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Global Development Assistance

Wind Atlas Armenia

Elke Krätzschmar & the GDA-Clean Energy Team
IABG

GDA Programme Clean Energy – 20 July 2023

UC1/ ADB/ Armenia – Wind Atlas

UseCaseStory
Development
Solution&next

GDA

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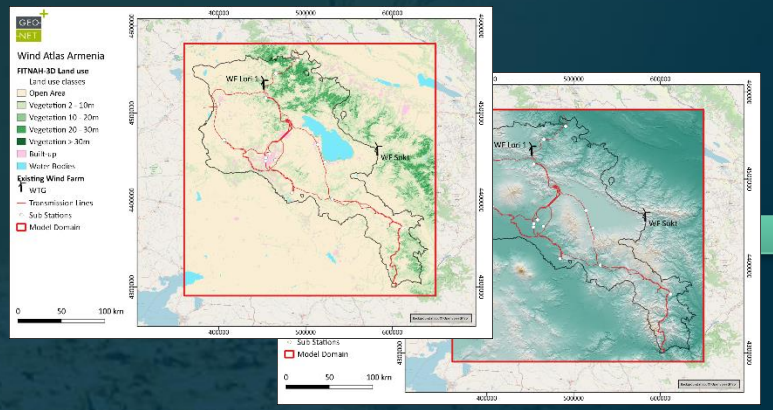
Asian Development Bank

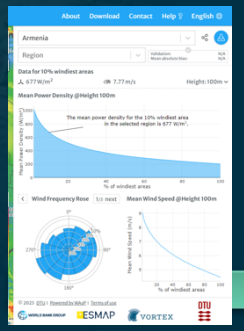
GDA Clean Energy

EO Solutions

Relevant input data



Other requirements



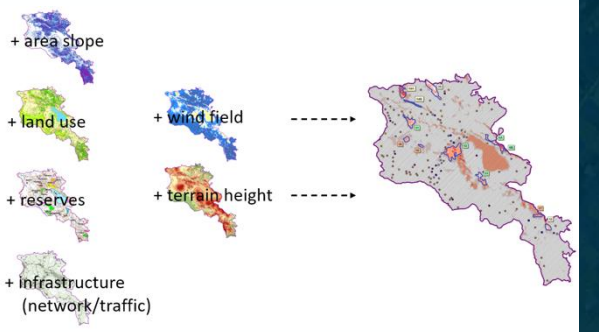
ADB:
- Feasibility study
- Requirements show many parallels to the Uzbekistan project
- Different Hub-height

Use Case Story

- **National Wind Atlas Armenia**
- TA-6959 ARM: Viability Assessment for Potential Wind Power Electricity Generation Projects
- Improvement by using current input data
- *Benefit: Supports wind park development*
  - *Choose right locations for met masts*
  - *Creation of preliminary plans for wind farms*
  - *Creation of initial estimates for the generated energy from wind power project*

national

Wind potential GEO-NET



Example: Wind Atlas Armenia, GEO-NET 2007

Areg Barseghyan, Garik Arabyan, Karine Minasyan, Narine Avetisyan

UC1/ ADB/ Armenia - Wind Atlas

Preparation of wind atlas simulations

Wind field simulation with flow model FITNAH-3D

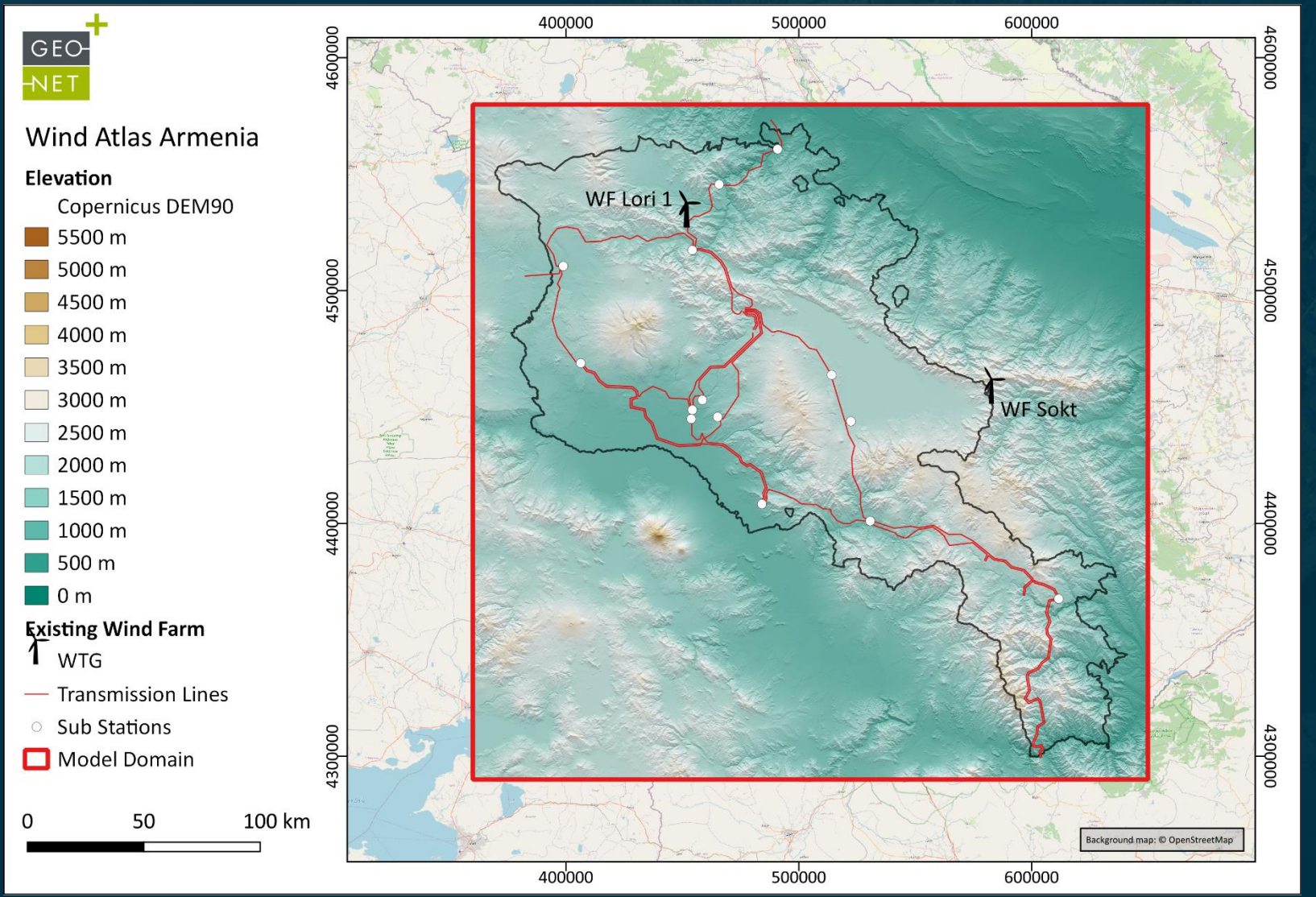
- Applied in resource assessment, wind potential studies and wind atlas generation for many years, continuous development & improvement

Setup of the simulation:

- Horizontal resolution: 200 m
- Domain size: 290 km x 290 km

Input Data for the simulation:

- **Copernicus DEM90**
- ESA WorldCover 10m
- GLAD vegetation heights
- EMD-WRF EUR+



