 tons per foundation)	2,730 tons
Crane hardstands (incl. design, materials, transport, labor)	Crane hardstands (50 x 100 m) using gravel	78 hardstands

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

- Civil works are including design, materials, transport and labor;
- Strengthening of highway bridges is excluded. It is assumed that these are strong enough;
- 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 16.

Table 16. A list of assumptions on the electrical works components.

Main component	Sub-component	Quantity
Transmission line (15 km, 44 towers)	Transmission towers	44 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

Main component	Sub-component	Quantity
	OPGW 70 mm^2 cable	1 set
Powerhouse (1 for the entire wind farm)	Incoming MV switchgear	78 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)	78 pcs
	Switchgear	78 pcs
	MVAC Cable (1 x 3c x 240) 50 and 300 meters	538 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 (four for the entire wind farm)	Transformer 150/20kV 30 MVA	8 pcs
	Neutral Grounding Resistor	8 pcs
	Switchyard	1 pc
	In/outgoing bays, coupler, busbars, Panel RCP	8 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 for approximately 50% of the project location (see section 2.2.4), assuming IDR 2 million/ha/year
- Insurances (e.g. machine breakdown insurance, third party liability)

2.9.2 Cost assumptions

In Table 17 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).

Table 17. Cost assumptions per cost component

Cost component	Baseline cost including VAT	Comment	Cost range
Preparation works	USD 6,375,000	DEVEX: Prior to Financial Close	90% - baseline -120%
Project management	USD 23,220,000	DEVEX: Until CoD	Baseline
Wind turbines	USD 217,408,000	CAPEX: Including transport and installation	90% - baseline -120%
Civil works: foundations	USD 31,255,000	CAPEX	80% - baseline -150%
Civil works: roads	USD 43,817,000	CAPEX	80% - baseline -150%
Civil works: crane hardstands	USD 10,940,000	CAPEX	80% - baseline -150%
Electrical works	USD 74,646,000	CAPEX	90% - baseline -120%
Land acquisition	USD 79,961,000	CAPEX	90% - baseline -150%
Risk contingencies	USD 37,152,000	DEVEX + CAPEX	Baseline
Lower bound total investment cost (DEVEX + CAPEX)	**USD 469,734,000**	**Investment cost per MW: USD 1,506,000**	
Baseline total investment cost (DEVEX + CAPEX)	**USD 524,776,000**	**Investment cost per MW: USD 1,682,000**	
Upper bound total investment cost (DEVEX + CAPEX)	**USD 667,449,000**	**Investment cost per MW: USD 1,901,000**	
Baseline operational expenditure (OPEX)	**USD 9,017,000 / year**	**Operational cost per MW / year: USD 29,000**	

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

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 1.1 for North Sumatera) = USD cent 10.49 / 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.

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

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 18. 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	12.93 %	10.80 %	6.77 %
Average Debt Service Coverage Ratio (DSCR) at P90	0.97	0.88	0.72
Net profit at P50 over 25 years	USD 417,987,000	USD 356,181,000	USD 210,654,000

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 North Padang Lawas – South Tapanuli could be relatively promising but requires further optimizations to increase the IRR and DSCR (currently below 1) to an attractive level. The wind speed varies significantly throughout the analyzed wind farm, meaning that some wind turbine positions have relatively low wind resource compared to other positions. This negatively influences the business case for the entire wind farm. The main cause for this is the lower wind speeds than expected at specific wind turbine locations. Although the initial wind resource assessment only included areas with wind speeds above 6 m/s, during the wind modelling stage the wind speed at some wind turbine locations turned out to be below this number (see Figure 49). This is likely caused by the effect of the topography on the wind characteristics, which is to a lesser extent notable when creating a wind speed map based on Global Wind Atlas

By conducting micro-siting and business case calculations per specific wind turbine position (e.g. selecting the best performing positions), the business case can be optimized in subsequent analyses. We recommend reconsidering the site layout during a follow up study. Herein the focus could be on the western turbine group or on the ridge extending to the far southeastern part of the area. Both of these areas have average wind speeds above 7m/s, which is beneficial for the business case. Furthermore, when looking at the breakdown of the investment cost, the cost for land acquisition and electrical works has a relatively large share of the total cost. In subsequent analyses, attempts can be made to lower these costs through optimizing the wind farm layout and minimizing the need for acquiring land.

