Wind Energy Development Booklet

2024 | Assessment of 8 onshore locations across Sumatra and Java

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

Wind Energy Development Booklet: Assessment of 8 locations across Sumatra and Java

“Wind Energy Development in Indonesia: Investment Plan” Project
July 2024

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).

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FOREWORD

By giving thanks to the presence of God Almighty, we hereby convey that the "Wind Energy Development Booklet" has been completed. This report is one of the deliverables of the Wind Energy Development in Indonesia: Investment Plan project. This project aims to push for the energy transition and the development of renewable energy, especially onshore wind energy, in Indonesia. The significant potential of onshore wind energy in Indonesia needs to be properly utilized in the short term and in the long term as an effort to achieve the targeted share of renewable energy in the national energy mix. This utilization is also important to support the Government of Indonesia's commitment on achieving Net Zero Emissions (NZE) by 2060, or sooner. Please allow us to express our deepest gratitude for the cooperation and valuable input of all parties involved in the preparation of this report, especially the Ministry of Energy and Mineral Resources, the Ministry of Agrarian and Spatial Planning / National Land Agency, Regional Governments and the related agencies, members of the Wind Power Technical Working Group, wind energy developers, and other parties.

Jakarta, 12 July 2024
Editorial Team

DISCLAIMER

Foreword by Director General of New Renewable Energy and Energy Conservation

Indonesia is committed to achieving a renewable energy mix target of 23% by 2025 and 31% by 2050. To achieve these targets, collaboration and hard work from all stakeholders are needed. Achieving these targets is very important to support the achievement of Indonesia's Enhanced Nationally Determined Contribution target, namely reducing carbon gas emissions by 32% (own efforts) and 43% (with international assistance) by 2030. One effort to achieve this target is to develop Wind Power Plants (*Pembangkit Listrik Tenaga Bayu*/PLTB). PLTB not only significantly contributes to reducing carbon emissions but also strengthens national energy resilience, improves environmental quality, and promotes local economic development.

"We hope that the Wind Energy Development Booklet can inform all relevant stakeholders about the promising potential of wind energy in Indonesia, so that various actions can be taken to accelerate the realization of quality and sustainable PLTB projects. Let us together drive the national energy transformation towards a greener and cleaner future."

This booklet presents a summary of the results of pre-feasibility studies on eight potential onshore wind power plants across Java and Sumatra. The study aims to assist policymakers and stakeholders in making the necessary next steps to improve the techno-economic feasibility of these wind power projects, before integrating them into future development plans. The study is also expected to attract investors and developers to develop and build the next wind power plants in Indonesia. The key aspects of wind power development that are the focus of this study are wind resource availability, location accessibility, biodiversity and environmental conditions, transmission network design, energy yield assessment, and business case assessment.

This booklet is also expected to increase awareness and understanding of the importance of renewable energy development as part of the energy transition, as well as motivate all parties to actively participate in supporting the formulation and implementation of government policies. Together, we can collectively realize Indonesia's commitment to reduce carbon emissions and combat global climate change.

We hope that this booklet will be useful for all stakeholders and encourage concrete steps to accelerate the energy transition in Indonesia. Let us continue to collaborate in order to create a better and more sustainable future for the next generations.

Director General of New Renewable Energy and Energy Conservation,

Prof. Dr. Eng. Eniya Listiani Dewi

Introduction

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.

The focus of this study is the technical and economic viability of onshore wind in Indonesia, for which the goal is to attract donor and business investment for potential wind sites. As shown below, the eight potential wind farm 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, and summarized in this Booklet. The eight wind farm prospectus are also publicly available for in-depth understanding of the conducted analyses.

Site selection criteria

Average yearly wind speed: > 6 m/s
at 100 m height

Slope: < 15 degrees
with a buffer of 100 m around steep ridges

Exclusion of roads and railways
with a buffer of 150 m

Exclusion of other no-go zones
with a buffer applied on protected areas, water bodies, airports, etc.

Reference wind turbine
Capacity: 4 MW
Rotor diameter: 170 m
Hub height: 140 m
Inter-turbine spacing: 5x rotor diameter

Turbine layout considerations
- Bundling of as many wind turbine positions as possible to increase cost effectiveness
- Selecting the area with the more promising wind climate
- Visual checks based on satellite images and site visit

120 MW Project
Aceh Besar, Aceh

Location and power demand

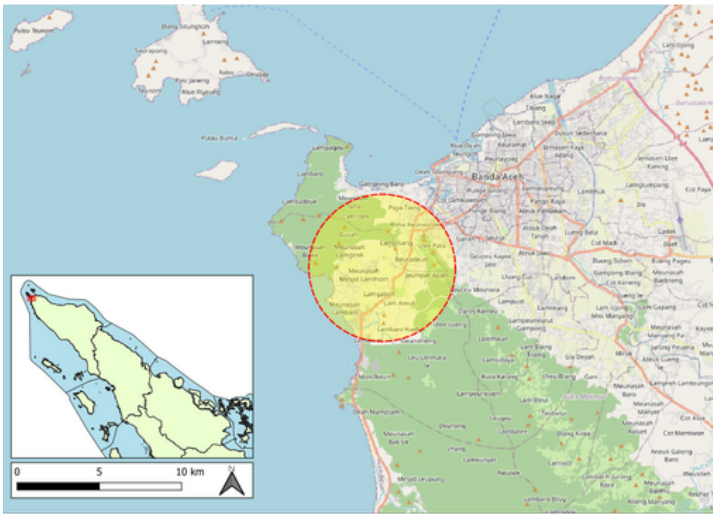
The envisioned wind farm is located in Aceh Besar Regency, Aceh Province. The electricity system at the province is connected to the Northern Sumatra (*Sumbagut*) grid.

The peak load in the province in 2021-2030 is expected to grow with an average annual growth rate of 4.7% from 542 MW (2020). In RUPTL PLN 2021-2030, the wind energy potential in Aceh is registered as 148 MW. An additional 110 MW is allocated for wind farm development in the Sumatra system in 2024 and 2025.

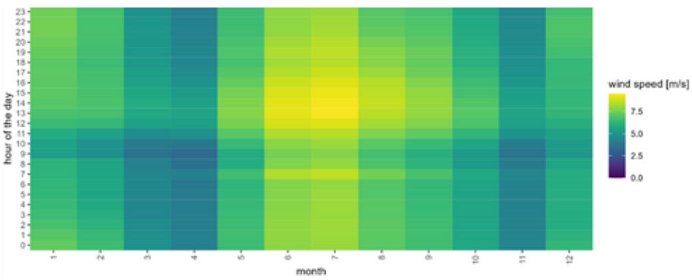
According to the Aceh Besar Regency Spatial Plan 2013-2033, the envisioned wind farm is located in areas with the following land use types:

Plantation Area
This area may be owned by private parties or a local community. Wind farm development is possible if a lease/purchase agreement is achieved with the landowner.

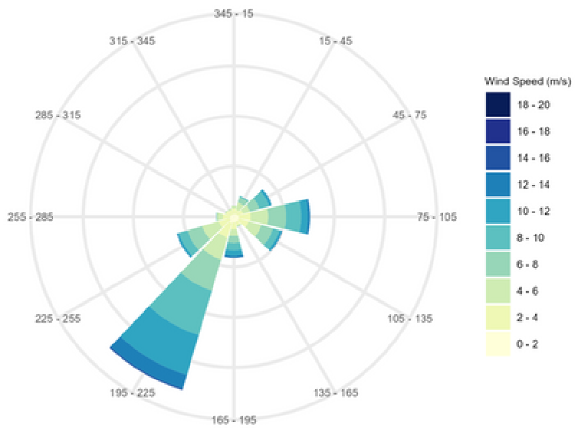
Wetland/Dryland Food Agriculture Area
This area may be owned by the community, private companies, or state-owned companies. Wind farm development is possible if a lease/purchase agreement is achieved with the landowner.



Wind characteristics



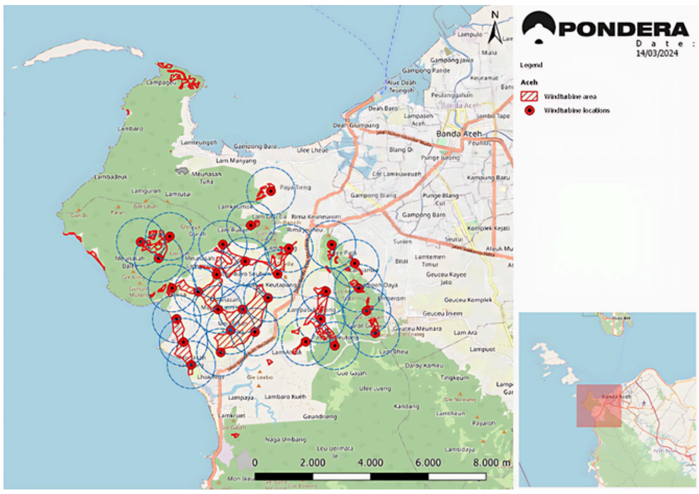
The wind climate in the region predominantly consists of wind from the southwestern direction. The highest wind speeds are observed in the period of May-October. El Niño and La Niña phenomena may cause variations interannual variations of wind speed.



Wind farm layout

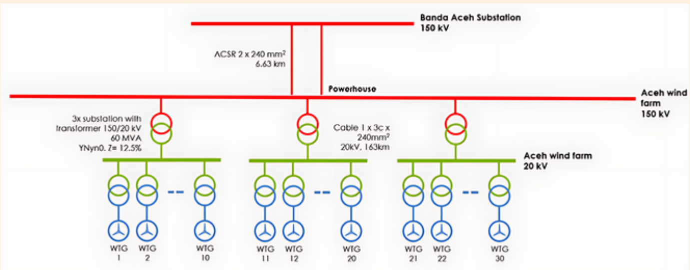
30
wind turbines

120 MW
total installed capacity



Logistic, civil- and electrical works

The Port of Malahayati is deemed to be the most suitable entry point of the turbines, with access to the site available via national and regional roads. No challenges expected from port until the project site. However, the internal access roads run through small villages with narrow streets, tight turns, and overhanging electricity and telephone wires.



The closest point of connection to the existing grid is the Banda Aceh 150 kV PLN substation. From this PLN substation to the wind farm's powerhouse, a 6 km transmission line is required. The generated electricity will be distributed to the powerhouse via three wind farm substations.

Within the site, new roads need to be constructed on flat-hilly and steep areas, and some existing roads and bridges must be upgraded.

23 km new road

12 km road upgrade

8 bridges strengthened

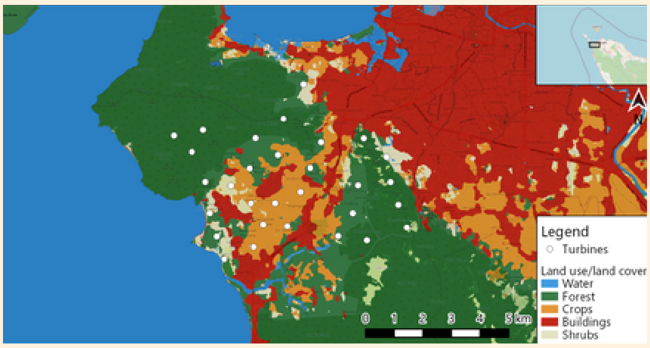
30 wind turbine foundations and crane hardstands

19 transmission towers

163 km electrical cable

Geology and seismic conditions

The wind farm area has low- to medium-risk of land movement vulnerability and potential to be hit by strong earthquakes. The foundation design should incorporate measures to mitigate these risks.



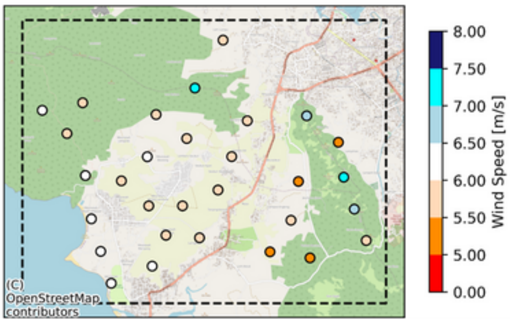
Biodiversity, social- and environmental conditions

Several (critically) endangered, vulnerable, and near threatened animal species were observed in the area. The endangered species including raptors, storks, swifts, and bats, and mammal species. Further research on the impact of the wind farm on the biodiversity is required. The envisioned turbines are planned in non-densely populated areas. However, visual impact and stakeholder engagement is critical in the early stage of project development.

Wind speed and energy yield

Parameter [Unit]	Amount
Number of new WTGs	30
Rated Power per WTG [MW]	4.0
Total rated Power [MW]	120.0
Rotor diameter [m]	~170
Hub height [m]	140
Air density [kg/m3]	1.151
Wind speed [m/s]	6.0
Gross result [MWh/yr]	398,549
Gross results including wake effects [MWh/yr]	365,114
P50 [MWh/yr]	317,543
P90 (25 yr) [MWh/yr]	236,154
P50 [hrs/yr]	2,646
P90 (25 yr) [hrs/yr]	1,968

The modelled long-term wind speed at the planned hub height of 140 m is between 5.0 - 7.5 m/s. The gross Annual Energy Production (AEP) is subsequently calculated based on the power curve of the 4 MW reference wind turbine. A production loss percentage of 20.5% is determined for the wind farm based on e.g. wake losses, non-availability, electrical losses, etc.



The net AEP is calculated by subtracting energy production losses from the gross AEP, at a P50 level. To determine the long-term (25 years) production, a P90 level is determined by incorporating an uncertainty of 20%. The determined number of full-load hours (2,646 hrs/yr) is equivalent to a wind farm capacity factor of 30%.

Business case

Input cost parameters are composed of surveys, design work, land acquisition, permits, wind turbines, civil works, electrical works, maintenance, project management, and risk contingencies.

Key assumed financial parameters include:

- 25 years of operation
- All cost including VAT
- Gearing 70/30
- Debt tenure: 10 years
- Interest rate: 9% p.a.
- Prospective electricity price*
  - Year 1-10: $10.49 cents/kWh
  - Year 11-25: $5.73 cents/kWh

**Based on Presidential Regulation 112/2022 ceiling tariff (with location factor)*

	Lower-bound	Baseline	Upper-bound
Development and Capital Expenditure	$171.1 million	$190.8 million	$240.2 million
Investment cost per MW	$1.42 million	$1.59 million	$2.02 million
Project IRR at P50 before taxes	11.25%	9.25%	5.52%
Average DSCR at P90	0.90	0.82	0.67
Net profit at P50 over 25 years	$119.2 million	$99.4 million	$50.9 million

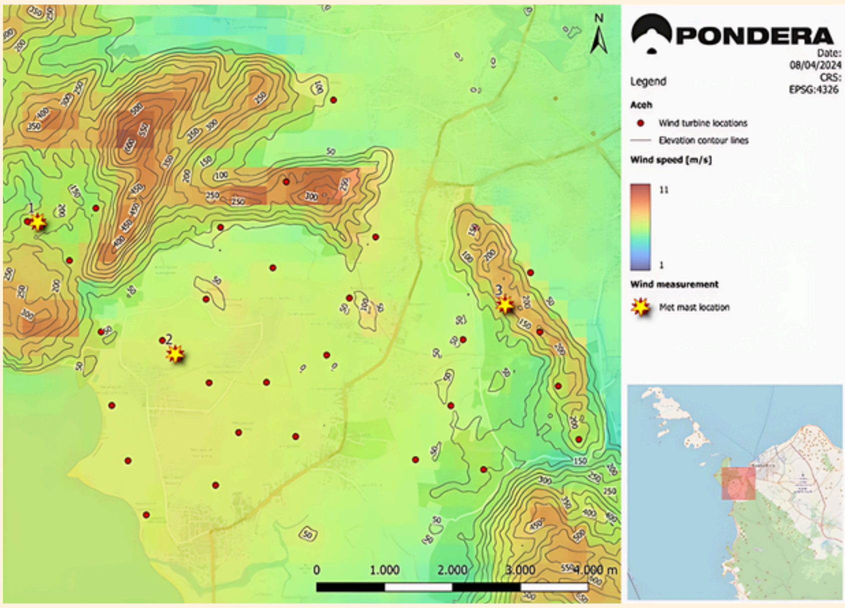
Conclusion

Based on the conducted analysis, it is concluded that the overall techno-economic viability of a wind farm in Aceh Besar region requires improvement. The relatively low average wind speed (still to be validated with wind measurements) at some turbine locations, is a significant contributor to the less promising business case. Reconsidering the site layout during a follow up study could improve this. This could lead to a wind farm size of approximately 50 MW, with likely an improved business case outcome.

Recommended next steps

Wind resource

Place at least three (3) met masts for data gathering for at least one year to cover the northwestern, central, and eastern part of the wind farm



Land use and permitting

- Assess the land use / ownership in greater detail
- Consulting the authorities about the willingness and possibility to issue approvals and permits
- Approach relevant landowners in order to achieve an agreement on the land

Grid connection and PPA

- Verify the suitability of Banda Aceh substation to facilitate the wind farm's grid connection
- Align with PLN on the PPA conditions and tender process set-up

Geology and seismicity

- Conduct geotechnical soil investigations and soil stability analyses, as input for the wind turbine foundation design and crane hardstand design
- Analyse soil stability in combination with the LiDAR-study for a more precise mapping of the topography
- Calculate the maximum expected peak ground acceleration to mitigate the earthquake risk

Environment, flora, and fauna

- Involve (potentially) affected stakeholders early in the wind farm development, to identify and mitigate specific objections from each stakeholder
- Conduct a biodiversity baseline study and risk assessment and mitigation measures as part of ESIA

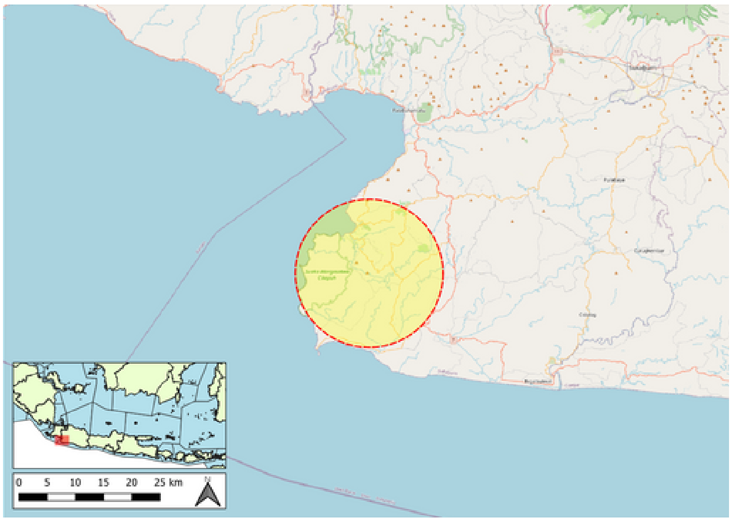
Transport

- Conduct a port survey to ensure that the Port of Malahayati is suitable for offloading and storing the wind turbine components
- A more extensive logistical survey is recommended to be conducted as part of the future feasibility study to obtain more details of the required infrastructure

Disclaimer
No rights can be derived from any of the presented information and results. Verification and validation through physical surveys, measurements, design, calculations, and stakeholder consultations are required.

