# Figure 7

7 PU-07-54 Filed 02/01/2008 Pages: 150
Ten Year Plan/Application for Certificate of Site Compability
Just Wind, LLC

**Just Wind - Wind Farm Development**

2470 Fairview Lane • Mound, Minnesota 55364 Phone (612) 245-6608

# Climatic Conditions

| **Client** | | **Site** | |
|---|---|---|---|
| Name | Just Wind | Name | Napoleon |
| Address 1 | | Latitude | 46 29 55 N |
| Address 2 | | Longitude | 99 41 55 W |
| Country | | Datum | WGS84 |
| Phone no. | | WTG model | |
| Fax no. | | Hub height [m] | 80 |
| E-mail | | No. of WTGs | |

| Parameter | Symbol | Site Avg[1] | Site Max[2] | Unit |
|---|---|---|---|---|
| **Normal wind conditions**[3] (annual) | | | | |
| Measurement period for conditions | - | 8/7/2001 to 9/24/2006 | | - |
| Height for conditions | m.a.g.l. | 80 | 80 | m |
| Weibull scale parameter | A | 10.16 | 11.18 | m/s |
| Weibull shape parameter | k | 2.697 | 3.525 | - |
| Mean wind speed | V | 9.04 | 9.96 | m/s |
| Mean ambient turbulence intensity[4] | TI | 13.325 | 13.6 | % |
| Mean ambient turbulence intensity at 15m/s | $TI_{15}$ | 13.62 | 14.2 | % |
| Standard deviation of TI at 15m/s | $\sigma_{15}$ | .278 | N/A | % |
| Mean air density | $\rho$ | 1.169 | 1.171 | kg/m$^3$ |
| Exponential wind shear coefficient[5] | $\alpha$ | .1925 | - | - |
| **Extreme wind conditions**[3] (50 yr return period) | | | | |
| Measurement period for conditions | - | 8/7/2001 to 9/24/2006 | | - |
| Height for conditions | m.a.g.l. | 80 | | m |
| Max 10 min. mean wind speed | $V_{10min}$ | 40.0 | | m/s |
| Max 3 sec. gust wind speed | $V_{3sec}$ | 60.0 | | m/s |
| **Environmental conditions** | | | | |
| Measurement period for conditions | - | 1889 to 1987 | | - |
| Mean annual ambient temperature | T | 4.4 | | deg. C |
| Extreme minimum ambient temperature | $T_{min}$ | -30 | | deg. C |
| Extreme maximum ambient temperature | $T_{max}$ | +30 | | deg. C |
| Days of temperature above 40°C | - | - | | days/yr |
| Days of temperature below -20°C | - | - | | days/yr |
| Days with ice buildup | - | - | | days/yr |
| Mean relative humidity | RH | - | | % |
| Salt spray present | - | ☐ yes ☒ no | | - |
| Lightning density | - | 1 to 2 | | Strikes/km$^2$/yr |
| **Topographic conditions** | | | | |
| Height above sea level | m.a.s.l. | 610 to 643 | | m |
| Max terrain slope in 100m radius of WTG(s) | - | 9 | | deg. |
| Mean roughness length | z0 | 1.2 | | m |

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| Layout conditions | | | |
|---|---|---|---|
| Distance between individual WTGs in a row | $L_{in\text{-}row}$ | 600 avg | m |
| Distance between individual rows | $L_{row}$ | 850 avg | m |

| | Wind rose[3] | | | Turbulence rose | | |
|---|---|---|---|---|---|---|
| Height for conditions | m.a.g.l | 50 | m | m.a.g.l | 50 | m |

| Sector | Degrees | A | k | Freq [%] | TI | $TI_{15}$ | $\sigma_{15}$ |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 7.28 | 2.111 | 4.9 | 9.9 | 9.1 | .017 |
| 2 | 30 | 7.48 | 2.127 | 5.4 | 9.5 | 8.9 | .029 |
| 3 | 60 | 8.3 | 2.49 | 6.5 | 8.9 | 8.1 | .016 |
| 4 | 90 | 8.07 | 2.818 | 7.6 | 10.9 | 9.7 | .018 |
| 5 | 120 | 9.58 | 2.787 | 9.1 | 9.9 | 9.2 | .018 |
| 6 | 150 | 9.90 | 3.107 | 10.8 | 8.5 | 8.4 | .020 |
| 7 | 180 | 8.54 | 3.365 | 9.7 | 8.2 | 9.3 | .046 |
| 8 | 210 | 7.70 | 2.943 | 6.4 | 8.0 | 9.5 | .018 |
| 9 | 240 | 8.51 | 2.779 | 7.6 | 8.4 | 7.8 | .028 |
| 10 | 270 | 9.67 | 2.494 | 13.1 | 9.0 | 8.7 | .022 |
| 11 | 300 | 9.34 | 2.408 | 11.7 | 9.6 | 9.1 | .018 |
| 12 | 330 | 7.97 | 2.334 | 7.2 | 10.5 | 10.0 | .027 |

In addition to the above the following shall be supplied:
Site layout coordinates and datum in .txt or .xls format.
Site digital contour map; contour equidistance max 20m, preferably < 10m (not required for US sites).

In addition to the above the following may be requested (attach if available):
Min, max and mean turbulence as a function of wind speed and wind direction (e.g. a plot).
Min, max and mean wind shear as a function of wind speed and wind direction (e.g. a plot).

Notes:

(1) Average conditions for all WTGs on site for contractual purposes. If not available for preliminary assessment purposes use measured conditions.
(2) Conditions for most energetic WTG on site for contractual purposes. If not available for preliminary assessment purposes leave blank.
(3) Shall be hub height for contractual purposes. Can be measurement height for preliminary assessment purposes.

(4) $$\text{Mean ambient turbulence intensity (TI\%)} = \frac{\text{Standard deviation}_{10\,MIN}}{\text{Average wind speed}_{10\,MIN}} \cdot 100\%$$

(5) $$\text{Exponential wind shear coefficient } (\alpha) = \frac{\log \cdot \left(\frac{WS_1}{WS_0}\right)}{\log \cdot \left(\frac{H_1}{H_0}\right)}$$

# Figure 8

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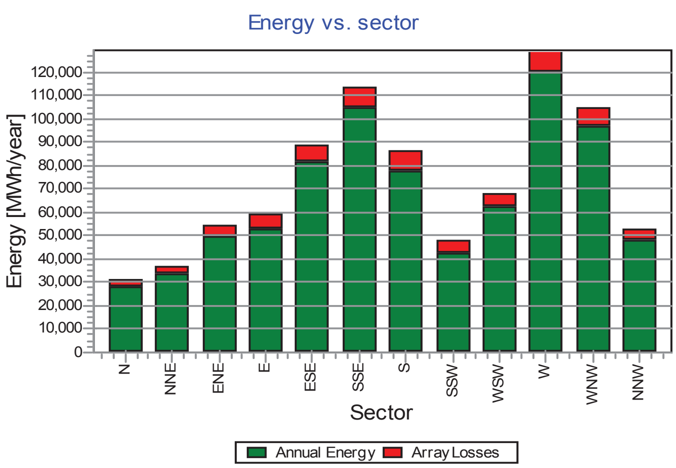
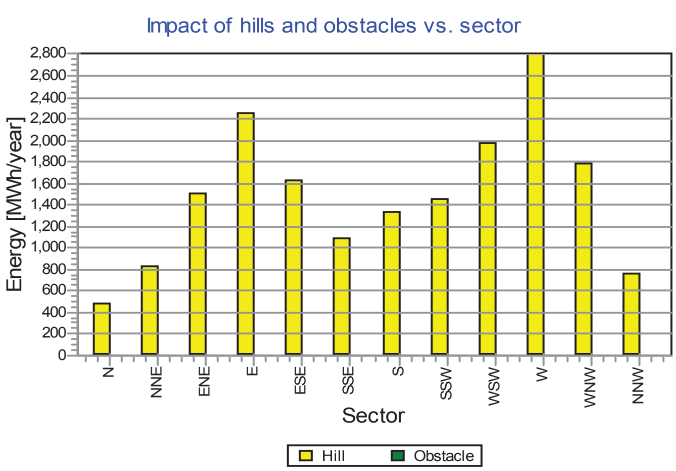
# PARK - Production Analysis

**Calculation:** 20070304 MWT 95-2.4 60Hz 2400 95.0 **WTG:** All new WTG's, Air density varies with WTG position 1.165 kg/m3 - 1.172 kg/m3

## Directional Analysis

| Sector | | 0 N | 1 NNE | 2 ENE | 3 E | 4 ESE | 5 SSE | 6 S | 7 SSW | 8 WSW | 9 W | 10 WNW | 11 NNW | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Roughness based energy | [MWh] | 30,751.7 | 36,271.2 | 52,930.7 | 56,884.1 | 86,931.2 | 111,948.6 | 85,245.7 | 46,502.6 | 66,124.8 | 126,499.8 | 103,114.5 | 51,801.7 | 855,007.0 |
| +Increase due to hills | [MWh] | 492.7 | 824.5 | 1,506.4 | 2,245.7 | 1,629.7 | 1,100.2 | 1,336.6 | 1,455.8 | 1,976.7 | 2,807.4 | 1,781.4 | 757.8 | 17,915.0 |
| -Decrease due to array losses | [MWh] | 3,264.9 | 3,602.0 | 4,740.1 | 6,257.0 | 6,917.5 | 8,275.8 | 9,286.5 | 5,548.2 | 6,003.9 | 9,236.9 | 8,069.2 | 4,948.5 | 76,150.4 |
| **Resulting energy** | **[MWh]** | **27,979.5** | **33,493.8** | **49,697.1** | **52,872.8** | **81,643.4** | **104,773.0** | **77,295.9** | **42,410.2** | **62,097.6** | **120,070.4** | **96,826.8** | **47,610.9** | **796,770.9** |
| Specific energy | [kWh/m2] | | | | | | | | | | | | | 1,405 |
| Specific energy | [kWh/kW] | | | | | | | | | | | | | 4,150 |
| Increase due to hills | [%] | 1.6 | 2.3 | 2.8 | 3.9 | 1.9 | 1.0 | 1.6 | 3.1 | 3.0 | 2.2 | 1.7 | 1.5 | 2.1 |
| Decrease due to array losses | [%] | 10.4 | 9.7 | 8.7 | 10.6 | 7.8 | 7.3 | 10.7 | 11.6 | 8.8 | 7.1 | 7.7 | 9.4 | 8.7 |
| Utilization | [%] | 27.6 | 26.8 | 27.2 | 30.2 | 25.5 | 26.0 | 30.9 | 31.6 | 28.0 | 22.8 | 23.9 | 27.7 | 26.4 |
| Operational | [Hours/year] | 420 | 467 | 570 | 649 | 766 | 909 | 831 | 562 | 663 | 1,121 | 979 | 612 | 8,550 |
| Full Load Equivalent | [Hours/year] | 146 | 174 | 259 | 275 | 425 | 546 | 403 | 221 | 323 | 625 | 504 | 248 | 4,150 |



# PARK - Wind Data Analysis

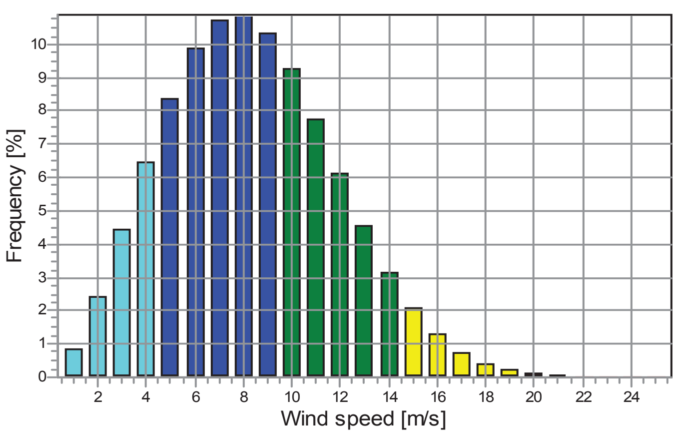
**Calculation:** 20070304 MWT 95-2.4 60Hz 2400 95.0 **Wind data:** A - Park/Wasp Calc; Hub height: 50.0

**Site Coordinates**
UTM WGS 84 Zone: 14 East: 442,927 North: 5,160,485
**Wind statistics**
US 45.00 m Napoleon Wind.wws

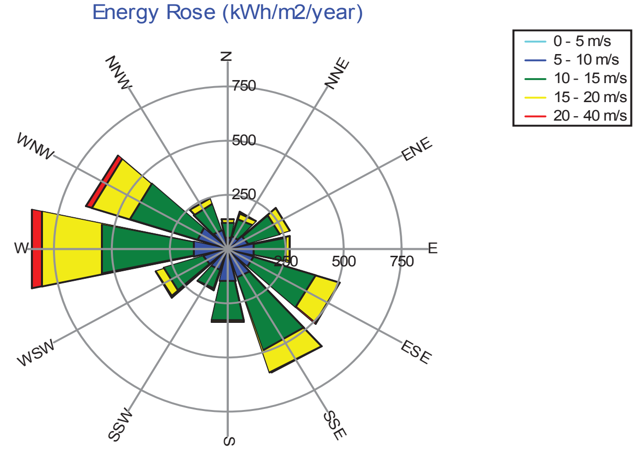
## Weibull Data

| | Current site | | | |
|---|---|---|---|---|
| Sector | A- parameter [m/s] | Wind speed [m/s] | k- parameter | Frequency [%] |
| 0 N | 7.72 | 6.84 | 2.111 | 4.8 |
| 1 NNE | 8.03 | 7.11 | 2.127 | 5.4 |
| 2 ENE | 9.07 | 8.05 | 2.486 | 6.7 |
| 3 E | 8.77 | 7.81 | 2.814 | 7.8 |
| 4 ESE | 10.21 | 9.09 | 2.799 | 9.1 |
| 5 SSE | 10.43 | 9.33 | 3.107 | 10.5 |
| 6 S | 9.01 | 8.09 | 3.365 | 9.5 |
| 7 SSW | 8.40 | 7.50 | 2.994 | 6.6 |
| 8 WSW | 9.24 | 8.22 | 2.768 | 7.8 |
| 9 W | 10.44 | 9.27 | 2.482 | 13.3 |
| 10 WNW | 9.89 | 8.76 | 2.396 | 11.5 |
| 11 NNW | 8.40 | 7.44 | 2.338 | 7.1 |
| All | 9.39 | 8.33 | 2.545 | 100.0 |

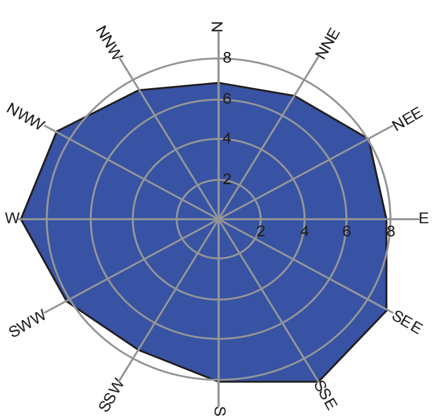
Weibull Distribution



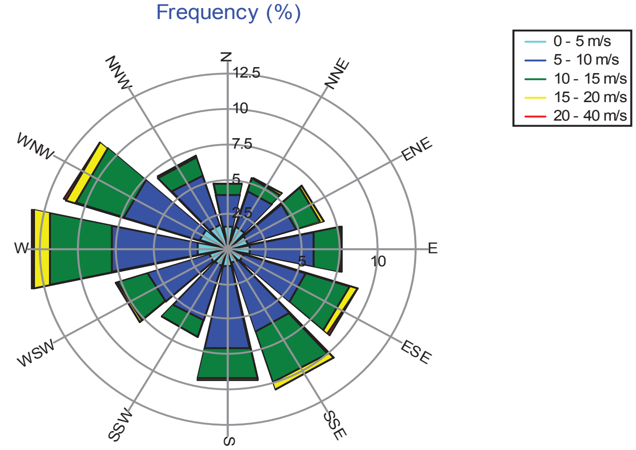

Energy Rose (kWh/m2/year)



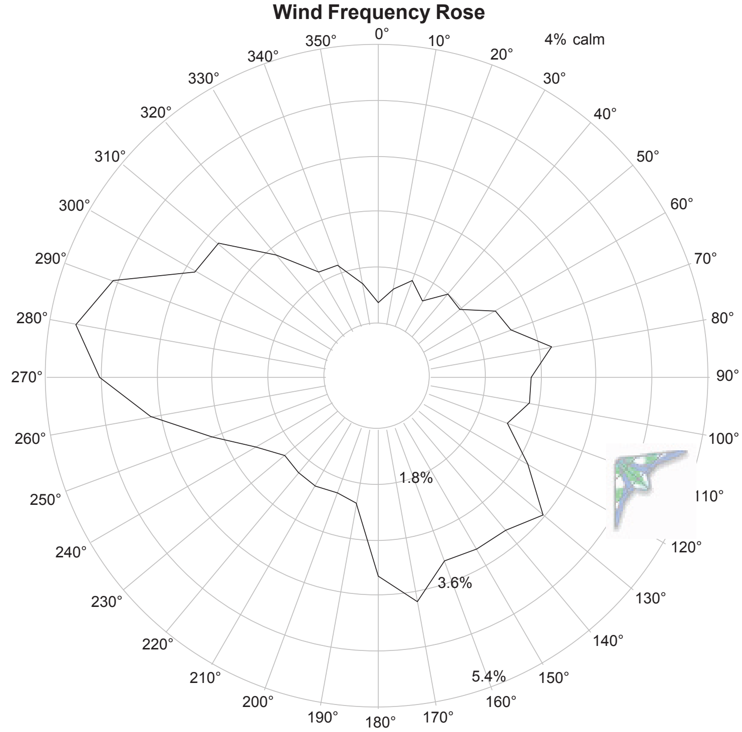

Mean w ind speed (m/s)