In addition to the required optimizations, the envisioned wind farm 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 a significant amount of 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 at least to place seven met masts for data gathering for at least one year, see Figure 51. In the background of the figure are the wind speeds from the Global Wind Atlas (GWA) shown. The elevation is shown with contour lines. The red dots indicate the wind turbine locations. The yellow icons show the global positioning of recommended met mast locations.

  The southwestern area of the site has the largest variations. Therefore, in the south, central and north part the met masts are positioned (numbers 1,2 and 3). Due to the mountain top in the central part, it is critical to additionally measure with an ultrasonic 3D anemometer. On the mountain top the wind turbines could possibly experience up and downdrafts. Using the ultrasonic 3D anemometer the horizontal velocity and vertical velocity will be measured. Northwest of the airport, a met mast in the valley and on the hill is recommended (numbers 4 and 5). For the met mast in the southeastern part on the ridge additionally using an ultrasonic 3D anemometer is recommended due to the possible up and downdrafts (number 7). Additionally, in the far northeastern part a met mast is recommended (number 6).

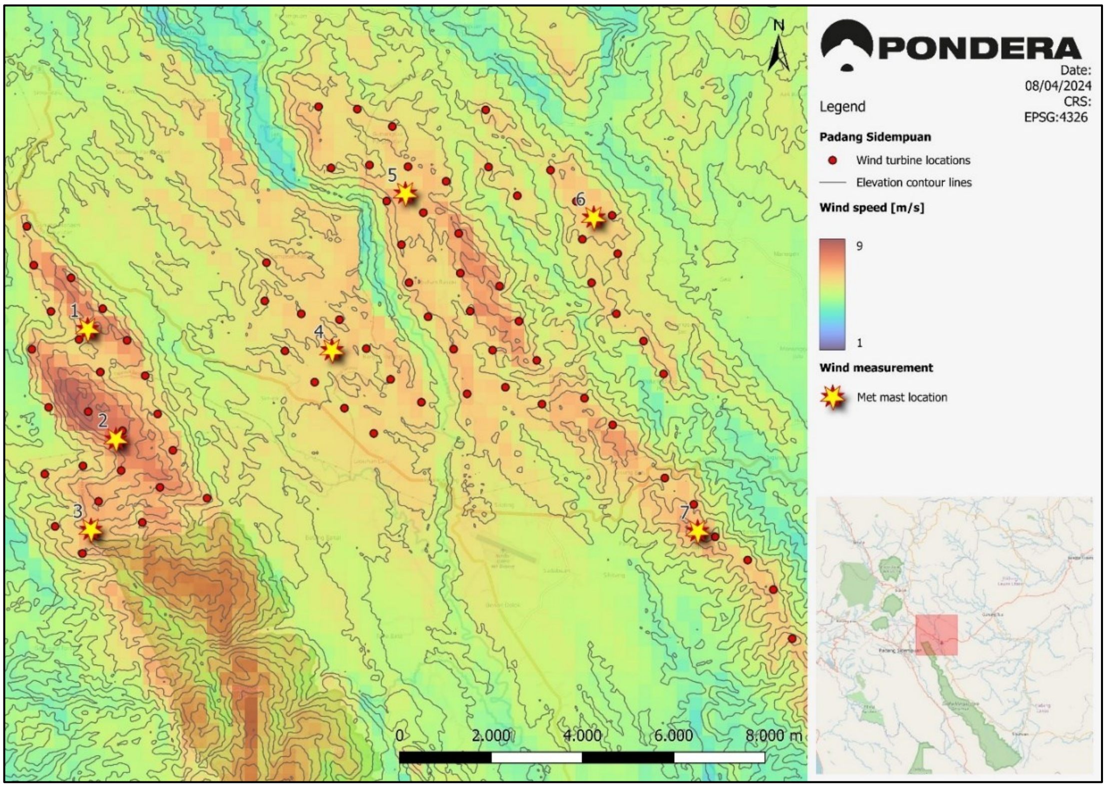

Figure 51. Recommended met mast locations.

- **Land use and permitting:** As mentioned in Subsection 2.2.5, the wind farm is planned in roughly a 50/50 split between Forest Area (Production Forest Area and Limited Production Forest Area) and Dryland Farming/Agricultural Area. For the former area, it will be mandatory for the future developer to obtain specific approvals and permits from the authorities; whereas for the latter area, a deal will need to be struck with the landowner to either acquire or lease the land. Considering these required actions, it is also important for the developer to assess the land use / ownership in greater detail early on in the development process. The developer is recommended to firstly start consulting the authorities about the willingness and possibility to issue these approvals and permits, and to approach the relevant landowners about the possibility of arriving at an agreement on the land.

- **Transport:** A limited accessibility analysis has been conducted for this prospectus, concluding that Dumai port is the most suitable as starting point for the transport over land. To ensure that the port in Dumai 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. Furthermore, large parts of the road to the site are in good condition and are in daily use by heavy traffic. It is expected that for a large section a highway from Dumai to Kota Pinang will be constructed in the near future (next years). However, precise planning is not available, which requires further inquiry in the next stage. Also, it is required to check whether the use of the old bridge in combination with the nearby existing hairpin roads over Aek Sihapas is technically feasible (~1.5 km northwest of Aek Godang Airport). A more extensive logistical survey is recommended to be carried out as part of the future feasibility study to obtain more details of the required infrastructure (adjustments).