400 MW Project
Ciracap, West Java

Location and power demand



The envisioned wind farm is located in Ciracap, West Java Province. The electricity system at the province is connected to the Java-Madura-Bali grid.

The peak load in the province in 2021-2030 is expected to grow with an average annual growth rate of 3.88% from 7,712 MW (2020). Wind energy potential in Sukabumi is registered as 670 MW in RUPTL PLN 2021-2030.

According to the Sukabumi Regency Spatial Plan 2012-2032, the envisioned wind farm is located in areas with the following land use types:

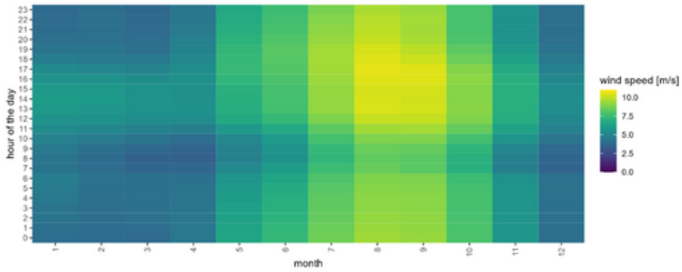
Plantation Area
This area may be owned by private parties or a local community. Wind farm development is possible in the area if the area is not part of the Sustainable Food Agriculture Area, and a lease/purchase agreement is achieved with the landowner.

Wetland/Dryland Farming Agriculture Area
This area may be owned by the community. Wind farm development in this area is possible if the area is not part of the Sustainable Food Agriculture Area, and if a lease/purchase agreement is achieved with the landowner.

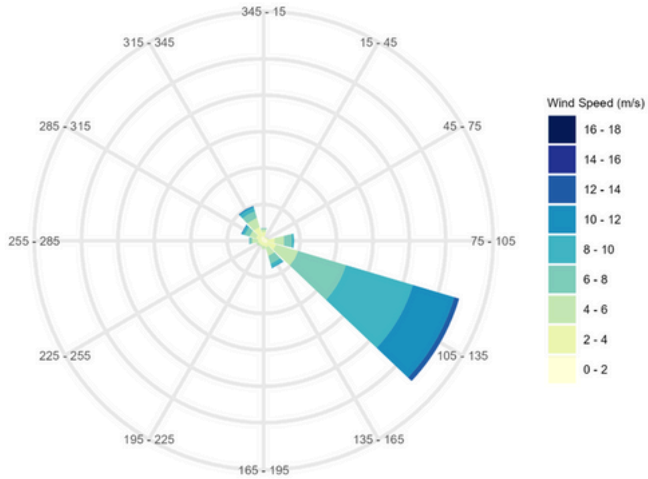
River Border/Beach Border Area
This area is under the ownership of the State and can be used for public interest activities such as power generation.

Rural Settlement Area
This area may be owned by a local community. Construction of wind power plants at these locations is possible if a lease/purchase agreement is achieved with the landowner.

Wind characteristics



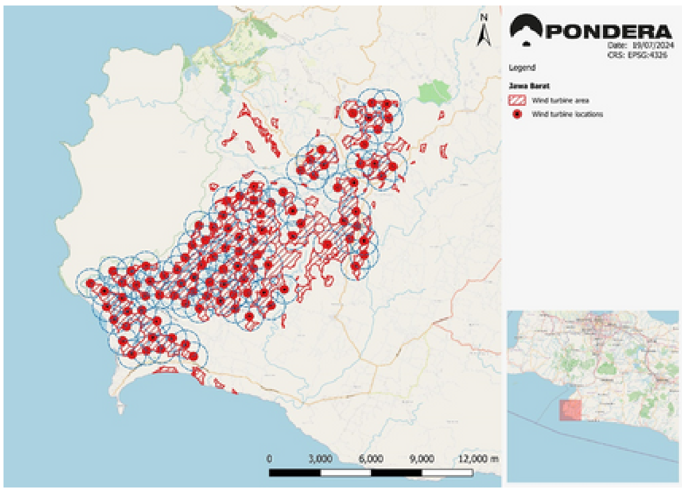
The wind climate in the region predominantly consists of wind from the southeastern direction. The highest wind speeds are observed in the period of May-October. El Niño and La Niña phenomena may cause variations interannual variations of wind speed.



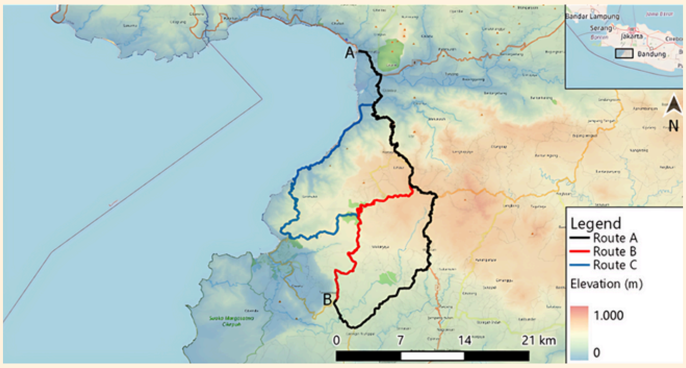
Wind farm layout

100
wind turbines

400 MW
total installed capacity



Logistic, civil- and electrical works

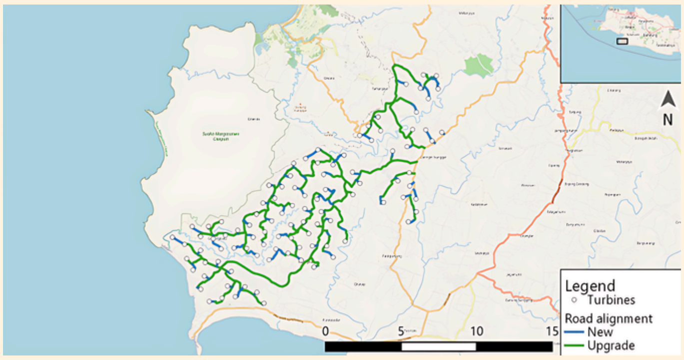


The Fishing Port of Pelabuhan Ratu is deemed to be the most suitable entry point of the turbines, with access to the site available via regional roads. Some challenges expected from the port exit to the site include a section of steep hills and cage design bridges.

The closest point of connection to the existing grid is the Pelabuhan Ratu Baru 150 kV PLN substation. From this PLN substation to the wind farm's powerhouse, a 8 km transmission line is required. The generated electricity will be distributed to the powerhouse via twenty wind farm substations.

Geology and seismic conditions

The wind farm area has medium-risk of land movement vulnerability, potential to be hit by strong earthquakes. The foundation design should incorporate measures to mitigate these risks.



Within the site, new roads need to be constructed, and some existing roads and bridges must be upgraded in the rural parts.

67 km new road

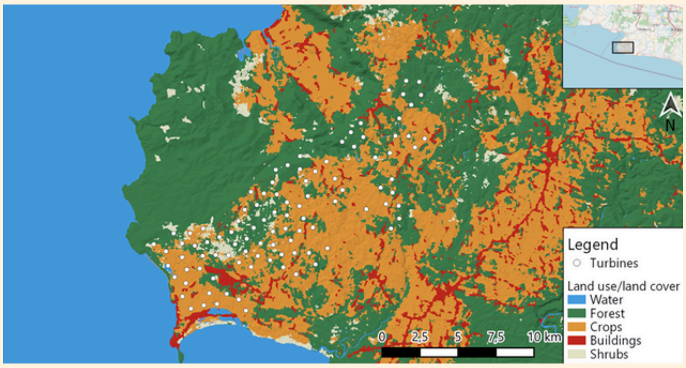
121 km road upgrade

13 bridges strengthened

100 wind turbine foundations and crane hardstands

22 transmission towers

1,434 km electrical cable



Biodiversity, social- and environmental conditions

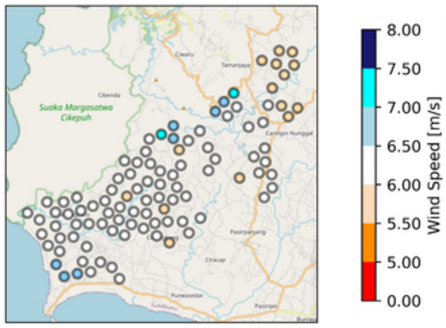
Several critically endangered, endangered, vulnerable, and near threatened animal and plant species were observed in the area. The critically endangered species include Javan slow loris and Malayan pangolin. Further research on the impact of the wind farm on the biodiversity is required. The envisioned turbines are planned in between villages, and tourist destination. The social impact could be the loss of agricultural land, reduced accessibility during road construction, and transport and visual impact.

Wind speed and energy yield

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

The modelled long-term wind speed at the planned hub height of 140 m, is 6.2 m/s. The gross Annual Energy Production (AEP) is subsequently calculated based on the power curve of the 4 MW reference wind turbine. A production loss percentage of 22.1% is determined for the wind farm based on e.g. wake losses, non-availability, electrical losses, etc.

The net AEP is calculated by subtracting energy production losses from the gross AEP, at a P50 level. To determine the long-term production (over 25 years), a P90 level is determined by incorporating an uncertainty of 20%. The determined number of full-load hours (2,829 hrs/yr) is equivalent to a wind farm capacity factor of 32%.



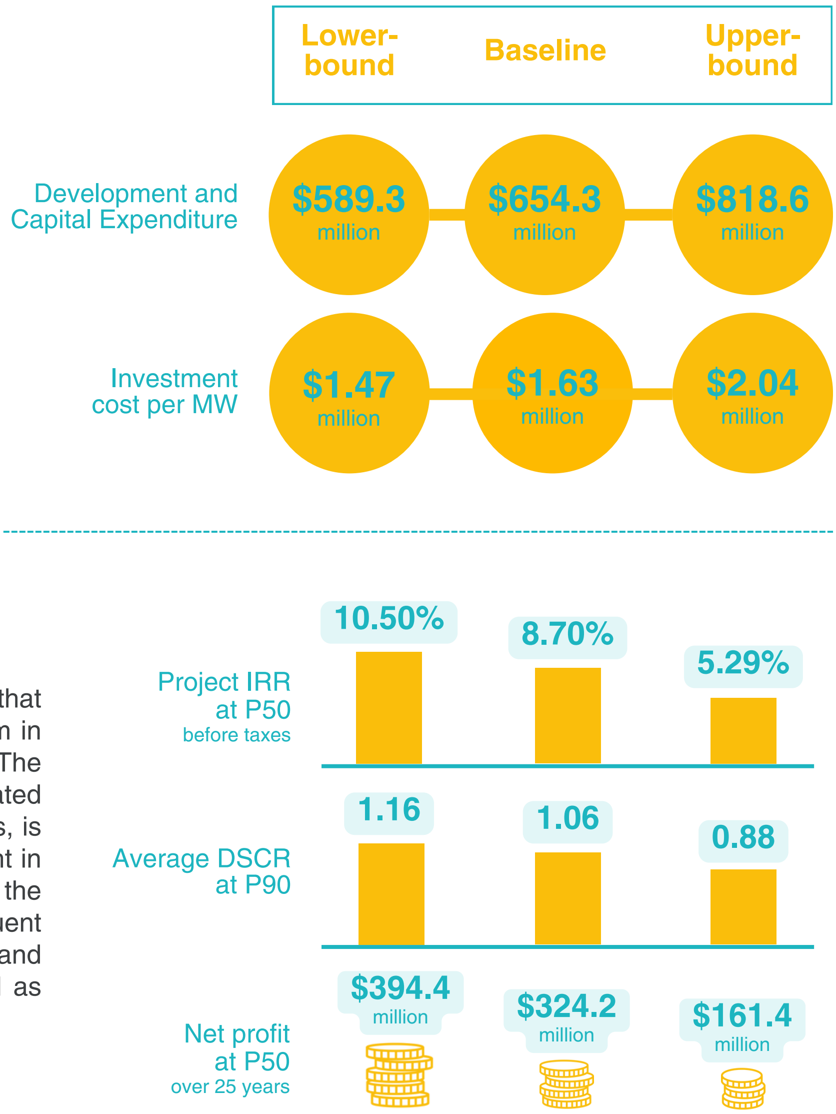
Business case

Input cost parameters are composed of surveys, design work, land acquisition, permits, wind turbines, civil works, electrical works, maintenance, project management, and risk contingencies.

Key assumed financial parameters include:

- 25 years of operation
- All cost including VAT
- Gearing 70/30
- Debt tenure: 10 years
- Interest rate: 9% p.a.
- Prospective electricity price*
  - Year 1-10: $9.54 cents/kWh
  - Year 11-25: $5.73 cents/kWh

**Based on Presidential Regulation 112/2022 ceiling tariff (with location factor)*



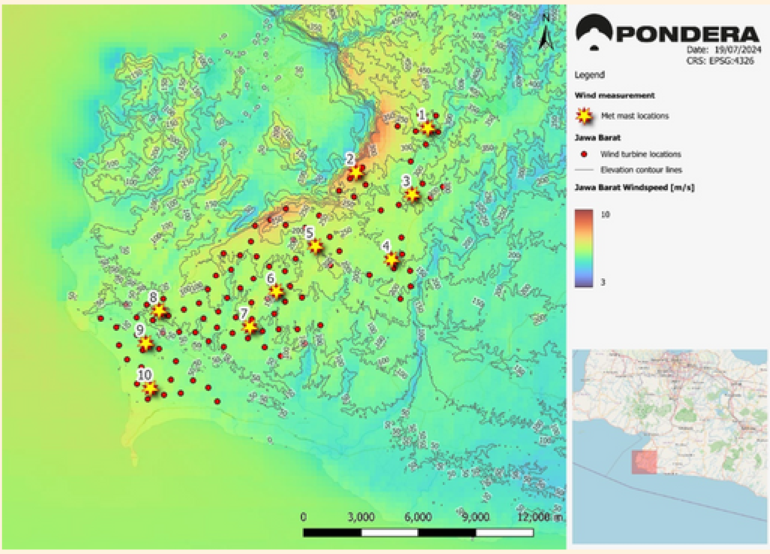
Conclusion

Based on the conducted analysis, it is concluded that the overall techno-economic viability of a wind farm in the Ciracap region requires improvement. The relatively low average wind speed (still to be validated with wind measurements) at some turbine locations, is a contributor to this. An improvement can be sought in subselecting the wind turbine locations with the highest yield and lowest cost. In this subsequent assessment, the cost for required infrastructure and the port selection are vital parts to be considered as well.

Recommended next steps

Wind resource

Place at least ten (10) met masts for data gathering for at least a year. The red dots indicate the wind turbine locations. The yellow icons show the global positioning of recommended met mast locations



Land use and permitting

- Assess the land use / ownership in greater detail
- Consulting the authorities about the willingness and possibility to issue approvals and permits
- Approach relevant landowners in order to achieve an agreement on the land

Grid connection and PPA

- Verify the suitability of Pelabuhan Ratu Baru substation to facilitate the wind farm's grid connection
- Align with PLN on the PPA conditions and tender process set-up

Geology and seismicity

- Conduct geotechnical soil investigations and soil stability analyses, as input for the wind turbine foundation design and crane hardstand design
- Calculate the maximum expected peak ground acceleration to mitigate the earthquake risk

Environment, flora, and fauna

- Involve (potentially) affected stakeholders early in the wind farm development, to identify and mitigate specific objections from each stakeholder
- Conduct a biodiversity baseline study and risk assessment and mitigation measures as part of ESIA

Transport

- Conduct a port survey to ensure that the fishing port in Pelabuhan Ratu is suitable for offloading and storing the wind turbine components
- Upgrading public roads and smaller bridges is recommended to be conducted as part of the future feasibility study to obtain more details of the required infrastructure

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92 MW Project
Dairi, North Sumatra

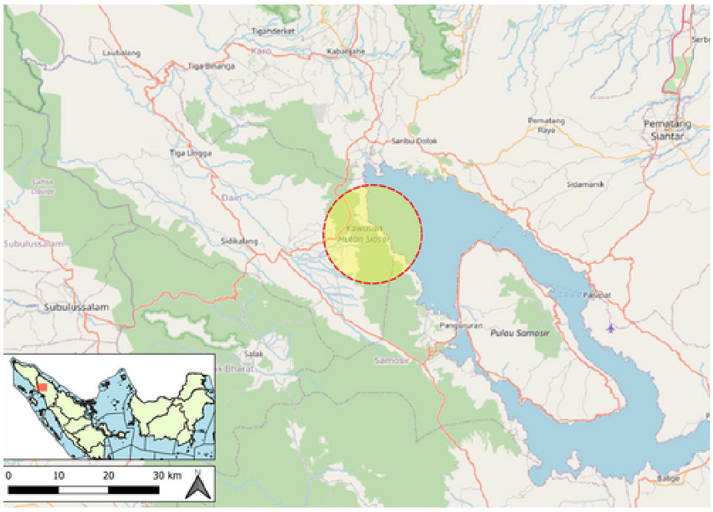
Location and power demand

The envisioned wind farm is located in Dairi Regency, North Sumatra Province. The electricity system at the province consists of the main island grid and the Nias Island grid.

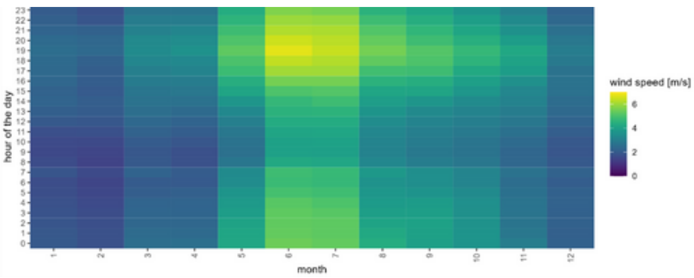
The peak load in the province in 2021-2030 is expected to grow with an average annual growth rate of 5.5% from 1,883 MW (2020). Wind energy potential in North Sumatra is registered as 198 MW in RUPTL PLN 2021-2030.