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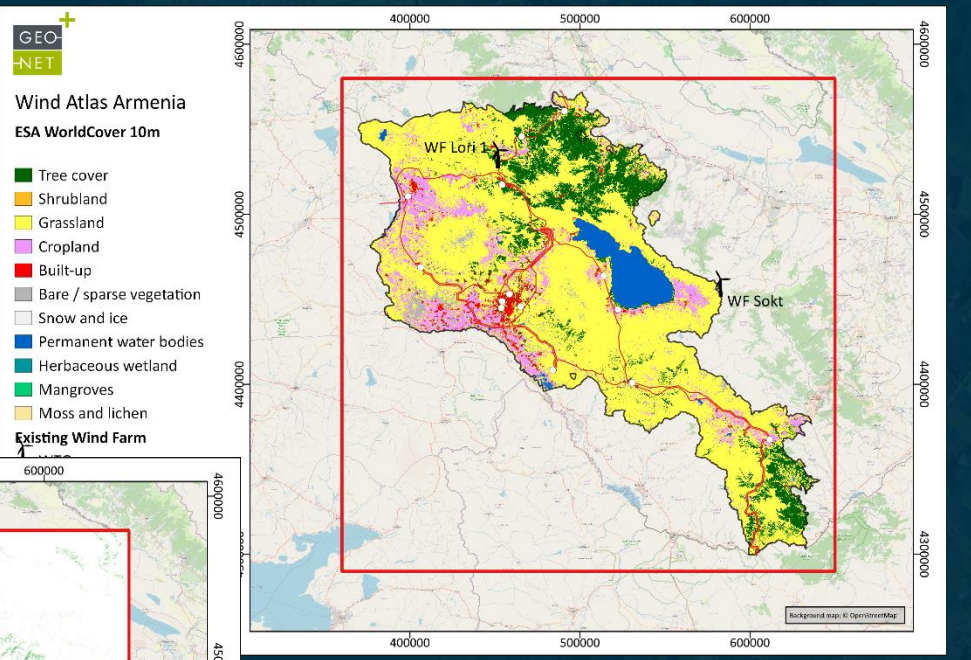

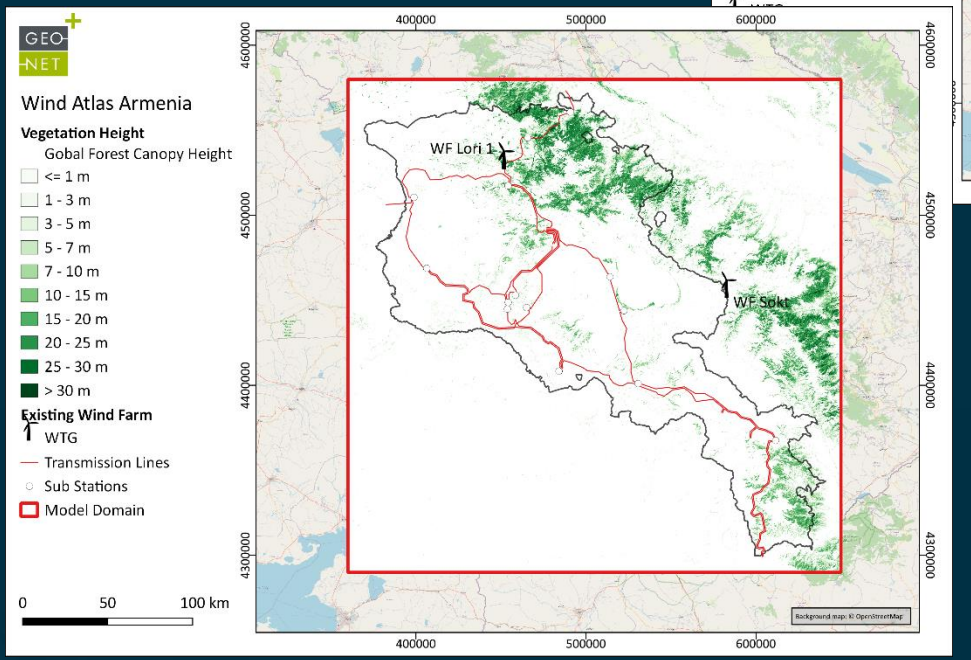

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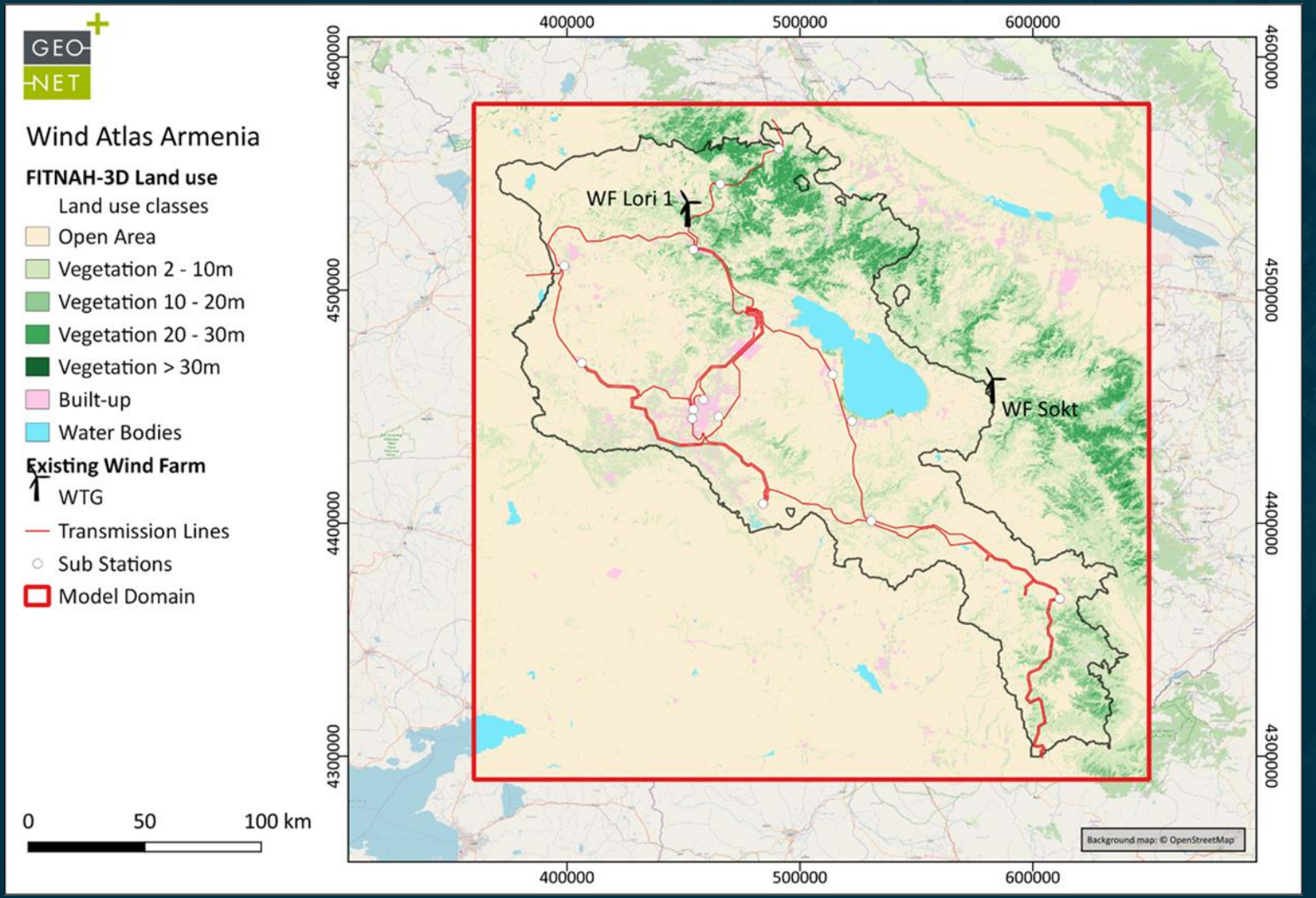