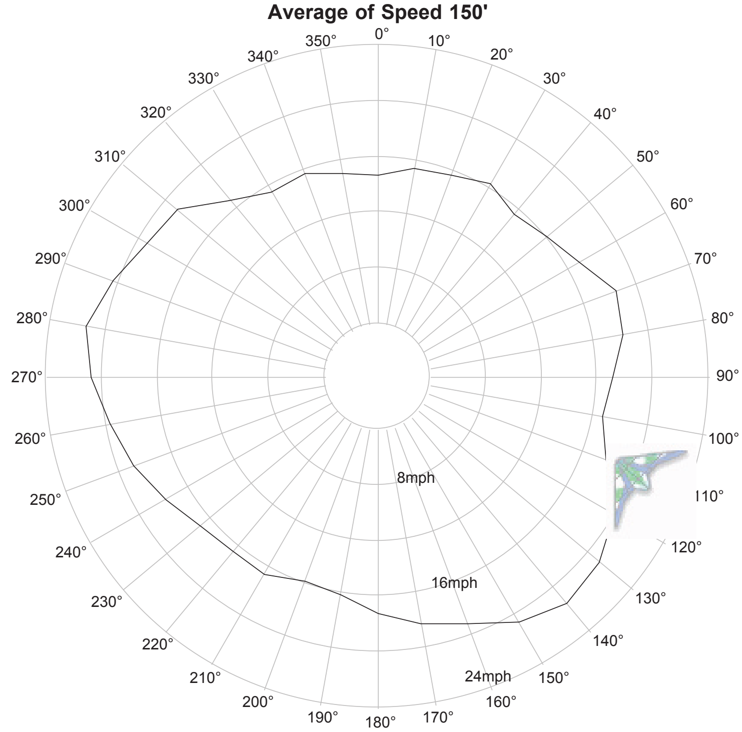

Frequency (%)

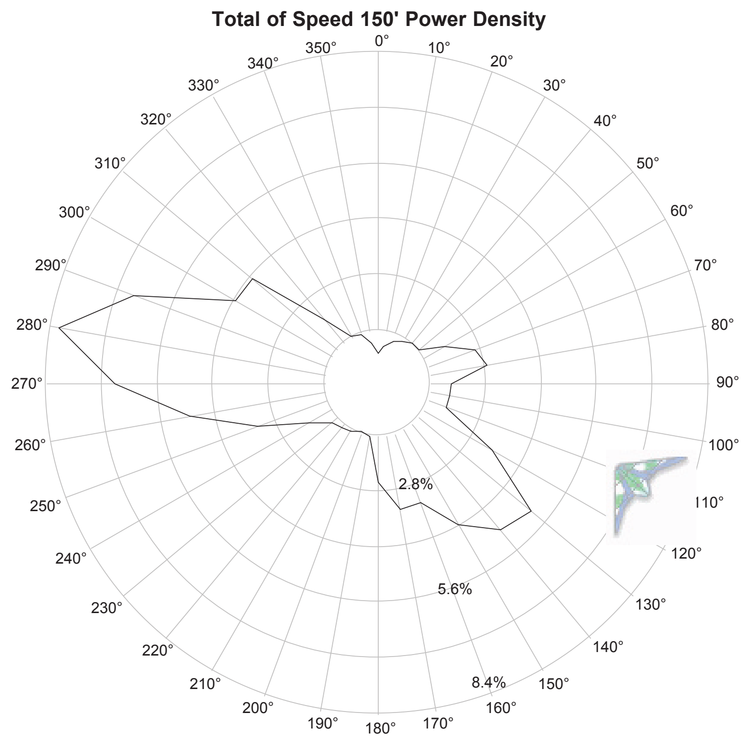


**Wind Frequency Rose**

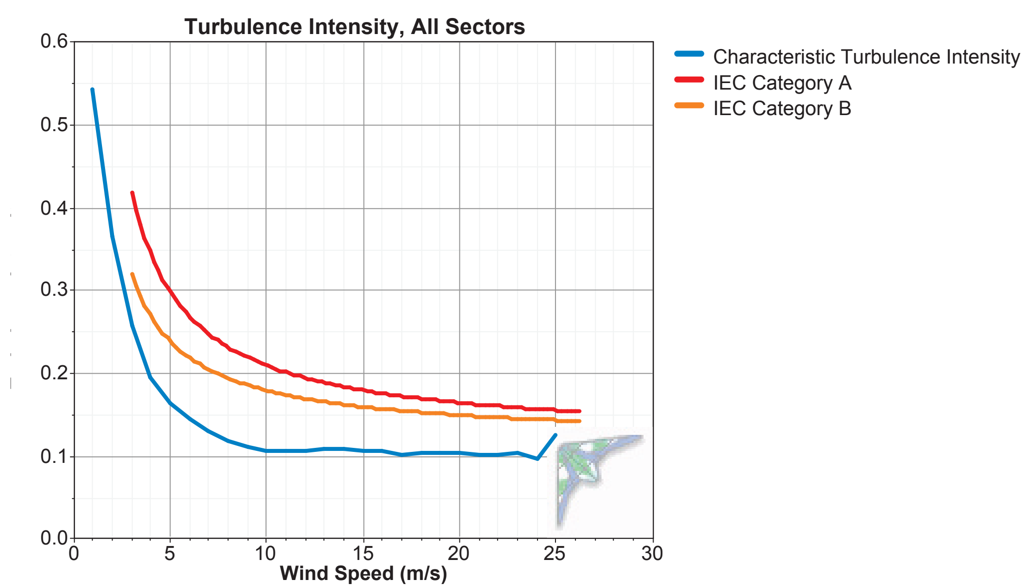



**Average of Speed 150'**






The data show quite low turbulence. The following graph shows the characteristic turbulence intensity versus wind speed, with the IEC category A and B wind regimes for comparison. The measured data set is considerably less turbulent than even the category B wind regime, which is considered low turbulence.



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# PARK - Park power curve

**Calculation:** 20070304 MWT 95-2.4 60Hz 2400 95.0

| Wind speed [m/s] | Power Free WTGs [kW] | Park WTGs [kW] | N [kW] | NNE [kW] | ENE [kW] | E [kW] | ESE [kW] | SSE [kW] | S [kW] | SSW [kW] | WSW [kW] | W [kW] | WNW [kW] | NNW [kW] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.5 | 1,311 | 482 | 464 | 515 | 509 | 469 | 461 | 501 | 447 | 504 | 502 | 471 | 470 | 497 |
| 4.5 | 8,792 | 6,492 | 6,422 | 6,484 | 6,580 | 6,462 | 6,469 | 6,552 | 6,399 | 6,480 | 6,552 | 6,475 | 6,479 | 6,546 |
| 5.5 | 20,284 | 16,302 | 16,178 | 16,280 | 16,449 | 16,252 | 16,270 | 16,406 | 16,141 | 16,279 | 16,403 | 16,271 | 16,287 | 16,393 |
| 6.5 | 36,635 | 30,049 | 29,844 | 30,028 | 30,288 | 29,965 | 29,987 | 30,220 | 29,783 | 30,015 | 30,213 | 30,000 | 30,017 | 30,202 |
| 7.5 | 58,770 | 48,592 | 48,282 | 48,565 | 48,960 | 48,464 | 48,495 | 48,854 | 48,183 | 48,542 | 48,849 | 48,515 | 48,542 | 48,827 |
| 8.5 | 87,924 | 72,998 | 72,542 | 72,954 | 73,542 | 72,808 | 72,856 | 73,383 | 72,400 | 72,922 | 73,368 | 72,886 | 72,927 | 73,339 |
| 9.5 | 123,059 | 103,562 | 102,957 | 103,464 | 104,289 | 103,316 | 103,397 | 104,058 | 102,771 | 103,435 | 104,054 | 103,417 | 103,490 | 104,007 |
| 10.5 | 159,324 | 137,652 | 136,948 | 137,426 | 138,471 | 137,395 | 137,531 | 138,224 | 136,756 | 137,418 | 138,201 | 137,488 | 137,606 | 138,156 |
| 11.5 | 184,438 | 170,708 | 170,133 | 170,429 | 171,443 | 170,639 | 170,799 | 171,023 | 170,026 | 170,177 | 171,245 | 170,503 | 170,759 | 171,141 |
| 12.5 | 192,000 | 190,371 | 190,293 | 190,139 | 190,489 | 190,377 | 190,586 | 190,301 | 190,300 | 190,035 | 190,483 | 190,344 | 190,549 | 190,335 |
| 13.5 | 192,000 | 191,998 | 191,999 | 191,998 | 191,999 | 191,999 | 192,000 | 191,998 | 191,999 | 191,995 | 191,999 | 191,999 | 192,000 | 191,998 |
| 14.5 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 |
| 15.5 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 |
| 16.5 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 |
| 17.5 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 |
| 18.5 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 |
| 19.5 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 |
| 20.5 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 |
| 21.5 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 |
| 22.5 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 |
| 23.5 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 |
| 24.5 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 | 192,000 |
| 25.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 26.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Description:**
The park power curve is similar to a WTG power curve, meaning that when a given wind speed appears in front of the park with same speed in the entire wind farm area (before influence from the park), the output from the park can be found in the park power curve. Another way to say this: The park power curve includes array losses, but do NOT include terrain given variations in the wind speed over the park area.
Measuring a park power curve is not as simple as measuring a WTG power curve due to the fact that the park power curve depends on the wind direction and that the same wind speed normally will not appear for the entire park area at the same time (only in very flat non-complex terrain). The idea with this version of the park power curve is not to use it for validation based on measurements. This would require at least 2 measurement masts at two sides of the park, unless only a few direction sectors should be tested, AND non complex terrain (normally only useable off shore). Another park power curve version for complex terrain is available in WindPRO.

**The park power curve can be used for:**

1. Forecast systems, based on more rough (approximated) wind data, the park power curve would be an efficient way to make the connection from wind speed (and direction) to power.
2. Construction of duration curves, telling how often a given power output will appear, the park power curve can be used together with the average wind distribution for the Wind farm area in hub height. The average wind distribution can eventually be obtained based on the Weibull parameters for each WTG position. These are found at print menu: >Result to file< in the >Park result< which can be saved to file or copied to clipboard and pasted in Excel.
3. Calculation of wind energy index based on the PARK production (see below).
4. Estimation of the expected PARK production for an existing wind farm based on wind measurements at minimum 2 measurement masts at two sides of wind farm. The masts must be used for obtaining the free wind speed. The free wind speed is used in the simulation of expected energy production with the PARK power curve. This procedure will only work suitable in non complex terrains. For complex terrain another park power curve calculation is available in WindPRO (PPV-model).

**Note:**
From the >Result to file< the >Wind Speeds Inside Wind farm< is also available. These can (e.g. via Excel) be used for extracting the wake induced reductions in measured wind speed.

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# PARK - Power Curve Analysis

**Calculation:** 20070304 MWT 95-2.4 60Hz 2400 95.0 **WTG:** 1 - MWT 95/2.4 60Hz 2400 95.0 !O! MWT 95/2.4, Hub height: 80.0 m

**Name:** MWT 95/2.4
**Source:** Mitsubishi

| Source/Date | Created by | Created | Edited | Stop wind speed [m/s] | Power control | CT curve type |
|---|---|---|---|---|---|---|
| 11/14/2006 | USER | 10/23/2006 | 11/16/2006 | 25.0 | Pitch | User defined |

Information obtained from manufacturer
MWT95/2.4 (60Hz, 80m hub) WTG
WT I-A-095-R2 (R2 18 OCTOBER 2006)

## HP curve comparison - Note: For standard air density and weibull k parameter = 2

| Vmean | [m/s] | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|
| HP value | [MWh] | 3,268 | 5,191 | 7,171 | 9,077 | 10,659 | 12,072 |
| 1 | [MWh] | 3,333 | 5,325 | 7,328 | 9,162 | 10,744 | 12,037 |
| Check value | [%] | -2 | -3 | -2 | -1 | -1 | 0 |

The table shows comparison between annual energy production calculated on basis of simplified "HP-curves" which assume that all WTG's performs quite similar - only specific power loading (kW/m^2) and single/dual speed or stall/pitch decides the calculated values. Productions are without wake losses.
For further details, ask at the Danish Energy Agency for project report J.nr. 51171/00-0016 or see WindPRO manual chapter 3.5.2.
The method is refined in EMD report "20 Detailed Case Studies comparing Project Design Calculations and actual Energy Productions for Wind Energy Projects worldwide", jan 2003.
Use the table to evaluate if the given power curve is reasonable - if the check value are lower than -5%, the power curve probably is too optimistic due to uncertainty in power curve measurement.

## Power curve

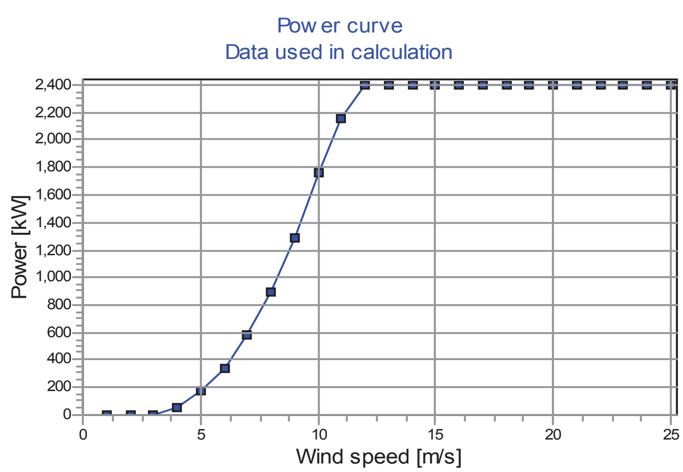
Original data from Windcat, Air density: 1.225 kg/m3

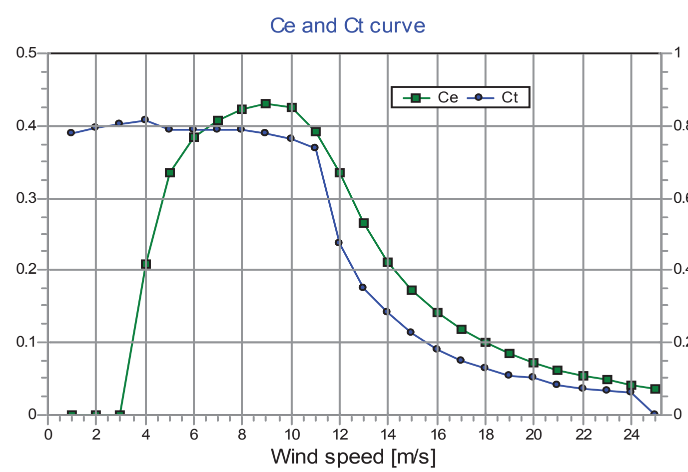
| Wind speed [m/s] | Power [kW] | Ce | Wind speed [m/s] | Ct curve |
|---|---|---|---|---|
| 3.5 | 17.0 | 0.09 | 3.5 | 0.81 |
| 4.0 | 58.0 | 0.21 | 4.0 | 0.82 |
| 4.5 | 114.0 | 0.29 | 4.5 | 0.81 |
| 5.0 | 182.0 | 0.34 | 5.0 | 0.79 |
| 5.5 | 263.0 | 0.36 | 5.5 | 0.79 |
| 6.0 | 361.0 | 0.38 | 6.0 | 0.79 |
| 6.5 | 475.0 | 0.40 | 6.5 | 0.79 |
| 7.0 | 608.0 | 0.41 | 7.0 | 0.79 |
| 7.5 | 762.0 | 0.42 | 7.5 | 0.79 |
| 8.0 | 941.0 | 0.42 | 8.0 | 0.79 |
| 8.5 | 1,140.0 | 0.43 | 8.5 | 0.79 |
| 9.0 | 1,361.0 | 0.43 | 9.0 | 0.78 |
| 9.5 | 1,595.0 | 0.43 | 9.5 | 0.77 |
| 10.0 | 1,828.0 | 0.42 | 10.0 | 0.76 |
| 10.5 | 2,035.0 | 0.41 | 10.5 | 0.77 |
| 11.0 | 2,203.0 | 0.39 | 11.0 | 0.74 |
| 11.5 | 2,322.0 | 0.36 | 11.5 | 0.57 |
| 12.0 | 2,396.0 | 0.33 | 12.0 | 0.47 |
| 12.5 | 2,400.0 | 0.29 | 13.0 | 0.35 |
| 13.0 | 2,400.0 | 0.26 | 14.0 | 0.28 |
| 13.5 | 2,400.0 | 0.23 | 15.0 | 0.23 |
| 14.0 | 2,400.0 | 0.21 | 16.0 | 0.18 |
| 14.5 | 2,400.0 | 0.19 | 17.0 | 0.15 |
| 15.0 | 2,400.0 | 0.17 | 18.0 | 0.13 |
| 15.5 | 2,400.0 | 0.15 | 19.0 | 0.11 |
| 16.0 | 2,400.0 | 0.14 | 20.0 | 0.10 |
| 16.5 | 2,400.0 | 0.13 | 21.0 | 0.09 |
| 17.0 | 2,400.0 | 0.12 | 22.0 | 0.07 |
| 17.5 | 2,400.0 | 0.11 | 23.0 | 0.07 |
| 18.0 | 2,400.0 | 0.10 | 24.0 | 0.06 |
| 18.5 | 2,400.0 | 0.09 | 25.0 | 0.00 |
| 19.0 | 2,400.0 | 0.08 | | |
| 19.5 | 2,400.0 | 0.08 | | |
| 20.0 | 2,400.0 | 0.07 | | |
| 20.5 | 2,400.0 | 0.07 | | |
| 21.0 | 2,400.0 | 0.06 | | |
| 21.5 | 2,400.0 | 0.06 | | |
| 22.0 | 2,400.0 | 0.05 | | |
| 22.5 | 2,400.0 | 0.05 | | |
| 23.0 | 2,400.0 | 0.05 | | |
| 23.5 | 2,400.0 | 0.04 | | |
| 24.0 | 2,400.0 | 0.04 | | |
| 24.5 | 2,400.0 | 0.04 | | |
| 25.0 | 2,400.0 | 0.04 | | |