According to the Dairi Regency Spatial Plan 2014-2034, the envisioned wind farm is located in areas with the following land use type:

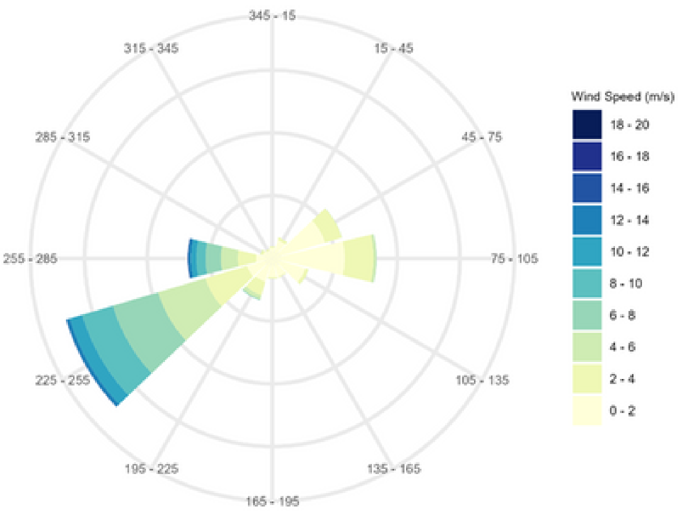
Protected Forest Area
Forest Area Use Approval (PPKH) to be issued by the Ministry of Environment and Forestry is needed to develop a wind farm at the area.



Wind characteristics



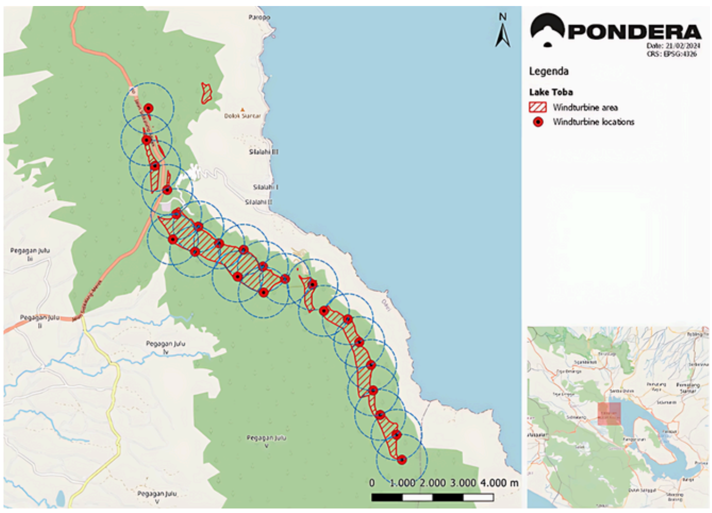
The wind climate in the region predominantly consists of wind from the southwestern direction. The highest wind speeds are observed in the period of May-October. El Niño and La Niña phenomena may cause variations interannual variations of wind speed.



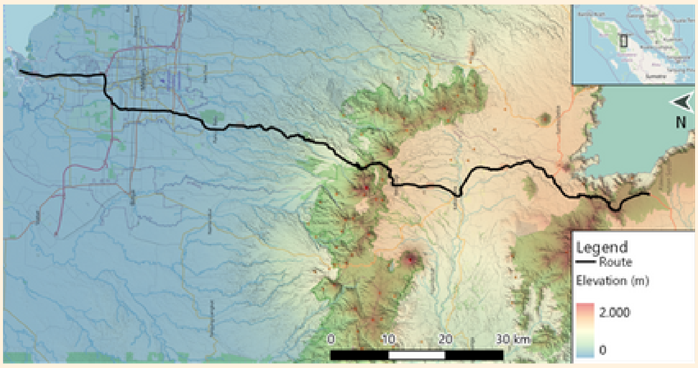
Wind farm layout

23
wind turbines

92 MW
total installed capacity

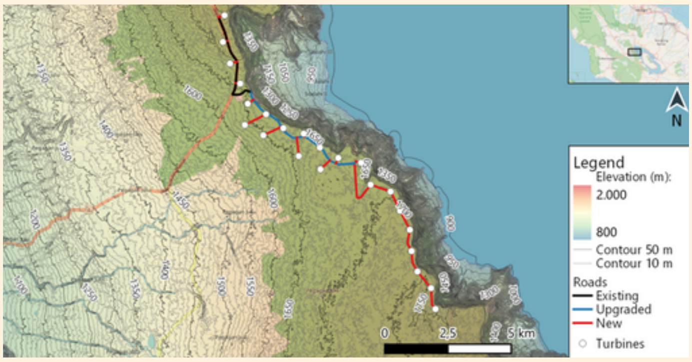


Logistic, civil- and electrical works



The Port of Belawan is deemed to be the most suitable entry point of the turbines, with access to the site available via highway. No challenges expected from port until the project site. However, the first 50 km from the port to the site are relatively flat, after which the road ascends to the plateau surrounding Lake Toba, Dairi.

The closest point of connection to the existing grid is the Sidikalang 150 kV PLN substation. From this PLN substation to the wind farm's powerhouse, a 19 km transmission line is required. The generated electricity will be distributed to the powerhouse via four wind farm substations.



Within the site, the route is mostly ascending with hairpins situated near Sibolangit village. One hairpin is particularly narrow and directly located next to water extraction site managed by PDAM.

13 km new road

8 km road upgrade

6 bridges strengthened

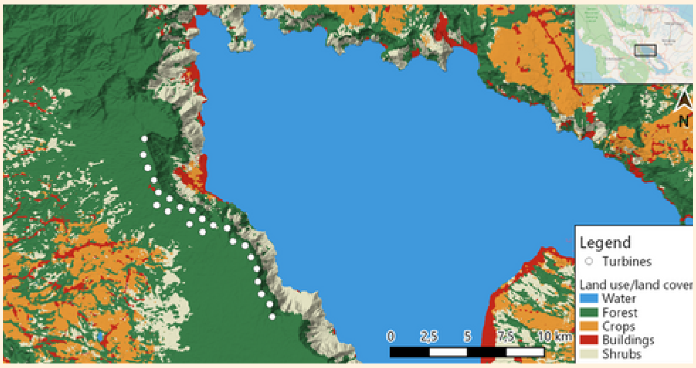
23 wind turbine foundations and crane hardstands

48 transmission towers

111 km electrical cable

Geology and seismic conditions

The wind farm area has low- to medium-risk of land movement vulnerability and potential to be hit by strong earthquakes. The foundation design should incorporate measures to mitigate these risks.



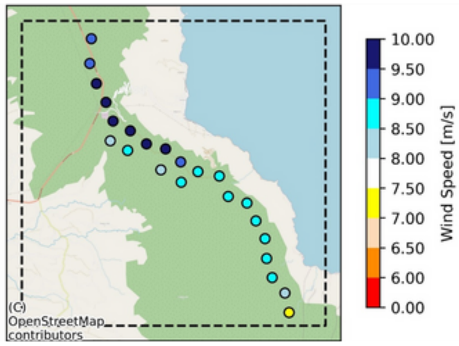
Biodiversity, social- and environmental conditions

Several endangered, vulnerable, and near threatened animal species were observed in the area. The endangered species including primates, birds, plants, and flowers species. Further research on the impact of the wind farm on the biodiversity is required. The envisioned turbines are planned in important tourism areas. Hence, stakeholder engagement is critical in the early stage of project development.

Wind speed and energy yield

Parameter [Unit]	Amount
Number of new WTGs	23
Rated Power per WTG [MW]	4.0
Total rated Power [MW]	92.0
Rotor diameter [m]	~170
Hub height [m]	140
Air density [kg/m³]	0.986
Wind speed [m/s]	9.0
Gross result [MWh/yr]	507,848
Gross results including wake effects [MWh/yr]	497,691
P50 [MWh/yr]	432,897
P90 (25 yr) [MWh/yr]	321,941
P50 [hrs/yr]	4,705
P90 (25 yr) [hrs/yr]	3,499

The modelled long-term wind speed, at the planned hub height of 140 m, is between 7.0 - 10.0 m/s. The gross Annual Energy Production (AEP) is subsequently calculated based on the power curve of the 4 MW reference wind turbine. A production loss percentage of 14.8% is determined for the wind farm based on e.g. wake losses, non-availability, electrical losses, etc.



The net AEP is calculated by subtracting energy production losses from the gross AEP, at a P50 level. To determine the long-term (25 years) production, a P90 level is determined by incorporating an uncertainty of 20%. The determined number of full-load hours (4,705 hrs/yr) is equivalent to a wind farm capacity factor of 53%.

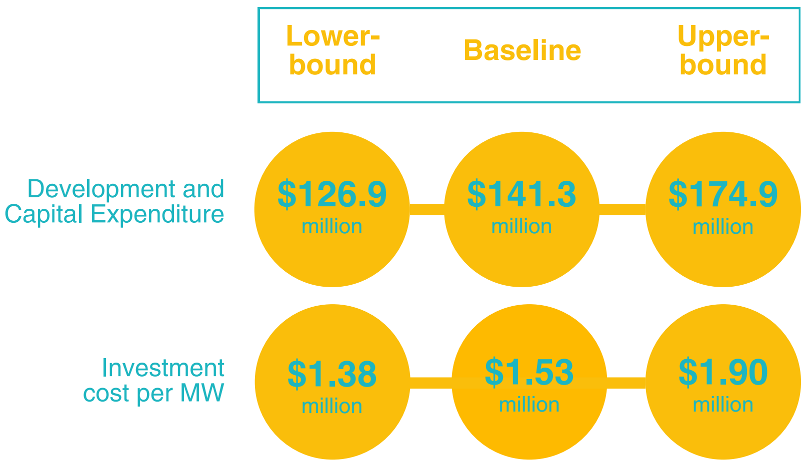
Business case

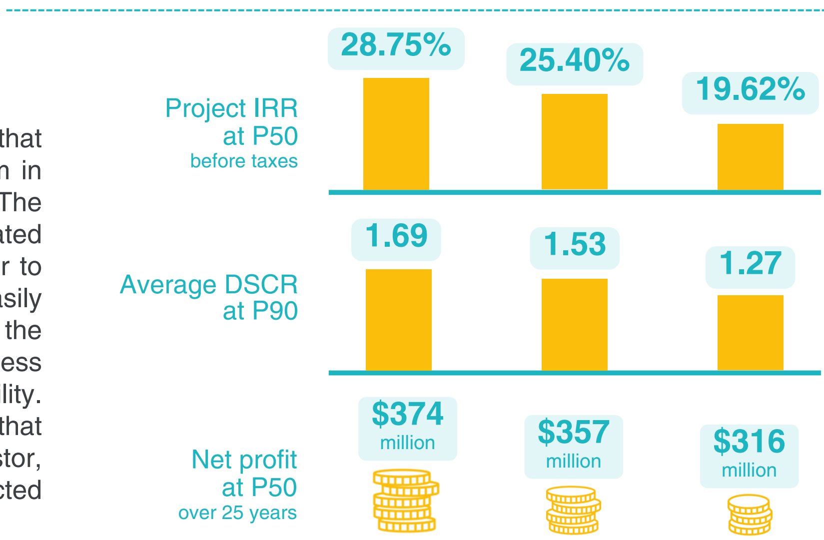
Input cost parameters are composed of surveys, design work, land acquisition, permits, wind turbines, civil works, electrical works, maintenance, project management, and risk contingencies.

Key assumed financial parameters include:

- 25 years of operation
- All cost including VAT
- Gearing 70/30
- Debt tenure: 10 years
- Interest rate: 9% p.a.
- Prospective electricity price*
  - Year 1-10: $10.49 cents/kWh
  - Year 11-25: $5.73 cents/kWh

**Based on Presidential Regulation 112/2022 ceiling tariff (with location factor)*





Conclusion

Based on the conducted analysis, it is concluded that the overall techno-economic viability of a wind farm in Dairi Regency near Lake Toba could be promising. The relatively high average wind speed (still to be validated with wind measurements) is a significant contributor to the promising business case. Furthermore, the easily accessible terrain and reasonable distance to the existing PLN grid could result in a favorable business case and potentially a good technical feasibility. However, the envisioned wind farm entails risks that should be considered by the developer and investor, specifically the location of the wind farm in a protected forest area.

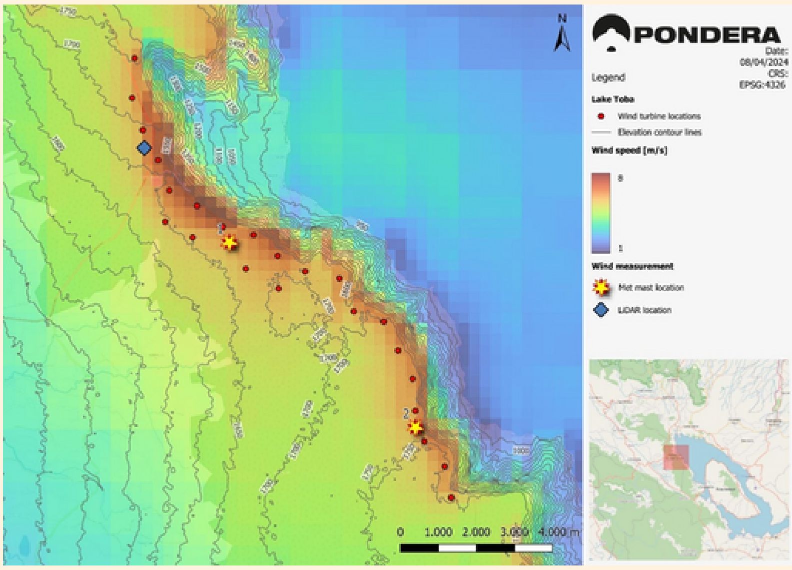
Recommended next steps

Wind resource

Place at least two (2) met masts and one LiDAR for data gathering to cover the central, southern, and northern part of the wind farm

Land use and permitting

- Assess the land use / ownership in greater detail early in the development process
- Consulting the authorities about the willingness and possibility to issue approvals and permits
- Approach relevant landowners in order to achieve an agreement on the land



Grid connection and PPA

- Verify the suitability of Sidikalang substation to facilitate the wind farm's grid connection
- Align with PLN on the PPA conditions and tender process set-up

Geology and seismicity

- Conduct geotechnical soil investigations and soil stability analyses, as input for the wind turbine foundation design and crane hardstand design
- Analyse soil stability in combination with the LiDAR-study for a more precise mapping of the topography
- Calculate the maximum expected peak ground acceleration to mitigate the earthquake risk

Environment, flora, and fauna

- Involve (potentially) affected stakeholders (for example in tourism) early in the wind farm development, to identify and mitigate specific objections from each stakeholder
- Conduct a biodiversity baseline study and risk assessment and mitigation measures as part of ESIA

Transport

- Conduct a port survey to ensure that the Port of Belawan is suitable for offloading and storing the wind turbine components
- Alignment with the local authorities and PDAM regarding the improvement of the road south of Merek and the hairpin in the south of Sibolangit, respectively, is required
- A more extensive logistical survey is recommended to be conducted as part of the future feasibility study to obtain more details of the required infrastructure

Disclaimer
No rights can be derived from any of the presented information and results. Verification and validation through physical surveys, measurements, design, calculations, and stakeholder consultations are required.

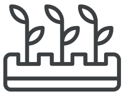
80 MW Project
Gunung Kidul, DI Yogyakarta

Location and power demand

The envisioned wind farm is located in Gunung Kidul Regency, DI Yogyakarta Province. The electricity system at the province is connected to the Java-Madura-Bali grid.

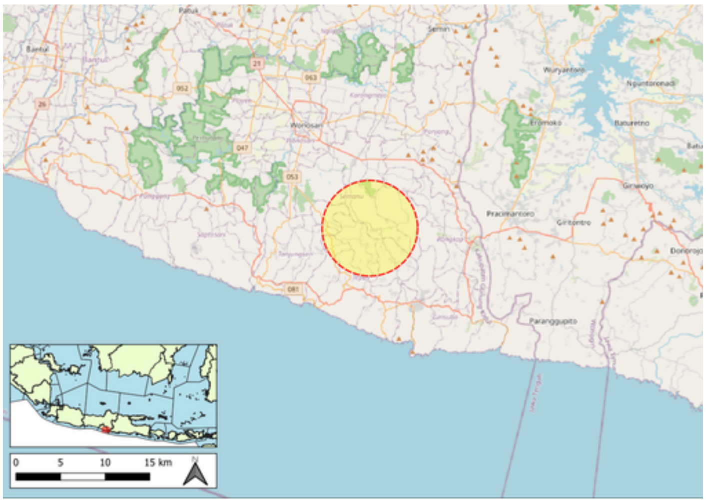
The peak load in the province in 2021-2030 is expected to grow with an average annual growth rate of 4.88% from 450 MW (2020). Wind energy potential in DI Yogyakarta is registered as 60 MW in RUPTL PLN 2021-2030.

According to the Gunung Kidul Regency Spatial Plan 2010-2030, the envisioned wind farm is located in areas with the following land use types:

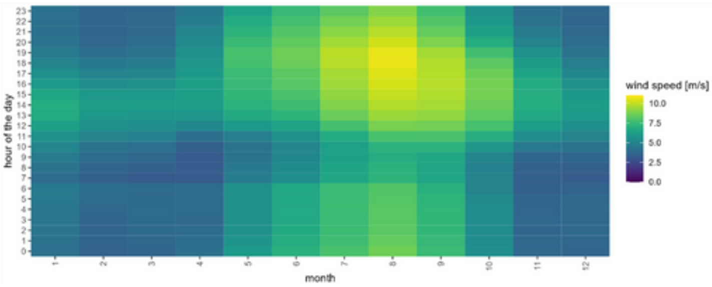


Dryland Farming Agriculture Area
This area may be owned by the community. Wind farm development in this area is possible if the area is not part of the Sustainable Food Agriculture Area, and if a lease/purchase agreement is achieved with the landowner.