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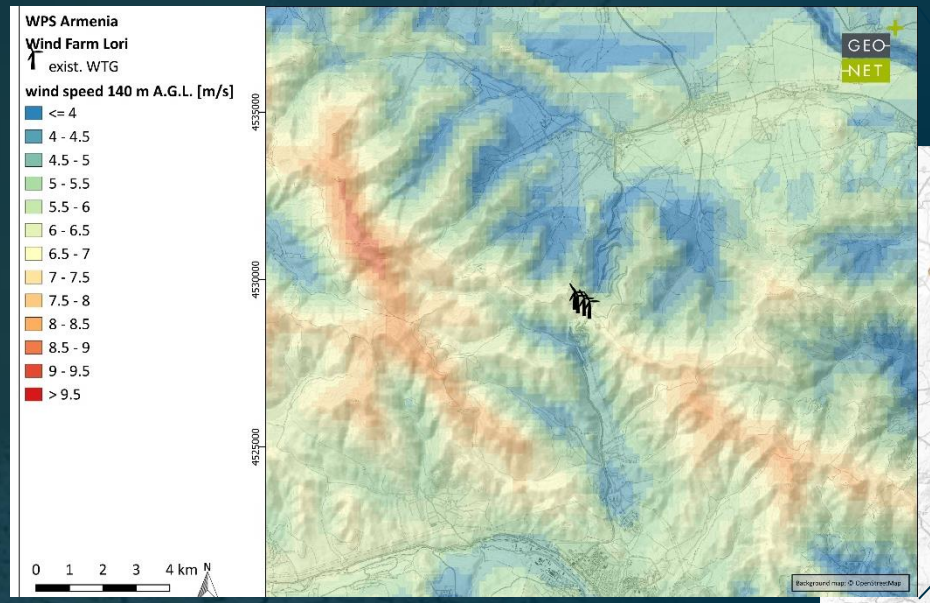
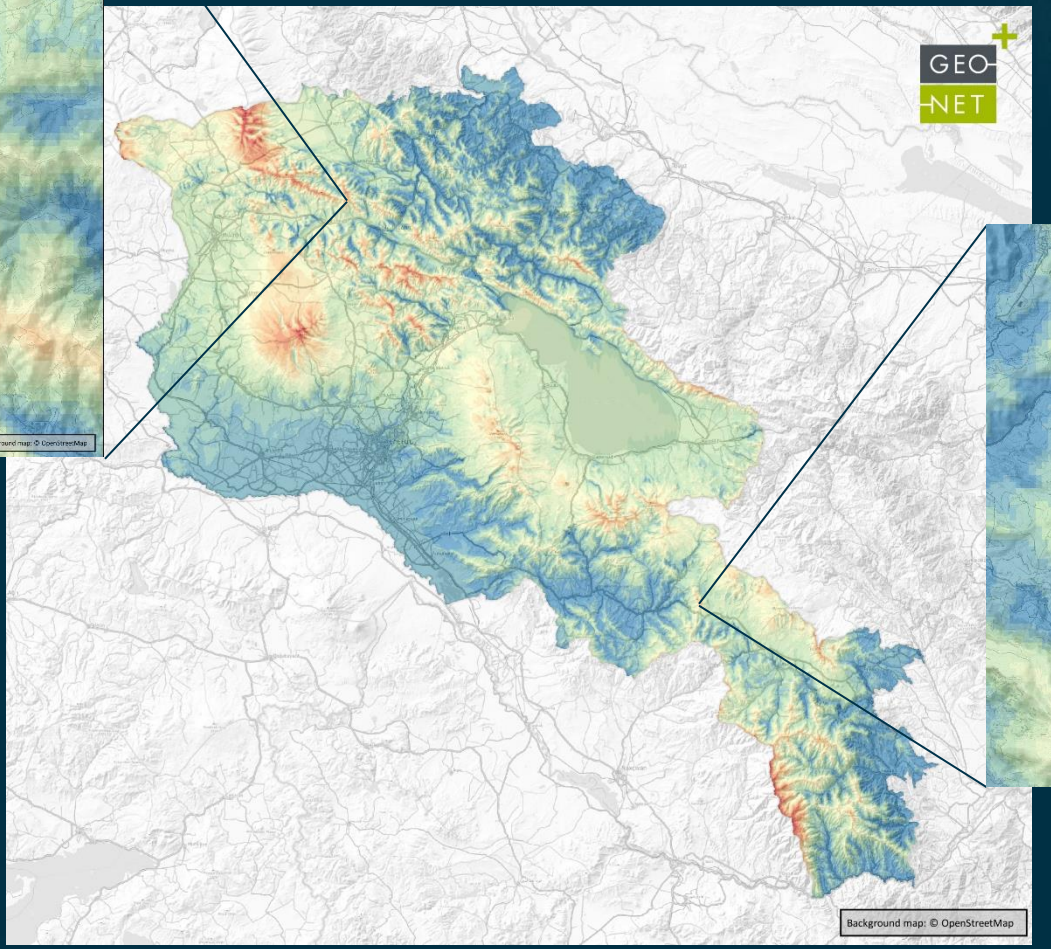
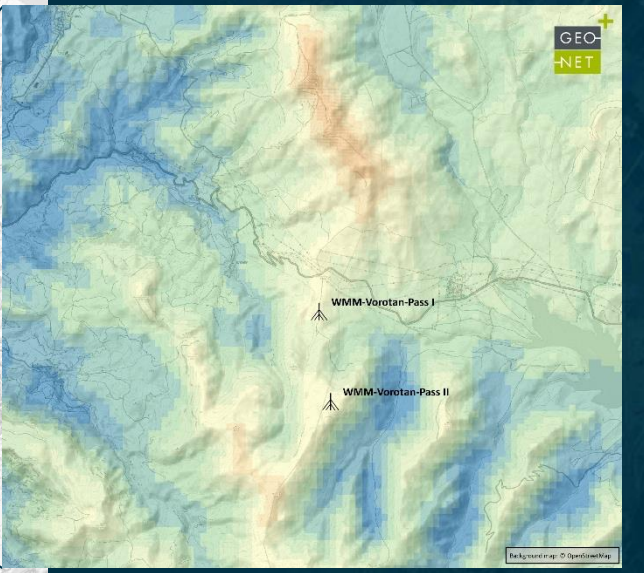






Validation of wind resource:

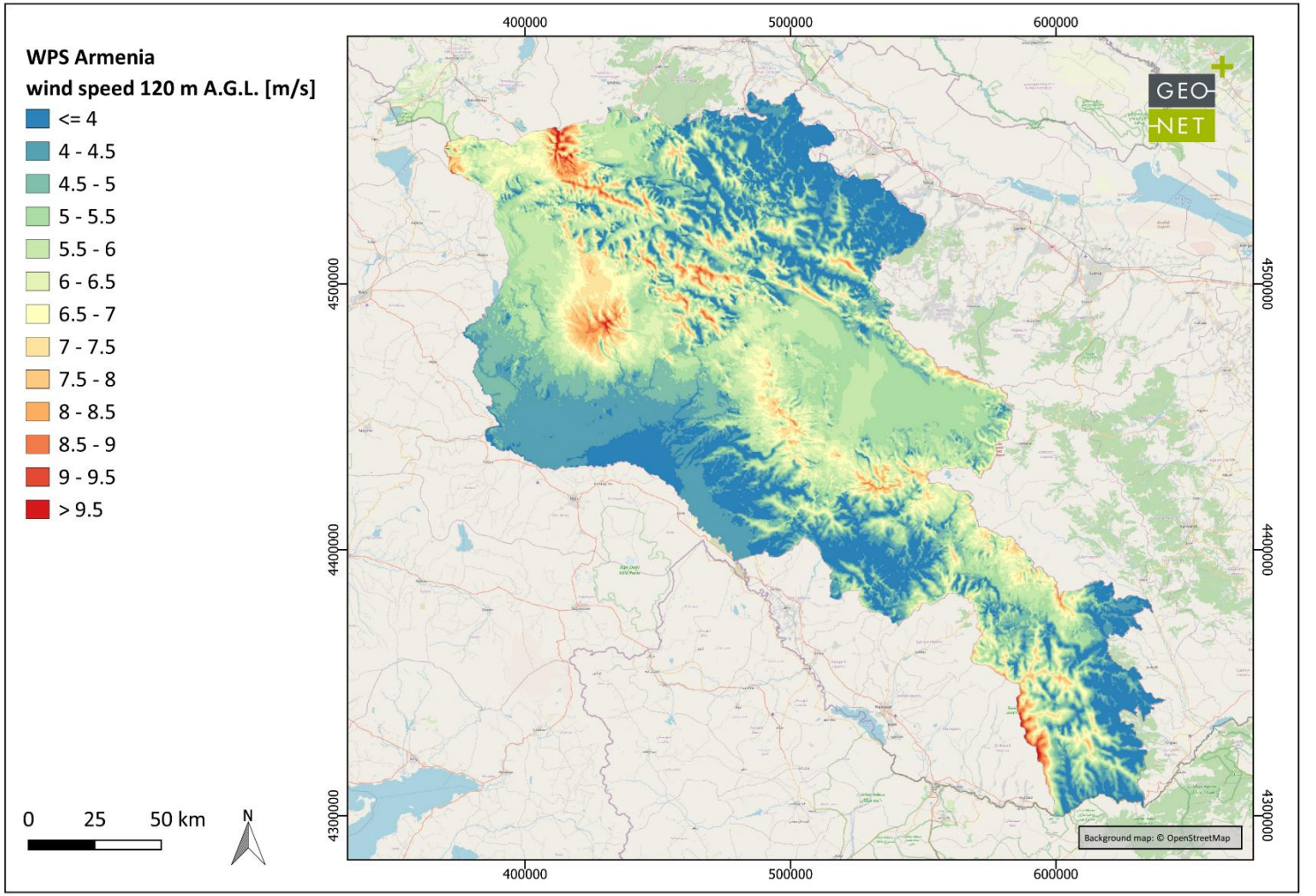
- Validation using 2 wind measurements (Vorontan Pass I + II)
- Production data of wind farm Lori 1

