# Utilization of Vertical Axis Wind Turbines in Port Areas


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# Description

- Simulation of the operation of a Gorlov Helical Wind Turbine model in an average port area, aiming to the creation of a safe and durable construction for this specific working environment by calculation of the mechanical loads exerted from the wind conditions and selection of an appropriate material and cost assessment for a small scale project.

# Why go “green” on Ports?

- IPCC: increase of Greenhouse Gases over the last 50 years.
- EU: Reduction of $CO_2$ emissions by 20% until 2020.
- ECLAC: 30% of electricity demands of ports is consumed by container terminals (40% freezing, 40% cranes, 12% lighting).
- EEA: Energy independence of large facilities.

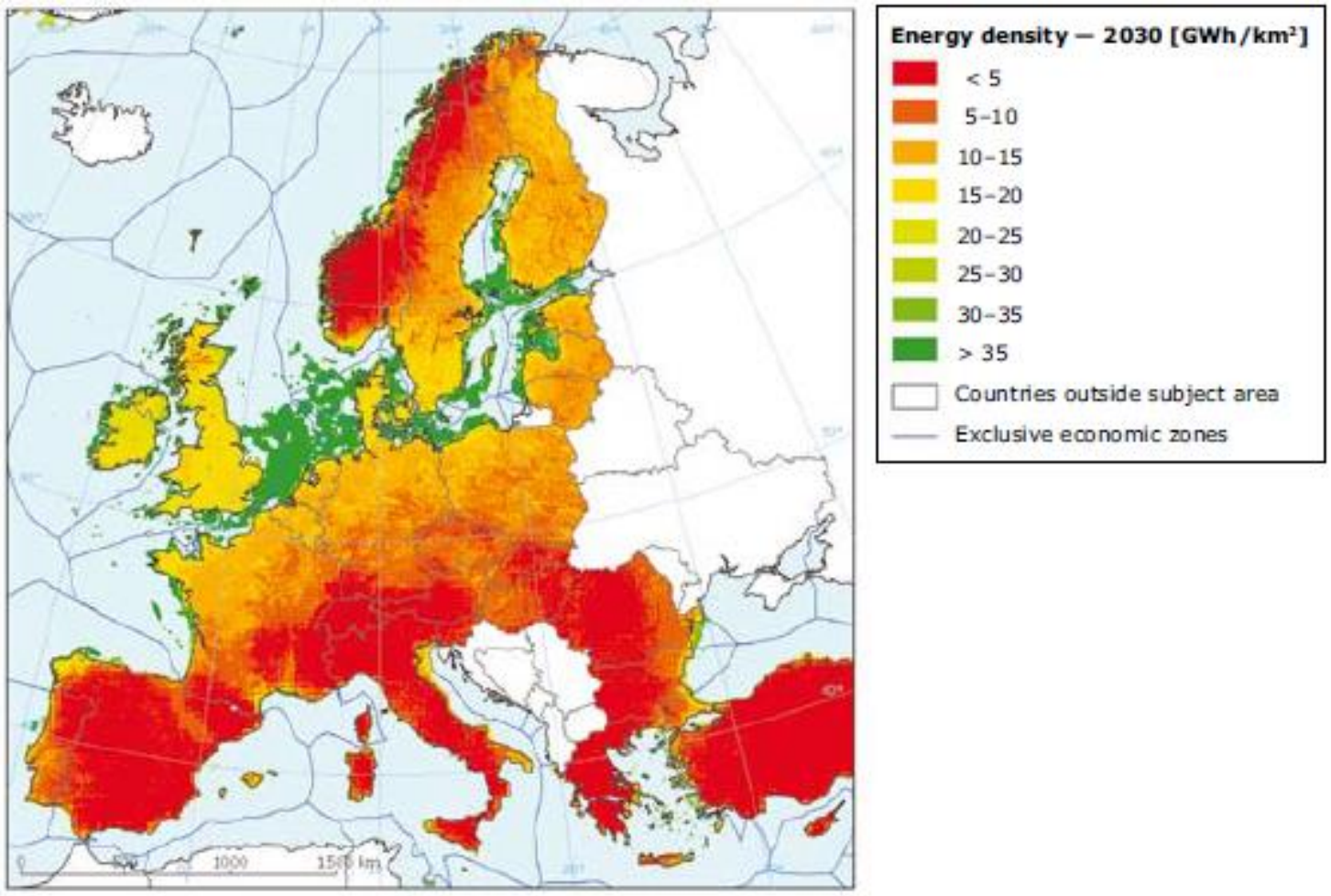
# Overview

- Port Areas Wind Statistics and Wind Turbines Utilization
- Design of the GHWT model
- CFD Analysis for a series of wind speed via Fluent Solver
- Structural Analysis
- Presentation of results
- Cost Assessment for a pilot installation

# Port Areas Wind Statistics and Wind Turbines Utilization

- EEA Report: 9 to 18 mph wind speed range on the Northern Sea coastline and Eastern Mediterranean, 1000 to more than 3000 hours of full potential annually.

