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The Comparative Study of Wind Turbines Parking Optimization between WindSim, WindFarmer and Openwind

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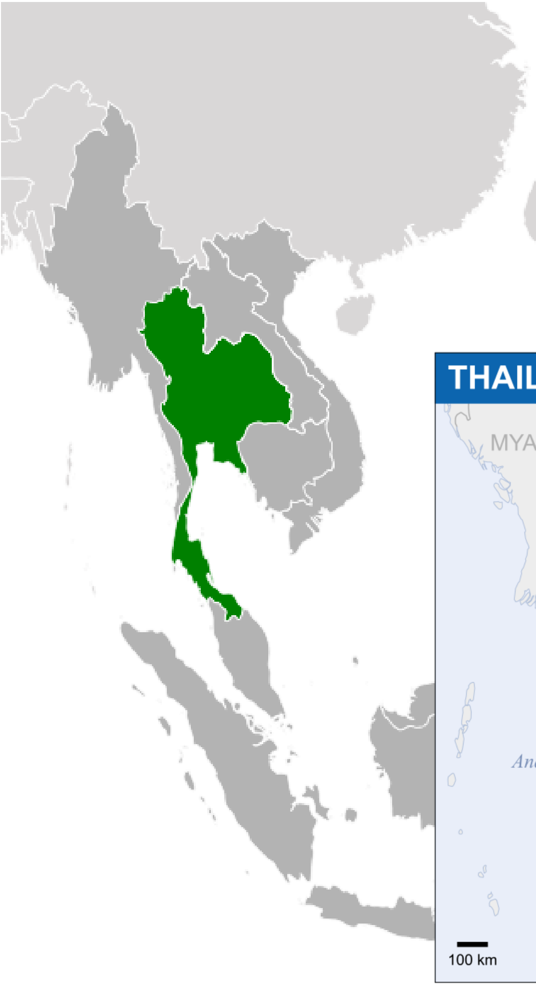
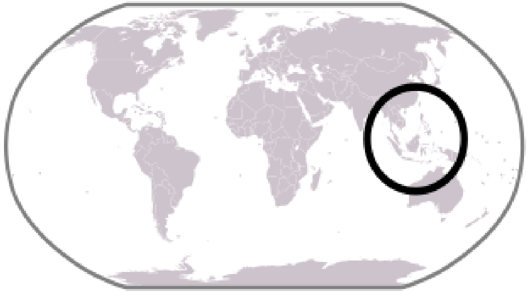
Topics

- Thailand : Outlook 2019
- Alternative Energy Development Plan (AEDP)
- Wind Resource in Thailand
- Current Status of Wind Power in Thailand
- Rationale
- Objective
- Methodology
- Results and Discussion
- Conclusion
- Further Works

Thailand : Outlook 2019





- Capital City: Bangkok
- Area: 513,120 sq.km. (50th)
- Population: 69.04 Million (21st)
- Currency: THB
- Time Zone: UTC+7
- Official Language: Thai
- Religion: Buddhism
- GDP/Capita: 20,474 US$ (20th)

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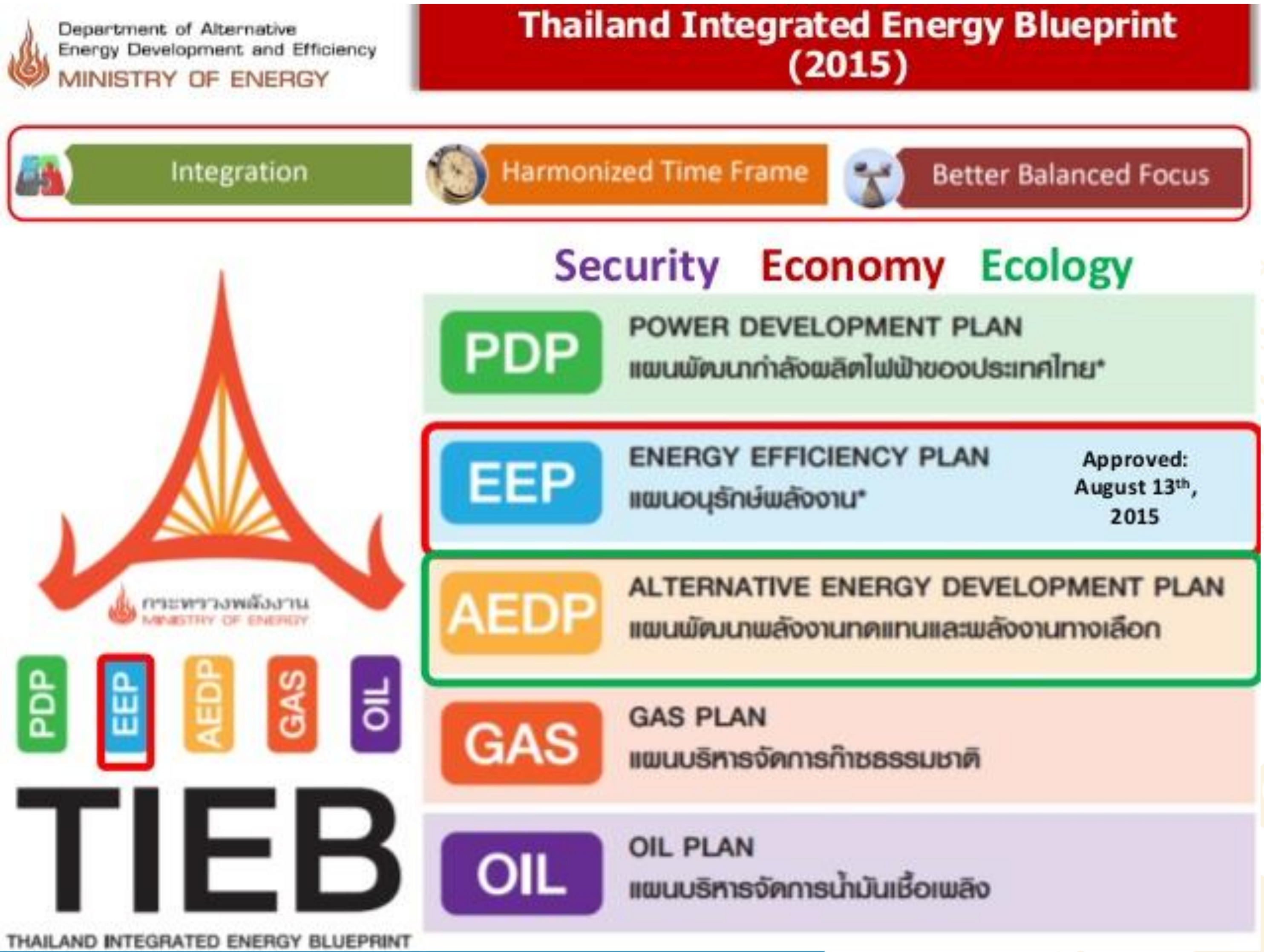
AEDP