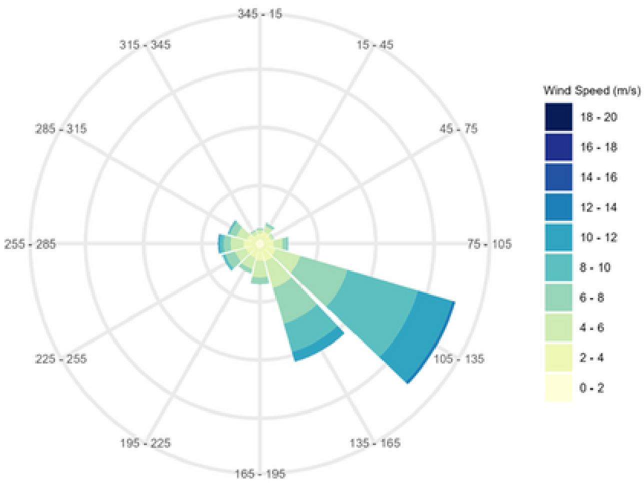
Residential Area
This area may be owned by a local community. Construction of wind power plants at these locations is possible if a lease/purchase agreement is achieved with the landowner.



Wind characteristics



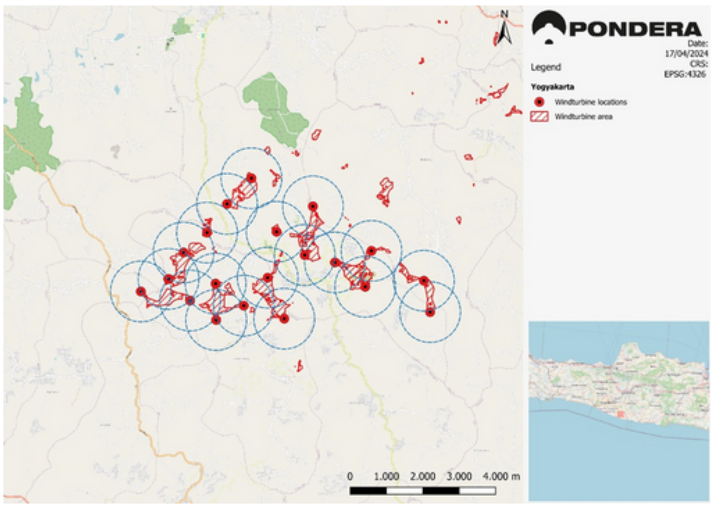
The wind climate in the region predominantly consists of wind from the southeastern direction. The highest wind speeds are observed in the period of June-October. El Niño and La Niña phenomena may cause variations interannual variations of wind speed.



Wind farm layout

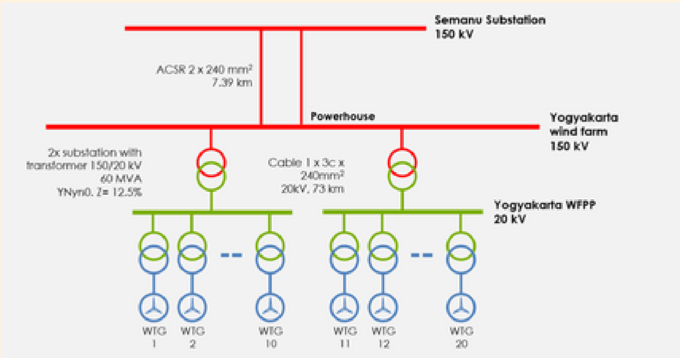
20
wind turbines

80 MW
total installed capacity



Logistic, civil- and electrical works

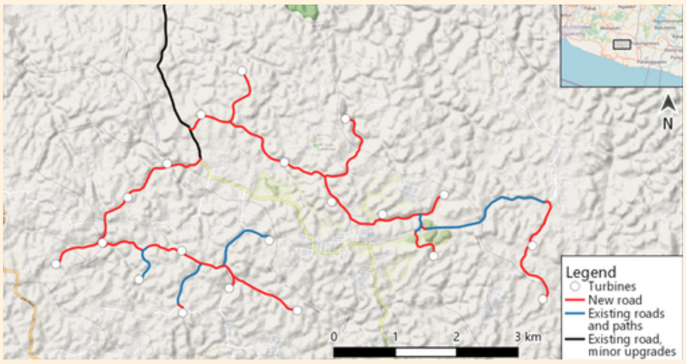
The Port of Semarang is deemed to be the most suitable entry point of the turbines, with access to the site available via highway/toll road. No challenges expected from port until the southeast of Yogyakarta, the road will ascend a plateau. The road features two hairpins in this ascent.



The closest point of connection to the existing grid is the Semanu 150 kV PLN substation. From this PLN substation to the wind farm's powerhouse, a 7 km transmission line is required. The generated electricity will be distributed to the powerhouse via two wind farm substations.

Geology and seismic conditions

The wind farm area has low-risk of land movement vulnerability and potential to be hit by strong earthquakes. The foundation design should incorporate measures to mitigate these risks.



Within the site, new roads need to be constructed on hilly and steep areas, and some existing roads and bridges must be strengthened.

18 km new road

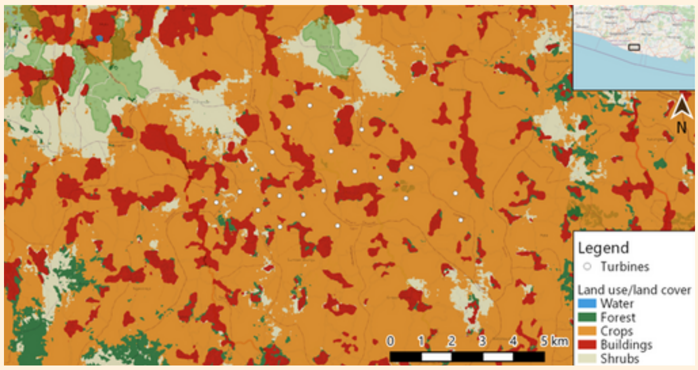
12 km road upgrade

23 bridges strengthened

20 wind turbine foundations and crane hardstands

21 transmission towers

73 km electrical cable



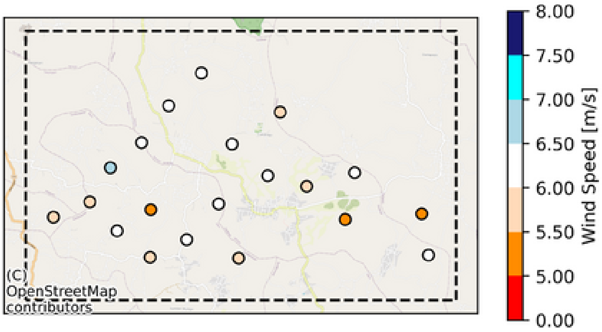
Biodiversity, social- and environmental conditions

In the area, there is one species being listed with at least ‘near threatened’ status. This species is Javan myna, which is categorized as vulnerable. Further research on the impact of the wind farm on the biodiversity is required. The envisioned turbines are planned in unpopulated valleys and/or hills away from the villages. Hence, the social impact is mainly limited to the loss of agricultural land, reduced accessibility during road construction, and transport and visual impact.

Wind speed and energy yield

Parameter [Unit]	Amount
Number of new WTGs	20
Rated Power per WTG [MW]	4.0
Total rated Power [MW]	80.0
Rotor diameter [m]	~170
Hub height [m]	140
Air density [kg/m3]	1.129
Wind speed [m/s]	6.0
Gross result [MWh/yr]	263,586
Gross results including wake effects [MWh/yr]	251,048
P50 [MWh/yr]	218,339
P90 (25 yr) [MWh/yr]	188,885
P50 [hrs/yr]	2,729
P90 (25 yr) [hrs/yr]	2,361

The modelled long-term wind speed, at the planned hub height of 140 m, is between 5.0 - 7.0 m/s. The gross Annual Energy Production (AEP) is subsequently calculated based on the power curve of the 4 MW reference wind turbine. A production loss percentage of 17.2% is determined for the wind farm based on e.g. wake losses, non-availability, electrical losses, etc.



The net AEP is calculated by subtracting energy production losses from the gross AEP, at a P50 level. To determine the long-term (25 years) production, a P90 level is determined by incorporating an uncertainty of 20%. The determined number of full-load hours (2,729 hrs/yr) is equivalent to a wind farm capacity factor of 31%.

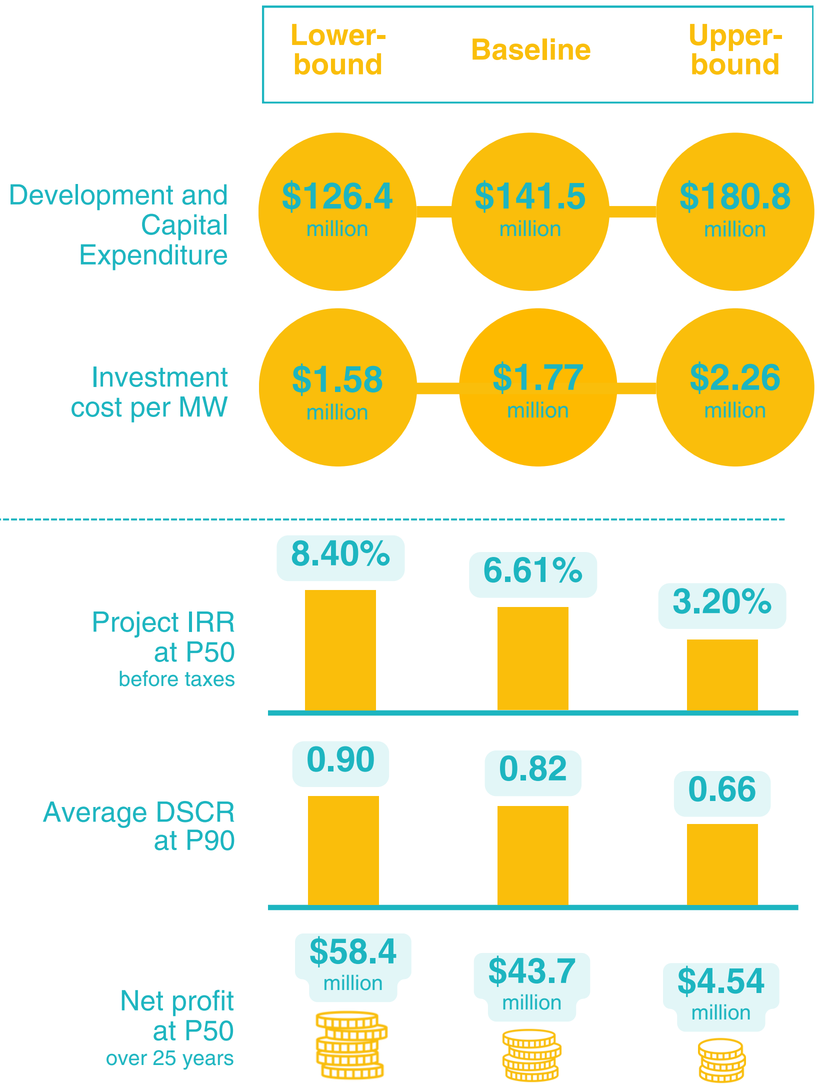
Business case

Input cost parameters are composed of surveys, design work, land acquisition, permits, wind turbines, civil works, electrical works, maintenance, project management, and risk contingencies.

Key assumed financial parameters include:

- 25 years of operation
- All cost including VAT
- Gearing 70/30
- Debt tenure: 10 years
- Interest rate: 9% p.a.
- Prospective electricity price*
  - Year 1-10: $9.54 cents/kWh
  - Year 11-25: $5.73 cents/kWh

**Based on Presidential Regulation 112/2022 ceiling tariff (with location factor)*



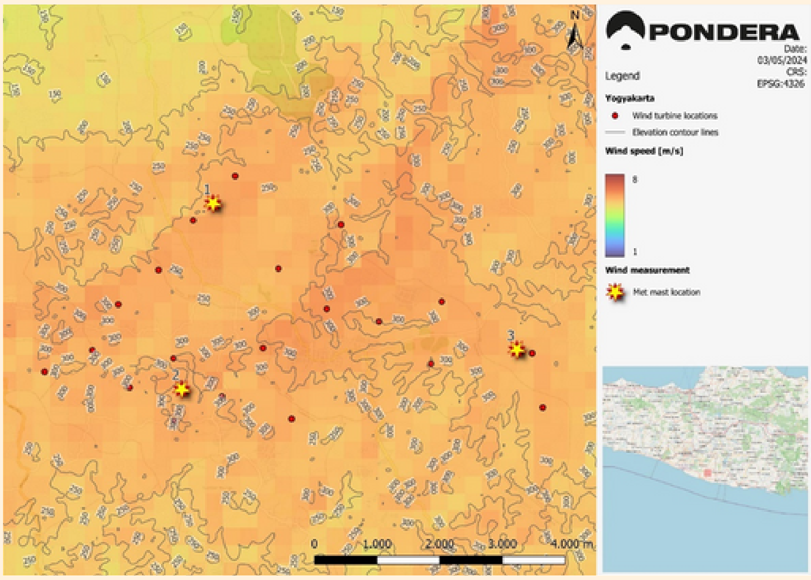
Conclusion

Based on the conducted analysis, it is concluded that the overall techno-economic viability of a wind farm in the Gunung Kidul region requires improvement. The relatively low average wind speed (still to be validated with wind measurements) at most turbine locations, is a contributor to the less promising business case. Reconsidering the site layout during a follow up study could improve this. This could lead to a wind farm size of approximately 30-40 MW, with likely an improved business case outcome.

Recommended next steps

Wind resource

Place at least three (3) met masts for data gathering for at least a year. The yellow icons on the right image show the global positioning of recommended met mast locations.



Land use and permitting

- Assess the land use / ownership in greater detail
- Approach the relevant landowners about the possibility of arriving at an agreement on the land

Grid connection and PPA

- Verify the suitability of Semanu substation to facilitate the wind farm's grid connection
- Align with PLN on the PPA conditions and tender process set-up

Geology and seismicity

- Conduct geotechnical soil investigations and soil stability analyses, as input for the wind turbine foundation design and crane hardstand design
- Analyse soil stability in combination with the LiDAR-study for a more precise mapping of the topography
- Calculate the maximum expected peak ground acceleration to mitigate the earthquake risk

Environment, flora, and fauna

- Involve (potentially) affected stakeholders early in the wind farm development, to identify and mitigate specific objections from each stakeholder
- Conduct a biodiversity baseline study and risk assessment and mitigation measures as part of ESIA

Transport

- Conduct a port survey to ensure that the Port of Semarang is suitable for offloading and storing the wind turbine components
- A more extensive logistical survey is recommended to be conducted as part of the future feasibility study to obtain more details of the required infrastructure

Disclaimer
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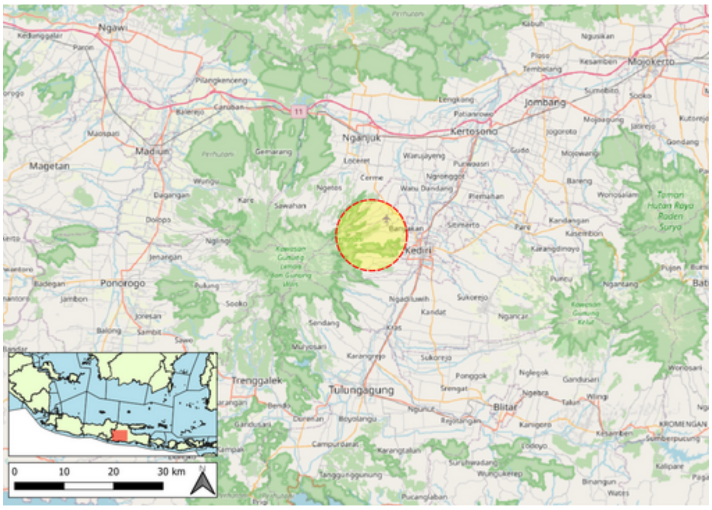
192 MW Project
Kediri, East Java

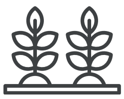
Location and power demand



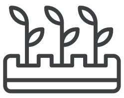
The envisioned wind farm is located in Kediri Regency, East Java Province. The electricity system at the province is connected to the Java-Madura-Bali grid.

The peak load in the province in 2021-2030 is expected to grow with an average annual growth rate of 3.7% from 5,935 MW (2020). Wind energy potential in East Java is registered as 331 MW in RUPTL PLN 2021-2030.

According to the Kediri Regency Spatial Plan 2011-2031, the envisioned wind farm is located in areas with the following land use types:



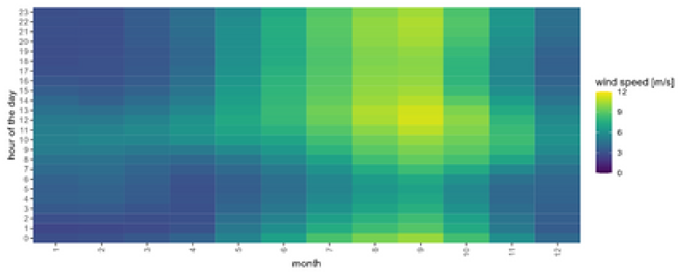
Plantation Area
This area may be owned by private parties or a local community. Wind farm development is possible if a lease/purchase agreement is achieved with the landowner.



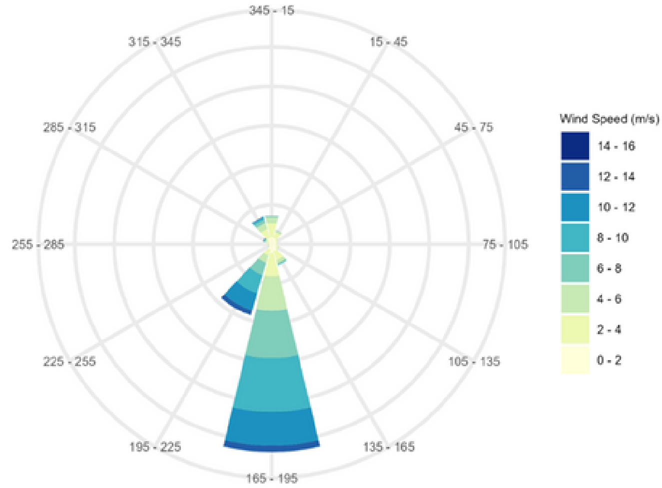
Dryland Farm Agriculture Area
This area may be owned by the community, private companies, or state-owned companies. Wind farm development in this area is possible if the area is not part of the Sustainable Food Agriculture Area, and if a lease/purchase agreement is achieved with the landowner.

Urban Settlement Area
This area may be owned by the local community. Construction of wind power plants at these locations is possible if a lease/purchase agreement is achieved with the landowner.