# Port Areas Wind Statistics and Wind Turbines Utilization (cont.)




Source: EEA, 2008.

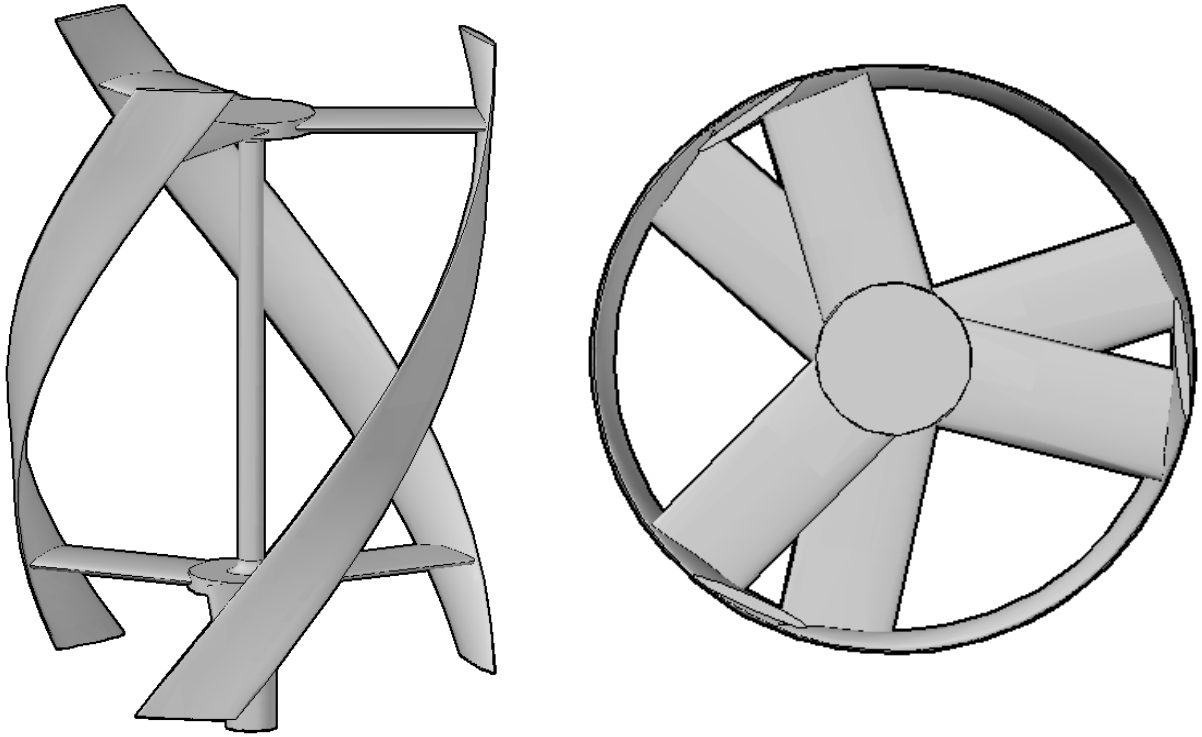
# Port Areas Wind Statistics and Wind Turbines Utilization (cont.)

- Consistent wind potential and energy supply.
- U.S. DOE: Low levelized cost for on-shore wind turbines in comparison to photovoltaic solutions.
- VAWT: more practical, more efficient in urban and industrial environments.

# Design of the GHWT model

- NACA 0020
- Three 16.40 ft S-shaped blades
- 12.63 ft diameter
- 6380 BTU/h or 1.87 kW rated at 9 mph (theoretical)