## Power, Efficiency and energy vs. wind speed

Data used in calculation, Air density: 1.165 kg/m3

| Wind speed [m/s] | Power [kW] | Ce | Interval [m/s] | Energy [MWh] | Acc.Energy [MWh] | Relative [%] |
|---|---|---|---|---|---|---|
| 1.0 | 0.0 | 0.00 | 0.50- 1.50 | 0.0 | 0.0 | 0.0 |
| 2.0 | 0.0 | 0.00 | 1.50- 2.50 | 0.0 | 0.0 | 0.0 |
| 3.0 | 0.0 | 0.00 | 2.50- 3.50 | 2.4 | 2.4 | 0.0 |
| 4.0 | 55.2 | 0.21 | 3.50- 4.50 | 26.1 | 28.6 | 0.3 |
| 5.0 | 173.1 | 0.34 | 4.50- 5.50 | 95.6 | 124.1 | 1.2 |
| 6.0 | 343.4 | 0.38 | 5.50- 6.50 | 229.1 | 353.2 | 3.3 |
| 7.0 | 578.4 | 0.41 | 6.50- 7.50 | 441.9 | 795.1 | 7.5 |
| 8.0 | 895.2 | 0.42 | 7.50- 8.50 | 734.7 | 1,529.8 | 14.5 |
| 9.0 | 1,294.8 | 0.43 | 8.50- 9.50 | 1,073.6 | 2,603.4 | 24.7 |
| 10.0 | 1,757.5 | 0.43 | 9.50-10.50 | 1,377.2 | 3,980.6 | 37.7 |
| 11.0 | 2,160.5 | 0.39 | 10.50-11.50 | 1,516.7 | 5,497.3 | 52.1 |
| 12.0 | 2,396.0 | 0.34 | 11.50-12.50 | 1,413.3 | 6,910.5 | 65.5 |
| 13.0 | 2,400.0 | 0.26 | 12.50-13.50 | 1,148.9 | 8,059.4 | 76.4 |
| 14.0 | 2,400.0 | 0.21 | 13.50-14.50 | 859.4 | 8,918.8 | 84.5 |
| 15.0 | 2,400.0 | 0.17 | 14.50-15.50 | 607.6 | 9,526.4 | 90.3 |
| 16.0 | 2,400.0 | 0.14 | 15.50-16.50 | 407.5 | 9,933.9 | 94.2 |
| 17.0 | 2,400.0 | 0.12 | 16.50-17.50 | 260.2 | 10,194.1 | 96.6 |
| 18.0 | 2,400.0 | 0.10 | 17.50-18.50 | 158.6 | 10,352.7 | 98.1 |
| 19.0 | 2,400.0 | 0.08 | 18.50-19.50 | 92.3 | 10,445.0 | 99.0 |
| 20.0 | 2,400.0 | 0.07 | 19.50-20.50 | 51.4 | 10,496.4 | 99.5 |
| 21.0 | 2,400.0 | 0.06 | 20.50-21.50 | 27.4 | 10,523.8 | 99.8 |
| 22.0 | 2,400.0 | 0.05 | 21.50-22.50 | 14.0 | 10,537.9 | 99.9 |
| 23.0 | 2,400.0 | 0.05 | 22.50-23.50 | 6.9 | 10,544.8 | 100.0 |
| 24.0 | 2,400.0 | 0.04 | 23.50-24.50 | 3.3 | 10,548.0 | 100.0 |
| 25.0 | 2,400.0 | 0.04 | 24.50-25.50 | 1.0 | 10,549.1 | 100.0 |



# Figure 9

Project:
**NAPOLEON.WIND**

Description:
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# PARK - Main Result

## Calculation: 20070304 MWT 95-2.4 60Hz 2400 95.0

**Wake Model** N.O. Jensen (RISØ/EMD)

**Calculation Settings**
Air density calculation mode Individual per WTG
Result for WTG at hub altitude 1.165 kg/m3 to 1.172 kg/m3
Hub altitude above sea level (asl) 683.2 m to 739.2 m
Annual mean temperature at hub alt. 3.5 °C to 3.9 °C
Pressure at WTGs 925.6 hPa to 932.0 hPa

**Wake Model Parameters**
Wake Decay Constant0.075

**Wind statistics** US 45.00 m Napoleon Wind.wws

Scale 1:2
New WTG Site Data

### Key results for height 80.0 m above ground level

**Terrain Geo DMS: WGS 84**

| Terrain | Longitude | Latitude | Name of wind distribution | Type | Wind energy [kWh/m2] | Mean wind speed [m/s] | Equivalent roughness |
|---|---|---|---|---|---|---|---|
| A | -99°44'42.38" East | 46°35'43.81" North | Park/Wasp Calc | WAsP (RVEA0011 1, 0, 0, 13) | 5,833 | 9.1 | 0.8 |

### Calculated Annual Energy for Wind Farm

| WTG combination | Annual Energy Result [MWh] | Annual Energy Result-10.0% [MWh] | Park Efficiency [%] | Mean WTG energy [MWh] | Capacity Factor for Result [%] | Capacity Factor for Result-10.0% [%] |
|---|---|---|---|---|---|---|
| Wind farm | 796,771.4 | 717,094.2 | 91.3 | 9,959.6 | 47.3 | 42.6 |

### Calculated Annual Energy for each of 80 new WTG's with total 192.0 MW rated power

| | Terrain | WTG type Valid | Manufact. | Type | Power [kW] | Diam. [m] | Height [m] | Power curve Creator | Name | Annual Energy Result [MWh] | Result-10.0% [MWh] | Park Efficiency [%] | Mean wind speed [m/s] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,549.1 | 9,494 | 90.5 | 9.3 |
| 2 | A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,122.5 | 9,110 | 89.3 | 9.1 |
| 3 | A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,691.6 | 9,622 | 93.6 | 9.1 |
| 4 | A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,414.4 | 9,373 | 91.3 | 9.1 |
| 5 | A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,135.4 | 9,122 | 92.9 | 8.9 |
| 6 | A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,559.6 | 9,504 | 94.5 | 9.0 |
| 7 | A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,176.2 | 9,159 | 91.5 | 9.0 |
| 8 | A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,963.1 | 8,967 | 89.3 | 9.0 |
| 9 | A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,005.6 | 9,005 | 90.2 | 8.9 |
| 10 | A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,261.2 | 9,235 | 90.5 | 9.1 |
| 11 | A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,330.9 | 9,298 | 93.3 | 8.9 |
| 12 | A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,186.2 | 9,168 | 90.5 | 9.0 |
| 13 | A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,388.6 | 9,350 | 92.8 | 9.0 |
| 14 | A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,063.7 | 9,057 | 91.4 | 8.9 |
| 15 | A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,148.9 | 9,134 | 91.0 | 9.0 |
| 16 | A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,190.8 | 9,172 | 92.1 | 8.9 |
| 17 | A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,485.5 | 9,437 | 92.2 | 9.1 |
| 18 | A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,330.8 | 9,298 | 94.0 | 8.9 |
| 19 | A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,947.9 | 8,953 | 89.9 | 8.9 |
| 20 | A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,177.4 | 9,160 | 92.1 | 8.9 |
| 21 | A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,500.8 | 9,451 | 95.8 | 8.9 |
| 22 | A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,861.2 | 8,875 | 90.5 | 8.8 |
| 23 | A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,882.4 | 8,894 | 90.1 | 8.9 |

*Continued on next page...*

## PARK - Main Result

**Calculation:** 20070304 MWT 95-2.4 60Hz 2400 95.0

*...continued from previous page*

| | | **WTG type** | | | | | **Power curve** | | **Annual Energy** | | **Park** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Terrain | Valid | Manufact. | Type | Power [kW] | Diam. [m] | Height [m] | Creator | Name | Result [MWh] | Result-10.0% [MWh] | Efficiency [%] | Mean wind speed [m/s] |
| 24 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,008.5 | 9,008 | 91.6 | 8.9 |
| 25 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,315.3 | 9,284 | 92.3 | 9.0 |
| 26 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,204.9 | 9,184 | 93.9 | 8.8 |
| 27 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,144.1 | 9,130 | 92.6 | 8.9 |
| 28 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,254.3 | 9,229 | 91.6 | 9.0 |
| 29 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,855.9 | 8,870 | 89.3 | 8.9 |
| 30 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,991.6 | 8,992 | 89.8 | 9.0 |
| 31 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,856.1 | 8,870 | 90.2 | 8.9 |
| 32 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,202.9 | 9,183 | 92.2 | 8.9 |
| 33 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,089.4 | 9,080 | 93.8 | 8.8 |
| 34 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,206.9 | 9,186 | 94.3 | 8.8 |
| 35 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,829.3 | 8,846 | 90.9 | 8.8 |
| 36 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,120.6 | 9,109 | 93.1 | 8.8 |
| 37 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,996.3 | 8,997 | 92.7 | 8.8 |
| 38 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,514.6 | 8,563 | 88.6 | 8.8 |
| 39 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,803.0 | 8,823 | 89.6 | 8.9 |
| 40 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,989.5 | 8,991 | 92.8 | 8.8 |
| 41 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,311.1 | 9,280 | 94.8 | 8.8 |
| 42 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,080.5 | 9,072 | 91.8 | 8.9 |
| 43 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,919.0 | 8,927 | 90.9 | 8.8 |
| 44 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,761.7 | 8,786 | 90.9 | 8.8 |
| 45 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,996.5 | 8,997 | 92.0 | 8.8 |
| 46 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,026.0 | 9,023 | 93.1 | 8.8 |
| 47 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,939.7 | 8,946 | 92.0 | 8.8 |
| 48 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,878.2 | 8,890 | 91.1 | 8.8 |
| 49 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,733.3 | 8,760 | 89.8 | 8.8 |
| 50 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,994.9 | 8,995 | 92.5 | 8.8 |
| 51 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,807.3 | 8,827 | 90.8 | 8.8 |
| 52 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,729.2 | 8,756 | 89.5 | 8.8 |
| 53 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,788.9 | 8,810 | 91.0 | 8.8 |
| 54 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,865.9 | 8,879 | 88.8 | 8.9 |
| 55 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,528.7 | 8,576 | 89.4 | 8.7 |
| 56 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,647.6 | 8,683 | 89.6 | 8.8 |
| 57 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,623.8 | 8,661 | 89.5 | 8.8 |
| 58 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,650.1 | 8,685 | 88.9 | 8.8 |
| 59 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,691.1 | 8,722 | 90.0 | 8.8 |
| 60 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,563.3 | 8,607 | 89.0 | 8.8 |
| 61 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,713.8 | 8,742 | 89.8 | 8.8 |
| 62 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,653.6 | 8,688 | 89.4 | 8.8 |
| 63 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,624.7 | 8,662 | 89.6 | 8.8 |
| 64 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,271.3 | 9,244 | 96.3 | 8.7 |
| 65 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,048.4 | 9,044 | 94.1 | 8.7 |
| 66 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 10,010.5 | 9,009 | 93.7 | 8.7 |
| 67 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,576.5 | 8,619 | 89.8 | 8.7 |
| 68 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,815.6 | 8,834 | 91.0 | 8.8 |
| 69 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,682.3 | 8,714 | 91.1 | 8.7 |
| 70 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,931.2 | 8,938 | 92.9 | 8.7 |
| 71 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,613.9 | 8,653 | 90.5 | 8.7 |
| 72 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,642.2 | 8,678 | 90.6 | 8.7 |
| 73 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,630.5 | 8,667 | 89.5 | 8.8 |
| 74 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,957.5 | 8,962 | 93.2 | 8.7 |
| 75 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,530.5 | 8,577 | 89.1 | 8.7 |
| 76 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,510.0 | 8,559 | 89.9 | 8.7 |
| 77 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,581.4 | 8,623 | 88.6 | 8.8 |
| 78 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,560.2 | 8,604 | 90.2 | 8.7 |
| 79 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,510.6 | 8,560 | 88.9 | 8.7 |
| 80 A | Yes | MWT | 95/2.4 | 2,400 | 95.0 | 80.0 | USER | MWT 95/2.4 | 9,613.3 | 8,652 | 89.9 | 8.7 |

# Figure 10

MapStats

## Logan County, North Dakota

| People MapStats | Logan County | North Dakota |
|---|---|---|
| Population, 2005 estimate | 2,059 | 636,677 |
| Population, percent change, April 1, 2000 to July 1, 2005 | -10.8% | -0.9% |
| Population, change, April 1, 2000 to July 1, 2005 | -249 | -5,527 |
| Population, 2000 | 2,308 | 642,200 |
| Persons under 5 years old, 2005 | 86 | 36,787 |
| Persons under 5 years old, percent, 2005 | 4.2% | 5.8% |
| Persons under 18 years old, 2005 | 393 | 136,518 |
| Persons under 18 years old, percent, 2005 | 19.1% | 21.4% |
| Persons 65 years old and over, percent, 2005 | 28.4% | 14.7% |
| Persons 65 years old and over, 2005 | 584 | 93,650 |
| Female persons, percent, 2005 | 50.5% | 50.1% |
| White persons, 2005 (a) | 2,037 | 587,504 |
| Black persons, 2005 (a) | 2 | 4,883 |
| American Indian and Alaska Native persons, 2005 (a) | 3 | 33,754 |
| Asian persons, 2005 (a) | 8 | 4,166 |
| Native Hawaiian and Other Pacific Islander, 2005 (a) | 0 | 258 |
| Persons reporting two or more races, 2005 | 9 | 6,112 |
| Persons of Hispanic or Latino origin, 2005 (b) | 16 | 10,179 |
| White persons not Hispanic, 2005 | 2,021 | 578,385 |
| White persons, percent, 2005 (a) | 98.9% | 92.3% |
| Black persons, percent, 2005 (a) | 0.1% | 0.8% |
| American Indian and Alaska Native persons, percent, 2005 (a) | 0.1% | 5.3% |
| Asian persons, percent, 2005 (a) | 0.4% | 0.7% |
| Native Hawaiian and Other Pacific Islander, percent, 2005 (a) | 0.0% | 0.0% |
| Persons reporting two or more races, percent, 2005 | 0.4% | 1.0% |
| Persons of Hispanic or Latino origin, percent, 2005 (b) | 0.8% | 1.6% |
| White persons not Hispanic, percent, 2005 | 98.2% | 90.8% |
| Births, 2003 | 18 | 7,972 |
| Deaths, 2003 | 29 | 6,090 |
| Infant deaths, 2003 | 0 | 58 |
| Living in same house in 1995 and 2000, pct 5 yrs old & over | 76.4% | 56.8% |
| Foreign born persons, percent, 2000 | 0.6% | 1.9% |
| Language other than English spoken at home, pct age 5+, 2000 | 25.5% | 6.3% |
| High school graduates, percent of persons age 25+, 2000 | 66.0% | 83.9% |

| | | |
|---|---|---|
| ? Bachelor's degree or higher, pct of persons age 25+, 2000 | 12.9% | 22.0% |
| ? Persons with a disability, age 5+, 2000 | 492 | 97,817 |
| ? Mean travel time to work (minutes), workers age 16+, 2000 | 20.4 | 15.8 |

| | | |
|---|---|---|
| ? Housing units, 2005 | 1,209 | 304,458 |
| ? Housing units, net change, April 1, 2000 to July, 2005 | 16 | 14,779 |
| ? Housing units, percent change, April 1, 2000 to July, 2005 | 1.3% | 5.1% |
| ? Homeownership rate, 2000 | 85.8% | 66.6% |
| ? Median value of owner-occupied housing units, 2000 | $30,200 | $74,400 |
| ? Households, 2000 | 963 | 257,152 |
| ? Persons per household, 2000 | 2.32 | 2.41 |
| ? Median household income, 2003 | $30,857 | $38,223 |
| ? Persons below poverty, percent, 2003 | 11.6% | 10.5% |

| **Business MapStats** | **Logan County** | **North Dakota** |
|---|---|---|
| ? Personal income, 2004 ($1000) | 65,956 | 18,767,503 |
| ? Personal income per capita, 2004 | $31,423 | $29,494 |
| ? Civilian labor force, 2005 | 938 | 358,960 |
| ? Unemployment rate, 2005 | 3.7% | 3.4% |
| ? Full-time and part-time employment by place of work, 2004 | 1,507 | 463,678 |
| ? Full-time and part-time employment, net change 2000 to 2004 | -95 | 16,298 |
| ? Employment in government, 2004 | 170 | 80,516 |
| ? Earnings, 2004 ($1000) | 36,921 | 14,966,009 |
| ? Average earnings per job, 2004 | $24,500 | $32,277 |
| ? Private nonfarm establishments, 2004 | 77 | 20,822[1] |
| ? Private nonfarm employment, 2004 | 360 | 265,663[1] |
| ? Private nonfarm employment, percent change 2000-2004 | -16.1% | 4.1%[1] |

| | | |
|---|---|---|
| ? Total number of firms, 2002 | 204 | 56,781 |
| ? Black-owned firms, percent, 2002 | NA | 0.1% |
| ? American Indian and Alaska Native owned firms, percent, 2002 | NA | 1.5% |
| ? Asian-owned firms, percent, 2002 | NA | 0.5% |
| ? Native Hawaiian and Other Pacific Islander owned firms, percent, 2002 | NA | 0.0% |
| ? Women-owned firms, percent, 2002 | NA | 23.3% |
| ? Hispanic-owned firms, percent, 2002 | NA | 0.4% |

| | | |
|---|---|---|
| ? Manufacturers shipments, 2002 ($1000) | NA | 6,856,653 |
| ? Accommodation and foodservices sales, 2002 ($1000) | 1,010 | 854,656 |
| ? Wholesale trade sales, 2002 ($1000) | 97,003 | 8,806,340 |
| ? Retail sales, 2002 ($1000) | 14,403 | 7,723,945 |
| ? Retail sales per capita, 2002 | $6,568 | $12,187 |
| Building permits, 2005 | | |

| | | |
|---|---|---|
| ? | 0 | 4,038 |
| ? Farm land, 2002 (acres) | 577,823 | 39,294,879 |
| ? Federal spending, 2004 ($1000) | 27,581 | 6,034,799[1] |
| ? Federal spending per capita, 2004 | $13,140 | $9,513[1] |

| Geography MapStats | Logan County | North Dakota |
|---|---|---|
| ? Land area, 2000 (square miles) | 992 | 68,975 |
| ? Persons per square mile, 2000 | 2.3 | 9.3 |
| ? FIPS Code | 047 | 38 |
| ? Metropolitan or Micropolitan Statistical Area | None | |

1: Includes data not distributed by county.