UC1/ ADB/ Armenia - Wind Atlas

Wind Atlas Armenia – Modelled average long term windspeed in 120m AGL

Setup of the simulation:

- Horizontal resolution: 200 m
- Domain size: 290 km x 290 km

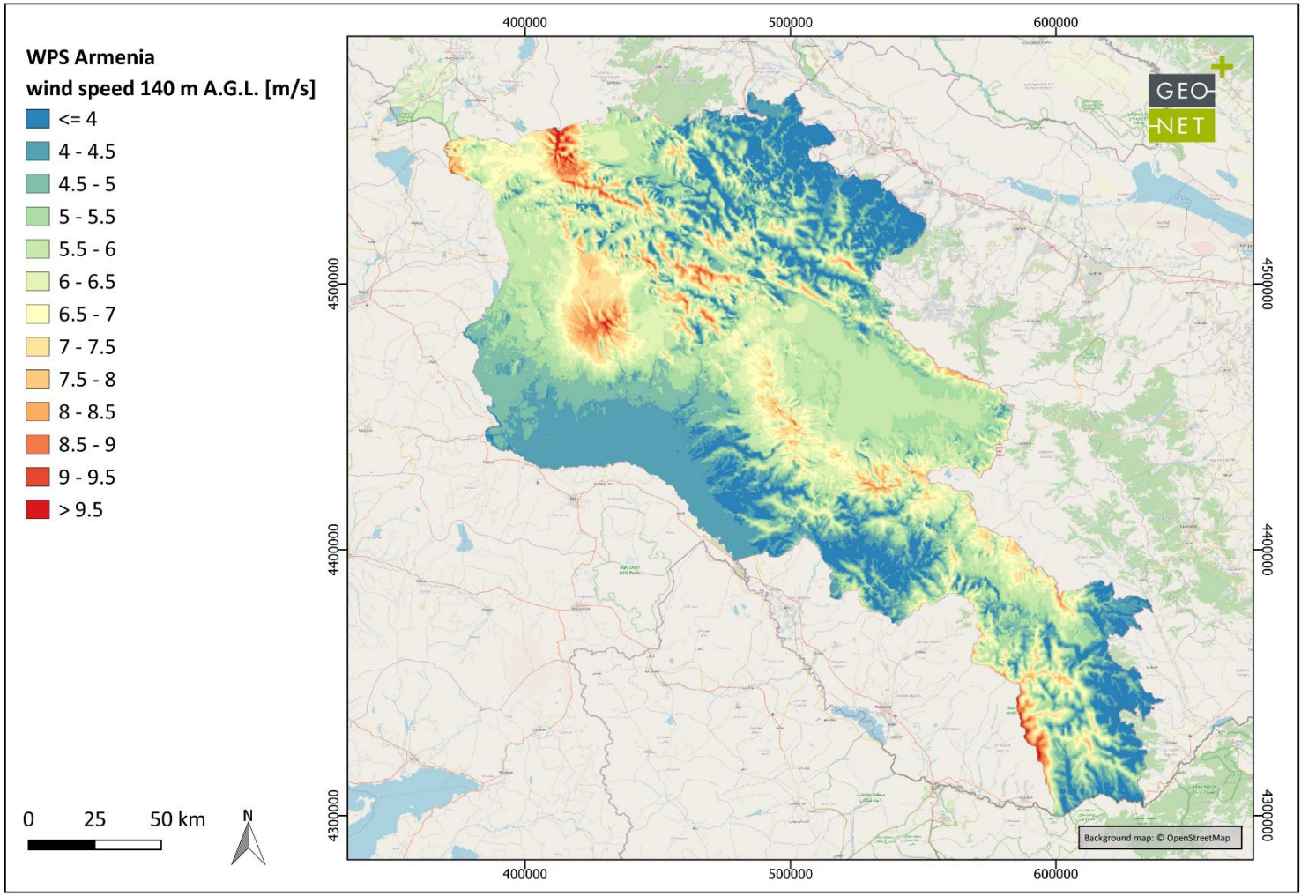


UC1/ ADB/ Armenia - Wind Atlas

Wind Atlas Armenia – Modelled average long term windspeed in 140m AGL

Setup of the simulation:

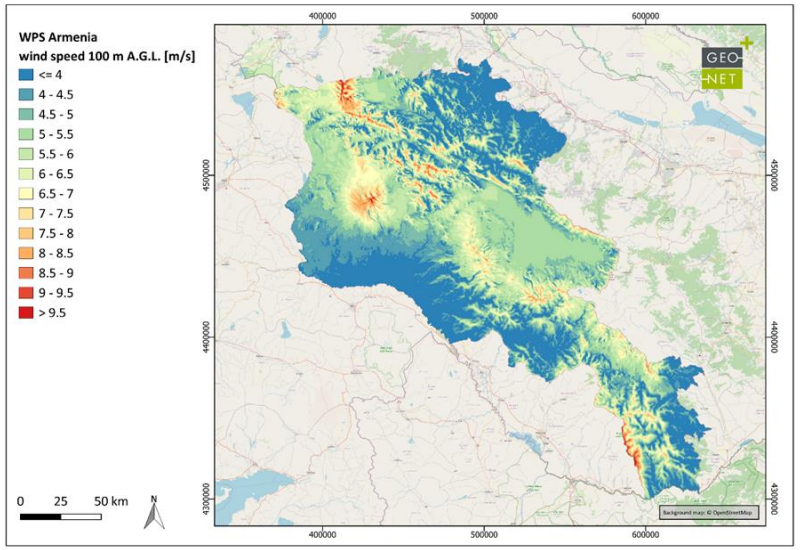
- Horizontal resolution: 200 m
- Domain size: 290 km x 290 km