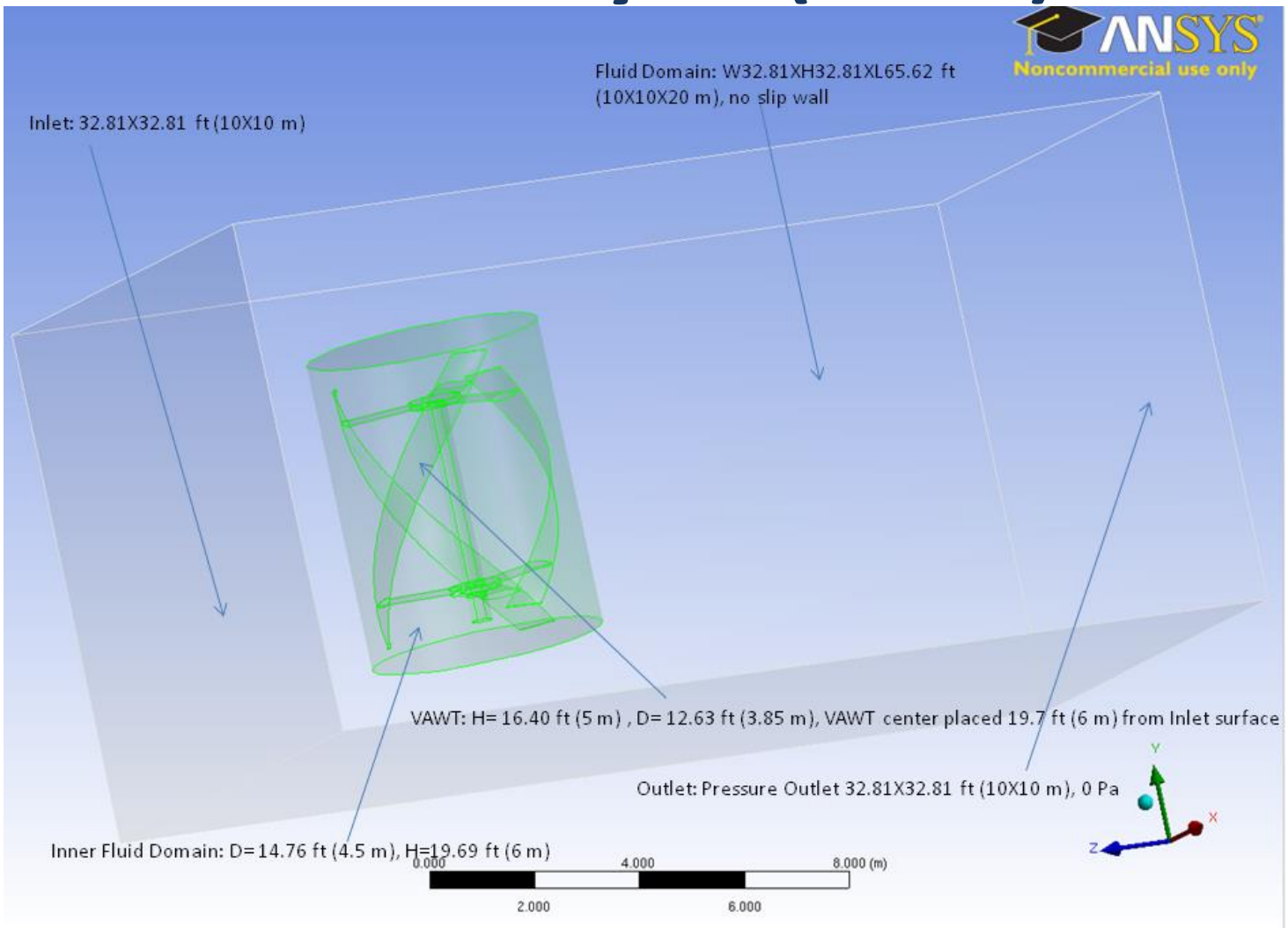
# Design of the GHWT model



# CFD Analysis

- Three case scenarios:
  - Extreme Wind (Hurricane Cat. 2) - 112 mph
  - Maximum operational wind speed - 45 mph
  - Average optional speed - 18 mph
- GHWT model as wall in fluid domain
- Theoretical rotational speed:
  - 10.38 rad/s at 18 mph wind speed
  - 18.70 rad/s at 45 mph wind speed
- Locked model for Extreme Wind scenario