Download the full data set

(a) Includes persons reporting only one race.
(b) Hispanics may be of any race, so also are included in applicable race categories.

Figures are in absolute numbers unless otherwise indicated.

FN: Footnote on this item for this area in place of data
NA: Not available
D: Suppressed to avoid disclosure of confidential information
X: Not applicable
S: Suppressed; does not meet publication standards
Z: Value greater than zero but less than half unit of measure shown
F: Fewer than 100 firms

Source: Bureau of Economic Analysis, Bureau of Labor Statistics, National Agricultural Statistics Service, National Center for Health Statistics, U.S. Census Bureau

Metadata powered by DataWeb
Last Revised: Wednesday, 17-Jan-2007 10:44:50 EST

# Figure 11

NORTH DAKOTA

# REPOWERING THE MIDWEST:

## THE CLEAN ENERGY DEVELOPMENT PLAN FOR THE HEARTLAND

### THE 21ST CENTURY OPPORTUNITIES FOR CLEAN ENERGY

North Dakota needs a strategic clean energy development plan that implements smart policies and practices to capture readily achievable environmental, public health and economic development benefits. This sustainable development strategy is good for the environment and the economy. The Clean Energy Development Plan proposes policies to implement underutilized energy efficiency technologies and to aggressively develop renewable energy resources. By diversifying its power supply, North Dakota will reduce pollution, improve electricity reliability, create new "green" manufacturing and installation jobs, and provide renewable energy "cash crops" for farmers. The Clean Energy Development Plan provides the strategies to achieve these goals.

### THE CLEAN ENERGY DEVELOPMENT PLAN

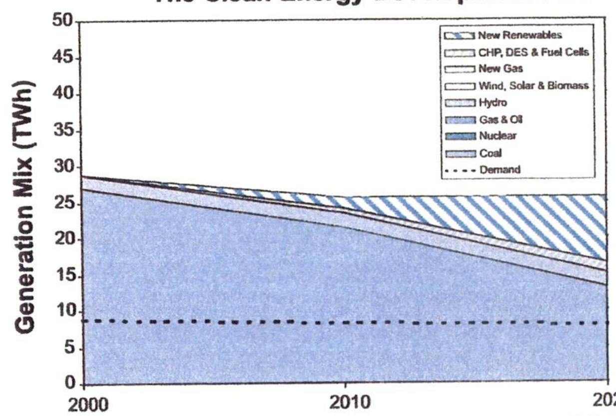
North Dakota should seize the opportunity to develop its clean energy resources: modern energy efficiency technologies and wind, biomass and solar power. The Clean Energy Development Plan achieves large environmental, public health and economic development benefits with only modest increases in cost. Moreover, investing in energy efficiency and renewable energy will diversify the region's electricity portfolio, thereby improving reliability. The Clean Energy Development Plan:

1. Aggressively implements the newest, as well as "tried and true," energy efficiency technologies.
2. Develops and implements renewable energy technologies – wind, biomass and solar power – so that they provide eight percent of the region's electricity generation by 2010 and 22 percent by 2020.
3. Develops and implements efficient natural gas uses in appropriate locations, especially combined heat and power (CHP), district energy systems and fuel cells, so that they provide 10 percent of the region's electricity generation by 2010 and 25 percent by 2020.
4. Retires selected older, less efficient and highly polluting coal plants.
5. Applies sustainable development strategies to aggressively link environmental improvement policies to economic development.

As Figure 1 shows, implementing the Clean Energy Development Plan in North Dakota means:

1. Energy efficiency measures reduce electricity demand, and therefore the need for generation.
2. Generation from renewable resources and efficient natural gas increases.
3. Generation from older, less efficient and highly polluting coal plants decreases.

**Figure 1. Sources of Electricity Generation: The Clean Energy Development Plan**




*The state's electricity demand is shown with a dashed line; when the dashed line is below generation, the state is a net exporter, and when above, the state is a net importer.*

### IMPLEMENTING THE CLEAN ENERGY DEVELOPMENT PLAN IN NORTH DAKOTA WILL ALSO PRODUCE:

1. Dramatic improvements in environmental quality by 2020, compared to business-as-usual practices, by reducing: sulfur dioxide ($SO_2$) pollution, which causes acid rain, by 53 percent; nitrogen oxides ($NO_x$) pollution, which causes smog, by 53 percent; and carbon dioxide ($CO_2$) pollution, which causes global warming, by 48 percent.
2. Improved electricity reliability thanks to a diversified power portfolio.
3. Economic development and job growth through wind power "cash crops" for farmers and clean energy exports, increased business for energy efficiency and renewable energy manufacturers, and new skilled jobs in installation and maintenance of this equipment.

### REAPING ENERGY EFFICIENCY OPPORTUNITIES

North Dakota has an opportunity to use energy in smarter, more efficient ways, thereby reducing pollution, saving money and creating jobs. This will produce the benefits summarized on the following page.

**Harnessing clean energy improves the environment and spurs economic growth.**

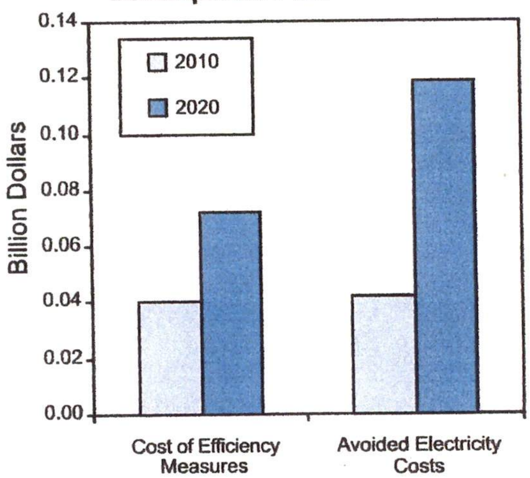
## HELP REPOWER NORTH DAKOTA!

For more information and resources to develop North Dakota's clean energy options, visit **www.repowermidwest.org** or contact Environmental Law & Policy Center of the Midwest, 35 East Wacker Drive, Suite 1300, Chicago, IL 60601, tel: 312-673-6500.

NORTH DAKOTA

1. Reduces net electricity costs by $46 million by 2020.
2. Saves 3,064 GWh of electricity – equal to about one large power plant – by 2020.
3. Reduces electricity demand 17 percent by 2010 and 28 percent by 2020.
4. Costs less – at an average cost of 2.4¢/kWh – than generating, transmitting and distributing electricity.

**Figure 2. Benefits from Energy Efficiency Investments: The Clean Energy Development Plan**




## DEPLOYING RENEWABLE RESOURCES AND EFFICIENT GENERATION

North Dakota has a tremendous opportunity to harness its abundant wind resources, which offer environmental benefits, improved reliability, and economic development in the growing renewable energy business sector. North Dakota can also develop efficient generators, such as CHP and district energy systems. Together, the opportunities shown in Figure 3 could supply 14 percent of North Dakota's generation capacity by 2010 and 35 percent by 2020.

The Clean Energy Development Plan's benefits can be achieved at a modest cost, as energy efficiency savings offset the cost of new generation. In North Dakota, it would increase overall electricity costs by only 1.5 percent in 2010 and 3.4 percent in 2020.

## 21ST CENTURY POLICIES FOR MODERN TECHNOLOGIES

Smart policies can overcome the many market and regulatory barriers that energy efficiency and renewable resources face. The key policy actions for achieving the Clean Energy Development Plan in North Dakota are to:

1. Establish an Energy Efficiency Investment Fund to support energy efficiency initiatives with a non-bypassable charge of 0.3¢/kWh.
2. Manage the Energy Efficiency Investment Fund by an independent third-party administrator overseen by a board composed of regulators, state energy offices, and consumer, efficiency and environmental advocates.
3. Evaluate and update North Dakota's efficiency standards and building codes. Establish or reinforce monitoring and enforcement practices.
4. Establish a North Dakota Renewables Portfolio Standard requiring all retail electricity sellers to provide eight percent of their electricity from renewable resources by 2010 and 20 percent by 2020.
5. Establish a Renewable Energy Investment Fund to support emerging renewable technologies with a non-bypassable charge of at least 0.1¢/kWh.
6. Ensure that transmission pricing policies and power pooling practices treat renewable resources fairly and account for their intermittent nature, remote locations, or smaller scale.
7. Remove the barriers to clean distributed generation by: (1) applying net metering policies to all wind and photovoltaics; (2) establishing standard business and interconnection terms; (3) establishing uniform safety and power quality standards to facilitate safe and economic interconnection to the electricity system; and (4) applying clean air standards to small distributed generation sources, thereby promoting clean power technologies and discouraging highly polluting diesel generators.

**Figure 3: New Generation Resources in the Clean Energy Development Plan**

| Generator Type | 2010 New Capacity (MW) | 2020 Cumulative New Capacity (MW) |
|---|---|---|
| Wind Turbines | 750 | 2,550 |
| CHP – Biomass | 0 | 4 |
| Biomass - Co-Firing | 0 | 0 |
| Photovoltaics | 1 | 4 |
| Biomass Gasification | 0 | 0 |
| Eff. Natural Gas Gen.* | 79 | 180 |
| **Total** | **830** | **2,738** |

*Includes CHP (natural gas), district energy systems, and fuel cells.

# WIND FARM TAX REVENUE

## BRYANT TOWNSHIP - LOGAN COUNTY

### Allocation of Taxes per Year - 2006

| | | ONE TURBINE | 80 TURBINES |
|---|---|---|---|
| Property Value | | $ 2,900,000.00 | $ 232,000,000.00 |
| Tax Revenue | | $ 13,443.24 | $ 1,075,459.20 |

| Tax Recipient | Percent | Tax Amount | Tax Amount |
|---|---|---|---|
| State | 0.32% | $ 43.02 | $ 3,441.47 |
| County | 35.50% | $ 4,772.35 | $ 381,788.02 |
| Township | 5.82% | $ 782.40 | $ 62,591.73 |
| School | 56.96% | $ 7,657.27 | $ 612,581.56 |
| Fire | 1.40% | $ 188.21 | $ 15,056.43 |
| TOTAL | 100.00% | $ 13,443.24 | $ 1,075,459.20 |

# Figure 12

American Wind Energy Association

# FACTS ABOUT WIND ENERGY AND NOISE

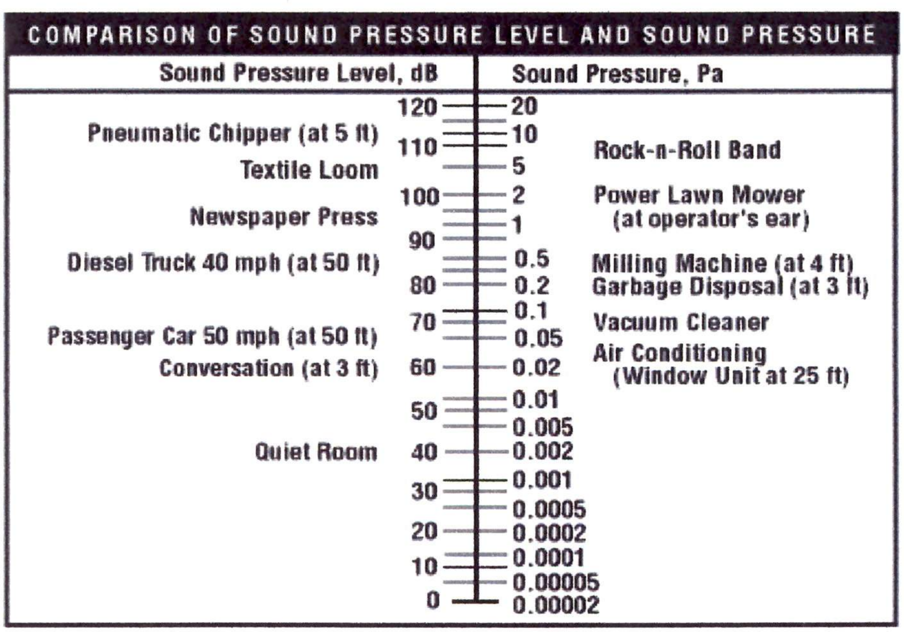
**<u>What is noise?</u>**

"Noise," when one is talking about wind energy projects, basically means "any unwanted sound."

Whether a noise is objectionable will vary depending on its type (tonal, broadband, low-frequency, impulsive, etc.) and the circumstances and sensitivity of the individual who hears it (often referred to as the "receptor").

As with beauty, often said to be "in the eye of the beholder," the degree to which a noise is bothersome or annoying is largely in the ear of the hearer. What may be a soothing and relaxing rhythmic swishing sound to one person may be quite troublesome to another.

Because of this, there is no completely satisfactory and impartial way to measure how upsetting a noise may be to any given person. Still, it **is** possible to objectively measure how loud a noise is. Here is a table showing the loudness ("sound pressure level") of some common noises:




Source: Canadian Centre for Occupational Health and Safety
(see www.ccohs.ca/oshanswers/phys_agents/noise_basic.html ).

**What kinds of noise do wind turbines produce?**

Wind turbines most commonly produce some **broadband** noise as their revolving rotor blades encounter turbulence in the passing air. Broadband noise is usually described as a "swishing" or "whooshing" sound.

Some wind turbines (usually older ones) can also produce **tonal** sounds (a "hum" or "whine" at a steady pitch). This can be caused by mechanical components or, less commonly, by unusual wind currents interacting with turbine parts. This problem has been nearly eliminated in modern turbine design.

**How noisy are wind farms?**

Good question, and a difficult one.

Wind plants are very, very quiet compared to other types of industrial facilities, such as manufacturing plants, but most industrial plants are not located in rural or low-density residential areas. In those types of areas, background noise tends to be lower than in urban areas.

On the other hand, wind plants are always located where the wind speed is higher than average, and the "background" noise of the wind tends to "mask" any sounds that might be produced by operating wind turbines—especially because the turbines only run when the wind is blowing. The only occasional exception to this general rule occurs when a wind plant is sited in hilly terrain where nearby residences are in dips or hollows downwind that are sheltered from the wind—in such a case, turbine noise may carry further than on flat terrain.

Virtually everything with moving parts will make some sound, and wind turbines are no exception. However, well-designed wind turbines are generally quiet in operation, and compared to the noise of road traffic, trains, aircraft, and construction activities, to name but a few, the noise from wind turbines is very low.

Noise used to be a very serious problem for the wind energy industry. Some early, primitive types of turbines built in the early 1980s were extremely noisy, to the point that it was annoying to hear them from as much as a mile away. The industry quickly realized that this problem needed to be dealt with, however (particularly in Europe, where turbines are often located in or near residential areas), and manufacturers went to work on making their machines quieter.

Today, an operating wind farm at a distance of 750 to 1,000 feet is no noisier than a kitchen refrigerator or a moderately quiet room.

| Source/Activity | Indicative noise level dB (A) |
|---|---|
| Threshold of hearing | 0 |
| Rural night-time background | 20-40 |
| Quiet bedroom | 35 |
| Wind farm at 350m | 35-45 |
| Car at 40mph at 100m | 55 |
| Busy general office | 60 |
| Truck at 30mph at 100m | 65 |
| Pneumatic drill at 7m | 95 |
| Jet aircraft at 250m | 105 |
| Threshold of pain | 140 |

Source: The Scottish Office, Environment Department, Planning Advice Note, PAN 45, Annex A: Wind Power, A.27. Renewable Energy Technologies, August 1994. Cited in "Noise from Wind Turbines," British Wind Energy Association, http://www.britishwindenergy.co.uk/ref/noise.html .