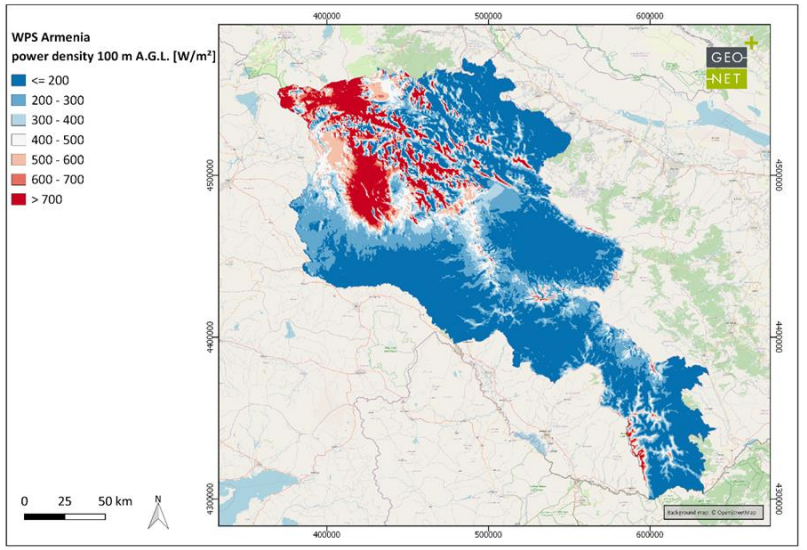
UC1/ ADB/ Armenia - Wind Atlas

Wind Atlas Armenia –

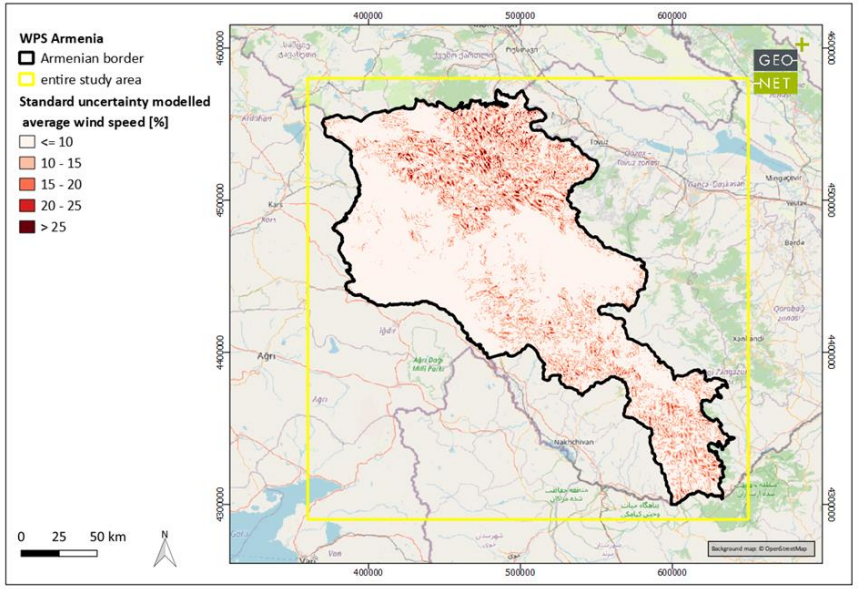
Modelled average long term wind speed



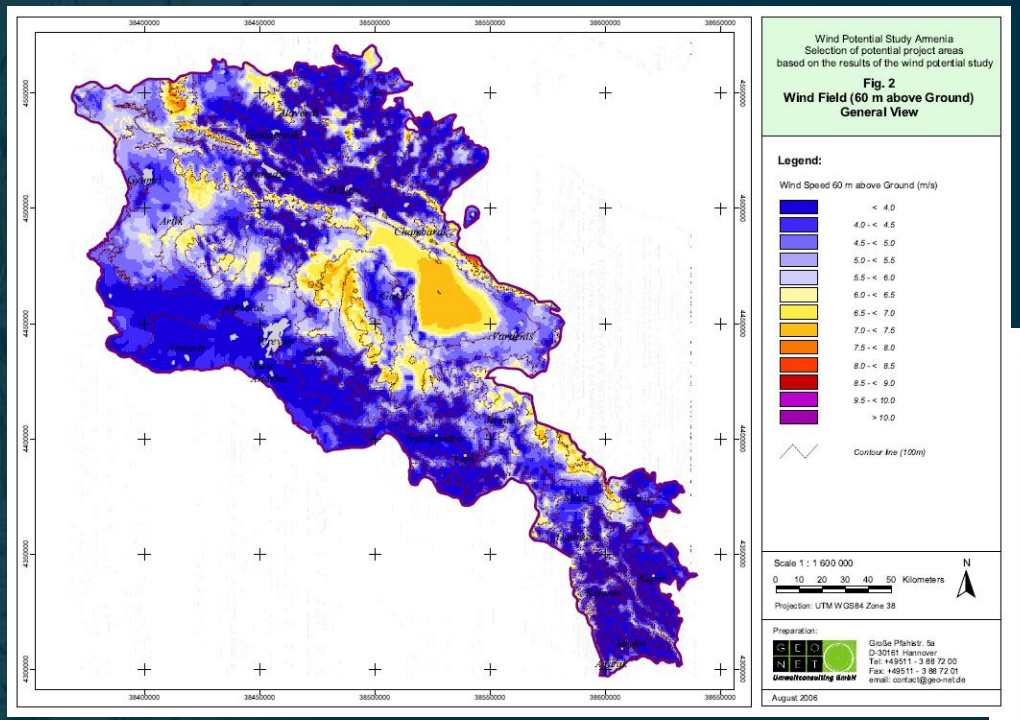
Modelled power density

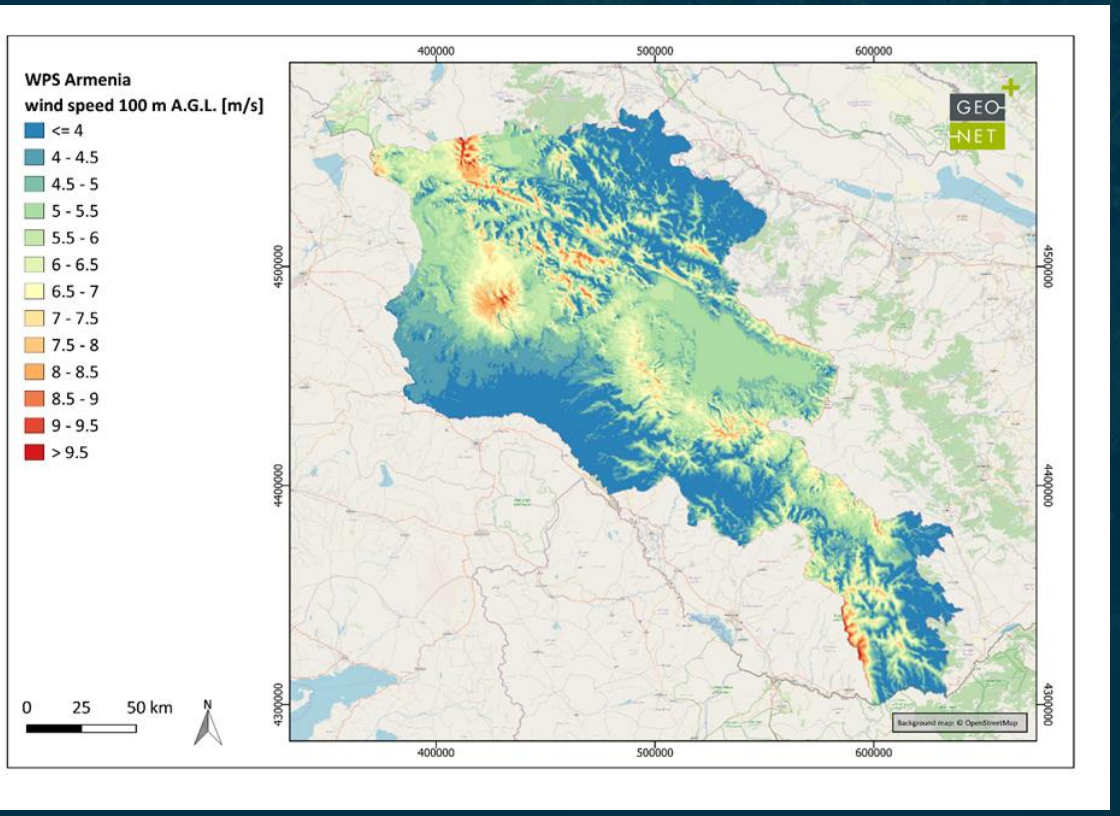


Modelled wind speed standa rd uncertainty



UC1/ ADB/ Armenia - Wind Atlas





Wind atlas Armenia – 2007 vs. 2024

Setup of the simulation:

- Horizontal resolution: 800 m -> 200 m
  16x as many grid points
- Improved resolution and accuracy of input data

UC1/ ADB/ Armenia - Wind Atlas

Outputs

- Resource maps:
    - Maps of average horizontal wind speed for standard heights
    - Maps of power density for standard heights
    - Can be integrated into any GIS system
- Report of applied methodology

Limitations & Uncertainties

- Wind conditions are highly site and terrain depending
- Wind atlases do in general represent relative differences between sites
- Absolute wind speeds are subject to high uncertainties
  => limited use for financial model for wind park financing
- (applies on any other wind atlas e.g. GWA as well)