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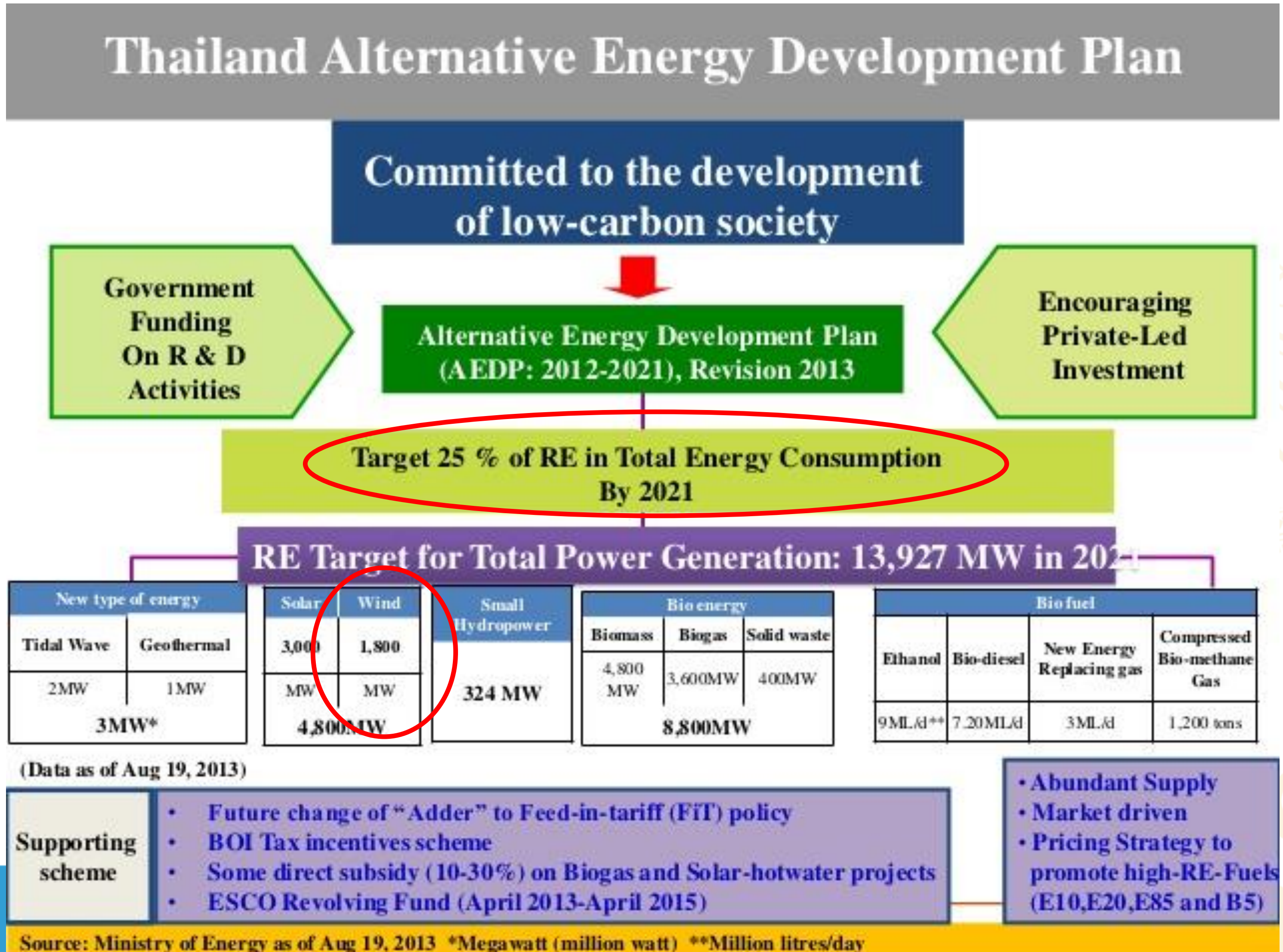
AEDP 2021



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Department of Alternative Energy Development and Efficiency
MINISTRY OF ENERGY

AEDP 2036

Alternative Energy Development Plan (AEDP) 2015-2036

Foundation: Commitment to the development of a low-carbon society

Facilitator: *Private-led investment*

Strategy: Alternative Energy Development Plan 2015-2036

Facilitator: *Government funded RD&D*

Goal: ***Target 30%*** renewables in Total Energy Consumption by 2036

Bio-Energy

Biomass	Biogas	MSW + Industrial Waste
5,570 MW	1,280 MW	550 MW
22,100 ktoe	1,283 ktoe	495 ktoe

6,720 MW Power | 23,878 Ktoe Heat

Bio-Fuel

Ethanol	Biodiesel	Pyrolysis Oil
11.3 ML/Day	14 ML/Day	0.53 ML/Day

CBG	Alt. Fuels*
4,800 t/Day	10 ktoe

Solar

6,000 MW

1,200 Ktoe

Wind

3,002 MW

9,002 MW Power | 1,200 Ktoe Heat

Hydro

Large Hydro	Small Hydro
2,906.40 MW	376 MW

3,282.40 MW

New-Energy

Geothermal, Used Tire Oil, etc.

10 ktoe

* Alternative fuels = Bio-oil, Hydrogen

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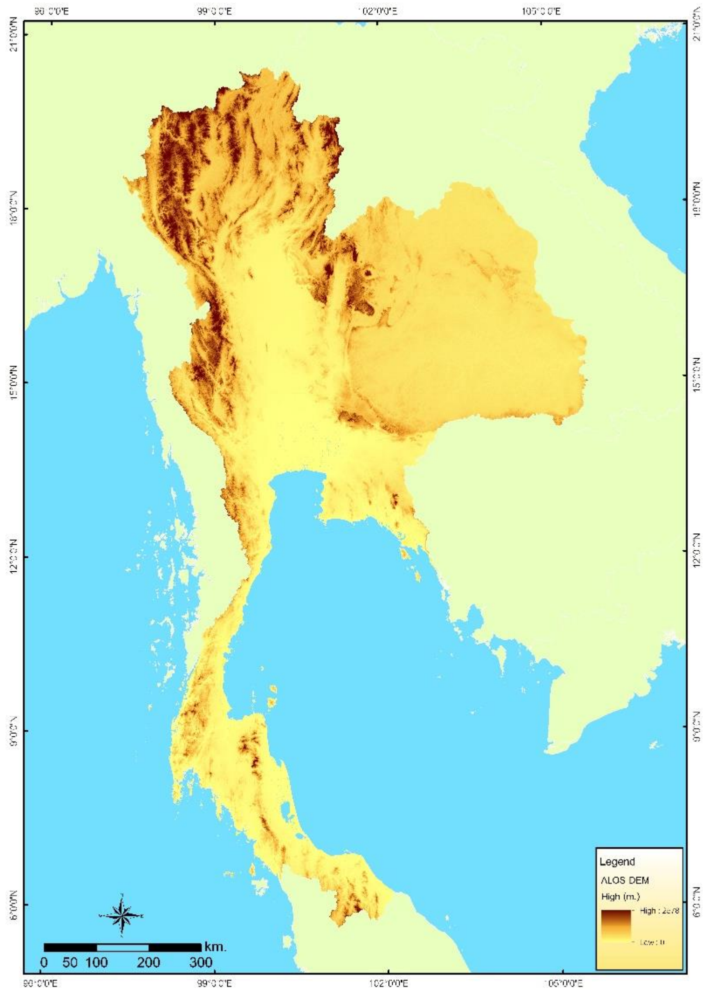
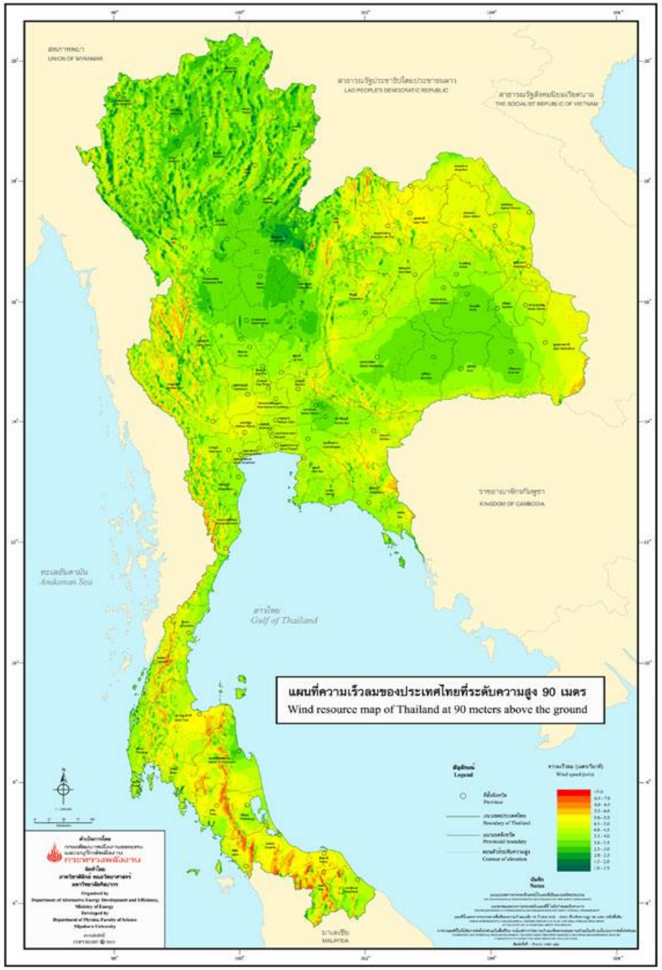
Wind Resource in Thailand