# Figure 13

# Figure 14

# MWT95/2.4 (60Hz,80m hub height)
# WIND TURBINE GENERATOR

# (WTI-A-095-R2)

**R2 18th.October.2006**

**MITSUBISHI HEAVY INDUSTRIES, LTD.**
**NAGASAKI SHIPYARD & MACHINERY WORKS**

**Contents**

# 1. INTRODUCTION

## 1.1 General Information of MWT95/2.4

In this document, the standard technical specification of MWT95/2.4 wind turbine generator will be described in a detailed manner. This intends to provide technical information regarding to the latest equipment and component installed in the wind turbine. Also included in this document is the latest outline and arrangement of the MWT95/2.4 Wind Turbine Generator.

Basically, MWT95/2.4 Wind Turbine Generator is the latest generation of wind turbine designed by Mitsubishi Heavy Industries (MHI) to meet the growing demand of the market in a high capacity but reliable and efficient wind turbine.

The design features of MWT95/2.4 wind turbine are as follows.

a.) Larger rotor diameter for high power capacity.
b.) Variable speed operation.
c.) Upwind, three blades with Individual Blade pitch control.
d.) Active Yaw System to track wind direction and Down Wind Soft Support for strong wind protection.
e.) High efficiency planetary/parallel/parallel in-house designed gearbox.
f.) Improved blade design for lightning protection and wind load reduction.

## 1.2 Outline of MWT95/2.4

MWT95/2.4 wind turbine generator is mainly composed of the following primary components and systems.

1. Rotor (Blades, Rotor Head, Pitch Control Equipment)
2. Power Train (Shaft, Gearbox, Generator)
3. Yaw System
4. Tower
5. Controller and Terminal for Communication

### 1.2.1. Rotor

The rotor is composed of three blades, the rotor head and the pitch control mechanism. The blade is attached in a blade bearing for longitudinal axis rotation. The blades can change pitch individually using the pitch control mechanism inside the rotor head. This is controlled using individual pitch control corresponding to the rotor azimuth angle and stress signal measured at the blade root. The rotor transmits the power to the power train through the mainshaft.

The blade bearing is lubricated with grease. Automatic Grease Distributor *) is prepared for easy maintenance to supply grease automatically during its operation as an option.

*) Option

#### 1.2.1.1 Blades

Blades are made from Glass Fiber Reinforced Plastic (GRFP). Each blade is approximately 46.2 m in length, and utilizes the modified NACA 63-XXX series airfoil. This type of blade has maximum lift for power generation but with low drag characteristics, which minimizes the propagated noise during operation.

The blade structure consists of two skins, the Low Pressure Skin and the High Pressure Skin and two shear webs, the Leading Edge Side Shear Web and the Trailing Side Shear Web. These parts are made from Glass Fiber Reinforced Plastic (GRFP) and core material and bonded together using resins and adhesive. MHI blades utilize stitch fabric material for its strength and lightweight properties.

For lightning strike protection, multiple metal receptors are installed along the body of each blade. These receptors are connected to a down conductor wire. This will conduct the surge of lightning current from the blade to the rotor head.

Blades are installed on the rotor head using T-bolts connections.

1.2.1.2 Rotor head (Hub)

The rotor head is the component on which the three blades are connected. The rotor head is made from cast iron. The pitch control mechanisms and hydraulic cylinders of the blades are attached to the rotor head. The static, dynamic and centrifugal force in the rotor head is transmitted to the nacelle bed-plate using the main shaft bearing.

1.2.1.3 Pitch Control Mechanism

Pitch control is used to control the power generated and to prevent the wind turbine from over-speeding. The pitch control mechanism controls the blade pitch individually with individual components such as hydraulic cylinders, control valves, accumulator, and feedback sensors.

In case of a hydraulic pump problem or leakage, there is an individual accumulator for each blade pitch control mechanism. During emergency situations, the accumulated pressure is sufficient enough to change the individual blade pitch into feathering position and stop or decrease the rotor rotation speed.

Also changing the blade pitch individually is a more effective way of aerodynamic brake. This is because in case that a single blade will not fully change into feather position, the remaining blades will be sufficient enough to decrease the rotor rotation.

1.2.2 Power Train

The power train is inclined at approximately 5° from the horizontal axis. The rotor is connected to the main shaft and rotates at 9-16.9 rpm and drives a speed increasing gearbox for wind turbine generator. The main shaft and gearbox are securely connected by a shrink disk.

The gearbox is connected to the generator by a flexible type shaft coupling. The high speed shaft has a steel mounted disk brake. This brake can be engaged during routine maintenance and emergency conditions.

1.2.2.1 Gearbox

The gearbox transmits torque and increases the rotational speed coming from the main shaft to the generator. The gearbox uses a 3 stage (planetary/parallel/parallel) gear arrangement. By using two oil pumps, the gearbox is lubricated and cooled by forcing the oil to flow through gears and bearings. To reduce mechanical noise propagation, the gearbox is mounted on the nacelle using anti-vibration bushings and torque arms.

1.2.2.2 Generator

The generator is doubly-fed asynchronous generator. It has self-lubricated bearing and uses an air cooling system. It has 6 poles and rating of 60±5% Hz, 690±10% volts. Generator conforms to IEC, JEC, and EMC standards and has a degree of protection of IP54.

1.2.2.3 Transformer

A step up transformer is mounted on the nacelle to step up the 690 V power generated to 34.5 kV* for standard option**. Installing the transformer on the nacelle enables a reduction in the installation cost of installing it outside the nacelle.

It has nominal capacity of 2700 kVA. The low voltage side is connected in star connection while the high voltage side is connected on delta connection.

*) This is the standard grid voltage. Depending on the request voltage, this is subjected to be changed based on the customer grid requirements with cost adjustment.

**) The requirement of installing the transformer outside the nacelle can be applied as an option. In this case, the transformer is to be supplied by the customer. The low voltage point 690V of the generator system is the connection between MHI and the customer. Details shall be estimated in accordance with the customer's request.

1.2.2.4 Braking System

There are two types of brakes. The first one is the aerodynamic brake which changes the pitch position of the blades. The second one is the high speed shaft brakes which use a brake disk mounted on the shaft and brake calipers.

Activation of each brake depends on the many different conditions. Generally, the pitch brake is used during normal braking conditions while the high speed shaft brake is used during emergency and maintenance. Also, the high speed shaft brake is used as parking brake.

### 1.2.3 Yaw System

The yaw system is composed of a yaw bearing, gears, and brake calipers. Yawing is automatically controlled to face the dominant wind direction.

The yaw bearing is lubricated with grease. Automatic Grease Distributor *) is prepared for easy maintenance to supply grease automatically during its operation as an option.

*) Option

### 1.2.4 Tower

The tower is the tapered mono-pole steel structure supporting the wind turbine generator. For a wind turbine hub height of 80m, the tower is divided into four sections. The base section has a diameter of approximately 4.8m and the top section has a diameter of 3 m. The sections of the tower are connected using bolts.

Tower accessories include the ladder, base for control panel, lights, safety ropes, etc.

### 1.2.5 Control and Safety System Concept

The Control and Safety System controls the blade pitch and yawing of the wind turbine during normal operating condition. The Control and Safety System protects the wind turbine using blade pitch, yaw, service brake, and generator contactors.

#### 1.2.5.1 Safety System

The safety system consists of hardwired circuits. This is completely different from software circuits. Along with protection device alarms, the hardwired circuits of the safety system can protect the wind turbine regardless of errors or incorrect actions of the controller.

The safety system will activate the safety action during grid loss or loss of power supply in equipments. The accumulator is used to put the blades in feather position. Appropriate control shutdown is done by UPS.

#### 1.2.5.2 Control System

During the normal condition, the wind turbine is controlled using the blade pitch control and the yaw control. The concept of control system, mainly in the power control of the wind turbine is shown in Figure 2.1.

a. Blade Pitch Control

A hydraulic cylinder is connected to each blade. MWT95/2.4 has blade pitch control that can change the blade pitch individually. Individual pitch control can reduce the fluctuating loads acting on the turbine as well as effective aerodynamic brake.

b. Yaw Control

During normal operation, the rotor is directed upwind and is redirected with changing direction for maximum power generation. The Yaw controls this changing of direction of the nacelle. During strong wind conditions, such as typhoon, the yaw control directs the rotor in downwind position for wind load reduction. This is smart yaw. If the wind speed goes back to normal condition, the rotor is directed again in the upwind position.

c. Service Brake

MWT95/2.4 has mechanical hydraulic disk brake installed in high speed shaft of gearbox. This service brake is used as a parking brake during maintenance and auxiliary brake during emergency conditions.

1.2.5.3 Arrangement of Control Device

Control and Safety System panel is classified according to their location and responsibility.

1. Hub Cabinet: Installed inside the rotor head and controls the blade pitch.
2. Top Cabinet: Installed inside the nacelle. It supervises the power generation control of wind turbine.
3. Converter Panel：Installed inside the nacelle and manages the power generation and conversion.
4. Ground Cabinet: Installed at the bottom of the tower and serves as the communication port for operation and data transmission.

## 2. GENERAL CONDITIONS

### 2.1 Design

The main parts of the wind turbine are designed with consideration of a theoretical 20 years lifetime under IEC (International Electro-technical Commission) Class IIA condition, except for seals and consumables.

- GFRP Blade
- Blade Bearing
- Rotor Head Structure
- Nacelle Bedplate
- Main Shaft
- Main bearing
- Gearbox
- Generator
- Yaw Gear
- Yaw Bearing
- Tower Structure

### 2.2 Service Interval

- Checking interval is every half year.
- Regular maintenance interval is one year.

### 2.3 Technical Standards

MWT95/2.4 wind turbine generator and its electrical equipment are manufactured in accordance with IEC and the following Japanese standards, which are applicable as of April 2006.

-JIS (Japanese Industrial Standard)

-JEM (The Standard of Japan Electrical Manufacturer Association)

-JEC (Japanese Electro-technical Committee)

### 2.4 Operating Grid Requirements

The required operating grid characteristic in which the wind turbine will be connected is according to IEC 61400. The grid voltage and frequency should have a nominal value of ±10% and ±2% respectively. Exceeding the stated tolerances may result in abnormal operation of the wind turbine and cause damage to electrical components.

Also, consideration to grid failure should be noted. The maximum power outages should not exceed once a week.

2.5 Painting and Corrosion Protection

The standard color of the MWT95/2.4 is light gray (Munsell Code N-8.5 equivalent). The paint grade that is used in the inside/outside surface of the nacelle and tower is according to ISO 12944. Applicable Corrosivity Categories are as follows.

a) For inland installation (Standard specification)

| | |
|---|---|
| Outside surface of Nacelle, Rotor Head and Tower | : C4 grade H |
| Inside surface of Nacelle, Rotor Head and Tower | : C3 grade H |

b) For near-shore installation (Optional specification)

| | |
|---|---|
| Outside surface of Nacelle, Rotor Head and Tower | : C5-M grade H |
| Inside surface of Nacelle, Rotor Head and Tower | : C4 grade H |

The corrosion protection of the blade is a Gel-coat.

2.6 Grounding System Requirements

The recommended transition resistance of the wind turbine to earth is below 2 ohm.

2.7 Environment Condition.

| | |
|---|---|
| Temperature | IEC 61400-1 Standard Condition<br>Operation: -10°C(-20°C*) ~ +40°C<br>Storage : -20°C(-30°C*) ~ +50°C<br>*) Option (under planning) |
| Elevation | below 1000 meters above sea level |
| Seismic condition | The area defined as the mapped spectral acceleration for a 1-second period, $S_1$<0.6g, as set forth in International Building Code 2006. |

2.8 Quality Control

MWT95/2.4 is manufactured at the facility in accordance with ISO-9001 (2000 edition)

2.9 Reservation of WTG Operation

MHI will determine the control strategy to prevent the loads of wind turbine from exceeding the designed load. MHI will immediately confirm the control strategy as soon as the owner provides the necessary site information. This includes basic site data, wind conditions, seismic loading, terrain characteristics, site lay-out, network condition including power station specification and project schedule.

MHI shall have no responsibility for project liabilities if the information given by the owner is inaccurate and not precise.

## 3. SCOPE

Normally, MWT95/2.4 has the primary parts and equipment already assembled at the MHI plant and can be delivered on the scheduled time; which the owner and MHI will mutually agreed to. But there is some equipment and parts of the wind turbine that the customer will need to provide in each project. These items are in the scope of responsibility of the owner.

Shown below is the table in which the MWT95/2.4 parts and equipment are itemized. This table will includes which party which will be responsible for the supply of particular equipment and which will install the equipment, etc. Also, attachment 3 shows the figure of the scope of responsibility between MHI and the customer.

Note that this arrangement is subjected to change based on the agreement between MHI and the customer. Also, the quantity of the wind turbines will depend on the customer requirements and decisions.

| MWT95/2.4 Parts and Equipments | | Party In-Charge | | Remarks |
|---|---|---|---|---|
| | | Supply | Installation | |
| 1 | Front Nacelle<br>·Gearbox<br>·LO Unit<br>·Other Front Nacelle Accessories | MHI | Customer | All equipments will be installed at the assembly shop |
| 2 | Rear Nacelle<br>·Generator<br>·Transformer(Standard Option)<br>·Control Cabinet<br>·Lightning Rod<br>·Ultrasonic Anemometer<br>·Cooling Equipments<br>·Other Nacelle Accessories | MHI | Customer | Except for the lightning rod and ultrasonic anemometer, all equipments will be installed at the assembly shop. |
| 3 | Yaw Module<br>·Yaw Motor<br>·GO Unit<br>·Other Yaw Module Accessories | MHI | Customer | All equipments will be installed at the assembly shop |
| 4 | Rotor<br>·Blades<br>·Rotor Head<br>·Pitch Control Mechanism<br>·Other Rotor Accessories | MHI | Customer | The blades will be separately transported and installed on the construction site prior to erection |

| MWT95/2.4 Parts and Equipments | | Party In-Charge | | Remarks |
|---|---|---|---|---|
| | | Supply | Installation | |
| 5 | Tower<br>Tower Climbing Ladder<br>Tower Connecting Bolts<br>Other Tower Accessories | MHI | Customer | The tower will be transported to the construction site by sections<br>Anchor Bolt and Template shall be provided by customer |
| 6 | Aviation Obstacle Light | Customer | Customer | |
| 7 | Switch Gear | Customer | Customer | The specification of switch gear will be recommended by MHI |
| 8 | Ground Cabinet | MHI | Customer | |
| 9 | Tower Grounding | Customer | Customer | |
| 10 | Tower Foundation | Customer | Customer | Tower foundation will be constructed by customer prior to WTG erection |
| 11 | Other WTG Accessories (Lifting Beams, Special Tools and Equipments, etc) | MHI | Customer | The quantity of tools shall be discussed between customer and MHI, and the price shall be separately quoted |
| 12 | Communication Cable | Customer | Customer | |
| 13 | Power Cable from Switchgear to Substation | Customer | Customer | |
| 14 | Substation | Customer | Customer | |
| 15 | Substation Ground System | Customer | Customer | |
| 16 | Utility Grid | Customer | Customer | The grid specification will depend on the customer |

## 4. SPECIFICATION OUTLINE

Primary Standard Specification of "MWT95/2.4" is as follows.

### 4.1 General Specification

| | |
|---|---|
| Rated output | 2,400 kW |
| Hub Height | 80 m |
| Power Regulation | Individual Pitch Control |
| Yaw Orientation | Active Yaw Control |
| Designed Wind Class | Extreme: IEC Class IIA |
| | Fatigue: IEC Class IIA |
| Rated wind speed | 12.5 m/s |
| Cut-in wind speed | 3.0 m/s at 10 minutes |
| Cut-out wind speed | 25.0 m/s at 10 minutes (30.0m/s during 2sec) |
| Reset from Cut-out | 20.0 m/s at 10 minutes |
| Power curve* | Refer to Attachment-2 |

* Air Density 1.225 kg/$m^3$ at 10 minutes average

### 4.2 Technical Specifications

#### 4.2.1 Rotor

| | |
|---|---|
| Number of Blades | 3 |
| Diameter | 95.0 m |
| Swept area | 7,088.2 $m^2$ |
| Rotation Speed | 9~16.9 rpm |
| Tip Speed | 75 m/s at 15 rpm |
| Rotational Direction | Clockwise against wind direction |
| Orientation | Upwind |
| Cone Angle | -2 degrees |
| Tilt Angle | approx. +5 degrees to horizontal axis |

4.2.1.1 Blades

| | | |
|---|---|---|
| Length | | 46.2 m |
| Material | | GFRP (Glass Fiber Reinforced Plastic) |
| Airfoil (profile) | | NACA 63-XXXX |
| Twist from root to tip | | approximately 20.8 degrees |
| Chord Length | Root | approximately 1136 mm |
| | Tip | approximately 3513 mm |

Each blade is fitted with multiple metal receptors and a down-conductor for lightning protection.