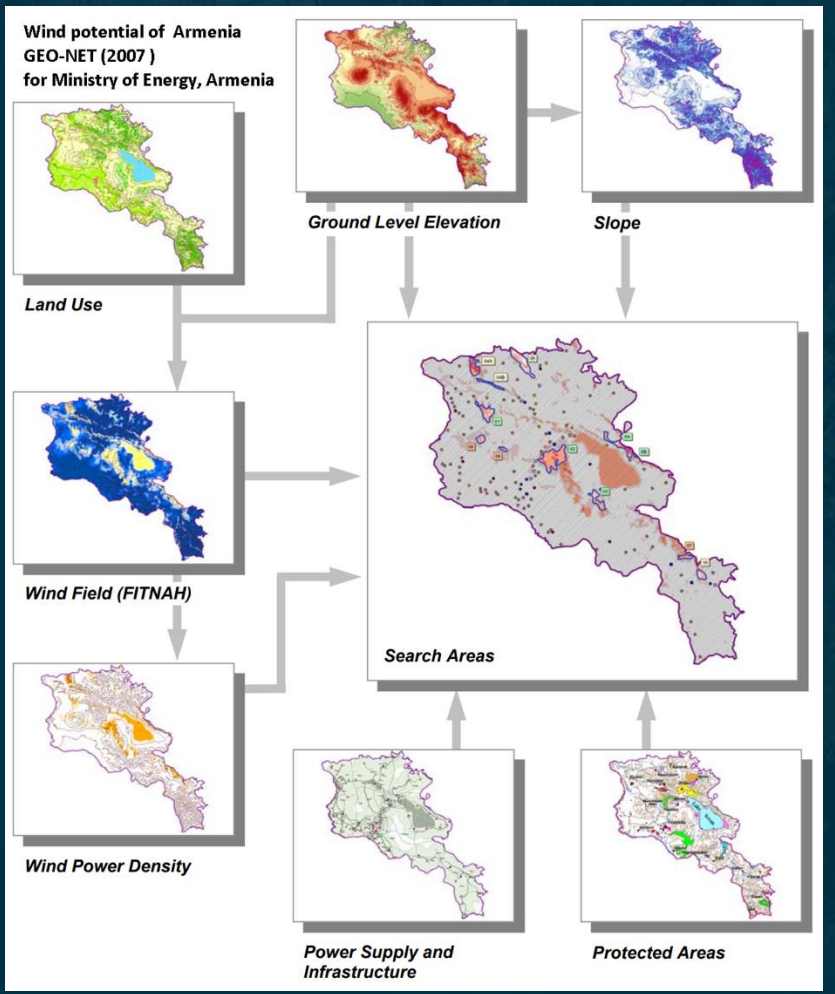
UC1/ ADB/ Armenia - Wind Atlas

Use case wind atlas for policymakers

- Estimate a national or regional wind power potential (installable capacity)
- Guide national / regional wind energy strategies
- Planning of infrastructure and grid

Use case for wind farm developers

- Allows selection and ranking of sites based on available infrastructure (grid, access routes), no-go areas and wind potential
- Preliminary wind resource estimation
  (For financial modelling, on site ground based wind measurements are mandatory)



Armenia Wind Power Electricity Generation Projects

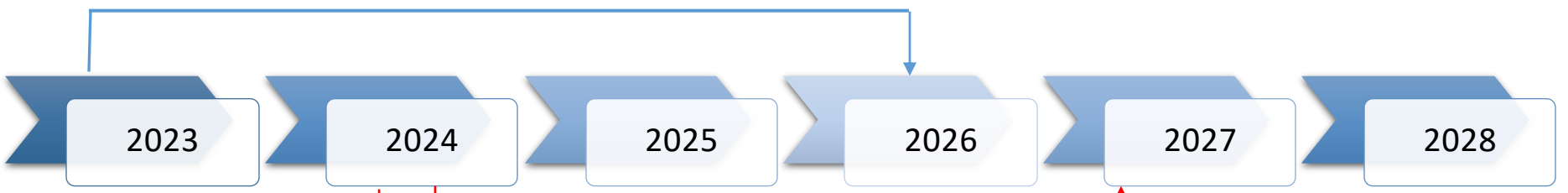
Phase I (2023 - 2025) TA 6959-ARM: Viability Assessment for Potential Wind Power Electricity Generation Projects

- TA will deliver a site-specific feasibility analysis of candidate wind power project sites and a robust utility-scale project pipeline
- TA will inform government decision-making on the scale and method of procurement
- TA will help lay the groundwork for a public-private partnership (PPP) option, should the requirements for it in Armenia's new Public Investment Management (PIM) framework and other fiscal management rules be met
- TA will support the Ministry of Territorial Administration and Infrastructure (MTAI) comply with the new PIM framework requirements of Armenia

Phase II (2024 - 2026) Preparation of Wind Power Electricity Generation Project TBD

- support the preparation of a sustainable PPP transaction, in full compliance with national PPP legislation and its competitive bidding principles.

TA 6959-ARM: Viability Assessment for Potential Wind Power Electricity Generation Projects



TA 10317-REG: Accelerating Clean Energy Transition in Asia and Pacific

TA 10375-REG: Development of Renewable Energy Public-Private Partnership Projects and Transaction Advisory Services

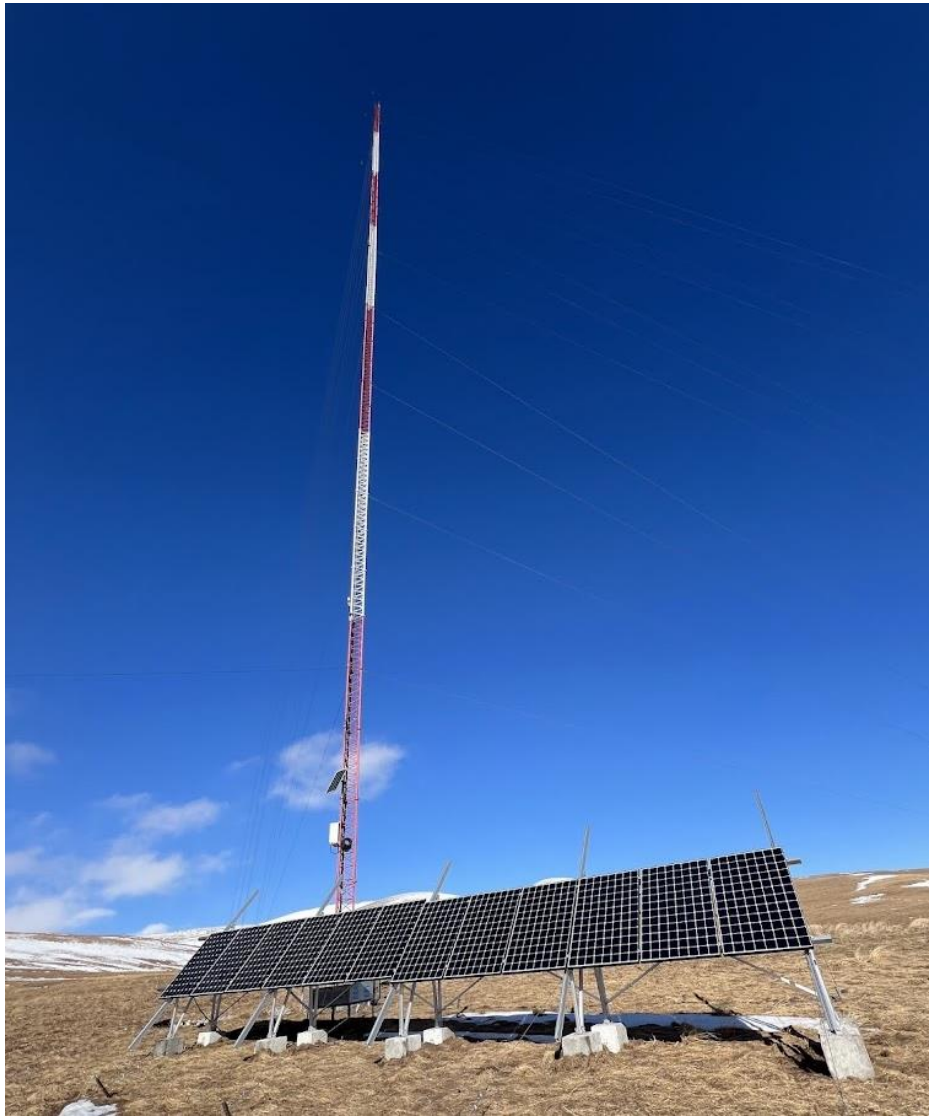
Output 1. Armenia's wind potential and grid stability assessed

- New wind atlas prepared in collaboration with GDA-ESA
- Selection of the top three ranked projects for further processing under PPP modality completed
- Identification of the optimum locations for installing the wind met masts completed
- Preparation of wind measurement campaign plan completed

Output 2: Capacity of Armenia's wind power potential development increased

- Installing wind monitoring stations and 12-month wind measurement campaign is in progress
- Preparing a conceptual design of the project is in progress
- Environmental and social assessments are in progress
- Final feasibility study, wind resource assessment, procurement options and financial model based on 12-month wind data