Wind characteristics



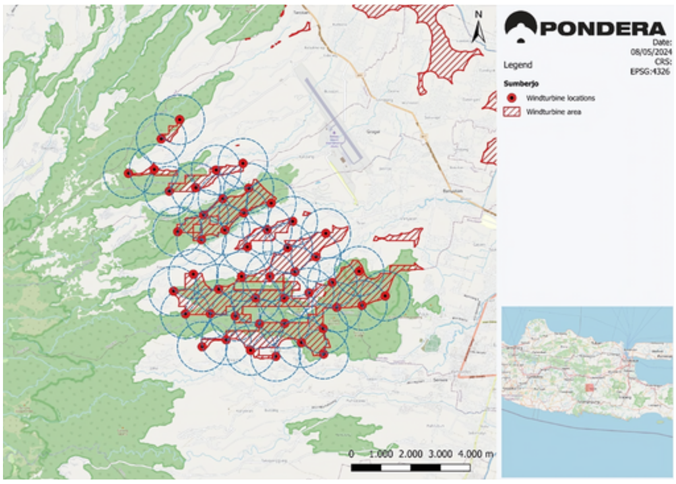
The wind climate in the region predominantly consists of wind from the south direction. The highest wind speeds are observed in the period of June-October. El Niño and La Niña phenomena may cause variations interannual variations of wind speed.



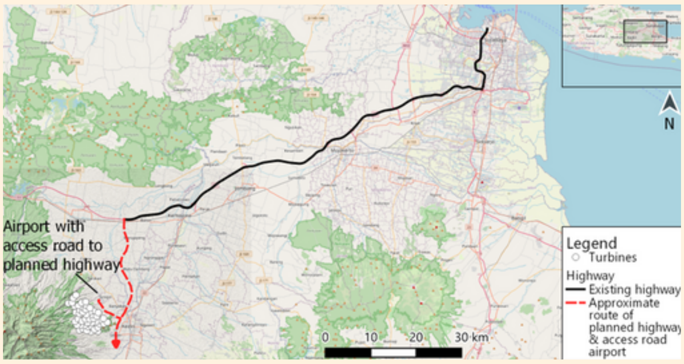
Wind farm layout

48
wind turbines

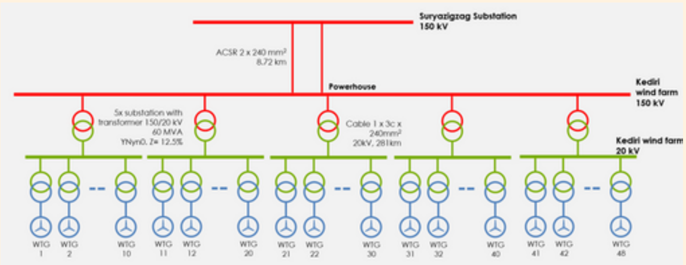
192 MW
total installed capacity



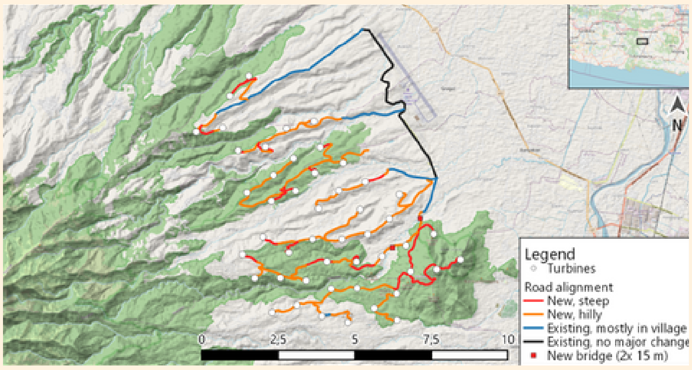
Logistic, civil- and electrical works



The Port of Surabaya is deemed to be the most suitable entry point of the turbines, with access to the site available via highway/toll road. No challenges expected from port until 25 km north of the site. A planned toll road until Kediri is in preparatory phase.



The closest point of connection to the existing grid is the Surya Zig Zag 150 kV PLN substation. From this PLN substation to the wind farm's powerhouse, a 9 km transmission line is required. The generated electricity will be distributed to the powerhouse via five wind farm substations.



Within the site, new roads need to be constructed, and some existing roads and bridges must be strengthened.

59 km new road

11 km road upgrade

6 bridges strengthened

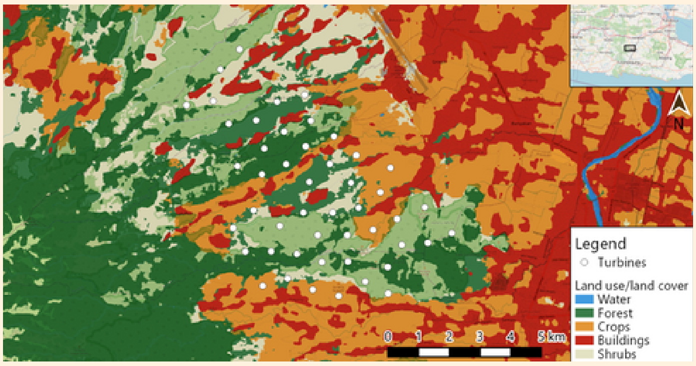
48 wind turbine foundations and crane hardstands

25 transmission towers

281 km electrical cable

Geology and seismic conditions

The wind farm area has medium-risk of land movement vulnerability and potential to be hit by strong earthquakes. The foundation design should incorporate measures to mitigate these risks.



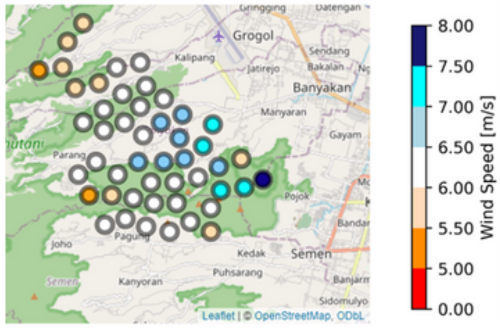
Biodiversity, social- and environmental conditions

Several (critically) endangered, vulnerable, and near threatened animal and plant species were observed in the area. One of these animal species is the critically endangered blue-banded kingfisher. Further research on the impact of the wind farm on the biodiversity is required. The envisioned turbines are planned in unpopulated valleys and/or hills away from the villages. Hence, the social impact is mainly limited to the loss of agricultural land, reduced accessibility during road construction, transport and visual impact.

Wind speed and energy yield

Parameter [Unit]	Amount
Number of new WTGs	48
Rated Power per WTG [MW]	4.0
Total rated Power [MW]	192.0
Rotor diameter [m]	~170
Hub height [m]	140
Air density [kg/m3]	0.986
Wind speed [m/s]	6.3
Gross result [MWh/yr]	652,994
Gross results including wake effects [MWh/yr]	603,366
P50 [MWh/yr]	519,135
P90 (25 yr) [MWh/yr]	386,075
P50 [hrs/yr]	2,704
P90 (25 yr) [hrs/yr]	2,011

The modelled long-term wind speed at the planned hub height of 140 m, is between 5.0 - 8.0 m/s. The gross Annual Energy Production (AEP) is subsequently calculated based on the power curve of the 4 MW reference wind turbine. A production loss percentage of 20.5% is determined for the wind farm based on e.g. wake losses, non-availability, electrical losses, etc.



The net AEP is calculated by subtracting energy production losses from the gross AEP, at a P50 level. To determine the long-term (25 years) production, a P90 level is determined by incorporating an uncertainty of 20%. The determined number of full-load hours (2,704 hrs/yr) is equivalent to a wind farm capacity factor of 31%.

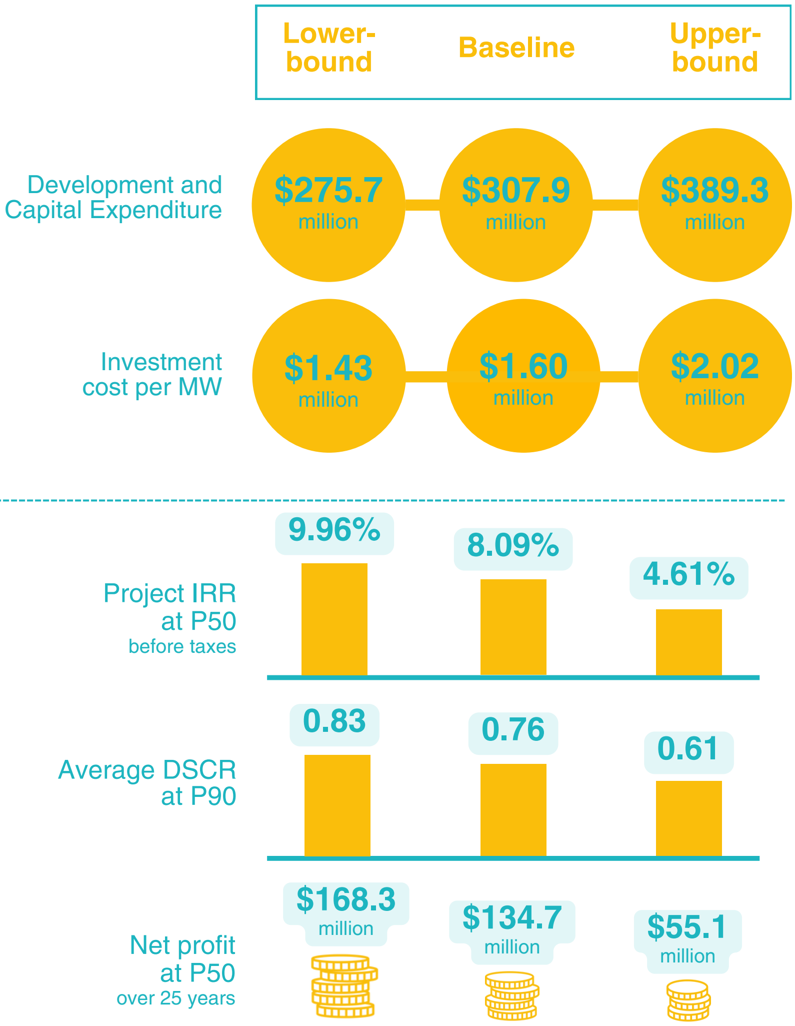
Business case

Input cost parameters are composed of surveys, design work, land acquisition, permits, wind turbines, civil works, electrical works, maintenance, project management, and risk contingencies.

Key assumed financial parameters include:

- 25 years of operation
- All cost including VAT
- Gearing 70/30
- Debt tenure: 10 years
- Interest rate: 9% p.a.
- Prospective electricity price*
  - Year 1-10: $9.54 cents/kWh
  - Year 11-25: $5.73 cents/kWh

**Based on Presidential Regulation 112/2022 ceiling tariff (with location factor)*



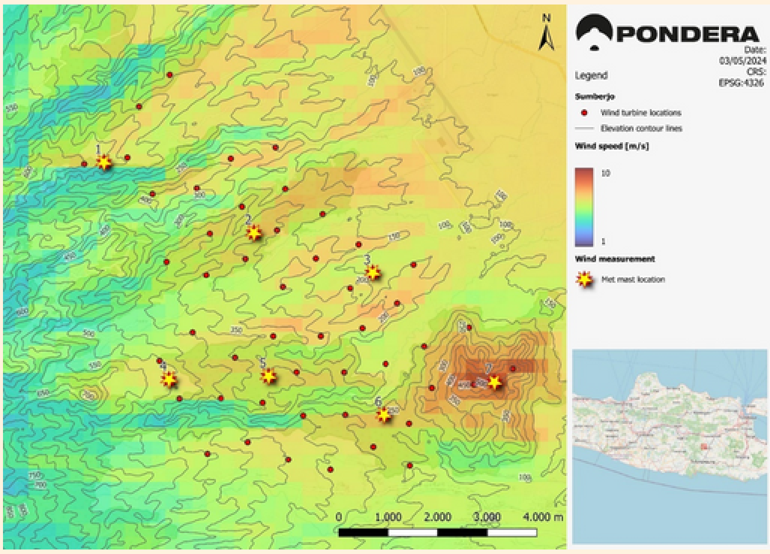
Conclusion

Based on the conducted analysis, it is concluded that the overall techno-economic viability of a wind farm in the Kediri region requires improvement. The relatively low average wind speed (still to be validated with wind measurements) at some turbine locations, is a contributor to the less promising business case. Reconsidering the site layout during a follow up study could improve this. This could lead to a wind farm size of approximately 120-150 MW, with likely an improved business case outcome.

Recommended next steps

Wind resource

Place at least seven (7) met masts for data gathering for at least a year. The yellow icons on the right image show the global positioning of recommended met mast locations.



Land use and permitting

- Assess the land use / ownership in greater detail
- Consulting the authorities about the willingness and possibility to issue approvals and permits
- Approach relevant landowners in order to achieve an agreement on the land

Grid connection and PPA

- Verify the suitability of Surya Zig Zag substation to facilitate the wind farm's grid connection
- Align with PLN on the PPA conditions and tender process set-up

Geology and seismicity

- Conduct geotechnical soil investigations and soil stability analyses, as input for the wind turbine foundation design and crane hardstand design
- Analyse soil stability study for a more precise mapping of the topography
- Calculate the maximum expected peak ground acceleration to mitigate the earthquake risk

Environment, flora, and fauna

- Involve (potentially) affected stakeholders early in the wind farm development, to identify and mitigate specific objections from each stakeholder
- Conduct a biodiversity baseline study and risk assessment and mitigation measures as part of ESIA

Transport

- Conduct a port survey to ensure that the Port of Surabaya is suitable for offloading and storing the wind turbine components
- A more extensive logistical survey is recommended to be conducted as part of the future feasibility study to obtain more details of the required infrastructure

Disclaimer
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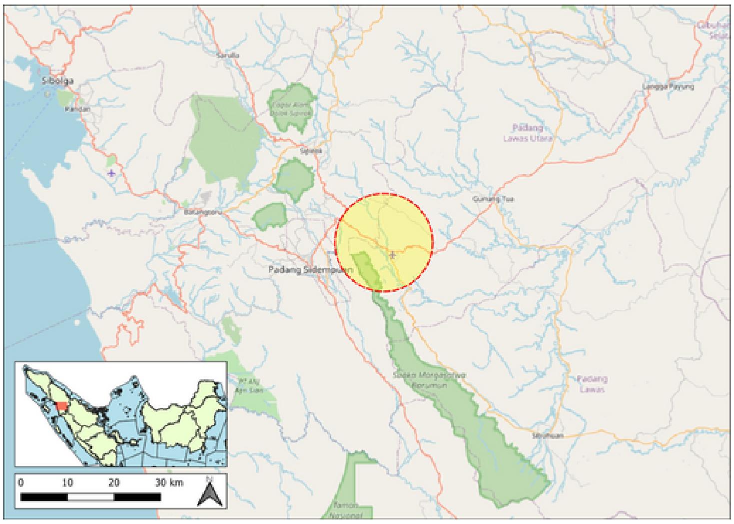
312 MW Project
North Padang Lawas - South Tapanuli, North Sumatra

Location and power demand



The envisioned wind farm is located in North Padang Lawas Regency and South Tapanuli Regency, North Sumatra Province. The electricity system at the province consists of the main island grid and the Nias Island grid.

The peak load in the province in 2021-2030 is expected to grow with an average annual growth rate of 5.5% from 1,883 MW (2020). Wind energy potential in North Sumatra is registered as 198 MW in RUPTL PLN 2021-2030.

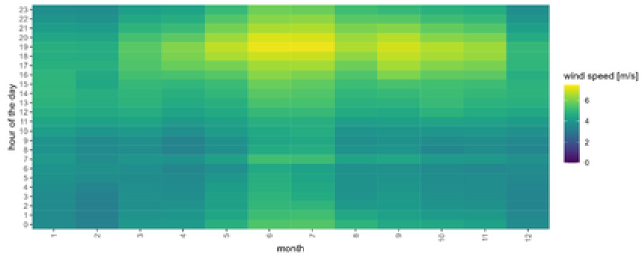
According to the North Sumatra Spatial Plan 2017-2037, North Padang Lawas Regency Spatial Plan 2015-2035, and South Tapanuli Regency Spatial Plan 2017-2037, the envisioned wind farm is located in areas with the following land use types:

Production Forest Area
Forest Area Use Approval (PPKH) to be issued by the Ministry of Environment and Forestry is needed to develop a wind farm at the area.

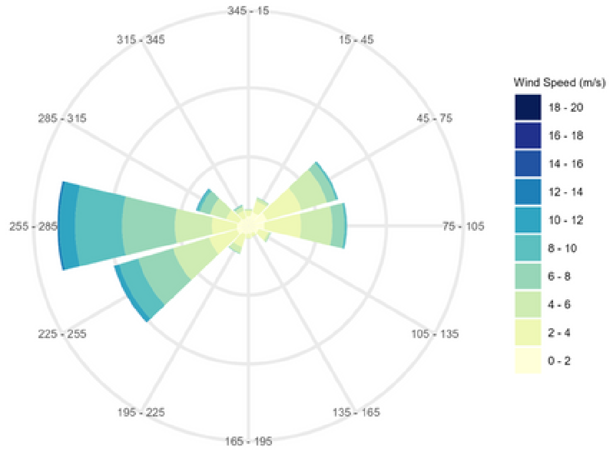
(Limited) Production Forest Area
Forest Area Use Approval (PPKH) to be issued by the Ministry of Environment and Forestry is needed to develop a wind farm at the area.

Dryland Farming/Agriculture Area
This area may be owned by the community. Wind farm development in this area is possible if the area is not part of the Sustainable Food Agriculture Area, and if a lease/purchase agreement is achieved with the landowner.

Wind characteristics



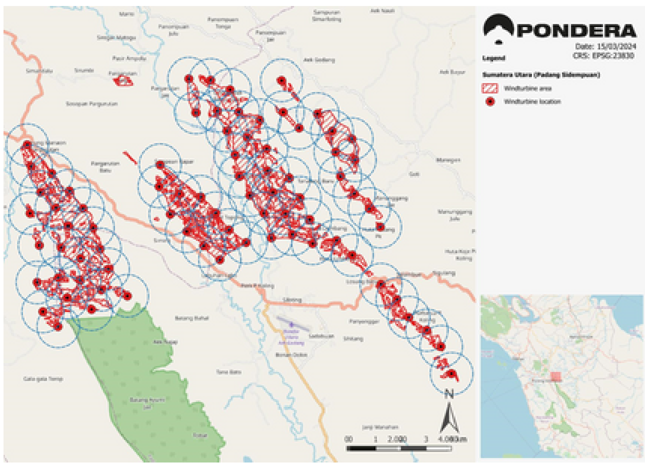
The wind climate in the region predominantly consists of wind from the western direction. The highest wind speeds are observed in the period of May-October.
El Niño and La Niña phenomena may cause variations interannual variations of wind speed.



