POLITECNICO DI TORINO

Master of science program in Energy and Nuclear Engineering

Course of Wind and Ocean Energy Plants - 01TVKND

# PW.1 – REPOWERING OF A WIND FARM

*WIND FARM: Veggerslev*

## Team n. 03


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**A.Y. 2025/26**

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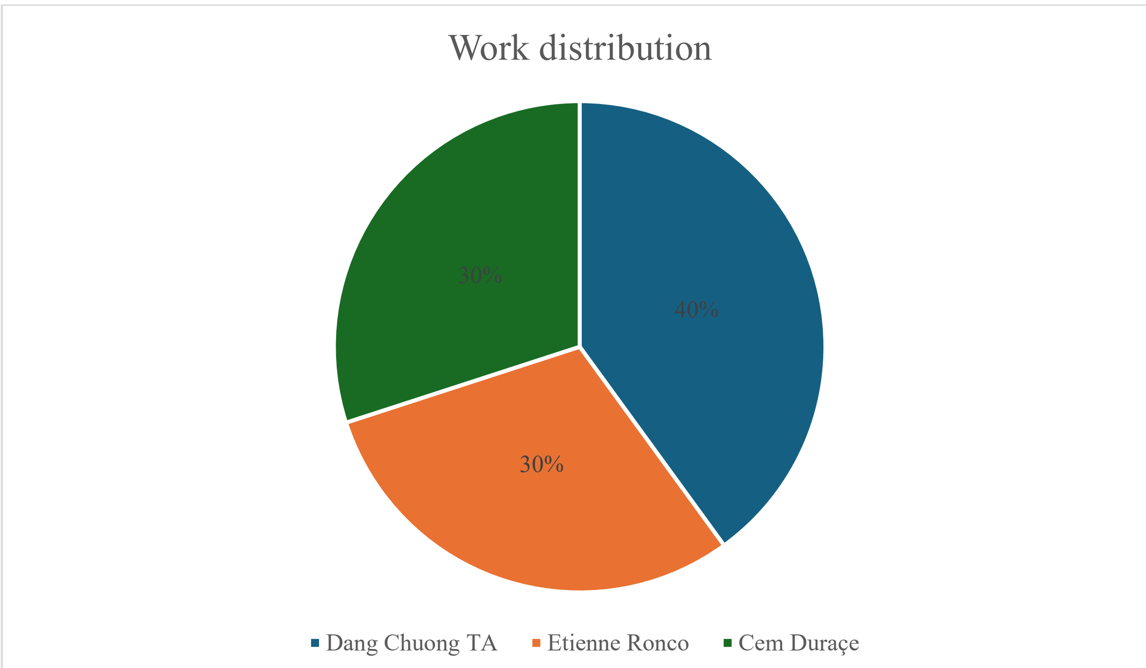
## 1. Work distribution

Under the responsibility of all project participants, it is declared that:

- *Dang-Chuong TA, S355289*, participated for *40%* to the realization of the project including: Part 4, 5 and 6 and formated report;
- *Etienne Ronco, S344086*, participated for *XX%* to the realization of the project including part 3, 4 and 7;
- *Cem Duraçe, S344953,* participated for *XX%* to the realization of the project including part 8.




## 2. Scope

This project evaluates the technical and economic feasibility of repowering the Veggerslev wind farm located in Norddjurs municipality, Denmark (56° 28' 25.1" N, 10° 50' 8.5" E). The study replaces three aging Vestas V44-600 turbines (1.8 MW total capacity, commissioned 1998) with a single modern Vestas V82-1.65 MW turbine at 80m hub height.

### Key Objectives

- Assess the territorial context and local energy needs of the Norddjurs region
- Characterize the site's wind climate using WAsP modeling and logarithmic wind profile analysis
- Simulate original and repowered wind farm performance using wake loss models
- Design grid connection infrastructure including MV cable sizing (7.5 km) and transformer specifications (30 kV/132 kV)

- Conduct comprehensive economic evaluation using LCOE, NPV, IRR, and simple payback time metrics over a 20-year project lifetime

**Expected Outcomes**

The repowering scenario demonstrates substantial improvements: 33.3% increase in annual energy production (4,750 to 6,331 MWh/year), 38.4% reduction in LCOE ($67.7 to $41.7/MWh), positive NPV of $1.38M, IRR of 11.2%, and payback period of 7.87 years. The analysis leverages existing site infrastructure, permits, and grid connections while addressing Denmark's spatial constraints and local opposition concerns for onshore wind development

Note: A digital version of this report can be accessed at https://chuongta.github.io/

## 3. Territorial context

Veggerslev wind farm is situated in Norddjurs municipality within the Midtjylland (Central Jutland) region of Denmark, specifically on the Djursland peninsula. Djursland comprises the two municipalities of Norddjurs and Syddjurs, forming a distinct geographical area in eastern Jutland [1].

### 3.1 Current wind energy exploitation

The Norddjurs region hosts multiple operational wind installations including Hollandsbjerg (16.5 MW), Hevring (5.25 MW), Bonnerup (4.2 MW), and multiple small wind farms with power smaller than 2 MW, including the Veggerslev facility with 1.8 MW capacity [2].