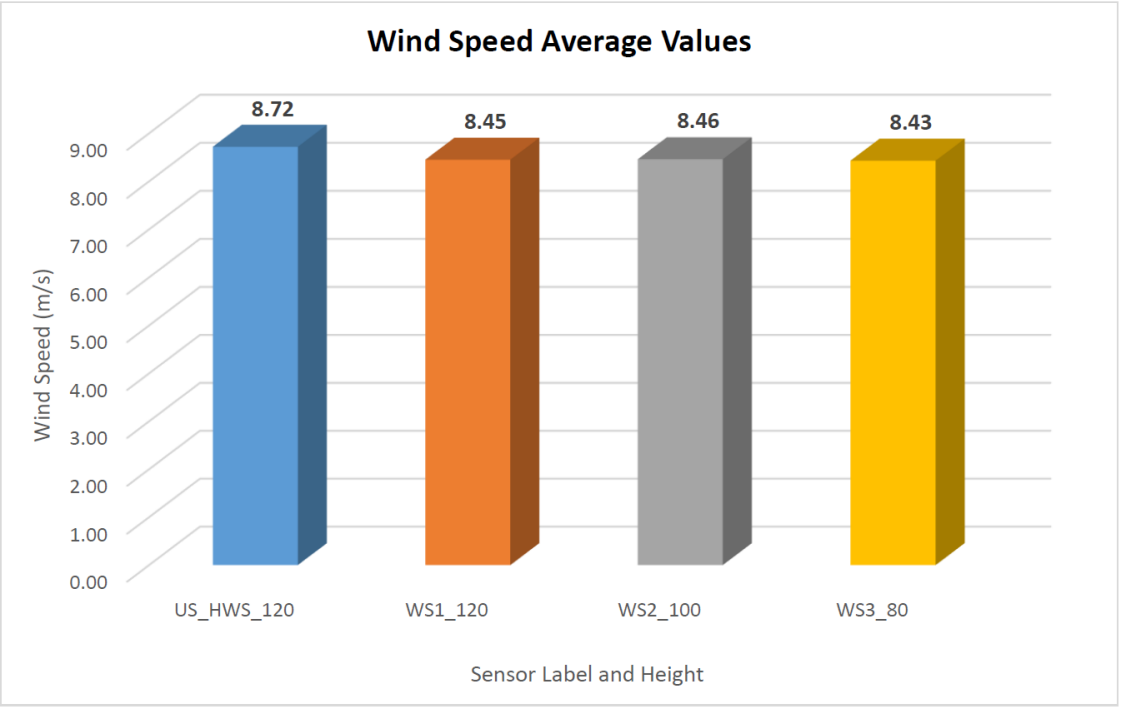
Wind measuring station 1 – Qarakhach area, Shirak Province, Armenia



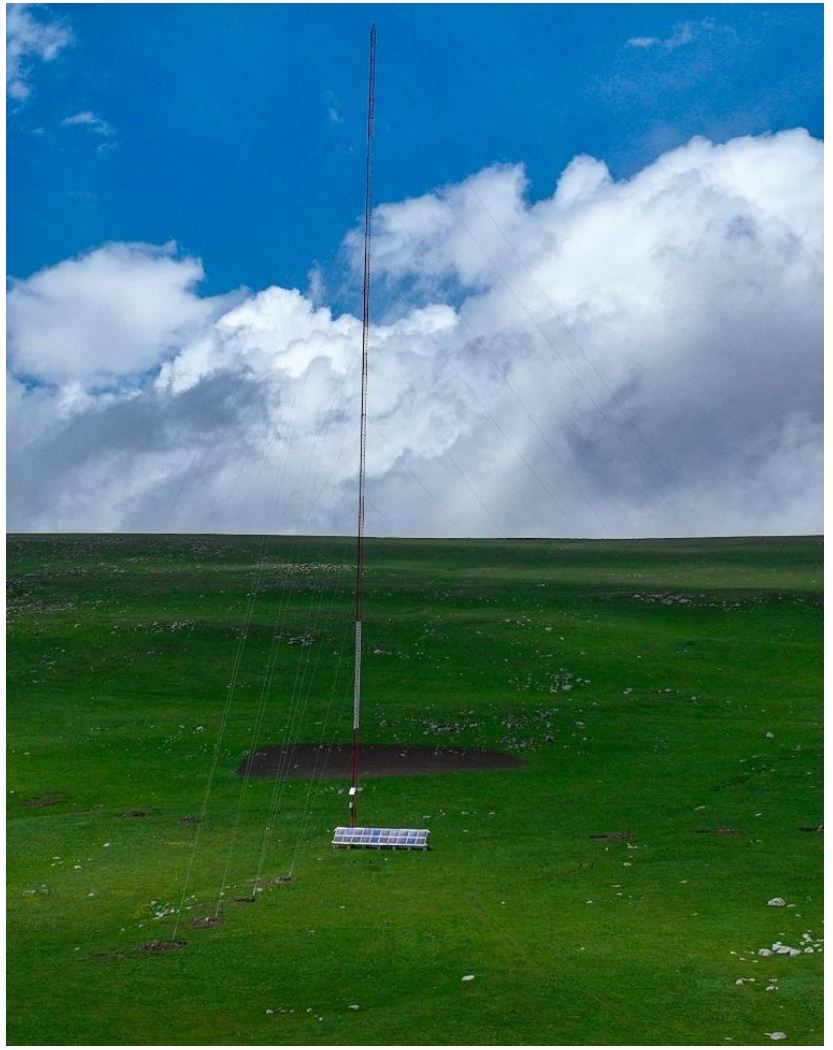
Commissioning date: October 17, 2024

Mast Name	K01	
Location	Shirak Province, Armenia	
Mast Coordinates	**Zone**	38T
	Easting [mE]	419085.206
	Northing [mN]	4543229.677
	Latitude [DMS]	41.03627°
	Longitude [DMS]	44.03737°

5.5 Summary from commissioning date to 2025-05-31

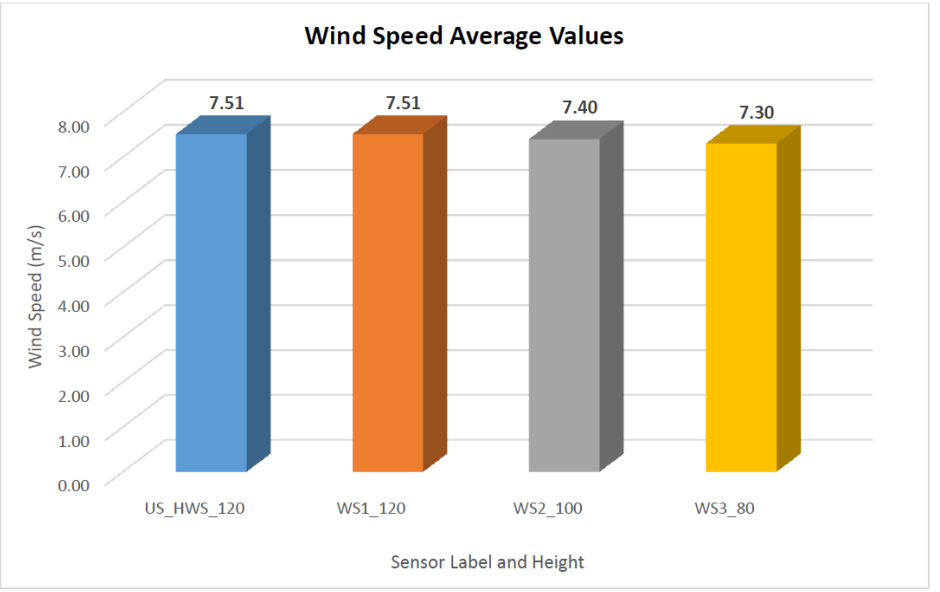


Wind measuring station 2 – Qarakhach area, Shirak Province, Armenia



Mast Name	K02	
Location	Shirak Province, Armenia	
Mast Coordinates	Zone	38 T
	Easting [mE]	415643.06 m E
	Northing [mN]	4543194.40 m N
	Latitude [WGS84]	41.035603°
	Longitude [WGS84]	43.996430°