Wind farm layout

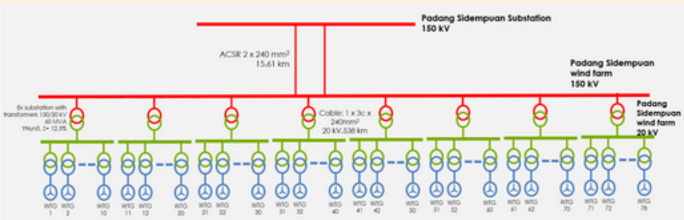
78
wind turbines

312 MW
total installed capacity



Logistic, civil- and electrical works

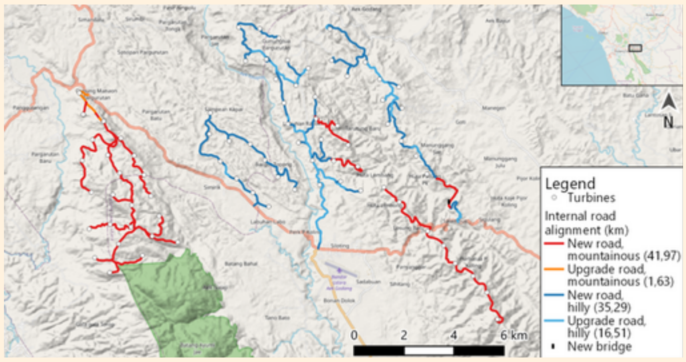
The Port of Dumai is deemed to be the most suitable entry point of the turbines, with access to the site available via regional roads (compared to the shorter but more challenging route from the Port of Sibolga). Still, some challenges are present on the chosen route, including hairpins in mountainous terrain. Finalization of Section 8 of the Rantauprapat-Dumai toll road is vital for the transport to the site.



The closest point of connection to the existing grid is the Padang Sidempuan 150 kV PLN substation. From this PLN substation to the wind farm's powerhouse, a 15 km transmission line is required. The generated electricity will be distributed to the powerhouse via eight wind farm substations.

Geology and seismic conditions

The wind farm area has medium- to high-risk of land movement vulnerability and potential to be hit by strong earthquakes. The foundation design should incorporate measures to mitigate these risks.



Within the site, new roads need to be constructed on hilly and steep areas. Some existing roads and bridges must be upgraded.

77 km new road

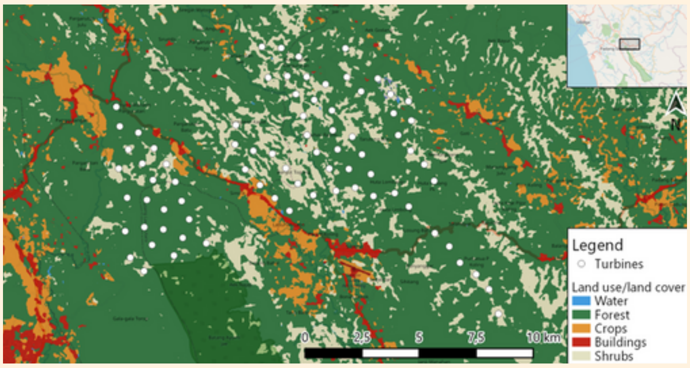
18 km road upgrade

8 bridges strengthened

78 wind turbine foundations and crane hardstands

44 transmission towers

538 km electrical cable



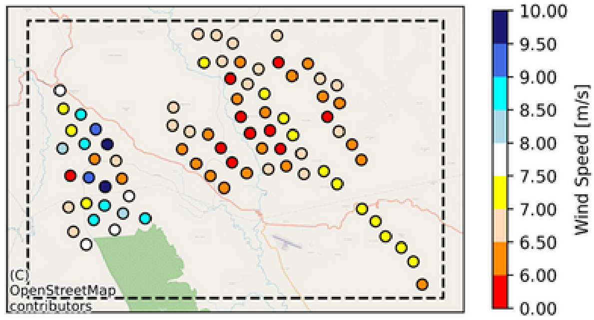
Biodiversity, social- and environmental conditions

One near threatened plant species was observed in the area, i.e. *Orania sylvicola*. Further research on the impact of the wind farm on the biodiversity is required. The envisioned turbines are planned in sparsely populated areas, and therefore the social impact is limited to the loss of agricultural land, reduced accessibility during road construction, and transport and visual impact.

Wind speed and energy yield

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]	918,143
P90 (25 yr) [MWh/yr]	682,813
P50 [hrs/yr]	2,943
P90 (25 yr) [hrs/yr]	2,189

The modelled long-term wind speed at the planned hub height of 140 m, is between 6.0 - 9.0 m/s. The gross Annual Energy Production (AEP) is subsequently calculated based on the power curve of the 4 MW reference wind turbine. A production loss percentage of 22.4% is determined for the wind farm based on e.g. wake losses, non-availability, electrical losses, etc.



The net AEP is calculated by subtracting energy production losses from the gross AEP, at a P50 level. To determine the long-term (25 years) production, a P90 level is determined by incorporating an uncertainty of 20%. The determined number of full-load hours (2,943 hrs/yr) is equivalent to a wind farm capacity factor of 34%.

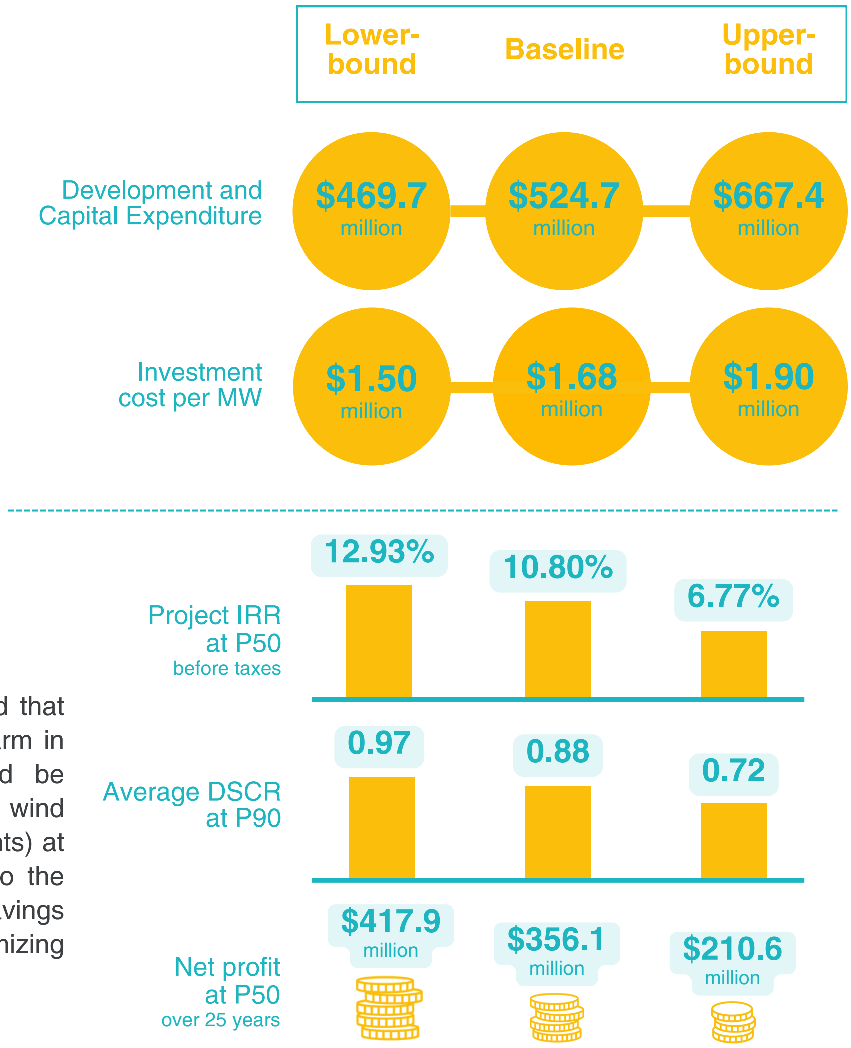
Business case

Input cost parameters are composed of surveys, design work, land acquisition, permits, wind turbines, civil works, electrical works, maintenance, project management, and risk contingencies.

Key assumed financial parameters include:

- 25 years of operation
- All cost including VAT
- Gearing 70/30
- Debt tenure: 10 years
- Interest rate: 9% p.a.
- Prospective electricity price*
  - Year 1-10: $10.49 cents/kWh
  - Year 11-25: $5.73 cents/kWh

**Based on Presidential Regulation 112/2022 ceiling tariff (with location factor)*



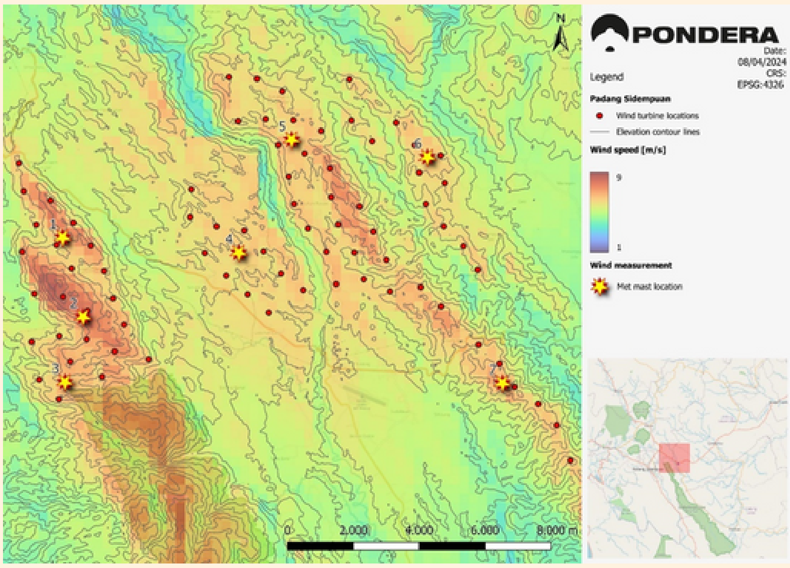
Conclusion

Based on the conducted analysis, it is concluded that the overall techno-economic viability of a wind farm in North Padang Lawas - South Tapanuli could be relatively promising. The relatively high average wind speed (still to be validated with wind measurements) at several wind turbine locations, is a contributor to the relatively promising business case. Cost savings through optimizing the wind farm layout and minimizing the need for acquiring land are vital.

Recommended next steps

Wind resource

Place at least seven (7) met masts for data gathering for at least one year to cover the southern, central, and northern part of the wind farm



Land use and permitting

- Assess the land use / ownership in greater detail
- Consulting the authorities about the willingness and possibility to issue approvals and permits
- Approach relevant landowners in order to achieve an agreement on the land

Grid connection and PPA

- Verify the suitability of Padang Sidempuan substation to facilitate the wind farm's grid connection
- Align with PLN on the PPA conditions and tender process set-up

Geology and seismicity

- Conduct geotechnical soil investigations and soil stability analyses, as input for the wind turbine foundation design and crane hardstand design
- Calculate the maximum expected peak ground acceleration to mitigate the earthquake risk

Environment, flora, and fauna

- Involve (potentially) affected stakeholders early in the wind farm development, to identify and mitigate specific objections from each stakeholder
- Conduct a biodiversity baseline study and risk assessment and mitigation measures as part of ESIA

Transport

- Conduct a port survey to ensure that the port in Dumai is suitable for offloading and storing the wind turbine components
- Execute a LiDAR-study on the topography and determine bridge/viaduct dimensions to determine the optimal transport route and infrastructure layout
- Determine the current strength of the bridges in combination with the nearby existing hairpin roads over Aek Sihapas is technically feasible (~1.5 km northwest of Aek Godang Airport)

Disclaimer
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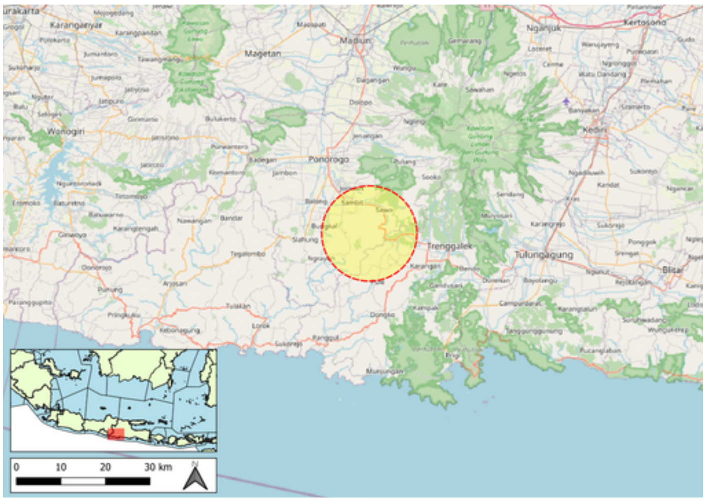
200 MW Project
Ponorogo, East Java

Location and power demand



The envisioned wind farm is located in Ponorogo Regency, East Java Province. The electricity system at the province is connected to the Java-Madura-Bali grid.

The peak load in the province in 2021-2030 is expected to grow with an average annual growth rate of 3.7% from 5,935 MW (2020). Wind energy potential in East Java is registered as 331 MW in RUPTL PLN 2021-2030.

According to the Ponorogo Regency Spatial Plan 2012-2031, the envisioned wind farm is located in areas with the following land use types:

Plantation Area
This area may be owned by private parties or a local community. Wind farm development is possible in the area if the area is not part of the Sustainable Food Agriculture Area, a lease/purchase agreement is achieved with the landowner.

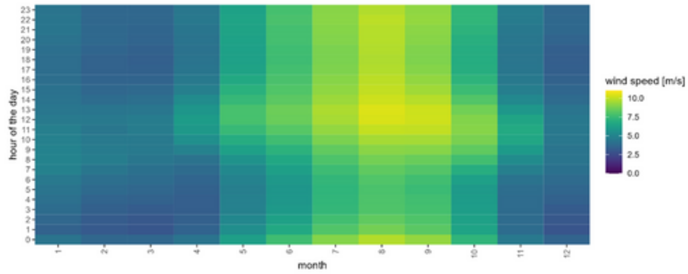
Wetland Food Agriculture Area
This area may be owned by the community, private companies, or state-owned companies. Wind farm development in this area is possible if the area is not part of the Sustainable Food Agriculture Area, a lease/purchase agreement is achieved with the landowner.

River Border Area
This area is under the ownership of the Government or the community. Wind farm development in this area is possible if the area is not part of the conservation area, and if the development complies with the applicable regulations.

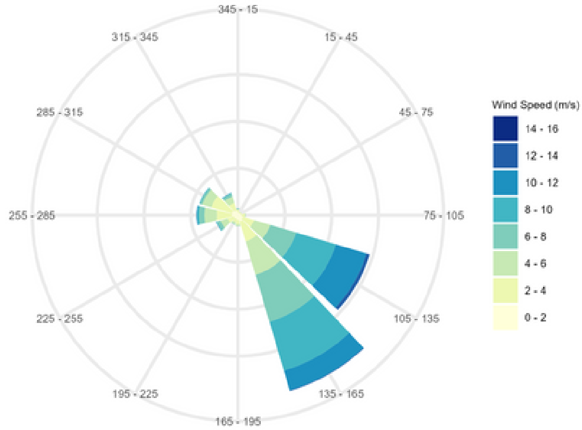
Grassland/Shrub Area
This area is under the ownership of the Government or the community. Wind farm development in this area is possible if the area is not part of the conservation area, and if the development complies with the applicable regulations.

Urban Settlement Area
This area may be owned by a local community. Construction of wind power plants at these locations is possible if a lease/purchase agreement is achieved with the landowner.

Wind characteristics



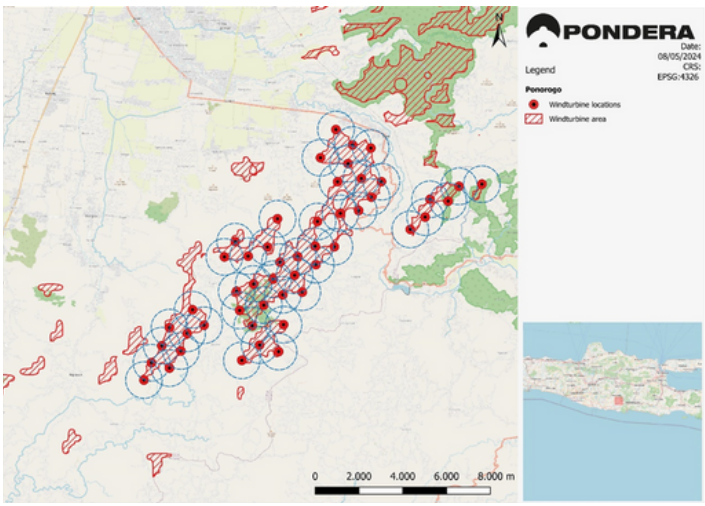
The wind climate in the region predominantly consists of wind from the southeastern direction. The highest wind speeds are observed in the period of May-October.
El Niño and La Niña phenomena may cause variations interannual variations of wind speed.



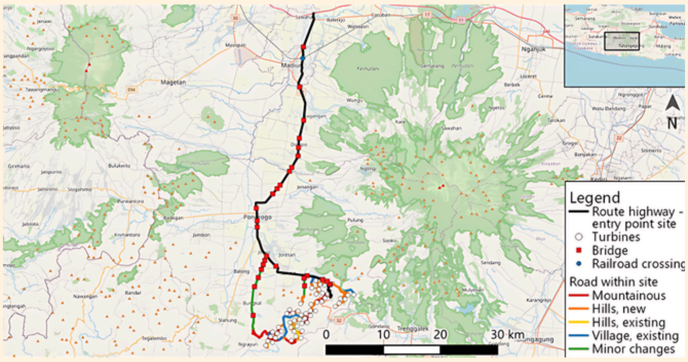
Wind farm layout

50
wind turbines

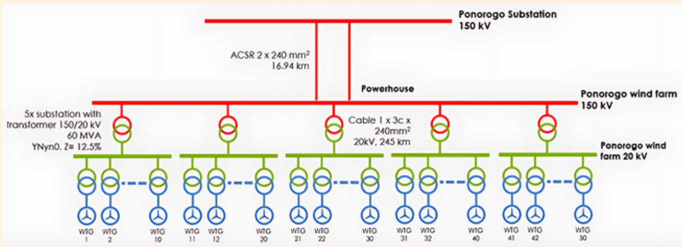
200 MW
total installed capacity



Logistic, civil- and electrical works



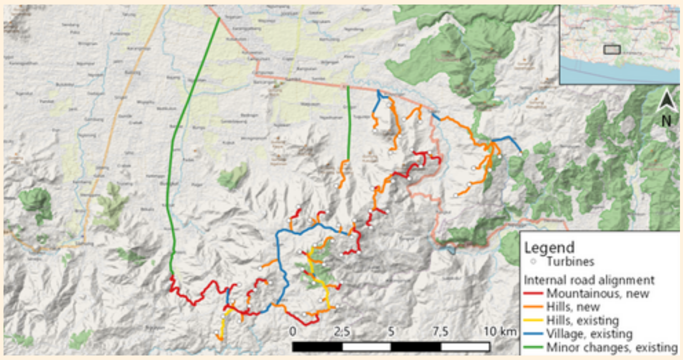
The Port of Surabaya is deemed to be the most suitable entry point of the turbines, with access to the site available via highway and regional roads. No challenges expected from toll-road up until Madiun exit of the highway. However, passing through Ponorogo, a number of bridges require strengthening.