### 3.2 Local energy needs

Norddjurs municipality has a population of 36,658 inhabitants as of January 2025, covering an area of 721 km² [3]. Based on Denmark's current electricity consumption of approximately 5,880 kWh per person per year, the estimated total electricity consumption for Norddjurs is approximately 215 GWh annually. However, electricity demand growth in Denmark has been declining historically, with per capita consumption dropping from a peak of 10,181 kWh in 1996 to current levels. Projected electricity demand is expected to increase by approximately 3.8 TWh nationally by 2023 and 13 TWh by 2040 compared to 2015 levels, primarily driven by new data centers and electrification initiatives. For Norddjurs municipality specifically, assuming a proportional share of Denmark's projected growth (approximately 2.4% of national consumption), local electricity demand could increase by an estimated 90-100 GWh by 2040. This represents approximately 40-45% growth from current levels [4].

### 3.3 Wind energy development

#### 3.3.1 Opportunities

The Djursland region is experiencing significant renewable energy expansion, with 25 local companies signing a joint Power Purchase Agreement for a new solar park in Mesballe that will produce 14,000,000 kWh annually, demonstrating strong local business engagement in clean energy[5].The proposed Energy Cluster Djursland project integrates biogas, wind, and solar installations to produce up to 350,000 MWh annually, with connections to district heating and Power-to-X facilities. The Port of Grenaa's strategic role as an offshore wind hub provides infrastructure and service capabilities that support both local and regional wind energy development [6].

#### 3.3.2 Limitations

Denmark faces recurring local opposition to new onshore wind turbines, with residents frequently citing concerns regarding noise, landscape intrusion, and potential reductions in property values. Spatial constraints in the Norddjurs area limit opportunities for large-scale standalone wind development, as evidenced by the prevalence of smaller installations and the strategic shift toward integrated multi-technology energy clusters. The extensive onshore infrastructure required for offshore wind projects, including cable connections and transformer stations, often generates disputes within affected communities [7].

## 4. Wind farm layout

The exact coordinates: Lattitude 56° 28' 25.1" N, Longitude 10° 50' 8.5" E (WGS84)

The Veggerslev wind farm comprises three Vestas V44/600 wind turbines, each with a rated power of 600 kW and a rotor diameter of 44 meters. The original layout was commissioned in 1998 and represents a typical configuration of small-to-medium sized turbines of that era[8]. Each turbine stands on a tower with a height of hub ranging between 40 to 64 meters, V44 model. The layout and detailed site map are illustrated in Fig. 1. Additionally, the terrain elevation is shown in Fig. 2.

- Latitude: 56° 28' 25.1"
- Longitude: 10° 50' 8.5"

DD: 56.47364°, 10.83569°


Fig. 1: The detailed wind farm layout

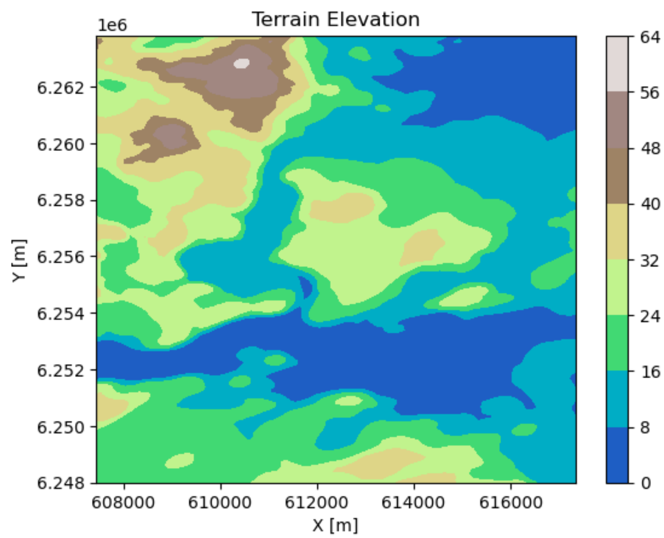



Fig. 2: Terrain Elevation of the site

## 5. Predicted Wind Climate

The wind rose and probability Fig. 3 and Fig. 4 show that winds at the site are strongest and most frequent from the west and southwest, especially for speeds between 4.6 and 13.87 m/s, providing the optimal conditions for wind energy generation.

First, we extract the grid site data, which includes geographic and terrain information, using WAsP. This data provides the necessary spatial coordinates and local terrain features for our wind farm site. Next, to estimate the wind speed at different heights (such as 50m and 80m), we apply the logarithmic wind profile formula:

$$U(z) = \frac{u^*}{k} \ln\left(\frac{z}{z_0}\right)$$

Where:

- $U(z)$ (m/s): Wind speed at height z
- $u^{*}$: friction velocity, a measure of the wind's speed at the surface, influenced by friction
- $k$: Von Karman's constant, a universal constant in fluid dynamics, approximately equal to 0.4.
- $z_0$: Surface roughness length, a parameter that represents the roughness of the terrain

The wind speed grid with different heights is presented in Fig. 5 and Fig. 6.