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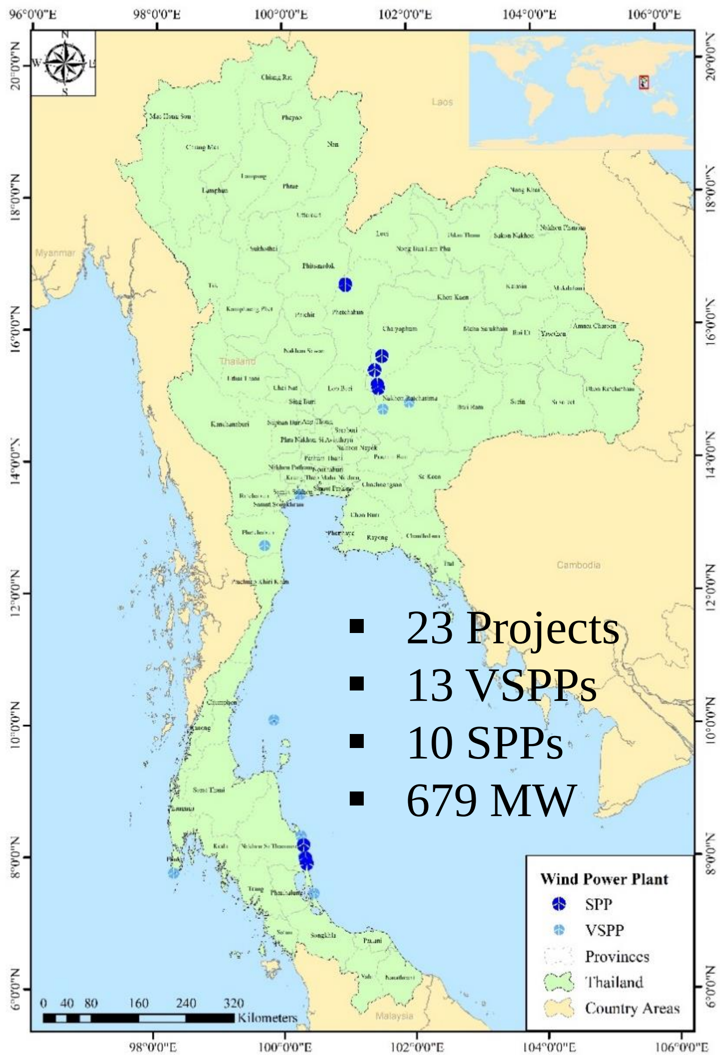
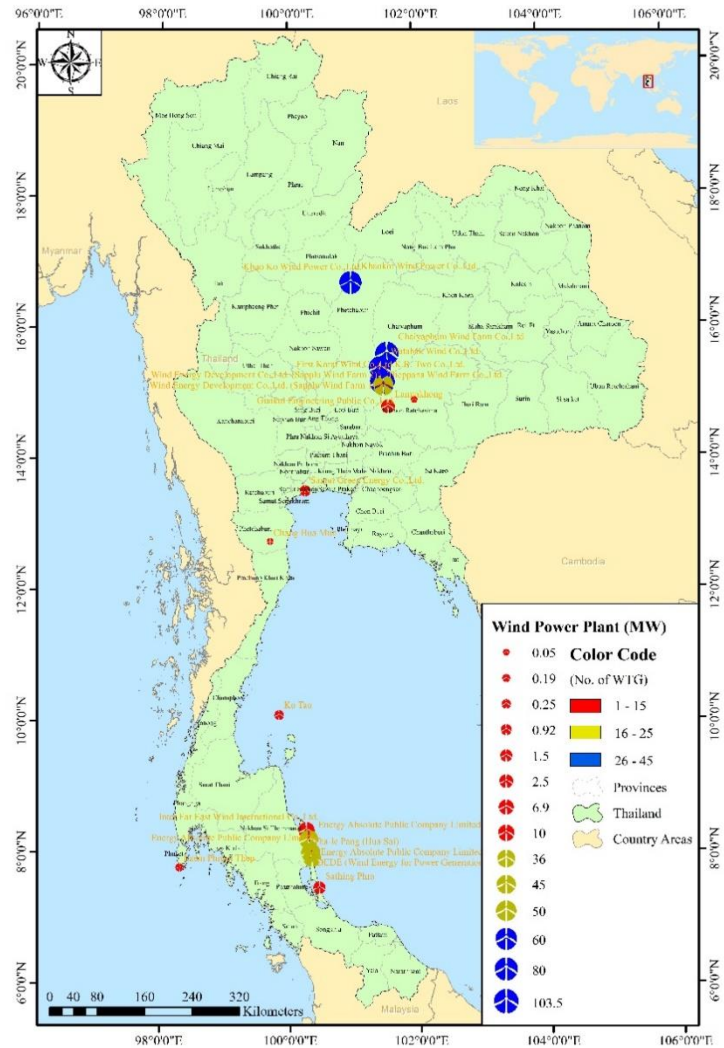
Current Status of Wind Power in Thailand



- 23 Projects
- 13 VSPPs
- 10 SPPs
- 679 MW



Rationale

- In recent years the trend has been to collect wind generators into larger and larger wind farms.
- As the investments are substantial, the optimization of the wind farm layout plays a major role today.
- Therefore, finding the optimal configuration in terms of placement of the wind turbine generators is becoming of major importance.

https://reneweconomy.com.au/upc-lands-investor-advance-huge-wind-solar-projects-17801/

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Objective

- To compare the performance of the wind turbines parking optimization between WindSim, WindFarmer, and Openwind

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Methodology

- WTGs Parking Optimization Algorithms
  - Park Optimizer (Heuristic Algorithm)
  - WindFarmer (Deterministic Algorithm)
  - Openwind (Greedy Heuristic Algorithm)
- 3 Test Cases: Flat, Semi-Complex, and Complex Terrains
- Input Data
  - MERRA 2 Wind Dataset (1980-2018) at 50 m AGL. and extrapolated to 90 m, 120 m and 137 m AGL. (HH)
- Outputs
  - AEP (GWh/year)
  - Wake Loss (%)
  - Capacity Factor (%)

Methodology

- The Performance Criteria of WTGs Parking Optimization
  - Maximum AEP
  - %Wake Loss Reduction
  - %Yield Improvement
  - Time Consumption

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Microscale Wind Resource Mapping

- CFD + standard k-epsilon turbulence wind flow modeling (WindSim)
- Height boundary layer 500 m AGL.
- Speed above boundary layer 10 m/s
- Boundary condition at the top : fixed pressure
- Solver : GCV
- Maximum iterations : 200
- Resolution 50 – 150 m
- N.O. Jensen Wake Model
- Microscale wind resource maps at HH (90 m, 120 m & 137 m AGL.)

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Optimization Algorithms and Strategies

Optimization Algorithm	Advantage	Disadvantage
Gradient Method (Hill Climbing)	Based on the generalized derivative of the objective function Converge quickly to local maxima.	To find a global maximum they need to start pretty close to it For multi-MW wind farm, two step strategy (refinement algorithm) is more appropriate.
Genetic Algorithm	The method inspired by the principles of genetics and natural selection/evolution and is often chosen because of the good quality of the solution.	There is no complete freedom in the placement of the WTGs. Different solutions have been tried to compensate for this.
Viral Algorithm	It is inspired by the replication mechanism of viruses Once a first attempt population of solution is set, the layouts with the best fit values are replicated according to the lytic cycle, which is a direct way of propagating a good solution within the evolutionary process.	-
Particle Swarm Optimization (PSO)	It is inspired by the behavior of bird in a swarm or fishes in a school.	Thinking of the wind farm layouts as particles of the swarm is quite difficult because we naturally tend to associate the turbines to particles and the wind farm to the swarm, which is wrong. In reality the whole wind farm layout is a bird/fish that is moved around by the algorithm, where “moved around” means that the position of the wind generators within the layout is changed.
Greedy Heuristic Algorithm	Greedy heuristic algorithms can be described in this way. First, an initial layout is guessed. Then, three different operations are performed on the guess layout: add a turbine, remove each turbine (one at a time), and move each turbine (up to prescribed distance). After each modification, the objective function is evaluated and the layout with the highest value is kept as best candidate solution	As this method consists of small perturbation on a initial layout, there is a risk that the algorithm get stuck in the closest local maximum.