The closest point of connection to the existing grid is the Ponorogo 150 kV PLN substation. From this PLN substation to the wind farm's powerhouse, a 17 km transmission line is required. The generated electricity will be distributed to the powerhouse via five wind farm substations.

Geology and seismic conditions

The wind farm area has medium- to high-risk of land movement vulnerability and potential to be hit by strong earthquakes. The foundation design should incorporate measures to mitigate these risks.



Within the site, new roads need to be constructed on flat-hilly and steep areas, and some existing roads and bridges must be upgraded.

74 km new road

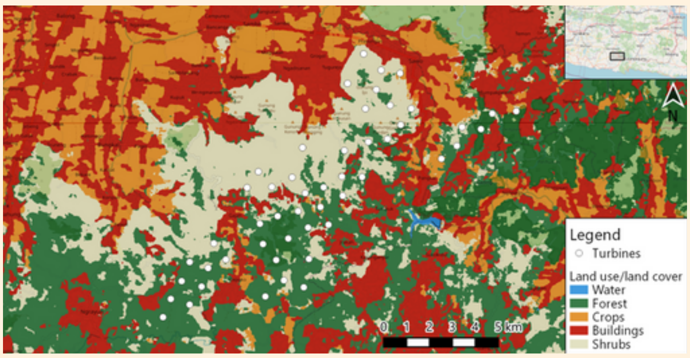
13 km road upgrade

28 bridges strengthened

50 wind turbine foundations and crane hardstands

46 transmission towers

245 km electrical cable



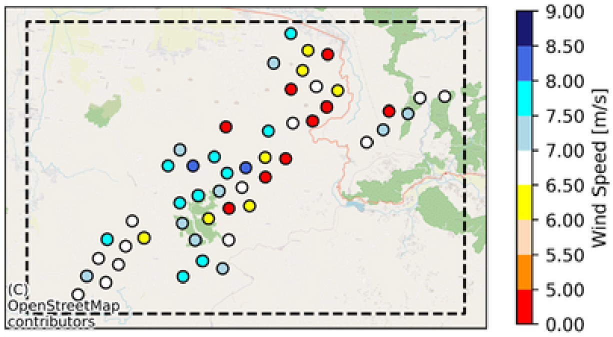
Biodiversity, social- and environmental conditions

One endangered plant species was observed in the area, i.e. *Myristica teysmannii*. Further research on the impact of the wind farm on the biodiversity is required. The envisioned turbines are planned away from villages, and therefore, the social impact is limited to the loss of agricultural land, reduced accessibility during road construction, and transport and visual impact. However, road construction might greatly improve accessibility for the local communities.

Wind speed and energy yield

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

The modelled long-term wind speed at the planned hub height of 140 m, is between 5.0 - 8.5 m/s. The gross Annual Energy Production (AEP) is subsequently calculated based on the power curve of the 4 MW reference wind turbine. A production loss percentage of 20.5% is determined for the wind farm based on e.g. wake losses, non-availability, electrical losses, etc.



The net AEP is calculated by subtracting energy production losses from the gross AEP, at a P50 level. To determine the long-term (25 years) production, a P90 level is determined by incorporating an uncertainty of 20%. The determined number of full-load hours (2,940 hrs/yr) is equivalent to a wind farm capacity factor of 34%.

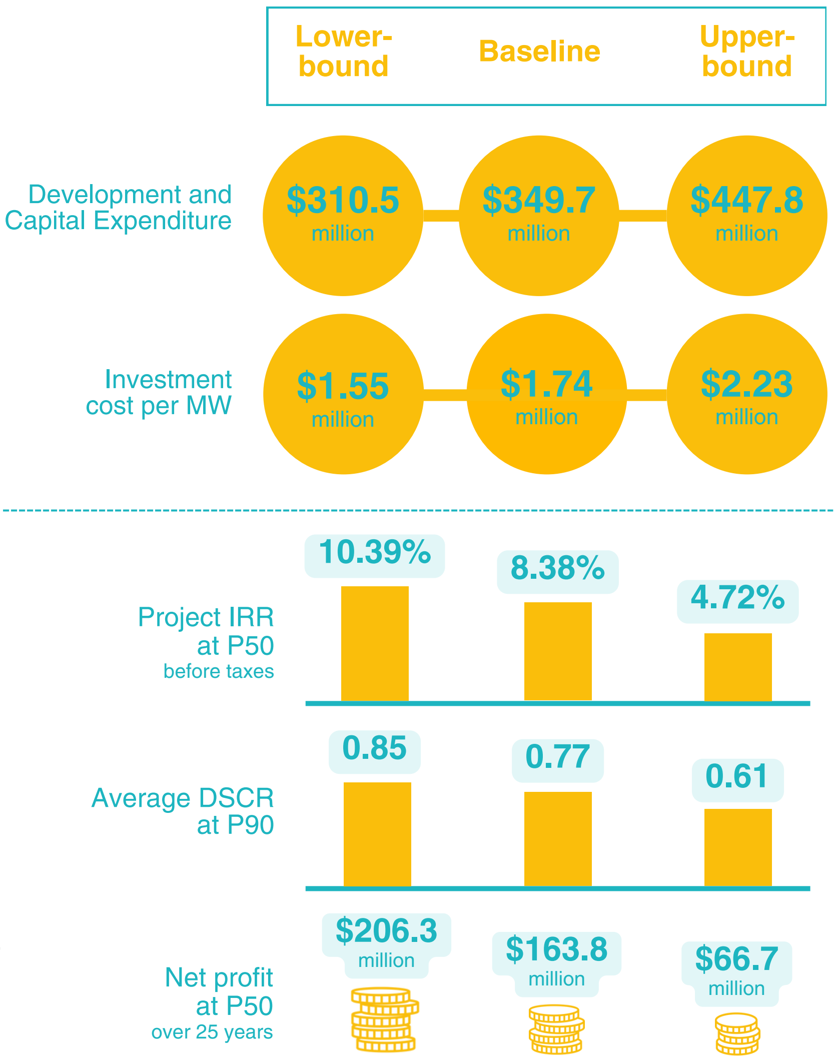
Business case

Input cost parameters are composed of surveys, design work, land acquisition, permits, wind turbines, civil works, electrical works, maintenance, project management, and risk contingencies.

Key assumed financial parameters include:

- 25 years of operation
- All cost including VAT
- Gearing 70/30
- Debt tenure: 10 years
- Interest rate: 9% p.a.
- Prospective electricity price*
  - Year 1-10: $9.54 cents/kWh
  - Year 11-25: $5.73 cents/kWh

Based on Presidential Regulation 112/2022 ceiling tariff (with location factor)



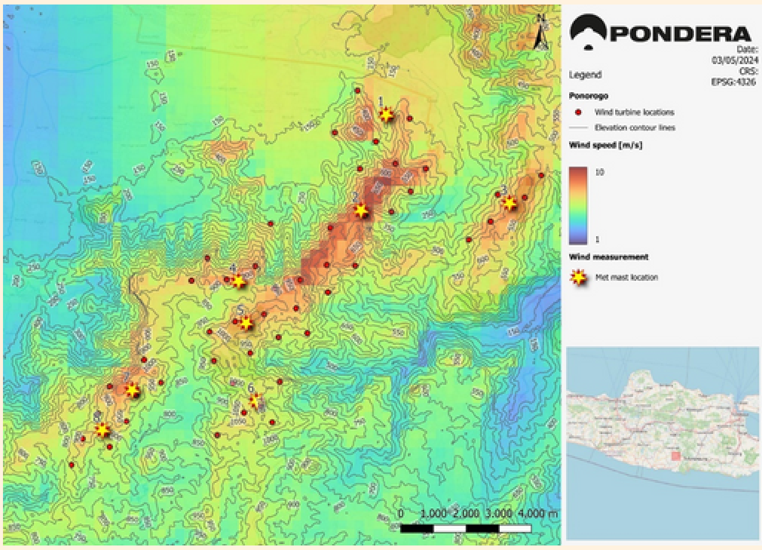
Conclusion

Based on the conducted analysis, it is concluded that the overall techno-economic viability of a wind farm in Ponorogo requires improvement. The relatively low average wind speed (still to be validated with wind measurements) at some turbine locations, is a contributor to the less promising business case. Reconsidering the site layout during a follow up study could improve this. Cost savings by determining the need for strengthening 28 bridges and building new infrastructure are vital.

Recommended next steps

Wind resource

Place at least eight (8) met masts for data gathering for at least one year to cover the northern, southeastern, and the southwestern part of the wind farm



Land use and permitting

- Assess the land use / ownership in greater detail
- Consulting the authorities about the willingness and possibility to issue approvals and permits
- Approach relevant landowners in order to achieve an agreement on the land

Grid connection and PPA

- Verify the suitability of Ponorogo substation to facilitate the wind farm's grid connection
- Align with PLN on the PPA conditions and tender process set-up

Geology and seismicity

- Conduct geotechnical soil investigations and soil stability analyses, as input for the wind turbine foundation design and crane hardstand design
- Calculate the maximum expected peak ground acceleration to mitigate the earthquake risk

Environment, flora, and fauna

- Involve (potentially) affected stakeholders early in the wind farm development, to identify and mitigate specific objections from each stakeholder
- Conduct a biodiversity baseline study and risk assessment and mitigation measures as part of ESIA

Transport

- Conduct a port survey to ensure that the Port of Surabaya is suitable for offloading and storing the wind turbine components
- Execute a LiDAR-study on the topography and determine bridge/viaduct dimensions to determine the optimal transport route and infrastructure layout
- Determine the current strength of the bridges to be crossed

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68 MW Project
Probolinggo – Lumajang, East Java

Location and power demand

The envisioned wind farm is located in Probolinggo and Lumajang Regency, East Java Province. The electricity system at the province is connected to the Java-Madura-Bali grid.

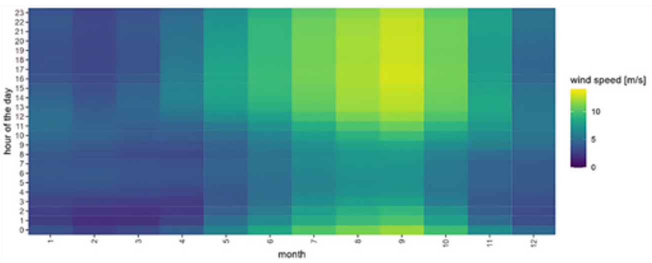
The peak load in the province in 2021-2030 is expected to grow with an average annual growth rate of 3.7% from 5,935 MW (2020). Wind energy potential in East Java is registered as 331 MW in RUPTL PLN 2021-2030.

According to the Probolinggo Regency Spatial Plan 2010-2029 and Lumajang Regency Spatial Plan 2023-2043, the envisioned wind farm is located in areas with the following land use types:

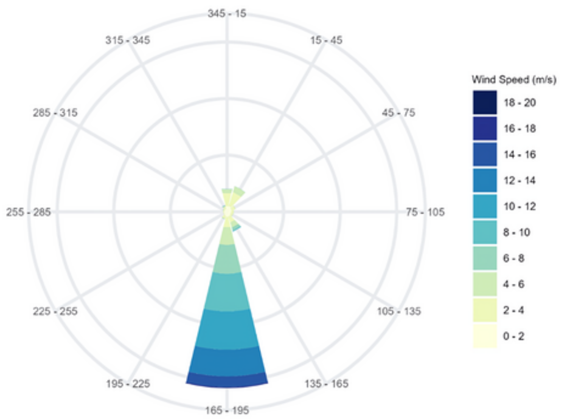
Plantation Area
This area may be owned by private parties or a local community. Wind farm development is possible in the area if the area is not part of the Sustainable Food Agriculture Area, and if a lease/purchase agreement is achieved with the landowner.

(Fixed) Production Forest Area
Forest Area Use Approval (PPKH) to be issued by the Ministry of Environment and Forestry is needed to develop a wind farm at the area.

Wind characteristics



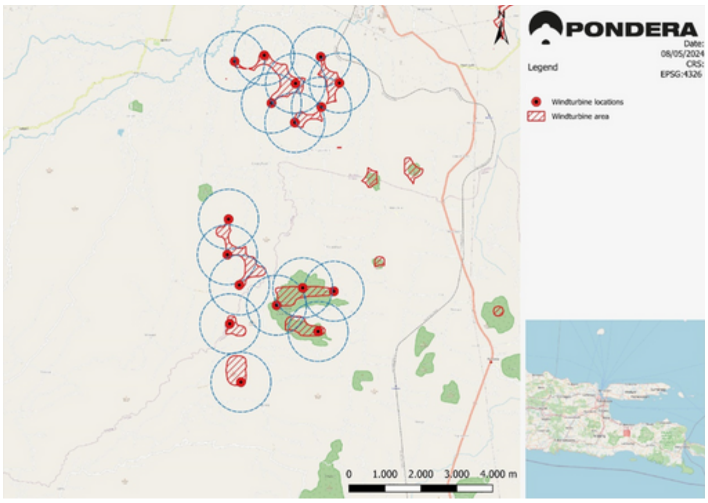
The wind climate in the region predominantly consists of wind from the southern direction. The highest wind speeds are observed in the period of June-October. El Niño and La Niña phenomena may cause variations interannual variations of wind speed.



Wind farm layout

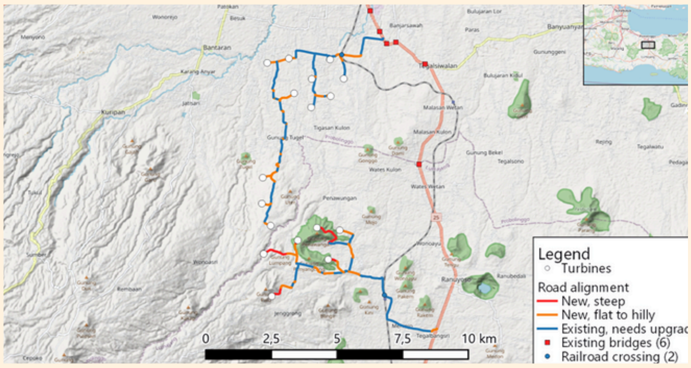
17
wind turbines

68 MW
total installed capacity

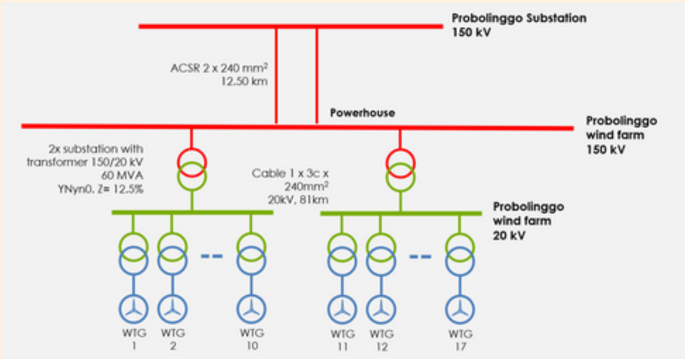


Logistic, civil- and electrical works

The Port of Surabaya is deemed to be the most suitable entry point of the turbines, with access to the site available via highway and regional roads.



Within the site, new roads need to be constructed on flat-hilly and steep areas, and some existing roads and bridges must be upgraded.



The closest point of connection to the existing grid is the Probolinggo 150 kV PLN substation. From this PLN substation to the wind farm's powerhouse, a 13 km transmission line is required. The generated electricity will be distributed to the powerhouse via two wind farm substations.

14 km new road

20 km road upgrade

6 bridges strengthened

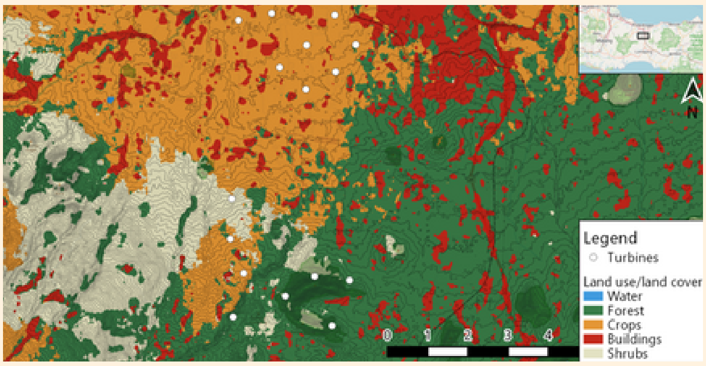
17 wind turbine foundations and crane hardstands

34 transmission towers

81 km electrical cable

Geology and seismic conditions

The wind farm area has very low- to high-risk of land movement vulnerability, potential to be hit by strong earthquakes, and medium risk of liquefaction. The foundation design should incorporate measures to mitigate these risks.



Biodiversity, social- and environmental conditions

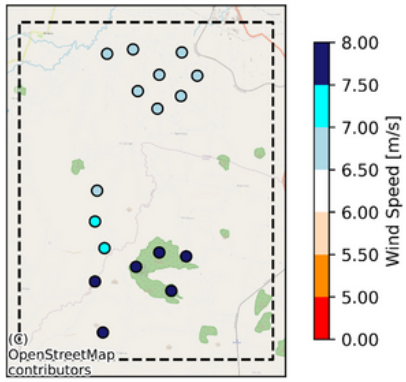
Several endangered, vulnerable, and near threatened animal and plant species were observed in the area. One of the endangered species include the Con Song Long-tailed Macaque. Further research on the impact of the wind farm on the biodiversity is required. The envisioned turbines are planned in between villages, and therefore, avoiding nuisance for the inhabitants is critical in the final wind farm design.