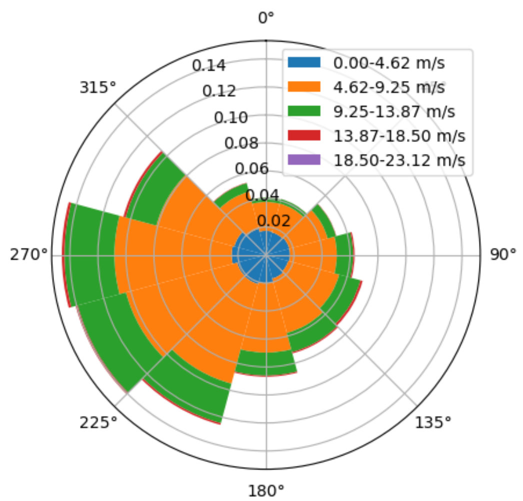



Fig. 3: Wind rose directional wind speed distribution

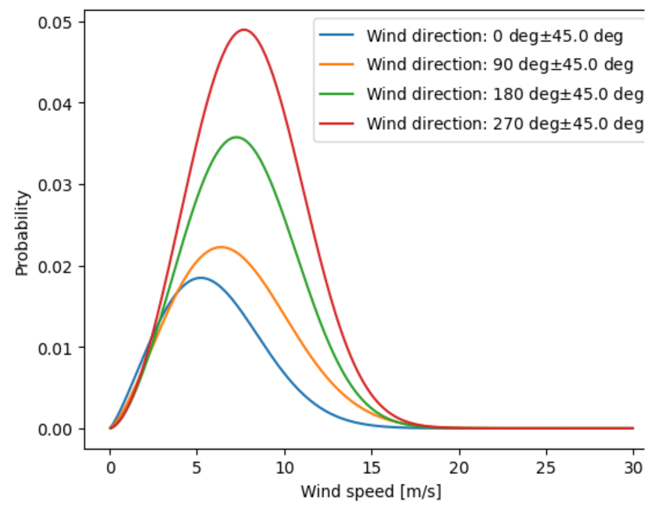



Fig. 4: Directional Weibull Wind Speed Probability Curves

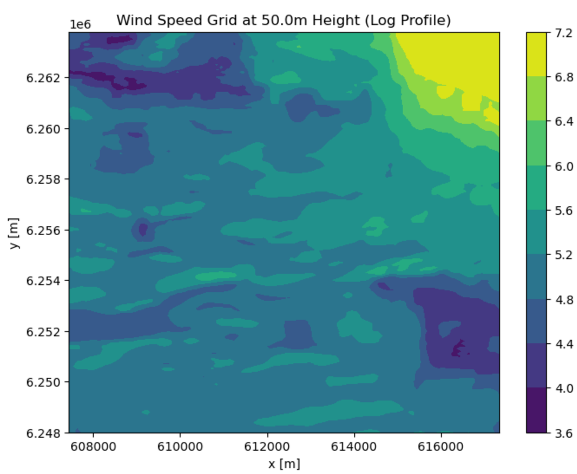



Fig. 5: Wind speed grid at 50.0 m height

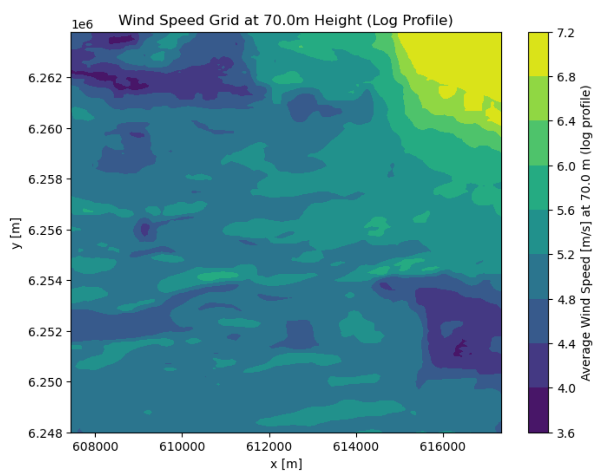



Fig. 6: Wind speed grid at 70.0 m height

## 6. Wind Farm simulation

In terms of wind farm set up, it is useful to compare the two types of wind turbines. Initially, the wind farm consists of three Vestas V44-600 turbines. These are older, smaller-scale turbines, each with a rated power output of 600 kW. Collectively, the three turbines provide a total installed capacity of 1.8 MW. In the repowered scenario, these three smaller turbines are replaced by a single Vestas V82 – 1.65 MW turbine. This is a modern, larger turbine designed for higher efficiency and energy capture, with a single unit. The power and thrust curve are visualized by Fig. 7 and Fig. 8.