- **Geology:** Based on the level of the study conducted for this prospectus, there are still significant uncertainties included in the design and construction of the foundations, roads, and crane hardstands, due to the geological circumstances and the impact of these circumstances. Therefore, it is recommended to further investigate the stability and capability of the soil to carry wind turbines. This need to be determined through a geotechnical soil investigation, which determines several soil characteristics (e.g. shear strength, density, permeability etc.), and a following soil stability analysis in combination with the LiDAR-study for a more precise mapping of the topography.

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

- **Environment:** Although the wind farm location is not a densely populated area, there will be visual impact on the area because of the use of wind turbines with a tip height of 200m. 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. Furthermore, the envisioned wind farm is located 3-5 km from the Aek Godang Airport. Given this proximity, a thorough check with the airport authority will be needed on whether flight navigation at the airport could be disrupted by the presence of the envisioned wind farm.

- **Flora and fauna:** Even though no endangered species are observed in the forest, development will still have an effect on biodiversity. Also, international funding for development within forests is not granted easily. Consequently, it is advised that as part of an Environmental and Social Impact Assessment, a biodiversity baseline study, and risk assessment and mitigation measures are carried out during the feasibility study.

- **Grid connection and PPA:** The wind farm is designed to be connected to the PLN grid. This assumes that the grid can integrate 312 MW of wind energy (with variable output), and that the substation in Padang Sidempuan is suitable to facilitate the wind farm's grid connection. These assumptions should be verified during the feasibility study. Additionally, the current result of business case assessment is based on the assumption that the PPA uses the ceiling electricity tariff as stipulated in Presidential Regulation 112/2022, and that no Annual Contracted Energy (ACE) is applied. The actual PPA conditions depend on PLN and on how the tender process is set-up. An early alignment with PLN on these PPA conditions and tender process set-up is recommended.

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

4 Disclaimer

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

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