4.2.1.2 Rotor Head (Hub)

| | |
|---|---|
| Type | Cast Iron |
| Material | JIS FCD400L-18L |
| Corrosion | Anti-Corrosion Painted |

4.2.2 Tower

| | |
|---|---|
| Type | Tapered Mono-pole |
| Materials | Steel |
| Hub Height | 80 m* |
| Ground Clearance | approximately 32.5 m (Hub Height 80 m) |
| Top Diameter | approximately 3.0 m |
| Base Diameter (max. dia.) | approximately 4.8 m |
| Tower utilities | A Ladder, Stage Floors, Safety Wire, Lights, Door, Pad Lock, and Base Floor for control panel |
| Number of sections | 4 sections |
| Foundation/Anchor System | Anchor Bolts |

*****This includes the distance from the top tower section flange to hub center.

### 4.2.3 Nacelle

#### 4.2.3.1 Nacelle Cover

| | |
|---|---|
| Material | GFRP |

#### 4.2.3.2 Nacelle frame

| | |
|---|---|
| Type | Cast Iron |
| Material | JIS FCD400-18L |
| Corrosion | Anti-Corrosion Painted |

#### 4.2.3.3 Main shaft

| | |
|---|---|
| Type | Forged Steel |
| Material | JIS S45C |

#### 4.2.3.4 Main bearing

| | |
|---|---|
| Type | Double Taper Roller Type |
| No. of bearing | 1 set |
| Oil Lubrication | Forced lubrication |

#### 4.2.3.5 Gearbox

| | |
|---|---|
| Type | 3 Stages, Planetary/Helical/Helical |
| Gear Ratio | approximately 1:90.6 for 60Hz |
| Nominal Rotational Speed | |
| High Speed Shaft to generator | about 1,359 rpm |
| Low Speed Shaft to Rotor | 15 rpm |
| Oil Lubrication | Oil bath, Splash, and Forced lubrication |

#### 4.2.3.6 Mechanical service brake

| | |
|---|---|
| Type | Disk brake, mounted on high speed shaft |
| Material | Steel |
| Number of caliper | 1 piece |

4.2.3.7 Coupling

| | |
|---|---|
| Type | Flexible type shaft coupling |

4.2.3.8 Generator

| | |
|---|---|
| Type | Doubly-fed Asynchronous Generator with Wound Rotor |
| Nominal Capacity | 2520 kW |
| Number of Poles | 6 poles |
| Synchronous Speed | 1200 rpm |
| Rated Voltage | 690 V±10% |
| Frequency | 60 Hz± 5% |
| Degree of Protection | IP54 |
| Rating | Continuous |
| Standards | IEC, JEC, and EMC standards |

4.2.3.9 Converter

| | |
|---|---|
| Type | PWM with IGBT Power Converter |
| Nominal Capacity | 800 kVA |
| Rated Voltage | 690 V |
| Frequency | 60 Hz |
| Power Factor Range | 0.9 (inductive) ~ 0.95 (capacitive) |

4.2.3.10 Transformer (Standard Option)

| | |
|---|---|
| Nominal Capacity | 2,700 kVA |
| Rated Voltage | 690V/34.5kV* |
| Connection | Y/△ |

*****) This is the standard voltage. This is subject to change depending on the customer's request based on grid requirements.

4.2.3.11 Hydraulic unit

| | |
|---|---|
| Function | Governing oil unit<br>To supply hydraulic oil (Control hydraulics for blade pitch, main shaft brake and yaw brake) with oil cooling |
| Working pressure | 25.0 MPa |
| Oil type | ISO VG32 |
| Pump capacity | 43.5 L/min @25.0 MPa, 22kW |

4.2.2.12 Yaw System

| | |
|---|---|
| Control type | Active feedback |
| Yaw Drive | Geared Induction Motor |
| Power Rating | 3.8 kW x 4sets |
| Orientation speed of nacelle | about 0.4° per second |
| Support | 4 points bearing |

4.2.13 Mechanical yaw brake

| | |
|---|---|
| Type | Disk brake mounted on yaw bearing |
| Material | Steel |
| Number of caliper | 9 pieces |

| | |
|---|---|
| 4.3 Nacelle Utilities | Emergency stop button, Service socket, Service valve for hydraulics, Lights, Lifting Winch, Access Hatch, Maintenance foothold area inside the nacelle. |

4.4 Wind Turbine Control System

| | |
|---|---|
| Power Regulation | Individual Pitch Control |
| Yaw Orientation | Active YAW control |
| Methodology | Two Ultrasonic Anemometers and Wind Vanes |
| Communication method | Ethernet |
| Control method | Manual at the site |

| | |
|---|---|
| | Remote start and/or stop by the SCADA System* |

*The owner shall decide for the SCADA System that will be used.

4.5 Lightning Protection (IEC Level 1)

| | |
|---|---|
| Blade | There are multiple metal receptors on the blade and a down-conductor wire inside of the blade. |
| Nacelle | The surge of current will be led away from the frame of nacelle to the tower. |
| Tower | The tower itself will become the conductor from the nacelle to the ground. |

## **5. Options**

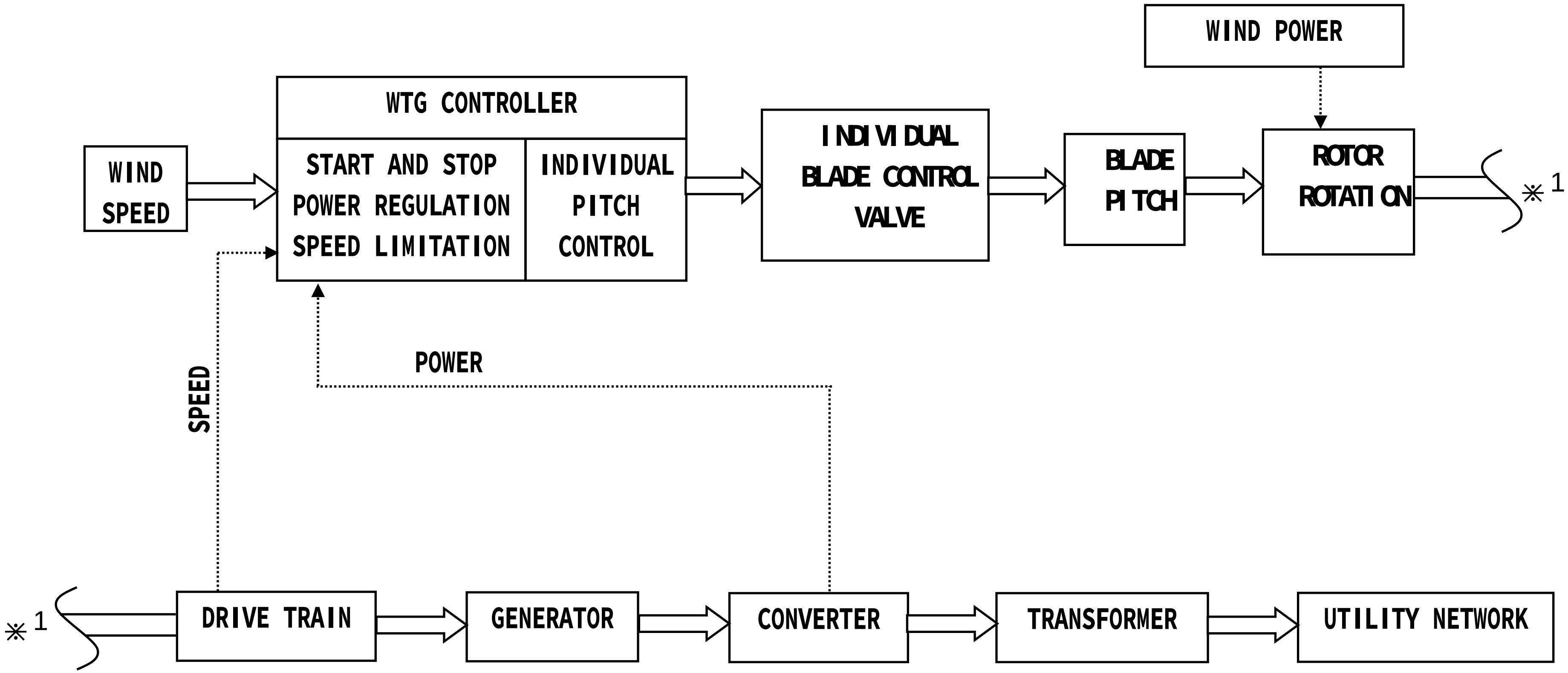
The following will be options.

- Elevator or Climb assist device
- Fire Extinguisher
- Special Rotor Turning Unit for Single Blade Installation ※
- Automatic Grease distributor :Blade Bearing<br>:Yaw Bearing
- Special service winch※※
- Cold Weather Package

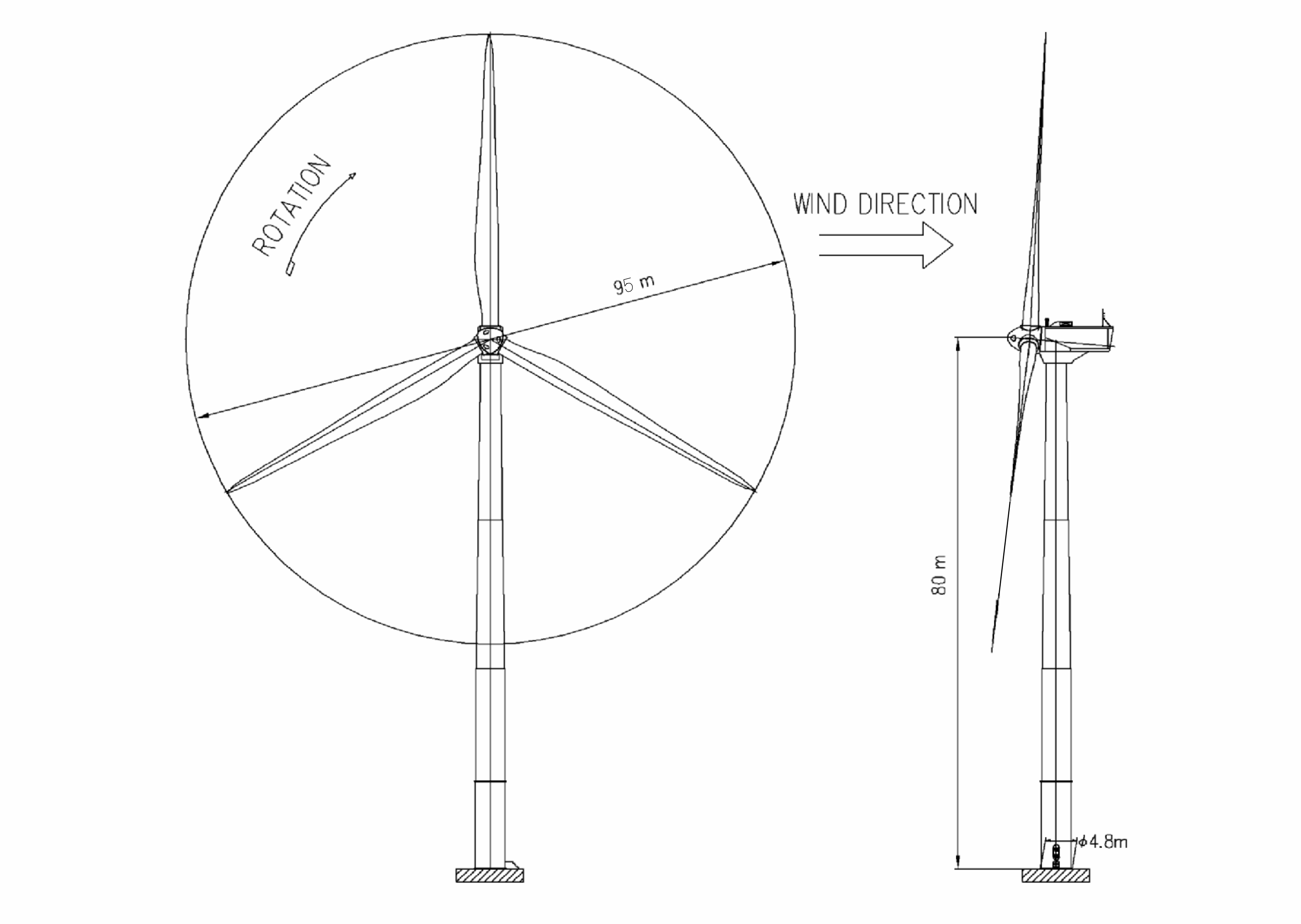
※ Standard Rotor Turning Unit for maintenance will be equipped as standard.

※※Standard service winch for maintenance (capacity : 500kg) will be equipped as standard.

Figure 2-1: Power Control System



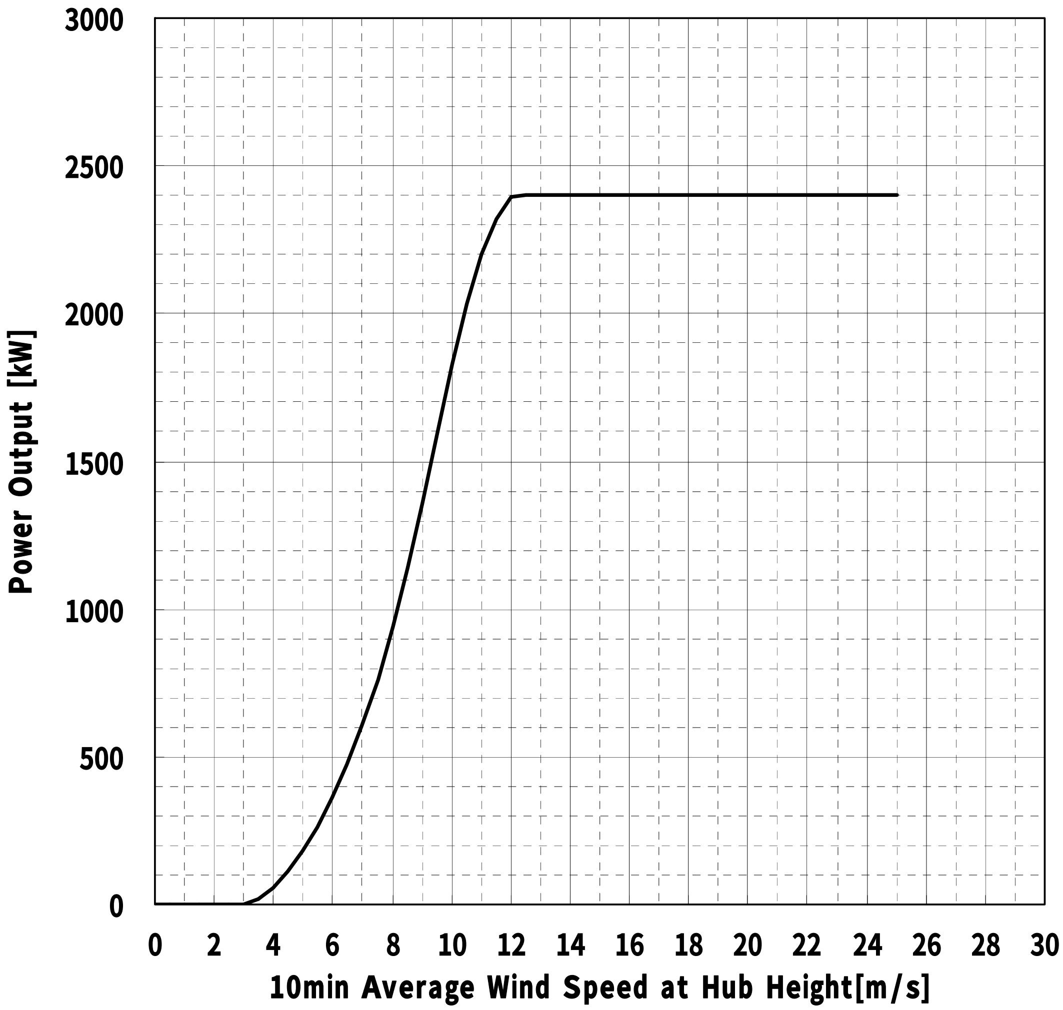
Attachment 1: Outline of MWT95/2.4 & 80m tower



**Attachment-2 Standard Power Curve of MWT95/2.4:**

The Standard power curve of MWT95/2.4 is shown below. Also corresponding values are arranged and shown in the table form in the following page.

Condition is the air density 1.225kg/m3 (15℃ of air temperature, 1013mbar of air pressure), clean rotor blades, horizontal and standard air flow.




**Remarks:**

The following assumptions and conditions are solely for the purpose of expressing the relationship between wind speed and kilowatt productions and do not constitute representations or warranties of actual conditions.

- The above data are valid at the 10 minutes average speed data measurement at the hub height only.
- The output is measured at the low voltage side of the transformer inside the nacelle.
- For the purpose of computing power output with respect to the power curve, the turbulence intensity is assumed to be 10%.
- This power curve assumes flat ground and the absence of any external factor that could affect the force or direction of wind transition of electrical energy. (for example, array loss, topography, grid loss, etc.)
- This power curve and the turbine specifications assume that the site wind condition is on or below IEC Class IIA Standards.

**Standard Power Curve for MWT95/2.4**

Condition is the air density 1.225kg/m3 (15℃ of air temperature, 1013mbar of air pressure), clean rotor blades, horizontal and standard air flow.