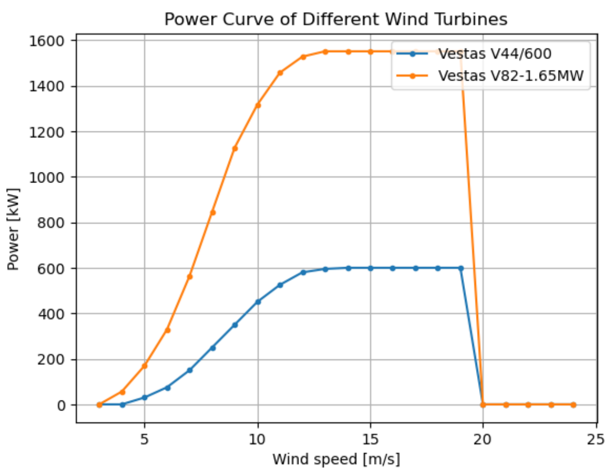



Fig. 7: Power curve of different wind turbines

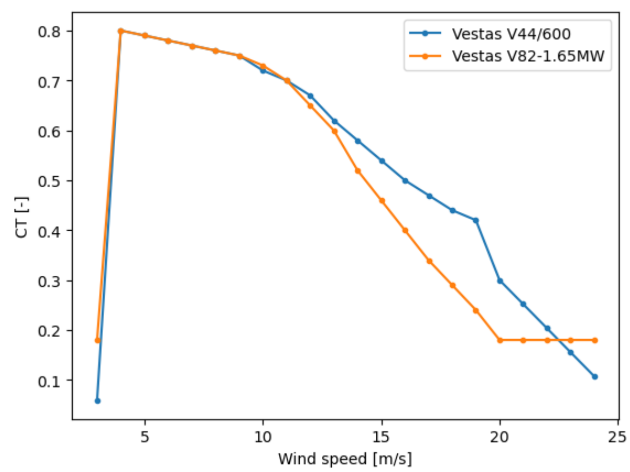



Fig. 8: Thrust coefficient curve of different wind turbine

### 6.1 Original Wind farm

Table 1 and Table 2 describe the individual Turbine and orginal wind farm annual performance. Focusing on individual turbines, Turbine 1 generated 1.56 GWh net energy at a mean wind speed of 7.05 m/s and a capacity factor of 29.7%. Turbine 2 produced 1.57 GWh net at 7.07 m/s with a 29.9% capacity factor, and Turbine 3 reached 1.62 GWh at 7.15 m/s and 30.7% capacity factor, demonstrating consistent site conditions and strong performance across all units.

Table 1: Individual Turbine Performance & Site Data

| Turbine | X-location [m] | Y-location [m] | Elev. [m] | Ht [m] | d [m] | U [m/s] | U(w) [m/s] | ρ [kg/m³] | Gross [GWh] | Net. [GWh] | Loss [%] | CF [%] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T1 | 613297.1 | 6259930.0 | 9.8 | 50.0 | 0.0 | 7.11 | 7.05 | 1.238 | 1.599 | 1.562 | 2.29 | 29.7 |
| T2 | 613299.5 | 6259709.0 | 11.9 | 50.0 | 0.0 | 7.14 | 7.07 | 1.237 | 1.612 | 1.574 | 2.38 | 29.9 |
| T3 | 613302.7 | 6259489.0 | 14.1 | 50.0 | 0.0 | 7.17 | 7.15 | 1.237 | 1.624 | 1.615 | 0.57 | 30.7 |

The wind farm as a whole achieved a total net annual energy production (AEP) of 4.75 GWh, with a gross output of 4.84 GWh and wake losses averaging 1.74%. The overall capacity factor reached 30.1%, while the mean wind speed at wake-reduced conditions was 7.09 m/s and the average air density was 1.237 kg/m³, yielding a mean power density of 349 W/m

Table 2: The orginal wind farm annual performance summary

| **Variable** | **Total** | **Mean** | **Min** | **Max** |
|---|---|---|---|---|
| Total gross AEP [GWh] | 4.835 | 1.612 | 1.599 | 1.624 |
| Total net AEP [GWh] | 4.751 | 1.584 | 1.562 | 1.615 |
| Proportional wake loss [%] | 1.74 | - | 0.57 | 2.38 |
| Capacity factor [%] | 30.1 | - | 29.7 | 30.7 |
| Mean speed [m/s] | - | 7.14 | 7.11 | 7.17 |
| Mean speed (wake-reduced) [m/s] | - | 7.09 | 7.05 | 7.15 |
| Air density [kg/m³] | - | 1.237 | 1.237 | 1.238 |
| Power density [W/m²] | - | 349 | 345 | 352 |
| RIX [%] | - | - | 0.0 | 0.0 |

### 6.2 Repowering the wind farm

The Table 3 illustrates the wind climate and power output of the single Vestas V82 1.65 MW turbine. Overall, an annual energy production of 6.331 GWh and a mean wind speed is 7.62 m/s across all wind directions. Sector-wise, the highest contributions to total power and energy yield come from directions with both higher wind frequencies and speeds (notably 210°, 240°, and 270°). Power density reaches up to 561 W/m² for favorable sectors, indicating efficient energy capture when wind conditions are optimal.