5.1 Summary from commissioning date to 2025-05-31

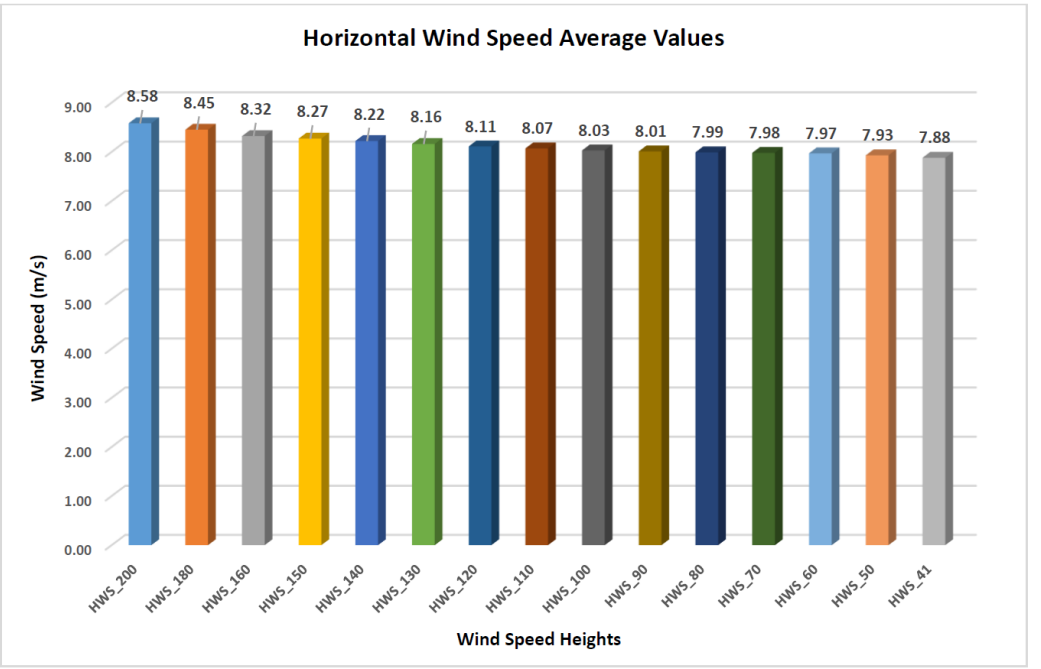


Commissioning date: March 18, 2025

Wind measuring station 3 – Qarakhach area, Shirak Province, Armenia

LiDAR Name	K03	
LiDAR Model	Vaisala WindCube	
Location	Shirak Province, Armenia	
LiDAR Coordinates	Zone	38T
	Easting[mE]	417976.050
	Northing [mN]	4541803.652
	Latitude [DMS]	41.023315°
	Longitude [DMS]	44.024366°

4.5 Summary from commissioning date to 2025-05-31

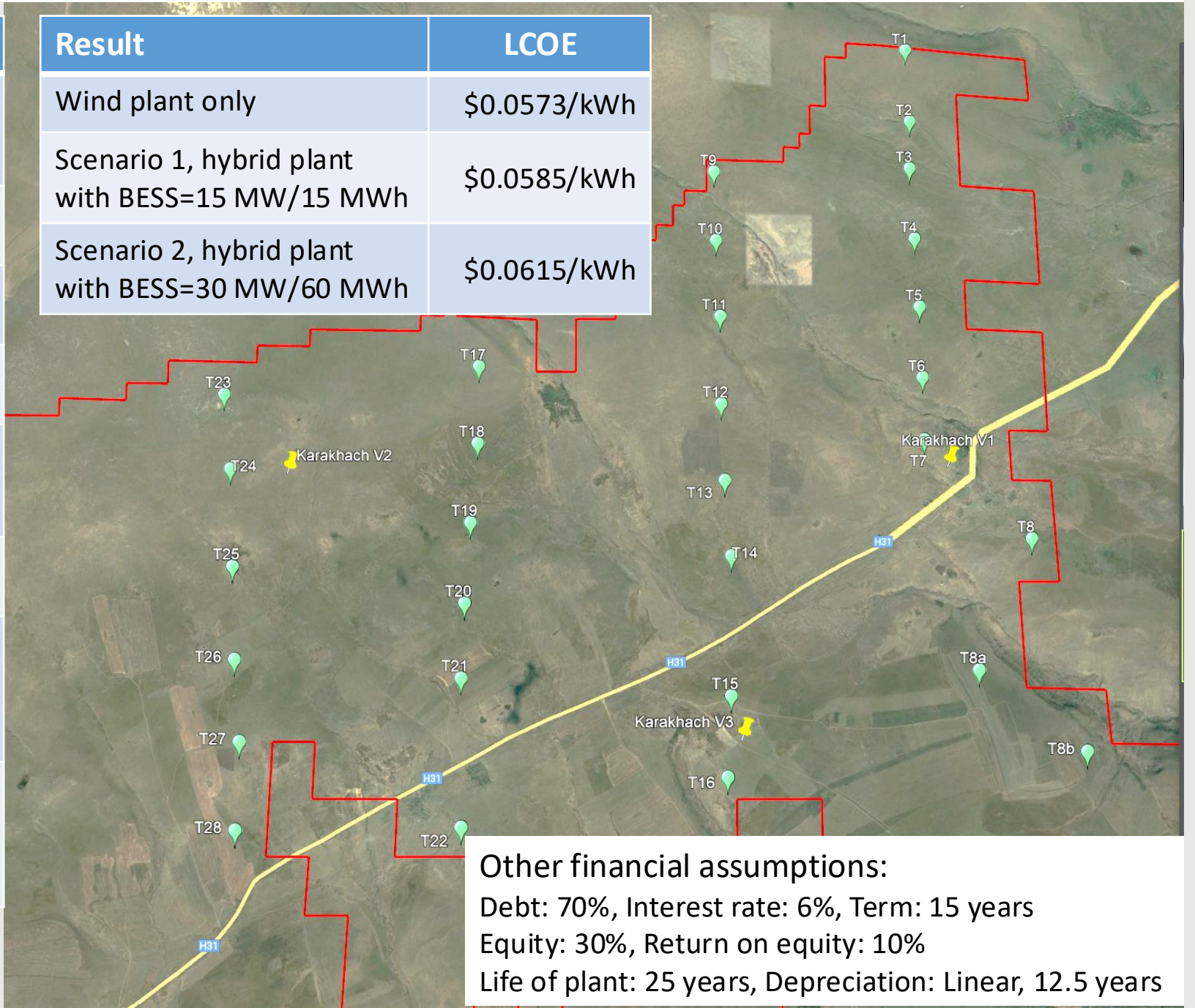


Commissioning date: October 17, 2024

PRELIMINARY RESULTS OF FINANCIAL MODEL OF PROPOSED 150 MW SHIRAK WIND POWER PLANT WITH BESS

Assumptions	Power Plant Specifications
Wind Turbine Generator	Capacity: 5 MW, IEC Class II Hub height: 120m Rotor diameter: 140m
Wind plant	Size: 150 MW Number: 30 turbines
Annual Energy Production	Net capacity factor: 37% Net AEP: 485.5 GWh/year
Infrastructure construction	Transmission (220 kV): 27.6 km Road: 15 km
Total installed cost (CAPEX)	Wind plant: $1,500/kW Total cost, wind plant: $225 mil Total cost, with infra: $236.7 mil
Total O&M cost (OPEX)	Wind plant: $32/kW-year Total OPEX: $4.8 mil/year
Scenario 1, hybrid plant with BESS	BESS size: 15 MW/15 MWh CAPEX: $4.5 mil ($300/kWh) OPEX: $0.15 mil/year ($10/kW-year)
Scenario 2, hybrid plant with BESS	BESS size: 30 MW/60 MWh CAPEX: $18 mil ($300/kWh) OPEX: $0.30 mil/year ($10/kW-year)

Result	LCOE
Wind plant only	$0.0573/kWh
Scenario 1, hybrid plant with BESS=15 MW/15 MWh	$0.0585/kWh
Scenario 2, hybrid plant with BESS=30 MW/60 MWh	$0.0615/kWh



Other financial assumptions:

Debt: 70%, Interest rate: 6%, Term: 15 years

Equity: 30%, Return on equity: 10%

Life of plant: 25 years, Depreciation: Linear, 12.5 years