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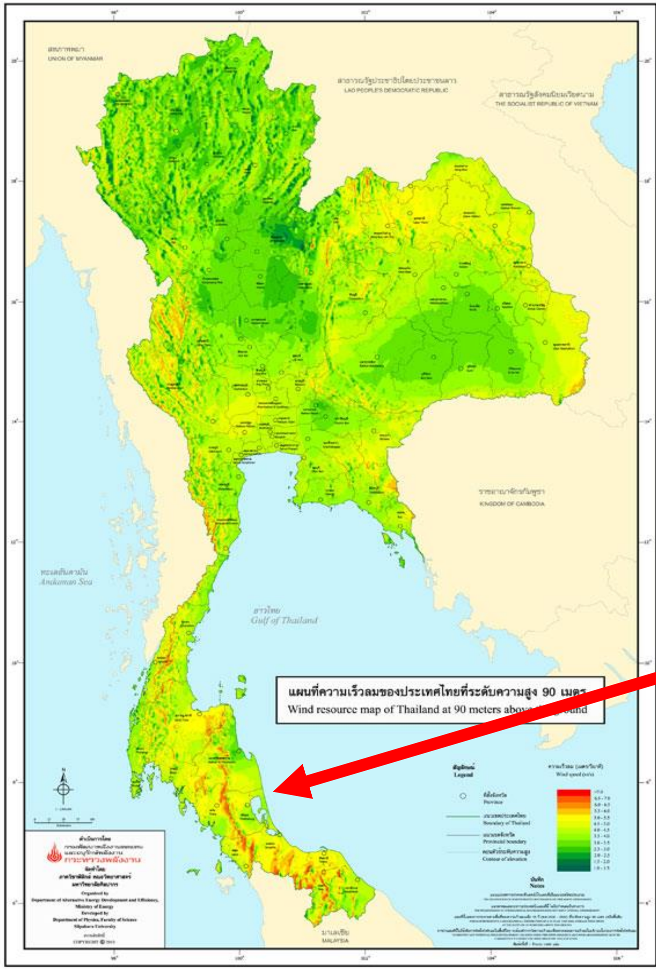
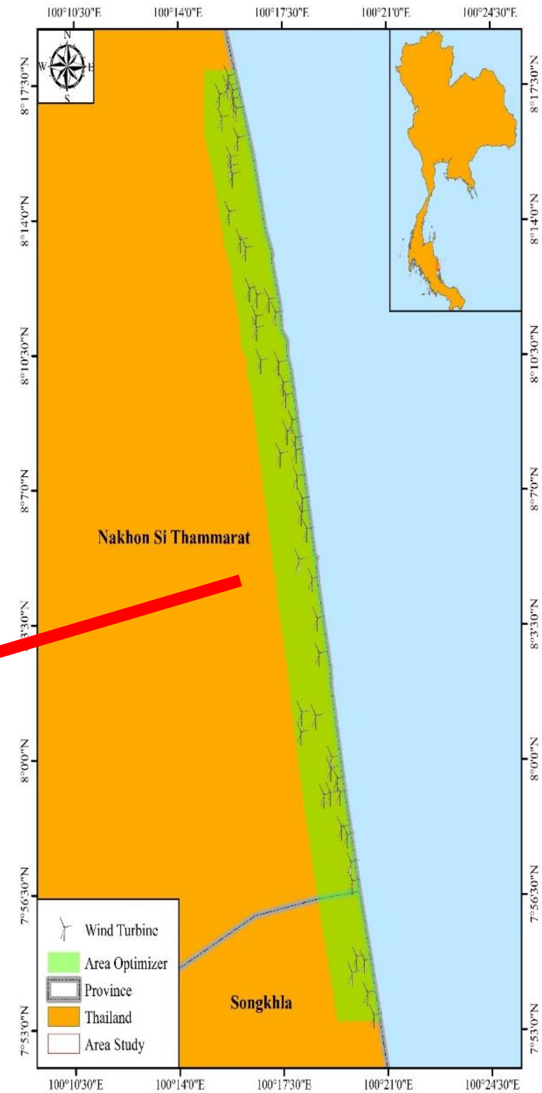
Test Case No. 1





Simple Terrain

55 Sets of V110 1.8 MW

Total Capacity 99 MW

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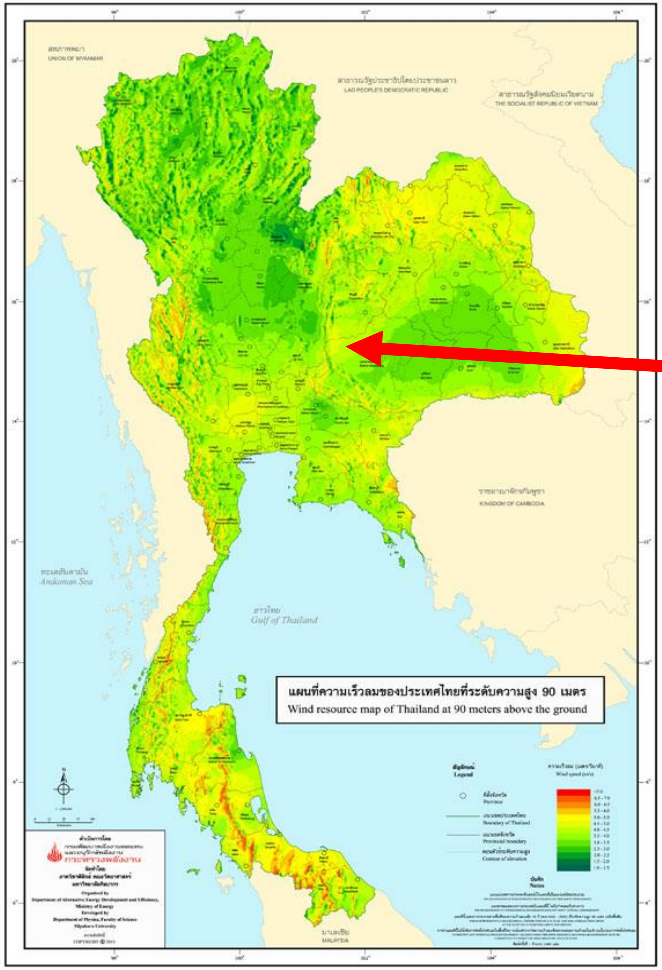
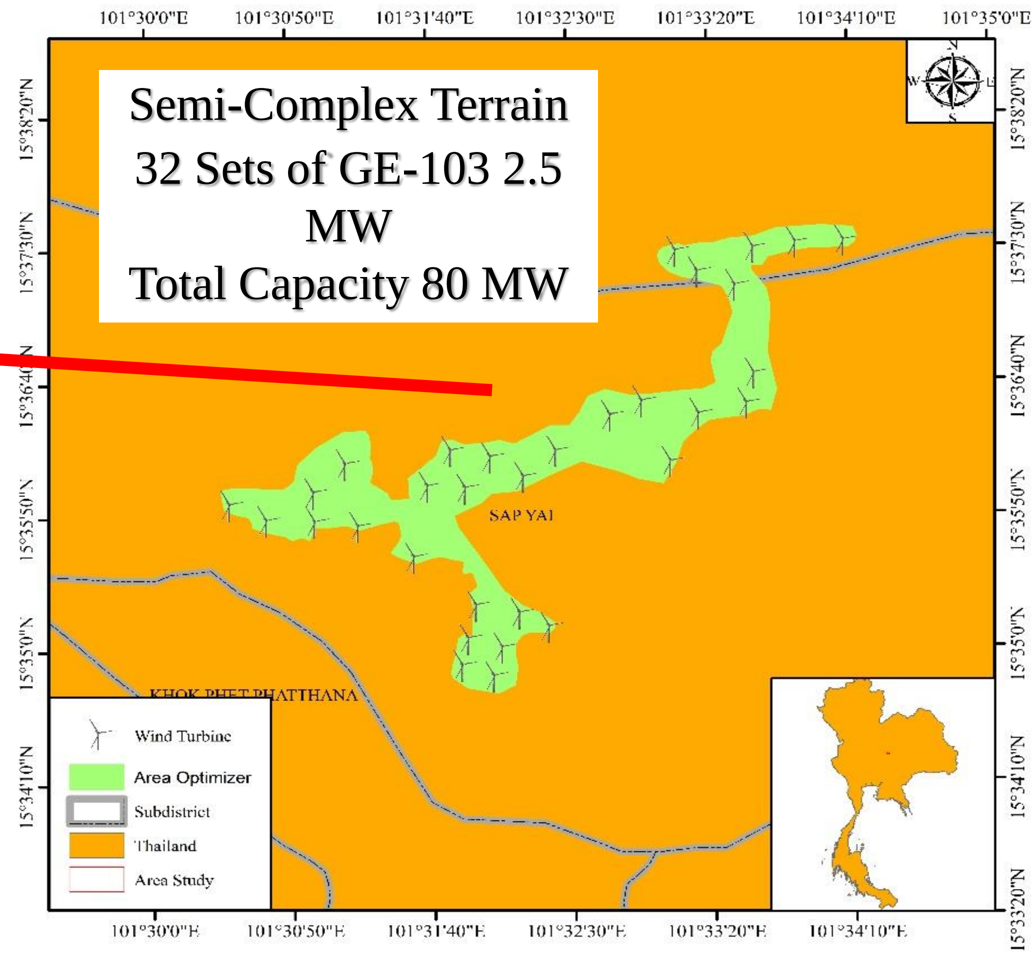
Test Case No. 2