Table 3: Wind climate and power output by wind direction

| Sector | Angle (°) | Frequency (%) | Weibul-A (m/s) | Weibul-K | Mean Speed (m/s) | Power Density (W/m²) | Annual Prod. (GWh) | Wake Losses (%) |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 4.0 | 6.2 | 2.28 | 5.45 | 169 | 0.122 | - |
| 2 | 30 | 3.8 | 6.4 | 2.28 | 5.69 | 193 | 0.131 | - |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 3 | 60 | 5.0 | 7.4 | 2.42 | 6.59 | 286 | 0.237 | - |
| 4 | 90 | 6.3 | 8.0 | 2.36 | 7.12 | 368 | 0.352 | - |
| 5 | 120 | 7.4 | 8.5 | 2.47 | 7.56 | 425 | 0.459 | - |
| 6 | 150 | 7.2 | 7.9 | 2.56 | 7.01 | 330 | 0.388 | - |
| 7 | 180 | 8.2 | 8.3 | 2.62 | 7.33 | 372 | 0.480 | - |
| 8 | 210 | 12.8 | 9.5 | 3.01 | 8.47 | 526 | 0.976 | - |
| 9 | 240 | 13.8 | 9.5 | 3.13 | 8.50 | 521 | 1.062 | - |
| 10 | 270 | 15.5 | 9.7 | 2.98 | 8.64 | 561 | 1.218 | - |
| 11 | 300 | 11.2 | 8.8 | 2.60 | 7.77 | 445 | 0.733 | - |
| 12 | 330 | 4.9 | 6.5 | 2.15 | 5.73 | 207 | 0.173 | - |
| All | | | | | 7.62 | 423 | 6.331 | |

## 7. Grid connection

Grid connection parameters

For this section, the data collection, such as cables parameters and transformers parameters, was based on the lecture slides provided by the professor Stefano Shubert named *'Grid connection'*. Instead, the distance $d$ to evaluate the losses of the cable was estimated using Google Earth and Maps.

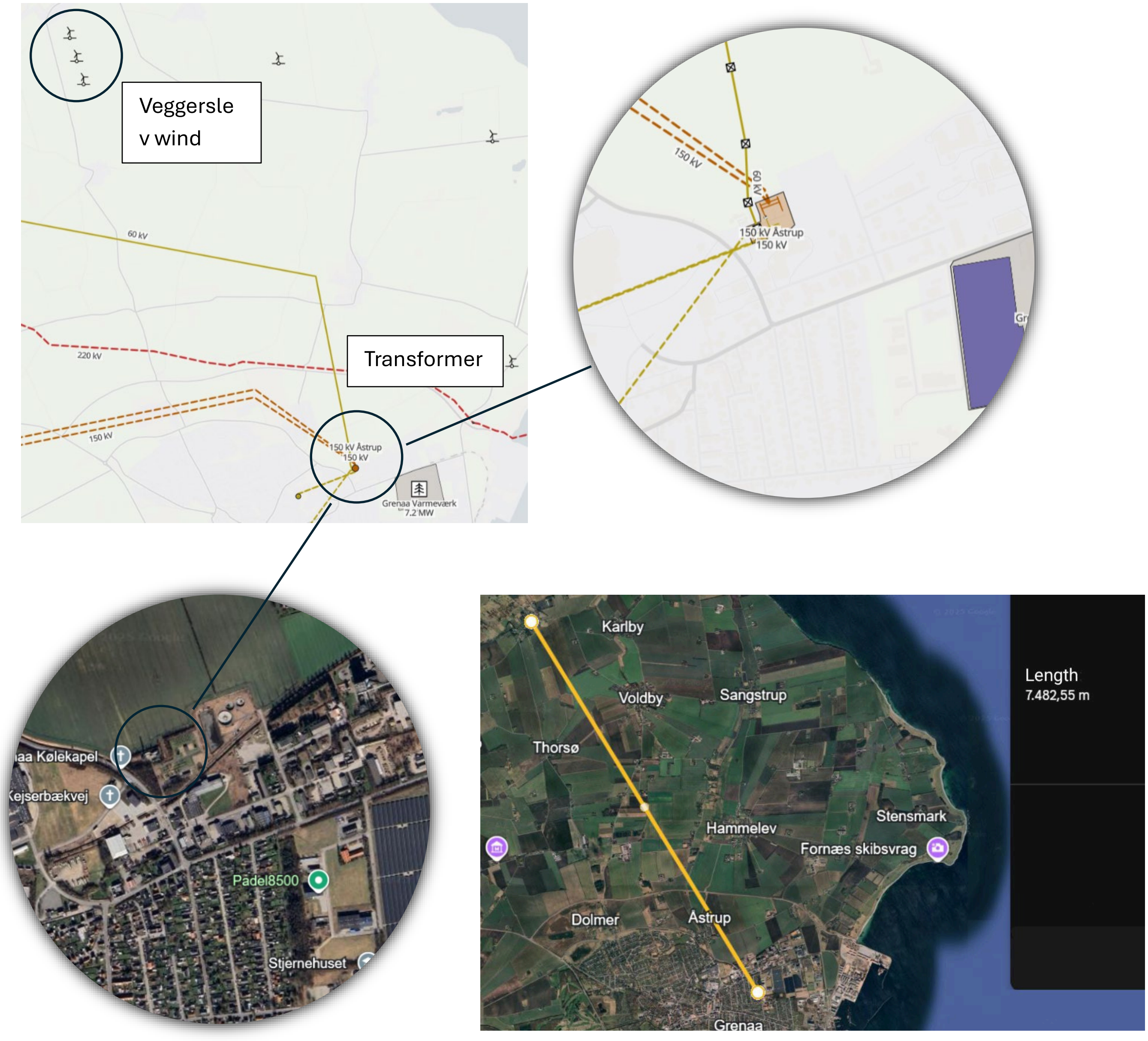



Fig. 9: The distance from wind farm to the substation

Inputs and selected equipment

- Cable length: $d = 7.5\ km$
- Wind farm rated active power: $P_{nom} = 1.65\ MW$
- Power factor: $cos\varphi = 0.976$
- Grid voltage (line-to-line): $V_{L-L} = 30\ kV$