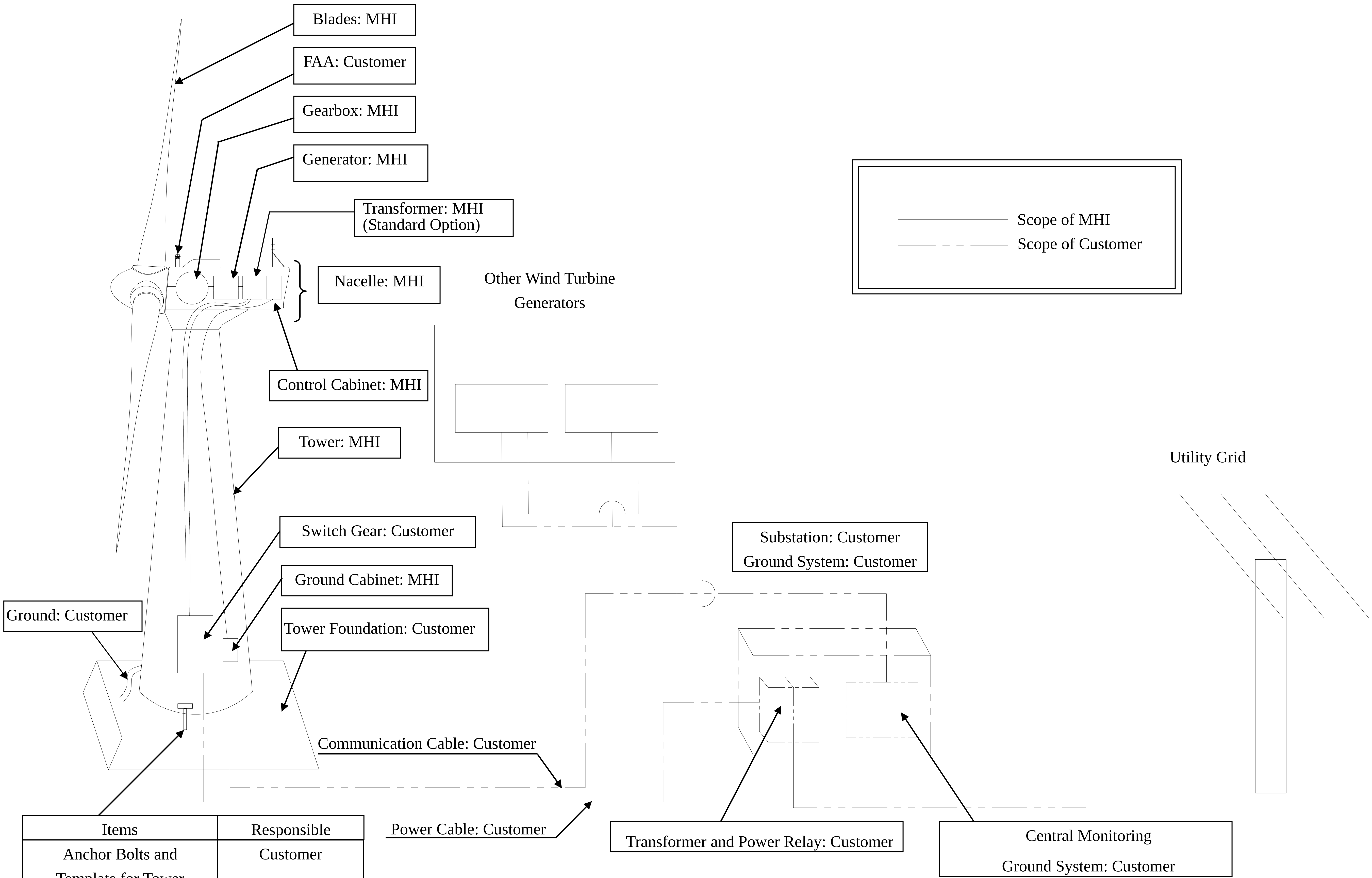
| Wind Speed @ Hub Height (m/s) | Output Power (kW) Air Density γ=1.225 | Wind Speed @ Hub Height (m/s) | Output Power (kW) Air Density γ=1.225 |
|---|---|---|---|
| 3.0 | 0 | 14.5 | 2400 |
| 3.5 | 17 | 15.0 | 2400 |
| 4.0 | 58 | 15.5 | 2400 |
| 4.5 | 114 | 16.0 | 2400 |
| 5.0 | 182 | 16.5 | 2400 |
| 5.5 | 263 | 17.0 | 2400 |
| 6.0 | 361 | 17.5 | 2400 |
| 6.5 | 475 | 18.0 | 2400 |
| 7.0 | 608 | 18.5 | 2400 |
| 7.5 | 762 | 19.0 | 2400 |
| 8.0 | 941 | 19.5 | 2400 |
| 8.5 | 1140 | 20.0 | 2400 |
| 9.0 | 1361 | 20.5 | 2400 |
| 9.5 | 1595 | 21.0 | 2400 |
| 10.0 | 1828 | 21.5 | 2400 |
| 10.5 | 2035 | 22.0 | 2400 |
| 11.0 | 2203 | 22.5 | 2400 |
| 11.5 | 2322 | 23.0 | 2400 |
| 12.0 | 2396 | 23.5 | 2400 |
| 12.5 | 2400 | 24.0 | 2400 |
| 13.0 | 2400 | 24.5 | 2400 |
| 13.5 | 2400 | 25.0 | 2400 |
| 14.0 | 2400 | >25.0 | 0 |

**Remarks:**

The following assumptions and conditions are solely for the purpose of expressing the relationship between wind speed and kilowatt productions and do not constitute representations or warranties of actual conditions.

- The above data are valid at the 10 minutes average speed data measurement at the hub height only.
- The output is measured at the low voltage side of the transformer inside the nacelle.
- For the purpose of computing power output with respect to the power curve, the turbulence intensity is assumed to be 10%.
- This power curve assumes flat ground and the absence of any external factor that could affect the force or direction of wind transition of electrical energy. (for example, array loss, topography, grid loss, etc.)
- This power curve and the turbine specifications assume that the site wind condition is on or below IEC Class IIA Standards.

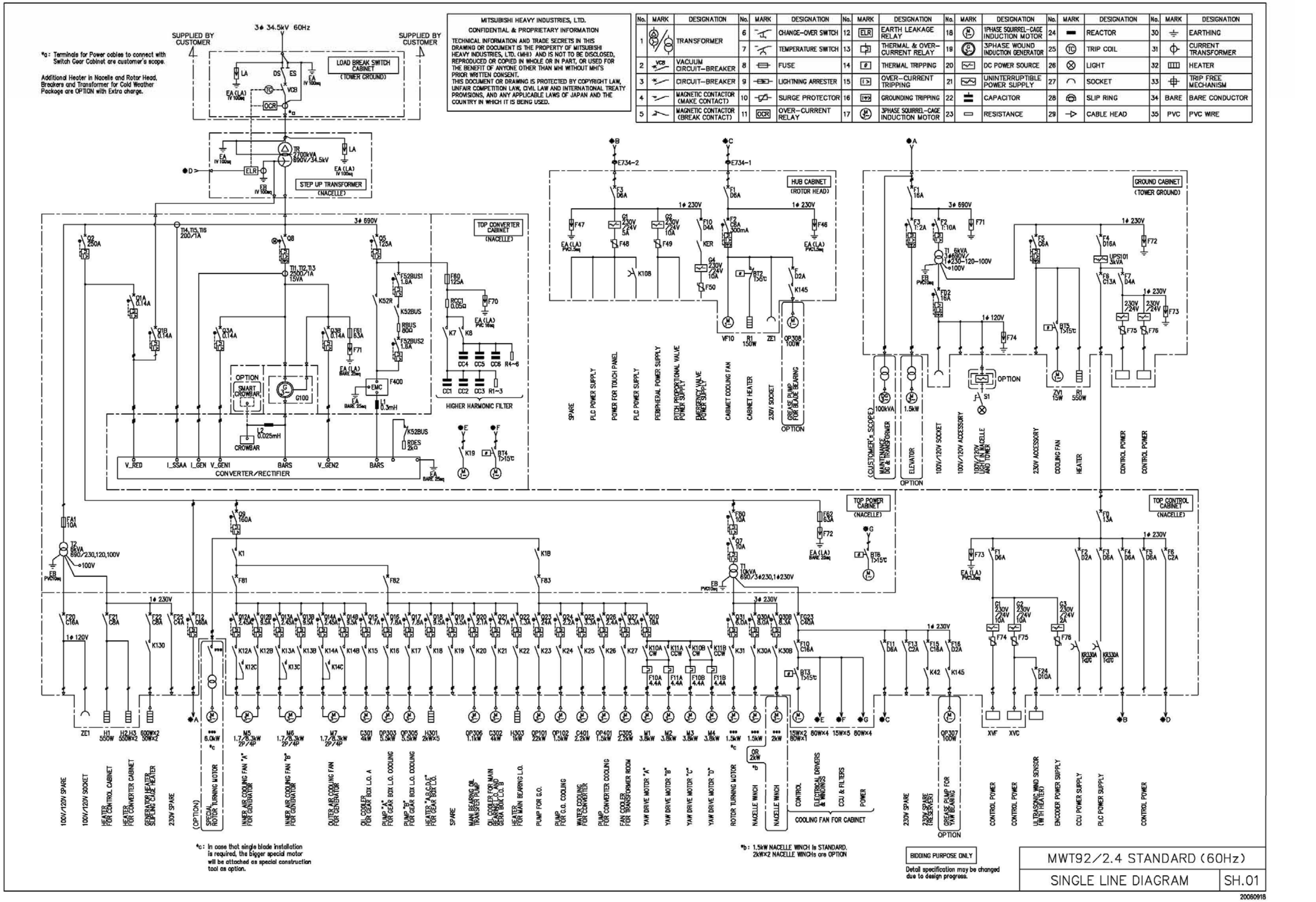
Attachment 3: Division of Responsibilities




| Items | Responsible |
|---|---|
| Anchor Bolts and Template for Tower | Customer |
| Other Accessories for Tower | MHI |

Attachment 4: Single Line Diagram for MWT92/2.4 <u>NOTE: For MWT95, the capacity of some auxiliary motors might be changed</u>.

Bidding Purpose Only



# MWT95/2.4

## 2.4MW-60Hz

Electrical-power[kW] is shown as a function of 10min. average wind speed[m/s] at hub height and air density[kg/m$^3$]

| Density | 0.9800 | 1.0000 | 1.0500 | 1.1000 | 1.1500 | 1.2000 | 1.2250 | 1.2500 |
|---|---|---|---|---|---|---|---|---|
| Wind Speed (m/s) | Power Output (kW) | Power Output (kW) | Power Output (kW) | Power Output (kW) | Power Output (kW) | Power Output (kW) | Power Output (kW) | Power Output (kW) |
| 0.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.5 | 4 | 5 | 8 | 10 | 13 | 15 | 17 | 18 |
| 4.0 | 35 | 37 | 41 | 46 | 50 | 56 | 58 | 61 |
| 4.5 | 78 | 81 | 88 | 96 | 103 | 110 | 114 | 117 |
| 5.0 | 132 | 136 | 146 | 156 | 166 | 176 | 182 | 186 |
| 5.5 | 198 | 203 | 216 | 230 | 243 | 256 | 263 | 270 |
| 6.0 | 276 | 283 | 300 | 318 | 335 | 353 | 361 | 370 |
| 6.5 | 367 | 376 | 398 | 420 | 442 | 464 | 475 | 485 |
| 7.0 | 473 | 485 | 512 | 540 | 567 | 594 | 608 | 622 |
| 7.5 | 596 | 610 | 644 | 678 | 711 | 745 | 762 | 779 |
| 8.0 | 740 | 757 | 798 | 838 | 879 | 921 | 941 | 962 |
| 8.5 | 899 | 918 | 968 | 1017 | 1067 | 1116 | 1140 | 1164 |
| 9.0 | 1077 | 1099 | 1158 | 1216 | 1275 | 1332 | 1361 | 1390 |
| 9.5 | 1270 | 1297 | 1365 | 1431 | 1498 | 1563 | 1595 | 1627 |
| 10.0 | 1473 | 1504 | 1580 | 1653 | 1726 | 1795 | 1828 | 1860 |
| 10.5 | 1678 | 1711 | 1792 | 1866 | 1939 | 2005 | 2035 | 2065 |
| 11.0 | 1876 | 1909 | 1988 | 2055 | 2121 | 2178 | 2203 | 2227 |
| 11.5 | 2052 | 2081 | 2151 | 2206 | 2260 | 2305 | 2322 | 2340 |
| 12.0 | 2197 | 2221 | 2279 | 2318 | 2358 | 2390 | 2396 | 2369 |
| 12.5 | 2280 | 2298 | 2340 | 2361 | 2388 | 2393 | 2400 | 2400 |
| 13.0 | 2358 | 2370 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 |
| 13.5 | 2397 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 |
| 14.0 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 |
| 14.5 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 |
| 15.0 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 |
| 15.5 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 |
| 16.0 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 |
| 16.5 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 |
| 17.0 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 |
| 17.5 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 |
| 18.0 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 |
| 18.5 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 |
| 19.0 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 |
| 19.5 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 |
| 20.0 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 |
| 20.5 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 |
| 21.0 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 |
| 21.5 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 |
| 22.0 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 |
| 22.5 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 |
| 23.0 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 |
| 23.5 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 |
| 24.0 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 |
| 24.5 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 |
| 25.0 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 | 2400 |

1) This power curve is provided for information purpose only and is not to be relied upon or considered to be anything but preliminary and estimated assumptions. Output Power means measured power at the end of the control panel.
2) Calculated values are based on the Rayleigh wind speed distribution
3) This document and the information contained is Confidential and therefore you are hereby notified that you must not use, disseminate or copy this document or take any action in reliance on this document or any information contained therein.

# Figure 16

# Report of Preliminary Soil Investigation

Proposed Wind Farm
Napoleon, North Dakota
MTL Project No B8300

**Midwest Testing Laboratory, Inc.**

1805 Hancock Dr
PO Box 2084
Bismarck, ND 58502-2084
Phone 701.258.2833
Fax 701.258.2857

*"Helping You Build!"*

MIDWEST TESTING LABORATORY, INC.

1805 Hancock Drive ▲ P.O. Box 2084 ▲ Bismarck, ND 58502-2084 ▲ 701-258-2833 ▲ Fax 701-258-2857

November 17, 2006

Mr. Rob Lee
Wanzek Construction, Inc
PO Box 2019
Fargo, ND 58107-2019

RE: Preliminary Soil Investigation
Proposed Wind Farm
Napoleon, North Dakota
MTL Project No B8300

Dear Rob:

The attached report covers the soil investigation we conducted for the above-referenced project. Three copies of our report are being furnished for your use. The work was conducted in accordance with your instructions and authorization.

Approximately 50 percent of the soil samples obtained will be held at our office for two months and will then be discarded unless we are notified to hold them for a longer period of time.

The evaluations contained in this report have considered the normal contingencies; however, should any questions arise pertaining to the soil conditions during preparation of the working drawings or unexpected conditions develop during construction, please contact us.

Sincerely,

MIDWEST TESTING LABORATORY, INC.

Steven S. Smith, P.E.

SSS/cb

## REPORT OF PRELIMINARY SOIL INVESTIGATION

**Proposed Wind Farm**
**Napoleon, North Dakota**
**MTL Project No B8300**

### INTRODUCTION

We understand the proposed project may consist of constructing 27 wind generators in the Napoleon area. The project is in the preliminary stages of development. In an effort to evaluate the proposed site, one soil test boring was performed on November 9, 2006. The purpose of this boring was to determine the soil conditions at the site and obtain samples for laboratory analysis. The following report will describe the soil conditions encountered and with the aid of laboratory analysis, evaluate these conditions in relation to the proposed construction.

### SITE AND SOIL CONDITIONS

The test boring was advanced within the NE¼ of Section 14, Township 135N, Range 72W in Logan County, North Dakota. This site is approximately four miles east and one-half mile south of the intersection of North Dakota State Highways 3 and 34.

Soil conditions encountered within our test boring consisted of lean clays with sand of a grayish brown to light olive brown color. These medium plasticity clays had field consistencies ranging from rather stiff to very stiff but generally were of a stiff consistency. Lean clays were identified to a depth of approximately 39 feet with our test boring then terminating in a sand with silt.

The preceding discussion is intended as a general review of the soil conditions encountered. For a more complete description, we refer you to the attached boring log.

## GROUNDWATER

Groundwater was not encountered within our test boring during advancement nor when rechecked upon completion. A summary of the times of recording is included on the attached boring log. Groundwater levels should be expected to vary on both a seasonal and annual basis. However, considering the proposed project, we would not anticipate any construction difficulties due to groundwater at this site.

## LABORATORY INVESTIGATION

Several samples of the soils encountered were selected for laboratory analysis. The testing program consisted of the determination of the soil's index properties including moisture, density and atterberg limits. Additionally, strength characteristics were evaluated utilizing unconfined compressive test procedures. All test results are included on the attached boring log opposite the samples on which they were performed.

## DISCUSSION

Based on information obtained, in our opinion, the proposed site as represented by the soil conditions encountered within our test boring would be suitable for supporting wind generator construction. Assuming foundations are obtaining support at a depth of six to seven feet below existing grades, soils providing direct support should consist of stiff lean clays with sand. Based on standard penetration resistance values, laboratory test results, and our past experience with similar soils, in our opinion, an allowable bearing capacity of 4000 psf (pounds per square foot) would be available at this location. A loading of this magnitude would provide a theoretical factor of safety of three against an actual shear failure and detrimental settlement should not occur.