Semi-Complex Terrain
32 Sets of GE-103 2.5 MW
Total Capacity 80 MW





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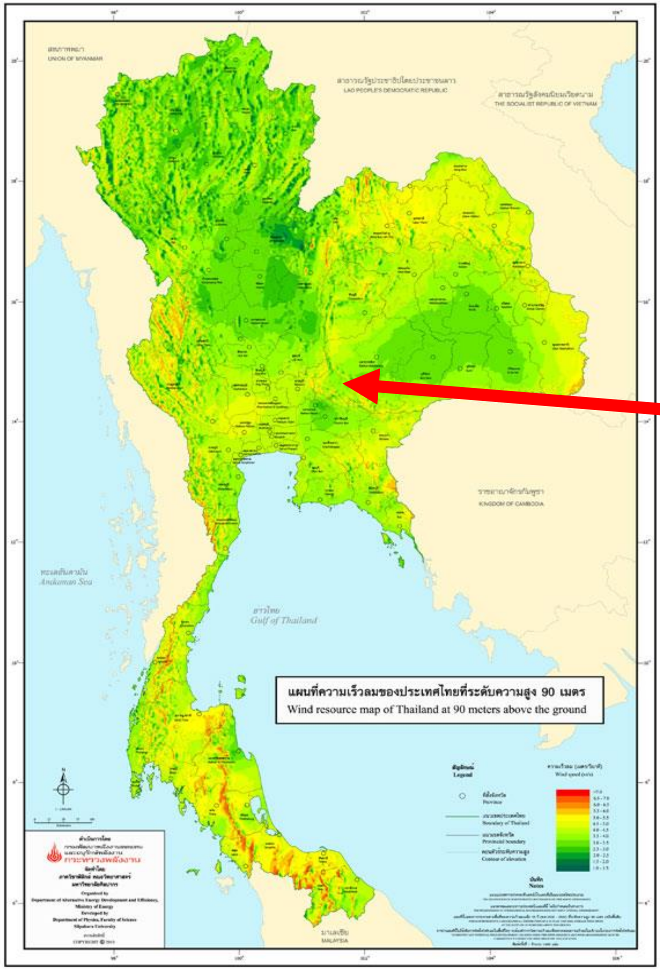
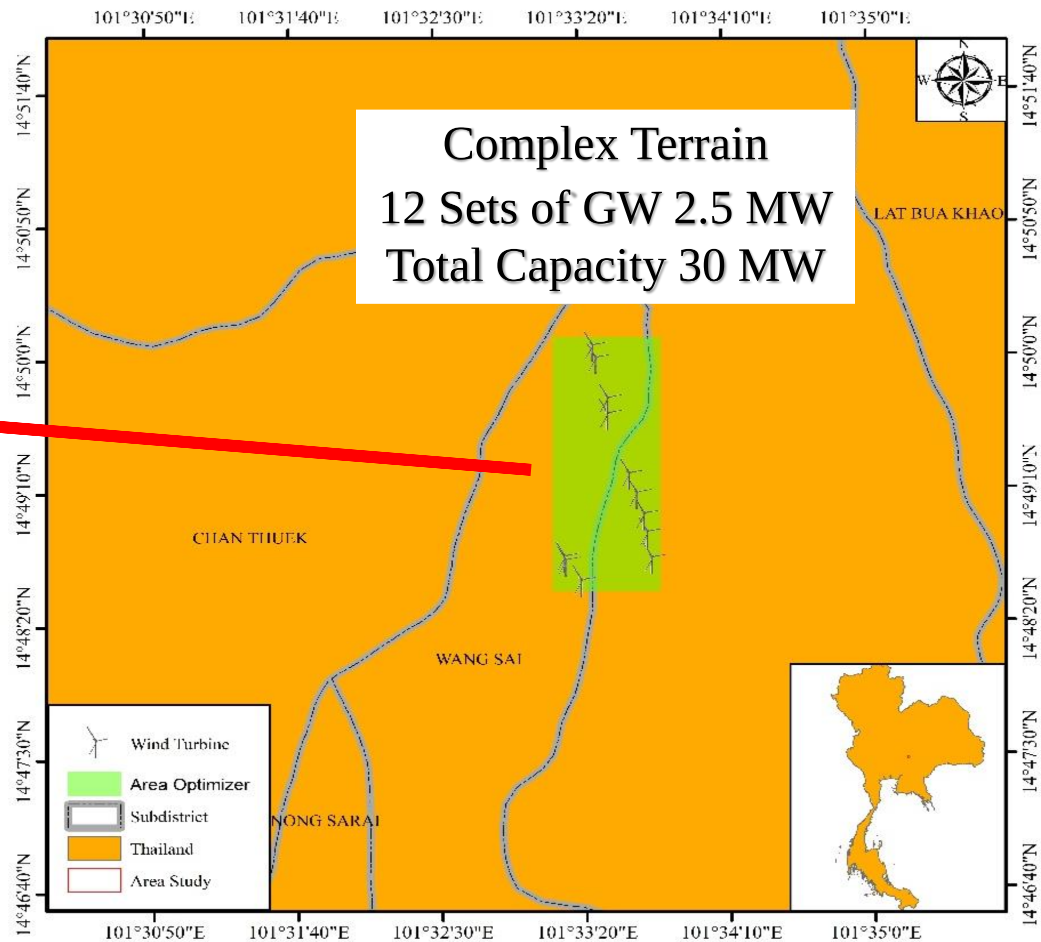
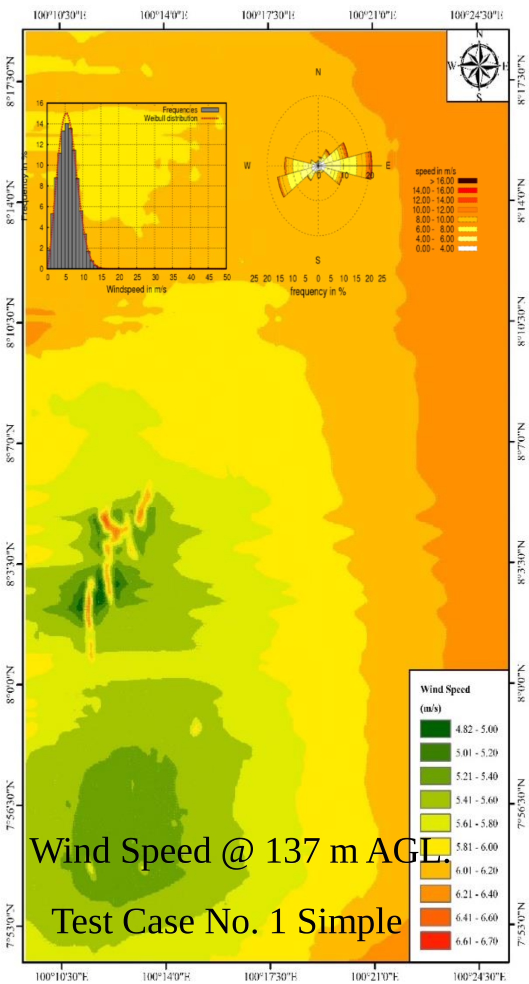
Test Case No. 3