Selected MV cable parameters

- Resistance at 20°C: $R_{cable} = 0.0754\ \Omega/km$
- Reactance at 50 Hz: $X_{cable} = 0.1\ \Omega/km$
- Capacitance: $C_{cable} = 0.41\ \mu F/km$
- Thermal current rating: $I_{max} = 567\ A$

Transformer parameters

- HV rated voltage: $V_{HV} = 132\ kV$
- MV rated voltage: $V_{MV} = 30\ kV$
- Rated power: $S_{tr} = 25\ MVA$
- No-load losses: $P_0 = 11.2\ kW$
- No-load current: $I_{0\,pct} = 0.4\ \%$
- Short-circuit losses: $P_{sc} = 135\ kW$
- Short-circuit voltage: $V_{sc\,pct} = 11\ \%$

**Calculation steps**

Apparent power & reactive power

$$S = P_{nom} * 10^6 * tan\big((acos(cos\varphi)\,)\big) = 368157{,}1315\ \text{VA}$$

$$Q = \frac{(P_{nom} * 10^6)}{cos\varphi} = 1690573{,}77\ \text{VAR}$$

Phase current at MV level

$$I_{phase} = \frac{P_{nom} * 10^6}{\sqrt{3} * cos\varphi * V_{L-L} * 10^3} = 32{,}54\ A$$

Voltage drop ratio

$$\frac{\Delta V}{V} = \frac{\sqrt{3} * I_{phase} * d * \Big((R_{cable} * cos\varphi) + \big(X_{cable} * \sqrt{(1 - cos\varphi\text{^}2)}\big)\Big)}{V_{L-L} * 10^3} = 0{,}001343548$$

Approximate three-phase voltage drop along the MV cable over distance d, using the chosen cable R and X and the assumed power factor. The result voltage drop ratio is lower than the admissible limit (< 0.03).

Cable active losses & cable reactive power

$$P_{cable} = 3 * R_{cable} * d * I_{phase}^2 = 1795{,}80W$$

$$Q_{cable} = 3 * d * X_{cable} * I_{phase}^2 = 2381{,}70\ VAR$$

Equivalent circuit of the transformer

To compute the quantities relative to the grid connection, it is necessary to work on this equivalent circuit of the transformer.

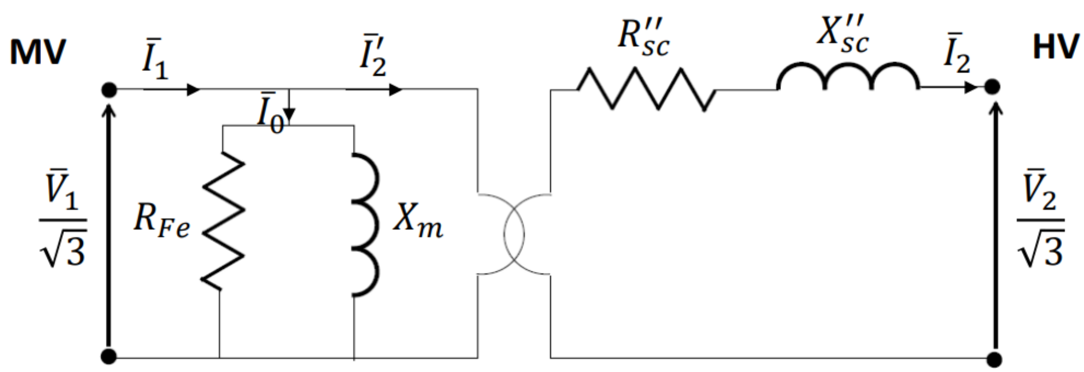



Fig. 10: The equivalent circuit of the transformer

Iron-loss equivalent resistance

$$R_{fe} = \frac{(V_{L-L} * 10^3)^2}{P_0 * 10^3} = 80357{,}14Ohm$$

No-load transformer quantities

$$I_0 = \frac{I_{0\,pct} * S_{tr} * 10^6}{(100) * \sqrt{3} * V_{MV} * 10^3} = 1{,}92\ A$$

$$Q_0 = P_0 * 10^3 * tan(acos\left(\frac{P_0 * 10^3}{\sqrt{3} * V_{L-L} * 10^3 * I_0}\right) = 99370{,}82\ VAR$$

$$X_m = \frac{(V_{MV} * 10^3)^2}{Q_0} = 9056{,}98\ H$$

$$I_{2n} = \frac{S_{tr} * 10^6}{\sqrt{3} * V_{HV} * 10^3} = 109{,}35\ A$$

$$V_{2n} = \frac{V_{HV} * 10^3 * V_{sc\,pct}}{100} = 14520\,V$$

Secondary windings

$$R'' = \frac{P_{sc} * 10^3}{3 * I_{2n}^2} = 3{,}763584\,Ohm$$

$$X'' = \frac{P_{sc} * 10^3 * tan\left(acos\left(\frac{P_{sc} * 10^3}{\sqrt{3} * V_{2n} * I_{2n}}\right)\right)}{3 * I_{2n}^2} = 76{,}57\,H$$