Wind speed and energy yield

Parameter [Unit]	Amount
Number of new WTGs	17
Rated Power per WTG [MW]	4.0
Total rated Power [MW]	68.0
Rotor diameter [m]	~170
Hub height [m]	140
Air density [kg/m³]	1.136
Wind speed [m/s]	7.2
Gross result [MWh/yr]	309,857
Gross results including wake effects [MWh/yr]	301,056
P50 [MWh/yr]	261,831
P90 (25 yr) [MWh/yr]	194,721
P50 [hrs/yr]	3,850
P90 (25 yr) [hrs/yr]	2,864

The modelled long-term wind speed at the planned hub height of 140 m, is between 6.5 - 8.0 m/s. The gross Annual Energy Production (AEP) is subsequently calculated based on the power curve of the 4 MW reference wind turbine. A production loss percentage of 15.6% is determined for the wind farm based on e.g. wake losses, non-availability, electrical losses, etc.

The net AEP is calculated by subtracting energy production losses from the gross AEP, at a P50 level. To determine the long-term (25 years) production, a P90 level is determined by incorporating an uncertainty of 20%. The determined number of full-load hours (3,850 hrs/yr) is equivalent to a wind farm capacity factor of 44%.



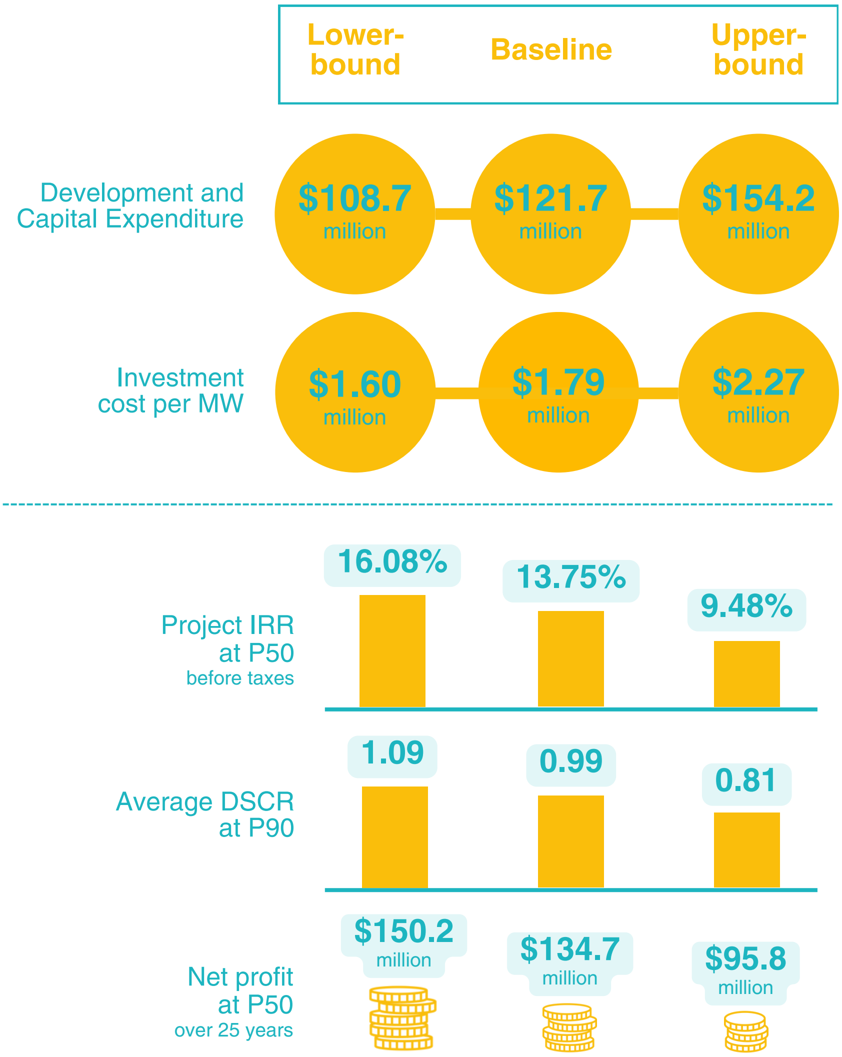
Business case

Input cost parameters are composed of surveys, design work, land acquisition, permits, wind turbines, civil works, electrical works, maintenance, project management, and risk contingencies.

Key assumed financial parameters include:

- 25 years of operation
- All cost including VAT
- Gearing 70/30
- Debt tenure: 10 years
- Interest rate: 9% p.a.
- Prospective electricity price*
    - Year 1-10: $9.54 cents/kWh
    - Year 11-25: $5.73 cents/kWh

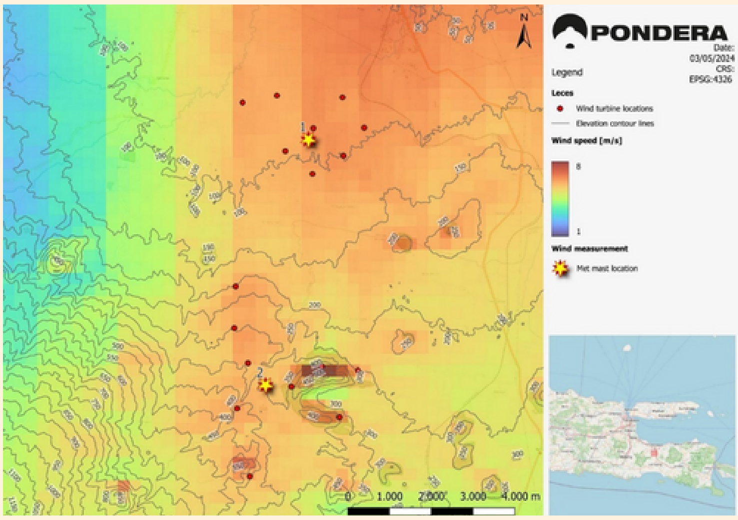
**Based on Presidential Regulation 112/2022 ceiling tariff (with location factor)*



Conclusion

Based on the conducted analysis, it is concluded that the overall techno-economic viability of a wind farm in Probolinggo-Lumajang could be promising. The relatively high average wind speed (still to be validated with wind measurements) is a significant contributor to the potentially promising business case. However, the DSCR needs to be increased to at least 1 to make the project bankable. A specific improvement can be sought in the cost for infrastructure (i.e. roads and bridges), which currently entails a significant portion of the project cost.

Recommended next steps



Wind resource

Place at least two met masts for data gathering for at least one year to cover both the northern and southern part of the wind farm

Land use and permitting

- Assess the land use / ownership in greater detail
- Consulting the authorities about the willingness and possibility to issue approvals and permits
- Approach relevant landowners in order to achieve an agreement on the land

Grid connection and PPA

- Verify the suitability of Probolinggo substation to facilitate the wind farm's grid connection
- Align with PLN on the PPA conditions and tender process set-up

Geology and seismicity

- Conduct geotechnical soil investigations and soil stability analyses, as input for the wind turbine foundation design and crane hardstand design
- Calculate the maximum expected peak ground acceleration to mitigate the earthquake risk
- Deeper examination of the liquefaction risk by examining the soil characteristics and local hydrogeology

Environment, flora, and fauna

- Involve (potentially) affected stakeholders early in the wind farm development, to identify and mitigate specific objections from each stakeholder
- Conduct a biodiversity baseline study and risk assessment and mitigation measures as part of ESIA

Transport

- Conduct a port survey to ensure that the Port of Surabaya is suitable for offloading and storing the wind turbine components
- Execute a LiDAR-study on the topography and determine bridge/viaduct dimensions to determine the optimal transport route and infrastructure layout
- Determine the current strength of the bridges to be crossed

Disclaimer
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Summary Table

Summary Table

	Aceh Besar (Aceh)	Ciracap (West Java)	Dairi (North Sumatra)	Gunung Kidul (DI Yogyakarta)	Kediri (East Java)	North Padang Lawas – South Tapanuli (North Sumatra)	Ponorogo (East Java)	Probolinggo – Lumajang (East Java)
Geographic location and demand								
Peak load in the province (2020)	542 MW	7,712 MW	1,883 MW	450 MW	5,935 MW	1,883 MW	5,935 MW	5,935 MW
Projected annual demand growth rate	4.7%	3.88%	5.5%	4.88%	3.7%	5.5%	3.7%	3.7%
Listing in RUPTL PLN 2021-2030 on wind energy as planned and potential	258 MW	965 MW	198 MW	60 MW	331 MW	198 MW	331 MW	331 MW
Wind farm layout								
Number of turbines (4 MW each)	30	100	23	20	48	78	20	17
Total installed capacity	120 MW	400 MW	92 MW	80 MW	192 MW	312 MW	80 MW	68 MW
Infrastructure and land use								
Suitable port (Distance)	Port of Malahayati (45 km)	Pelabuhan Ratu fishing port (60 km)	Port of Medan (140 km)	Port of Semarang (170 km)	Port of Surabaya (100 km)	Port of Dumai (300 km)	Port of Surabaya (220 km)	Port of Surabaya (100 km)
Inflicted land use type according to regency spatial plan	1. Plantation Area 2. Dryland Farming/ Agricultural Area 3. Wetland Farming/ Agricultural Area	1. Plantation Area 2. Wetland Farming/ Agricultural Area 3. Dryland Farming/ Agricultural Area 4. Beach Border Area 5. River Border Area 6. Rural Settlement Area	Protected Forest Area	1. Dryland Farming/ Agricultural Area 2. Residential Area	1. Plantation Area 2. Dryland Farming/ Agricultural Area 3. Urban Settlement Area	1. Production Forest Area 2. Limited Production Forest Area 3. Dryland Farming/ Agricultural Area	1. Plantation Area 2. Wetland Food Agriculture Area 3. River Border Area 4. Urban Settlement Area 5. Grassland/Shrub Area	1. Plantation Area 2. (Fixed) Production Forest Area

	Aceh Besar (Aceh)	Ciracap (West Java)	Dairi (North Sumatra)	Gunung Kidul (DI Yogyakarta)	Kediri (East Java)	North Padang Lawas – South Tapanuli (North Sumatra)	Ponorogo (East Java)	Probolinggo – Lumajang (East Java)
Biodiversity and social impact								
General impression	Primary and secondary forests, with a mix of small villages, small farms, and rice paddy fields	• A variation between a stretched ridge, hills and flatter areas mainly used for larger plantations	• Primary forest, part of a larger elongated forested area with a length of about 60 km • Complex of PLTA Lau Renun nearby	• Homogeneous topography and land use • Small but steep hills which are used for agroforestry, and valleys in between which are in use by farmers	• Villages are mostly located in the valleys, surrounded by mainly rice paddies • East-west oriented ridges are mostly covered by forest and shrubs, small scale farming, and agroforestry	Variation between valley terrain (west), deep gorge (central) and steeper slopes (east)	The area can be divided into several sections: • Mountains surrounding the plateau • Plateau valley • Hills at base of the plateau • Eastern hills	The northern part (coastal plains) and southern part (foot of Mount Bromo) of the site differ from each other both in topography, land use, and population density
Biodiversity based on listing of at least 'near threatened' in IUCN global red list	Several (critically) endangered animal species listed	Several animal and plant species listed	Several animal and plant species listed	Very limited animal and plant species listed	Several animal and plant species listed	No listed animal or plant species in recent times	Very limited animal and plant species listed	Several animal and plant species listed
Social impact	• The central section of the project site consists of a series of rural villages and rice paddy fields • The beachfront is an important source of income (tourism) • The social impact is mainly limited to the loss of agricultural land, reduced accessibility during road construction and transport, and visual impact	• Villages and scattered houses are present • The social impact could be loss of agricultural land, reduced accessibility during road construction and transport and visual impact • The area is branded as a tourist destination (UNESCO Geopark)	• Apart from a few houses on and near the power plant complex, the area within and directly around the wind farm is inhabited by humans • Wind turbine placement may lead to local resistance from the hospitality industry at Lake Toba	As the turbines are mostly built in unpopulated valleys and/or hills away from the villages, the social impact is mainly limited to the loss of agricultural land, reduced accessibility during road construction, and transport and visual impact	• Several villages are located in the valleys, in between the ridges • The potential turbines are placed on the slopes or at the top of the ridges, away from these villages at a distance of at least 300 meters	• Apart from the villages near the main road, the area is sparsely populated • The social impact is mainly limited to the loss of agricultural land, reduced accessibility during road construction and transport and visual impact	• As most turbines will be built further away from the villages, the social impact is mainly limited to the loss of agricultural land, reduced accessibility during road construction and transport, and visual impact • Road construction can greatly improve accessibility on the plateau which may have a positive impact on the local economy	• Numerous small villages are located in the area • The visual impact in the southern part (east of the gorge) of the site may be quite limited • The mobility of the population nearby is likely to be increased when public roads are upgraded

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Transmission network								
Point of connection (PLN substation)	Banda Aceh 150 kV	Pelabuhan Ratu Baru 150 kV	Sidikalang 150 kV	Semanu 150 kV	Surya Zig Zag 150 kV	Padang Sidempuan 150 kV	Semanu 150 kV	Probolinggo 150 kV
Distance to connection	6 km	8km	19 km	7 km	9 km	15 km	17 km	13 km
Required number of transmission towers	19	22	48	21	25	44	46	34
Energy yield								
Average wind speed	5.0 – 7.5 m/s	5.5 – 7.5 m/s	7.0 – 10.0 m/s	5.0 – 7.0 m/s	5.0 – 8.0 m/s	6.0 – 9.0 m/s	5.0 – 8.5 m/s	6.5 – 8.0 m/s
P50 Annual Energy Production	317,543 MWh/yr	1,31,551 MWh/yr	432,897 MWh/yr	218,339 MWh/yr	519,135 MWh/yr	918,143 MWh/yr	564,393 MWh/yr	261,831 MWh/yr
P90 Annual Energy Production	236,154 MWh/yr	841,523 MWh/yr	321,941 MWh/yr	188,885 MWh/yr	386,075 MWh/yr	682,813 MWh/yr	419,733 MWh/yr	194,721 MWh/yr
P50 full load hours	2,646 hrs/yr	2,829 hrs/yr	4,705 hrs/yr	2,729 hrs/yr	2,704 hrs/yr	2,943 hrs/yr	2,940 hrs/yr	3,850 hrs/yr
P90 (25 yr) full load hours	1,968 hrs/yr	2,104 hrs/yr	3,499 hrs/yr	2,361 hrs/yr	2,011 hrs/yr	2,189 hrs/yr	2,186 hrs/yr	2,864 hrs/yr
Business case calculation[6]								
Assumed tariff Year 1-10 Year 11-25	$10.49 cents / kWh $5.73 cents / kWh	$9.54 cents / kWh $5.73 cents / kWh	$10.49 cents / kWh $5.73 cents / kWh	$9.54 cents / kWh $5.73 cents / kWh	$9.54 cents / kWh $5.73 cents / kWh	$10.49 cents / kWh $5.73 cents / kWh	$9.54 cents / kWh $5.73 cents / kWh	$9.54 cents / kWh $5.73 cents / kWh
Lower-bound investment cost Total (per MW)	USD 171,123,000 (USD 1,423,000)	USD 589,312,000 (USD 1,473,000)	USD 126,978,000 (USD 1,380,000)	USD 126,452,000 (USD 1,581,000)	USD 275,730,000 (USD 1,436,000)	USD 469,734,000 (USD 1,506,000)	USD 310,548,000 (USD 1,553,000)	USD 108,732,000 (USD 1,599,000)

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Baseline investment cost Total (per MW)	USD 190,803,000 (USD 1,590,000)	USD 654,386,000 (USD 1,635,000)	USD 141,373,000 (USD 1,537,000)	USD 141,578,000 (USD 1,770,000)	USD 307,995,000 (USD 1,604,000)	USD 524,776,000 (USD 1,682,000)	USD 349,783,000 (USD 1,749,000)	USD 121,663,000 (USD 1,789,000)
Upper-bound investment cost Total (per MW)	USD 240,249,000 (USD 2,022,000)	USD 818,661,000 (USD 2,045,000)	USD 174,913,000 (USD 1,901,000)	USD 180,857,000 (USD 2,261,000)	USD 389,374,000 (USD 2,028,000)	USD 667,449,000 (USD 1,901,000)	USD 447,836,000 (USD 2,239,000)	USD 154,218,000 (USD 2,268,000)
Baseline annual operational expenditure (per MW)	USD 3,577,000 /yr (USD 29,000 /yr)	USD 11,778,000 /yr (USD 29,000 /yr)	USD 2,759,000 /yr (USD 30,000 /yr)	USD 2,404,000 /yr (USD 30,000 /yr)	USD 5,602,000 /yr (USD 29,000 /yr)	USD 9,017,000 /yr (USD 29,000 /yr)	USD 5,951,000 /yr (USD 30,000 /yr)	USD 2,093,000 /yr (USD 31,000 /yr)
Business case results								
Project IRR before taxes at P50 (lower-bound / baseline / upper-bound cost)	11.25% / 9.25% / 5.52%	10.50% / 8.70% / 5.29%	28.75% / 25.40% / 19.62%	8.40% / 6.61% / 3.20%	9.96% / 8.09% / 4.61%	12.93% / 10.80% / 6.77%	10.39% / 8.38% / 4.72%	16.08% / 13.75% / 9.48%
Average DSCR at P90 (lower-bound / baseline / upper-bound cost)	0.90 / 0.82 / 0.67	1.16 / 1.06 / 0.88	1.69 / 1.53 / 1.27	0.90 / 0.82 / 0.66	0.83 / 0.76 / 0.61	0.97 / 0.88 / 0.72	0.85 / 0.77 / 0.61	1.09 / 0.99 / 0.81
Net profit at P50 over 25 years (lower-bound / baseline / upper-bound cost)	USD 119,250,000 / USD 99,468,000 / USD 50,970,000	USD 394,436,000 / USD 324,240,000 / USD 161,459,000	USD 373,619,000 / USD 356,350,000 / USD 316,159,000	USD 58,488,000 / USD 43,708,000 / USD 4,547,000	USD 168,362,000 / USD 134,719,000 / USD 55,086,000	USD 417,987,000 / USD 356,181,000 / USD 210,654,000	USD 206,311,000 / USD 163,811,000 / USD 66,725,000	USD 150,155,000 / USD 134,675,000 / USD 95,760,000

DISCLAIMER

This booklet and underlying wind farm prospectus have 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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