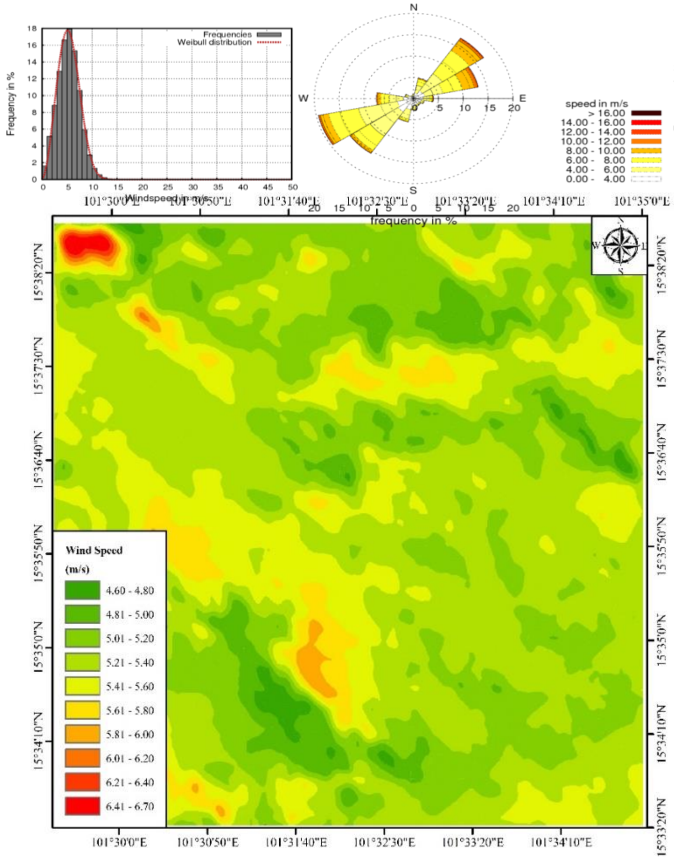


Results and Discussion



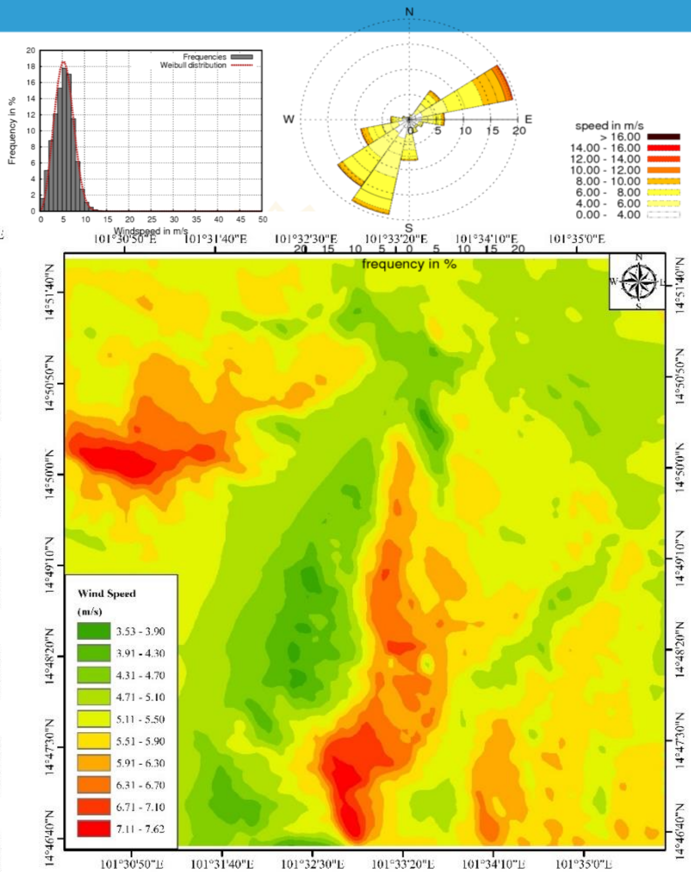
Wind Speed @ 137 m AGL.

Test Case No. 1 Simple



Wind Speed @ 120 m AGL.

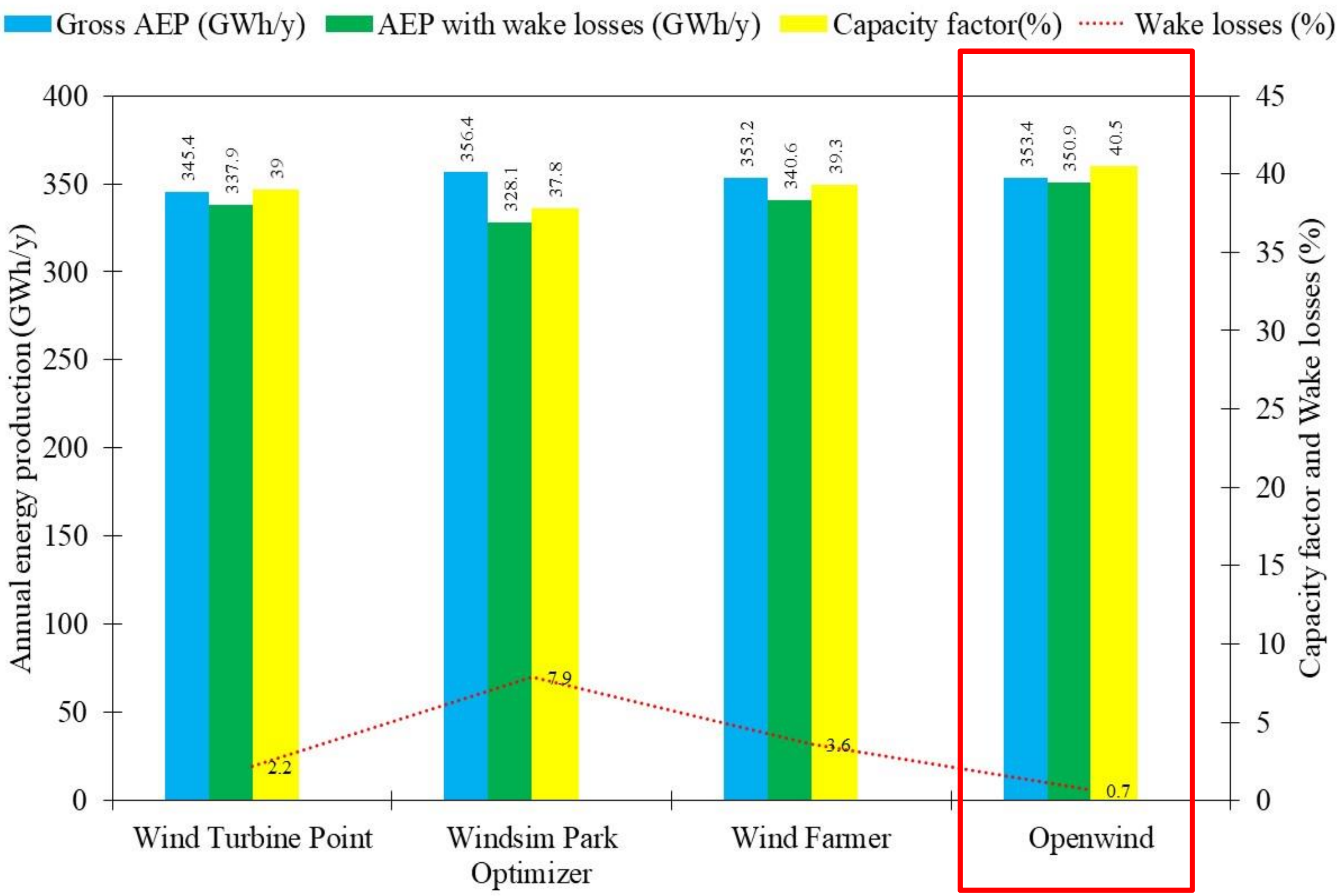
Test Case No. 2 Semi-Complex



Wind Speed @ 90 m AGL.