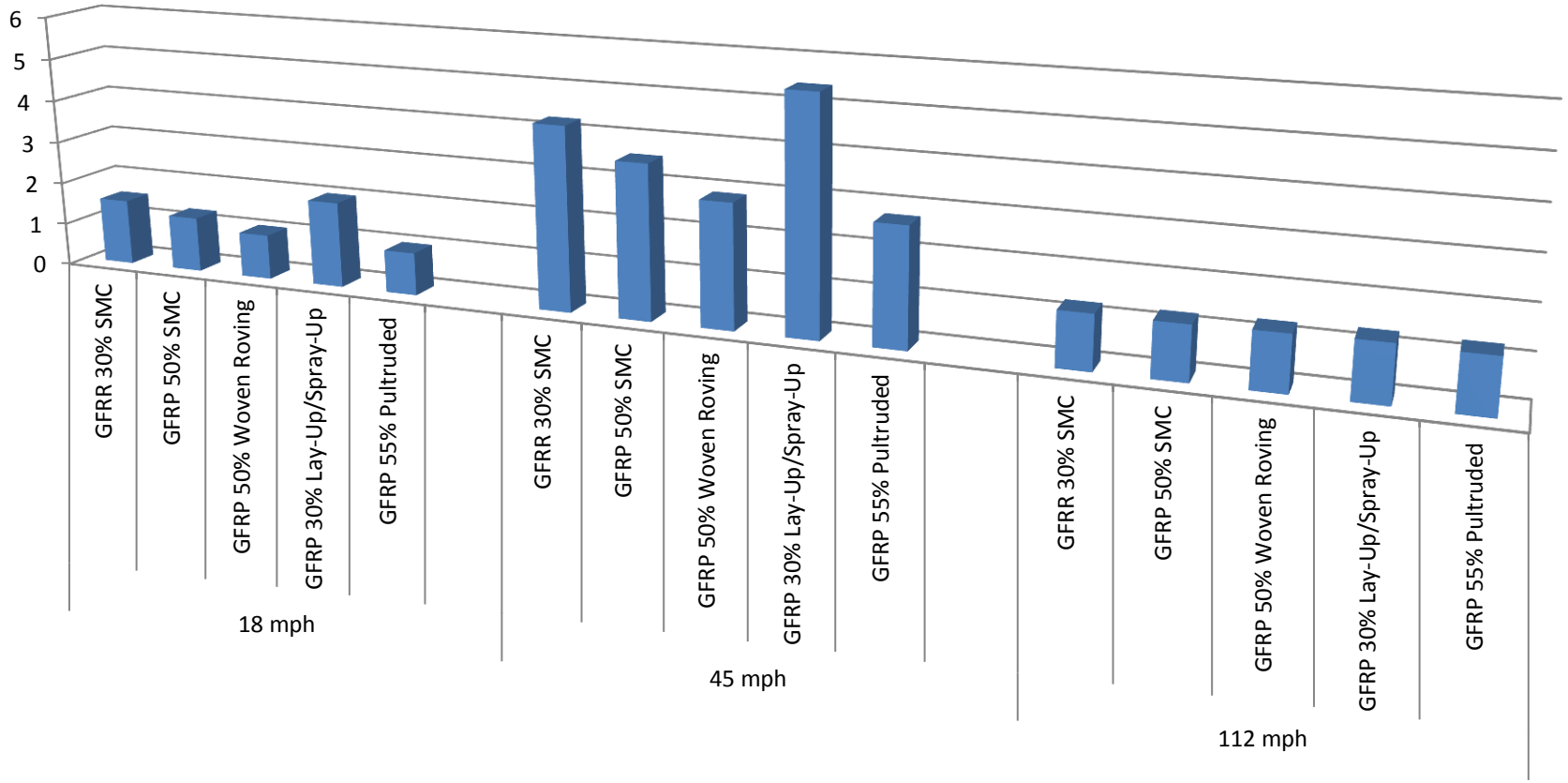
# CFD Analysis (cont.)



# Structural Analysis

- Use of three different fiberglass reinforced polyester (GFRP) composites:
  - GFRP 30% SMC
  - GFRP 50% SMC
  - GFRP 50% Woven Roving
- Shell-shaped blades with 0.394 in (10 mm) initial thickness
- Anodized aluminum axis
- Selection of the most appropriate materials based on total deformation

# Results


6
5
4
3
2
1
0
GFRR 30% SMC
GFRP 50% SMC
GFRP 50% Woven Roving
GFRP 30% Lay-Up/Spray-Up
GFRP 55% Pultruded
18 mph
GFRR 30% SMC
GFRP 50% SMC
GFRP 50% Woven Roving
GFRP 30% Lay-Up/Spray-Up
GFRP 55% Pultruded
45 mph
GFRR 30% SMC
GFRP 50% SMC
GFRP 50% Woven Roving
GFRP 30% Lay-Up/Spray-Up
GFRP 55% Pultruded
112 mph

# Results (cont.)

- Worst case of loading: 45 mph – 18.70 rad/s (≈180 RPM)
- Appropriate material: GFRP 50% Woven Roving (Total Deformation: 2.88 in or 73 mm at 45 mph wind speed)
- Crucial factor of deformation: **Centrifugal forces**

# Cost Assessment

- Estimated electricity production: $22.2X10^6$ BTU or 6,500 kWh annually
- Estimated cost of the GHWT: USD 4,700
- Two cases of pilot application:
  - Off-grid (mainly for small ports in remote areas)
  - On-grid (larger ports)

# Cost Assessment (cont.)

- Off-grid project:
  - 5 GHWT's
  - 170,000 BTU (50 kWh) battery array: USD 45,000
  - Inverter and components: USD 5,000
- On-grid:
  - 5 GHWT's and components: USD 25,000
- Price of W/T produced electricity: USD 270 per MWh

# Cost Assessment (cont.)

- Annual reduction of energy expenses (On-grid): USD 8,700
- $CO_2$ emissions avoided: 25,800 lb in lignite combustion equivalent
- Reimbursement: 5 years for a 20-year lifespan

# Suggestions

- Applications:
  - Administration building terraces
  - Remote areas
  - Lighting pillars
- The application of sustainable energy technologies enhance the eco-friendly image of the port and creates a sense of environmental responsibility.

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