$$Q_2 = Q - Q_{cable} - Q_0 = 1588821{,}3\,VAR$$

$$P_2 = (P_{nom} * 10^6) - P_{cable} - (P_0 * 10^3) = 1637004{,}20\,W$$

$$cos\varphi_2 = cos\left(atan\left(\frac{Q_2}{P_2}\right)\right) = 0{,}718$$

$$I_2 = \frac{P_2}{\sqrt{3} * cos\varphi_2 * V_{2n}} = 90{,}71\,A$$

Grid connection efficiency

$$\eta = \frac{(P_{nom} * 10^6) - P_{cable} - (P_0 * 10^3) - (3 * R'' * I_2^2)}{P_{nom} * 10^6} = 0{,}936$$

Efficiency computed as delivered active power divided by produced active power, accounting for cable losses, transformer no-load losses, and copper losses ($3 \cdot R'' \cdot {I_2}^2$).

## 8. Economic Evaluation

### 8.1. Data

Table 4 shows the annual performance of the old and new wind farms as shown before but with the inclusion of economic metrics as the economic analysis will be carried out in this section.

Table 4: Comparison of Old and New Wind Farm Configurations [9]

| Parameter | Old Farm (V44) | New Farm (V82) |
|---|---|---|
| Total Capacity | 1.8 MW | 1.65 MW |
| Number of Turbines | 3 | 1 |
| Turbine Model | Vestas V44/600 | Vestas V82-1.65 MW |
| Hub Height | ~40 m | 80 m |
| Mean Wind Speed | ~7.09 m/s | 7.62 m/s |
| Capacity Factor | 30.1% | 43.7% |
| Annual Energy Production | 4,750 MWh/year | 6,331 MWh/year |
| Availability | ~93% | ~98% |
| CAPEX | $2,340,000 | $2,664,750 |
| OPEX (annual) | $126,000/year | $41,250/year |
| Grid Connection Efficiency | ~90% | 93.6% |
| Project Lifetime | 20 years | 20 years |
| WACC (discount rate) | 5.5% | 5.5% |
| Electricity Price | $0.06/kWh | $0.06/kWh |

**Old Farm:** Original configuration consists of three old Vestas V44/600 turbines (1.8 MW total) with 30.1% capacity factor as described previously, typical of 1990s Danish onshore turbines, high OPEX ($70/kW/year) reflects older technology maintenance requirements and reduced availability.[10]

**New Farm:** Repowered with single modern Vestas V82-1.65 MW turbine at 80m hub height, the V82 has a larger rotor diameter (82m) with lower specific capacity optimized for moderate wind sites, higher wind speeds (7.62 m/s) and advanced technology yield 43.7% capacity factor. CAPEX based on current European onshore benchmark of approximately $1,615/kW, OPEX reduced to $25,000/MW/year through modern contracts, and improved reliability raises availability to approximately 98%.[10], [11]

## 8.2. Economic Metrics

### 8.2.1 Levelized Cost of Energy (LCOE)

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

Where:

- $I_t$ = Investment costs at time $t$
- $M_t$ = Operations and maintenance costs at time $t$
- $F_t$ = Fuel costs at time $t$ (≈ 0 for wind)
- $E_t$ = Energy produced at time $t$
- $r$ = Discount rate (WACC)
- $t$ = Time period (years)
- $n$ = Project lifetime

For constant annual O&M and energy production:

$$LCOE = \frac{C_0 + \sum_{k=1}^{n} \frac{C_{O\&M}}{(1+r)^k}}{\sum_{k=1}^{n} \frac{E_G}{(1+r)^k}}$$

Where:

- $C_0$ = Initial capital investment (CAPEX)

- $C_{O\&M}$ = Annual operating and maintenance costs (OPEX)
- $E_G$ = Annual energy production
- $r$ = Discount rate (WACC)
- $k$ = Year (from 1 to n)
- $n$ = Project lifetime

### 2.2 Net Present Value (NPV)

$$NPV = -C_0 + \sum_{k=1}^{n} \frac{[R_{WT} - C_{O\&M}]}{(1+r)^k}$$

Where:

- $C_0$ = Initial capital investment (CAPEX)
- $R_{WT}$ = Annual revenue from electricity sales
- $C_{O\&M}$ = Annual operating and maintenance costs (OPEX)
- $r$ = Discount rate (WACC)
- $k$ = Year (from 1 to n)
- $n$ = Project lifetime

### 8.2.3 Internal Rate of Return (IRR)

The discount rate $x$ where NPV equals zero:

$$0 = -C_0 + \sum_{k=1}^{n} \frac{[R_{WT} - C_{O\&M}]}{(1+x)^k}$$

Where:

- $C_0$ = Initial capital investment (CAPEX)
- $R_{WT}$ = Annual revenue from electricity sales
- $C_{O\&M}$ = Annual operating and maintenance costs (OPEX)

- $x$ = Internal rate of return
- $k$ = Year (from 1 to n)
- $n$ = Project lifetime

### 8.2.4 Simple Payback Time (SPT)

$$SPT = \frac{C_0}{R_{WT} - C_{O\&M}}$$

Where:

- $C_0$ = Initial capital investment (CAPEX)
- $R_{WT}$ = Annual revenue from electricity sales
- $C_{O\&M}$ = Annual operating and maintenance costs (OPEX)

## 8.3. Results and Economic Comparison

Using a 20-year project lifetime and 5.5% WACC, the present value factor is 11.95. All metrics are calculated using the formulas above with the input data from Table 5.