Test Case No. 3 Complex

Results and Discussion



Test Case No. 1 Simple

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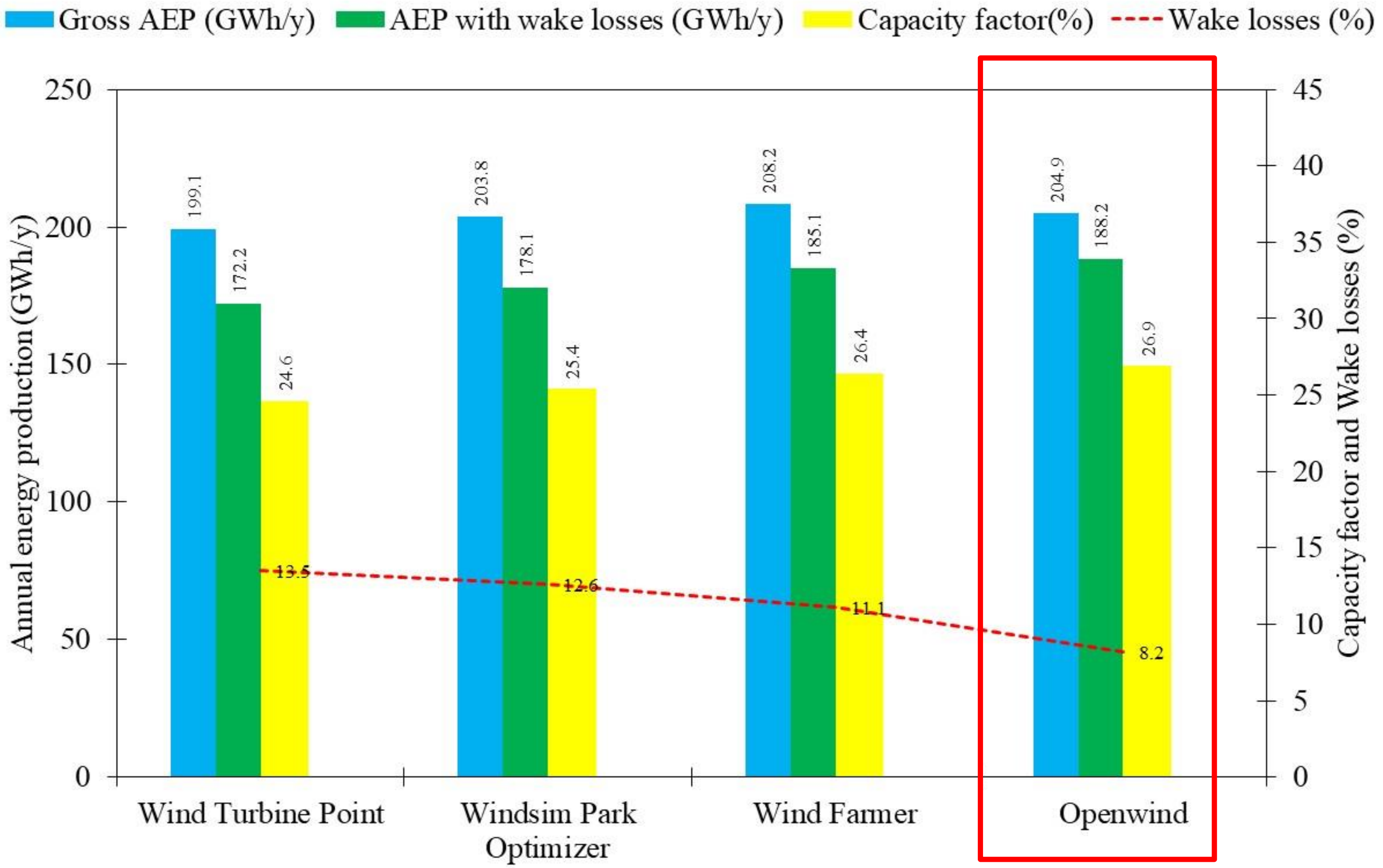
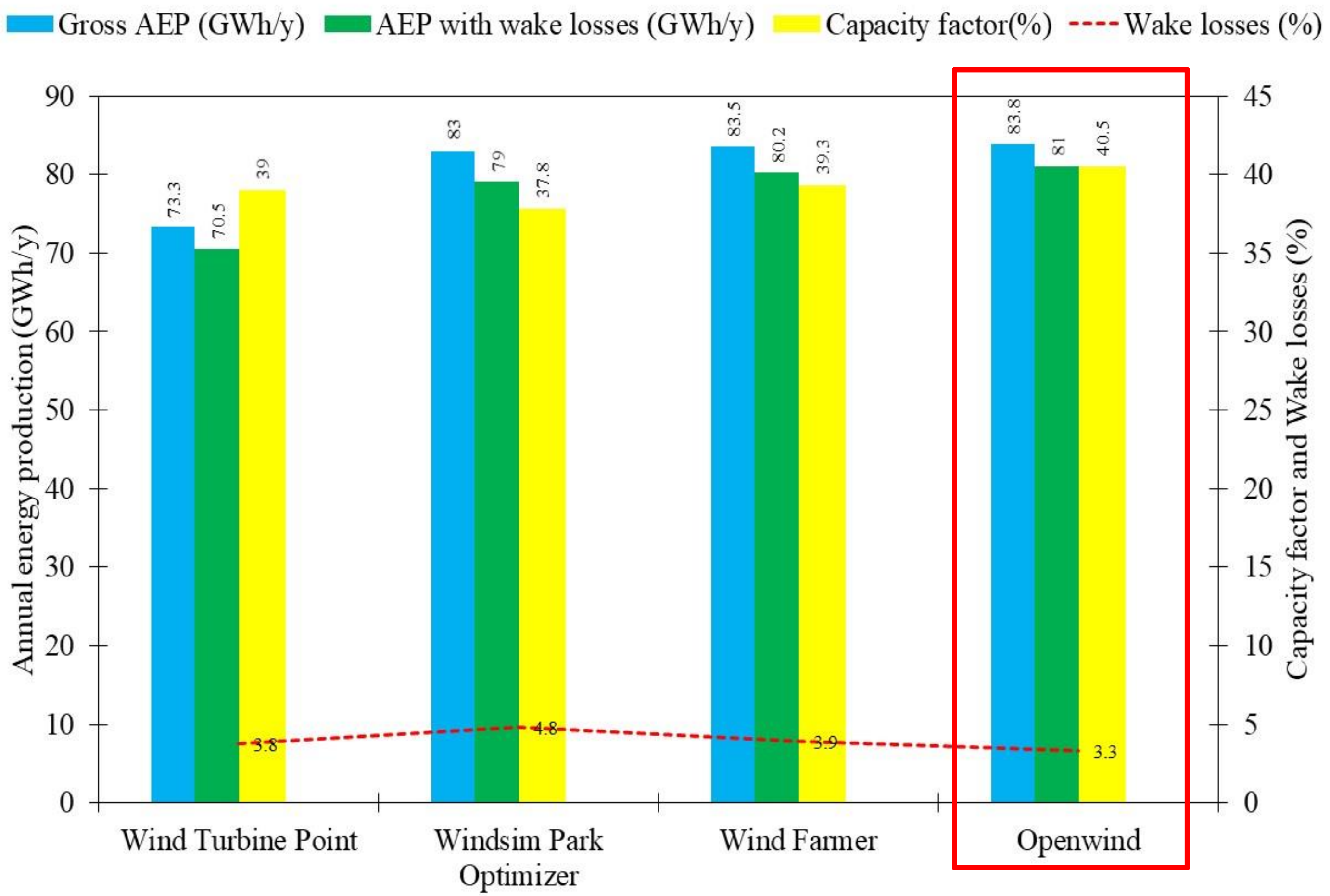
Results and Discussion