For lateral loads, the friction factor between the bottom of the mass concrete mat foundation and the underlying stiff clays can be taken as 0.30. This frictional resistance will give the ultimate resistance to lateral loads. A minimum safety factor of two should be applied.

As previously stated, 27 wind towers are proposed at the site. It is imperative that one boring be performed at each of the proposed tower locations in order to provide design recommendations for each specific wind generator. Midwest Testing Laboratory is prepared to provide these services should the decision be made to proceed with the project.

## FIELD INVESTIGATION PROCEDURES

One soil test boring was performed at the site on November 9, 2006. The boring was advanced at a location discussed with you and as shown on the attached sketch.

### Soil Sampling

The boring was advanced with 3¼ inch hollow stem auger, with split barrel samples obtained in accordance with ASTM:D1586-99. Using this procedure, a two-inch O.D. split barrel sampler is driven by a 140-pound weight falling 30 inches. The number of blows required to drive the sampler twelve inches after a six-inch initial set is the standard penetration resistance and will be referred to as N value, an index related to the consistency of cohesive soils and the relative density of cohesionless soils.

### Soil Classifications

As the boring was advanced in the field and samples obtained, they were visually and manually classified in accordance with ASTM:D2488-00. Representative portions of all samples were returned to the laboratory for review of the field classifications. Selected samples were submitted to a program of laboratory tests to aid in determining the characteristics of the soil. A log of the boring, laboratory test results and charts illustrating the soil classification procedures and descriptive terminology are attached.

## LIMITATIONS OF INVESTIGATION

The area of the boring in relation to the entire site is relatively small and therefore, should not be assumed to be necessarily typical of the entire area of the site. Also, this investigation cannot represent soil conditions below the depth of our boring. Because of these and other reasons, we recommend close observation during construction for soil conditions not typical of the strata logged.


I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly Registered Professional Engineer in the state of North Dakota.

Steven S. Smith, P.E.

Date: Nov. 17, 2006 Reg. No: 2863

# MIDWEST TESTING LABORATORY

JOB NO.: B8300 LOG OR TEST BORING NO.: 1 (page 1) VERTICAL SCALE: 1"=4'

PROJECT: Proposed Wind Farm, Napoleon, North Dakota

| DEPTH IN FEET | SOIL DESCRIPTION<br>SURFACE ELEVATION: --- | SAMPLE | | N | LABORATORY TESTS | | | |
|---|---|---|---|---|---|---|---|---|
| | | NO. | TYPE | | MOISTURE | DENSITY | LL/PL | $Q_u$ (psf) |
| | LEAN CLAY WITH SAND-grayish brown, rather stiff to very stiff to stiff, with gravel, surface vegetation in upper 5" (CL) | 1 | SS | 17 | | | | |
| | | 2 | SS | 36 | | | | |
| | | 3 | SS | 24 | | | | |
| 6½ | LEAN CLAY WITH SAND-light olive brown, very stiff to stiff to rather stiff to stiff to very stiff, trace of gravel @ 12', rock @ 35' (CL) | 4 | SS | 35 | 20 | 107 | | 6300 |
| | | 5 | SS | 26 | | | 46/14 | |
| | | 6 | SS | 14 | | | | |
| | | 7 | SS | 28 | 18 | 114 | | 9100 |
| | | 8 | SS | 33 | | | | |
| | | 9 | SS | 35 | | | 41/14 | |
| | | 10 | SS | 39 | 19 | 112 | | 10,700 |
| 31 | (continued on next page) | | | | | | | |

# MIDWEST TESTING LABORATORY

JOB NO.: B8300 LOG OR TEST BORING NO.: 1 (page 2) VERTICAL SCALE: 1"=4'

PROJECT: Proposed Wind Farm, Napoleon, North Dakota

| DEPTH IN FEET | SOIL DESCRIPTION<br>SURFACE ELEVATION: | SAMPLE NO. | SAMPLE TYPE | N | MOISTURE | DENSITY | LL/PL | $Q_u$ |
|---|---|---|---|---|---|---|---|---|
| | (continued from page 1)<br><br>LEAN CLAY WITH SAND-light olive brown, very stiff to stiff to rather stiff to stiff to very stiff, trace of gravel @ 12, rock @ 35' (CL) | 11 | SS | 91 | | | | |
| 39½ | SAND WITH SILT-light brown, fine-grained, very dense to dense (SP-SM) | 12 | SS | 59 | | | | |
| | | 13 | SS | 24 | | | | |
| 46 | END OF BORING | | | | | | | |

WATER LEVEL DATA

| DATE | TIME | CAVE IN DEPTH | WATER LEVEL |
|---|---|---|---|
| 11-9-06 | 10:55 | HSA 44½' | None |
| 11-9-06 | 11:12 | 43' | None |
| | | | |
| | | | |

BORING DATA

**STARTED:** 11-9-06 **COMPLETED:** 11-9-06 @ 11:12

**METHOD USED:** 3¼" ID HSA 0-44½'

**CREW CHIEF:** M. Roberts

# Classification of Soils For Engineering Purposes

ASTM:D 2487-98

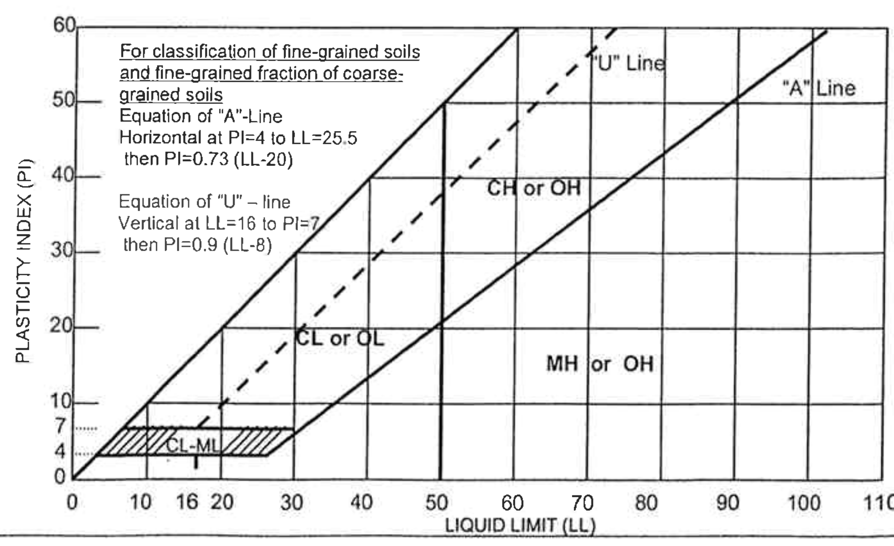
| Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[A] | | | | Soil Classification | |
|---|---|---|---|---|---|
| | | | | Group Symbol | Group Name[B] |
| Coarse-Grained Soils More than 50% retained on No. 200 Sieve | Gravels More than 50% coarse fraction retained on No. 4 Sieve | Clean Gravels Less than 5% fines[C] | Cu≥4 and 1≤Cc≤ 3[E] | GW | Well graded gravel[F] |
| | | | Cu<4 and/or 1>Cc>3[E] | GP | Poorly graded gravel[F] |
| | | Gravels with Fines More than 12% fines[C] | Fines classify as ML or MH | GM | Silty gravel[F.G.H.] |
| | | | Fines classify as CL or CH | GC | Clayey gravel[F.G.H.] |
| | Sands 50% or more of coarse fraction passes No. 4 Sieve | Clean Sands Less than 5% fines | Cu≥6 and 1≤Cc≤3[E] | SW | Well-graded sand[I] |
| | | | Cu<6 and/or 1>Cc>3[E] | SP | Poorly graded sand[I] |
| | | Sands with Fines More than 12% fines[D] | Fines classify as ML or MH | SM | Silty sand[G.H.I.] |
| | | | Fines classify as CL or CH | SC | Clayey sand[G.H.I.] |
| Fine-Grained Soils 50% or more passes the No. 200 Sieve | Silts and Clays Liquid limit less than 50 | Inorganic | PI> 7 and plots on or above "A" line[J] | CL | Lean clay[K.L.M.] |
| | | | PI<4 or plots below "A" line[J] | ML | Silt[K.L.M.] |
| | | Organic | (Liquid limit - oven dried) / (Liquid limit - not dried) <0.75 | OL | Organic clay[K.L.M.N.] |
| | | | | | Organic silt[K.L.M.O.] |
| | Silts and Clays Liquid limit 50 or more | Inorganic | PI plots on or above "A" line | CH | Fat clay[K.L.M.] |
| | | | PI plots below "A" line | MH | Elastic silt[K.L.M.] |
| | | Organic | (Liquid limit - oven dried) / (Liquid limit - not dried) <0.75 | OH | Organic clay[K.L.M.P] |
| | | | | | Organic silt[K.L.M.Q] |
| Highly organic soils Fibric Peat > 67% Fiber | Primary organic matter, dark in color, and organic odor Hemic Peat 33%-67% Fibers | | | PT | Peat Sapric Peat < 33% Fibers |

[A]Based on the material passing the 3-in. (75mm) sieve.
[B]If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.
[C]Gravels with 5 to 12% fines require dual symbols:
- GW-GM well-graded with silt
- GW-GC well-graded gravel with clay
- GP-GM poorly graded gravel with silt
- GP-GC poorly graded gravel with clay

[D]Sands with 5 to 12% fines require dual symbols:
- SW-SM well-graded sand with silt
- SW-SC well-graded sand with clay
- SP-SM poorly graded sand with silt
- SP-SC poorly graded sand with clay

[E] $Cu = D_{60} / D_{10}$ $\quad Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$

[F]If soil contains ≥15% sand, add "with sand" to group name.
[G]If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.
[H]If fines, are organic, add " with organic fines" to group name.
[I]If soil contains ≥ 15% gravel, add "with gravel" to group name.
[J]If Atterberg limits plot in hatched area, soil is CL-ML, silty clay.
[K]If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel", whichever is predominant.
[L]If soil contains ≥ 30% plus no. 200, predominantly sand, add "sandy" to group name.
[M]If soil contains ≥ 30% plus no. 200, predominantly gravel, add "gravelly" to group name.
[N]PI≥ 4 and plots on or above "A"line.
[O]PI<4 or plots below "A" line.
[P]PI plots on or above "A" line.
[Q]PI plots below "A" line.



# DESCRIPTIVE TERMINOLOGY

### RELATIVE DENSITY

| Term | "N" Value |
|---|---|
| Very Loose | 0 – 4 |
| Loose | 5 – 8 |
| Medium Dense | 9 – 15 |
| Dense | 16 – 30 |
| Very Dense | Over 30 |

### THICKNESS OF SOIL INTRUSIONS

| Term | Range |
|---|---|
| Lense / Lamination | 0 – 1/8" |
| Seam | 1/8" – 1" |
| Layer | 1" – 12" |

### CONSISTENCY OF COHESIVE SOILS

| Term | "N" Value |
|---|---|
| Soft | 0 – 4 |
| Medium | 5 – 8 |
| Rather Stiff | 9 – 15 |
| Stiff | 16 – 30 |
| Very Stiff | Over 30 |

### RELATIVE PROPORTIONS

| Term | Range |
|---|---|
| Trace | 0 – 5% |
| A Little | 5 – 15% |
| With | 15 – 50% |

### PARTICLES SIZES

| Term | Range |
|---|---|
| Boulders | Over 8" |
| Cobbles | 3"– 8" |
| Gravel | |
| Coarse | 3/4" – 3" |
| Fine | #4 – 3/4" |
| Sand | |
| Coarse | #4 - #10 |
| Medium | #10 - #40 |
| Fine | #40 - #200 |
| Silt | #200 – 0.005 mm |
| Clay | Less than 0.005 mm |

Note: Sieve sizes shown are U.S. Standard

### DRILLING & SAMPLING SYMBOLS

| Symbol | Definition |
|---|---|
| FA | Flight Auger |
| SS | Split Spoon |
| TW | Thin-Walled Tube |
| HSA | Hollow Stem Auger |
| N | Penetration Resistance: blows required to drive a two-inch OD split spoon sampler one foot by means of a 140-pound hammer falling 30 inches |

### LABORATORY TEST SYMBOLS

| Symbols | Definition |
|---|---|
| LL | Liquid Limit, % |
| PL | Plastic Limit, % |
| $Q_u$ | Unconfined Compressive Strength, psf |

Additional insertions in $Q_u$ column

| Symbols | Definition |
|---|---|
| G | Specific Gravity |
| SL | Shrinkage Limit, % |
| pH | Hydrogen Ion Content-Meter Method |
| O | Organic Content, % - Combustion Method |
| M.A. | Grain Size Analysis - Mechanical Method |
| Hyd. | Grain Size Analysis - Hydrometer Method |
| C | One-Dimensional Consolidation |
| $Q_c$ | Triaxial Compression |
| Chem | Chemical analysis |

### WATER LEVEL INFORMATION

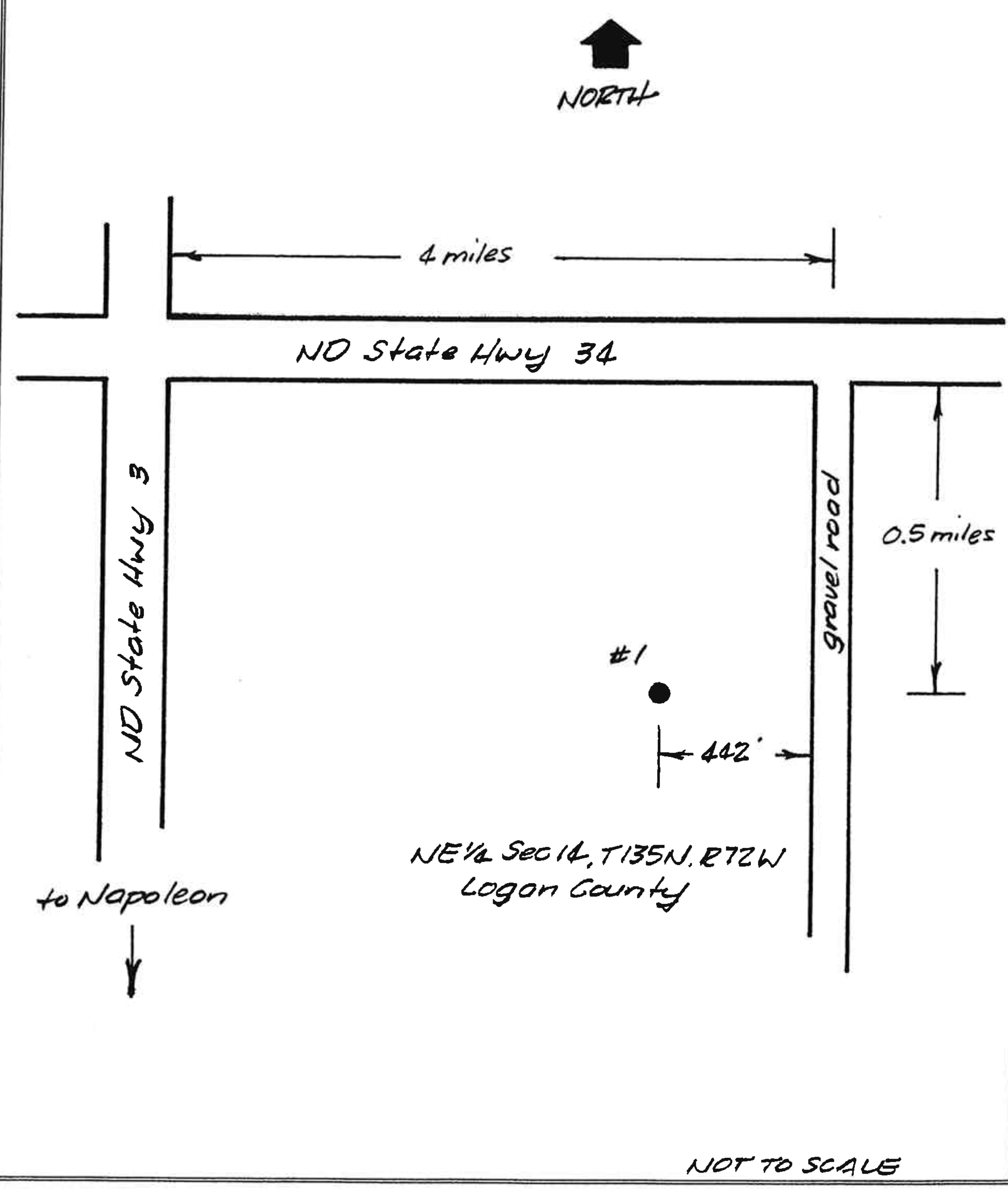
Water levels shown on the boring logs are levels measured in the borings at the time and under the conditions noted. In sand, the indicated levels can be considered reliable. In clay soil, it is not possible to determine the ground water level within the normal scope of a test boring investigation, except where lenses or layers of more pervious water-bearing soils are present. Even then, a long period of time may be necessary to reach equilibrium. Therefore, the position of the water level noted on the boring logs for cohesive or mixed-texture soils may not indicate the true level of the ground water table.

### SOIL STRATIFICATION BOUNDARIES

The soil stratification lines shown on the boring logs indicate the approximate boundary between different soil types. In the field, the transition between soil types may be gradual.

# MIDWEST TESTING LABORATORY

TEST BORING LAYOUT




PROJECT: Proposed Wind Farm
Napoleon, North Dakota

JOB NO.: B8300