Table 5: Economic Performance Metrics

| Metric | Old Farm (V44) | New Farm (V82) | Improvement |
|---|---|---|---|
| AEP (MWh/year) | 4,750 | 6,331 | +33.3% |
| Capacity Factor | 22.0% | 43.7% | +21.7 pp |
| CAPEX ($) | 2,340,000 | 2,664,750 | +13.9% |
| OPEX ($/year) | 126,000 | 41,250 | −67.3% |
| Availability | 93% | 98% | +5.0 |
| LCOE ($/MWh) | 67.7 | 41.7 | −38.4% |
| NPV ($) | −439,889 | 1,381,769 | +$1.82M |
| IRR (%) | 3.1 | 11.2 | +8.1 |
| SPT (years) | 14.7 | 7.87 | −46.5% |

#### 8.3.1 Results

**Economic Superiority of Repowering:** The V82 repowering demonstrates much higher economic performance across all metrics. LCOE decreases by 38.4% (from \$67.7 to \$41.7/MWh) despite a modest 13.9% increase in CAPEX, driven by 33.3% higher energy production and 67.3% lower operating costs. The project transforms from NPV: −\$0.44M, IRR: 3.1% to very profitable NPV: +\$1.38M, IRR: 11.2%, with NPV improving by \$1.82 million and IRR now exceeding WACC by 5.7 percent, showing strong financial viability for investors [11].

**Technical-Economic Drivers:** The combination of higher hub height (80m vs 40m), improved turbine efficiency (43.7% vs 30.1% capacity factor), and modern reliability (98% vs 93% availability) enables 33% more annual energy output from 8% less installed capacity. Capacity factor improvements of this magnitude when replacing 1990s turbines with modern technology reflect the significant advances in rotor design and generator technology over the past two decades. At the same time, advanced full service contracts and reduced failure rates cut annual OPEX by two-thirds, creating a dual benefit of higher revenue and lower costs. The payback period shortens from 14.7 to 7.87 years, recovering capital in less than 40% of project lifetime and reducing investment risk, in accordance with typical onshore wind payback periods for modern projects. [10], [11].

**Financial Viability:** With an IRR of 11.2% and positive NPV of \$1.38M at 5.5% discount rate, the repowered configuration meets typical investor return requirements for renewable energy projects. The improved grid connection efficiency (93.6%) minimizes transmission losses, while the higher capacity factor makes the project competitive with modern onshore wind turbines. By utilizing existing infrastructure, site permits, and grid connections, the repowering approach maximizes project value and positions the Veggerslev site as a productive asset for another generation of renewable energy generation. [10], [11].

## References


[1] "Djursland - Wikipedia." [Online]. Available: https://en.wikipedia.org/wiki/Djursland

[2] "Norddjurs (Midtjylland) (Denmark) - Areas - Countries - Online access - The wind Power." [Online]. Available: https://www.thewindpower.net/zones_en_6_276.php

[3] "Urban Settlements in Norddjurs (Midtjylland, Denmark) - Population Statistics, Charts, Map, Location, Weather and Web Information." [Online]. Available: https://citypopulation.de/en/denmark/midtjylland/707__norddjurs/

[4] "Electricity sector in Denmark - Wikipedia." [Online]. Available: https://en.wikipedia.org/wiki/Electricity_sector_in_Denmark

[5] "Reel." [Online]. Available: https://reel.energy/press-releases/25-companies-sign-historic-ppa-to-build-a-new-solar-park-in-denmark

[6] "Trekløver vil opføre energiklynge på Djursland." [Online]. Available: https://www.doi.dk/en/vindkraft/artikel/trekloever-vil-opfoere-energiklynge-paa-djursland

[7] J. Sun, Y. Yang, and P. Zhou, "Mitigating local opposition in renewable energy projects expansion: Evidence from Denmark," *Renew Energy*, vol. 257, p. 124902, Dec. 2026, doi: 10.1016/J.RENENE.2025.124902.

[8] "Veggerslev (Denmark) - Wind farms - Online access - The Wind Power." [Online]. Available: https://www.thewindpower.net/windfarm_en_8613_veggerslev.php

[9] I. Renewable Energy Agency, "Renewable power generation costs in 2019," 2020, Accessed: Dec. 29, 2025. [Online]. Available: www.irena.org

[10] "Levelized Cost of Energy (LCOE) - Overview, How To Calculate." Accessed: Dec. 29, 2025. [Online]. Available: https://corporatefinanceinstitute.com/resources/valuation/levelized-cost-of-energy-lcoe/

[11] T. Stehly, P. Duffy, and D. Mulas Hernando, "Cost of Wind Energy Review: 2024 Edition," p. 627281636, 2024, Accessed: Dec. 29, 2025. [Online]. Available: https://www.energy.gov/eere/wind/wind-market-reports-2024-edition