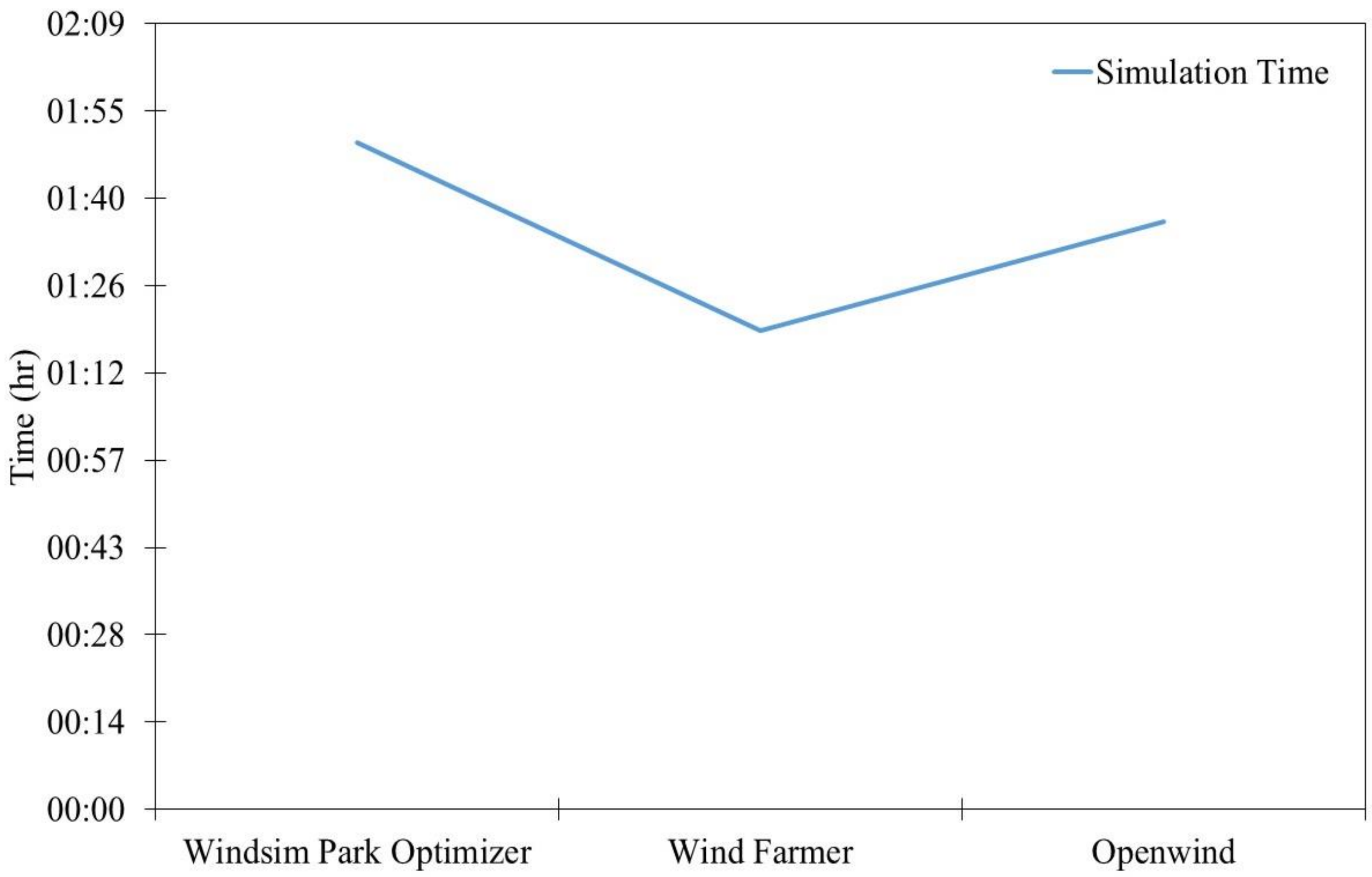
Test Case No. 2 Semi-Complex

Results and Discussion



Test Case No. 3 Complex

Results and Discussion



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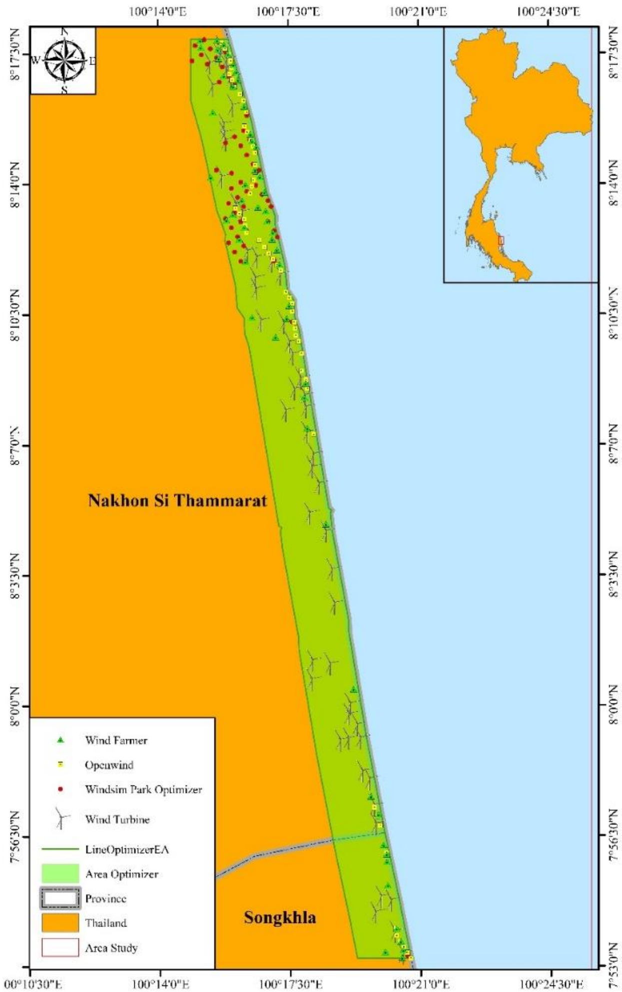
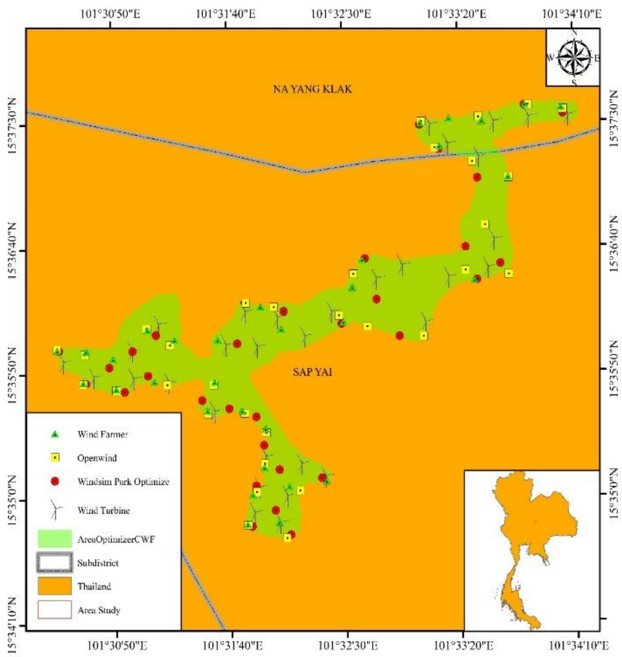
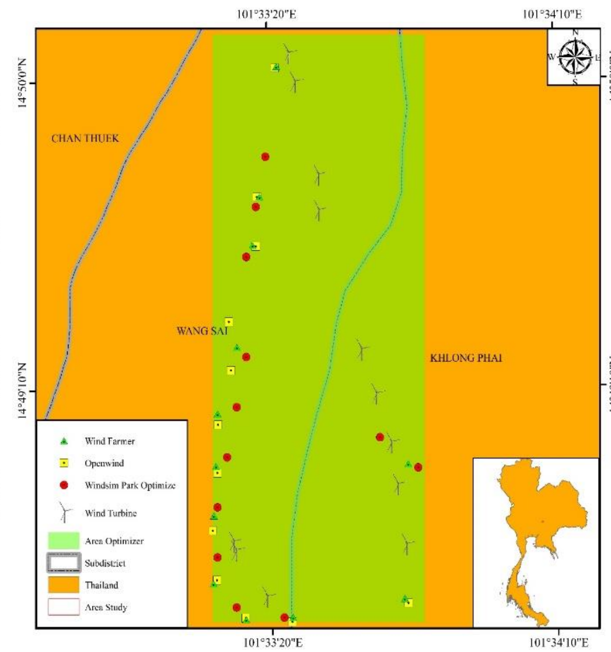
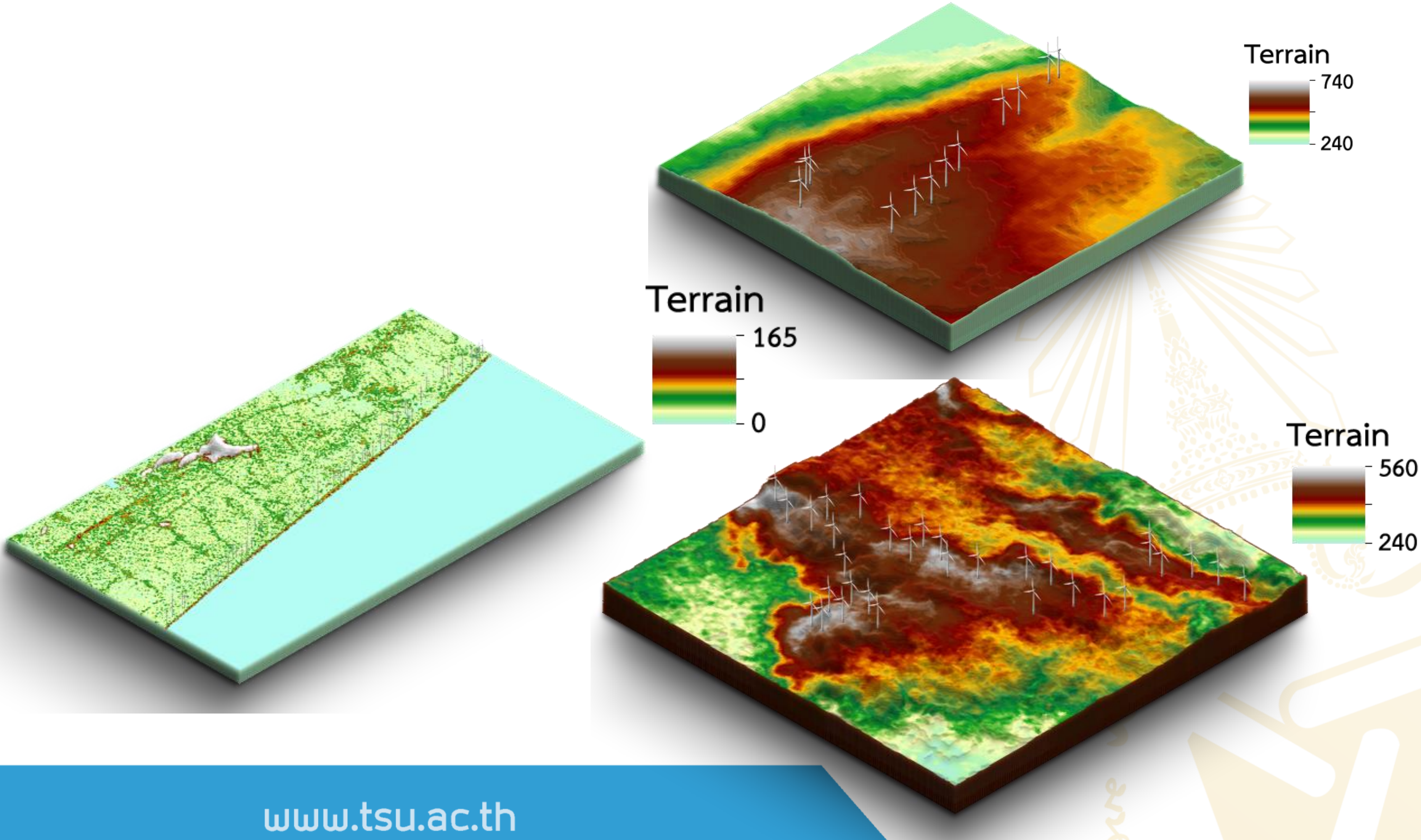
Optimum WTGs Placement







3-D Optimum WTGs Placement



Conclusion

- Openwind gave the maximum net AEP and the lowest wake loss for all 3 test cases.
- Openwind improved yield much better than WindSim and WindFarmer for a semi-complex terrain.
- WindFarmer consumed less time in optimization iteration than WindSim and Openwind but the time difference was insignificant.

Further Works

- In-house MATLAB code will be developed to evaluate the performance of GA and then to compare with optimization techniques in WindSim, WindFarmer and Openwind.
- The objective functions should be more complicated (financial balance, NPV and LCOE) rather than energy yield only.

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Thank You for Your Kind Attention

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