# Vermessene Leistungskennlinie

# VENSYS 126 - 3,8 MW

# Mode 0

**VENSYS Energy AG**
Im Langental 6 · 66539 Neunkirchen
T +49 6821 95 17 - 0 · F +49 6821 95 17 - 111

| Daten der Windenergieanlage | |
|---|---|
| Anlagentyp: | VENSYS 126 |
| Nennleistung: | 3800 kW |
| Rotordurchmesser: | 126 m |
| Einschaltgeschwindigkeit: | 3,0 m/s |
| Abschaltgeschwindigkeit: | 25,0 m/s* |

* 22m/s bei IEC IIIA Anlagen

| Leistungskurvenvermessung- und Auswertung | |
|---|---|
| Standort: | Wieringermeer (Niederlande) |
| Original Vermessungsbericht: | LK20008B2 |
| Vermessung & Auswertung gemäß: | FGW TR 2 Rev. 17 |
| Windgeschwindigkeit: | 10 min Mittelwert auf Nabenhöhe (keine rotoräquivalente Windgeschw.) |
| Energiemessung: | Niederspannung, 620 V |
| Referenz-Luftdichte: | 1,225 kg/m$^3$ |
| Referenz-Turbulenzintensität: | 10% |
| Höhenwindexponent: | 0.273 |

# Vermessene Leistungskennlinie
# VENSYS 126 - 3,8 MW - Mode 0

| $v_{Nabe}$ [m/s] | Leistung [kW] |
|---|---|
| 3,0 | 10,6 |
| 3,5 | 90,5 |
| 4,0 | 170,3 |
| 4,5 | 283,5 |
| 5,0 | 429,8 |
| 5,5 | 601,2 |
| 6,0 | 806,8 |
| 6,5 | 1015,9 |
| 7,0 | 1270,9 |
| 7,5 | 1550,4 |
| 8,0 | 1846,7 |
| 8,5 | 2119,1 |
| 9,0 | 2616,0 |
| 9,5 | 2884,7 |
| 10,0 | 3205,7 |
| 10,5 | 3461,7 |
| 11,0 | 3679,3 |
| 11,5 | 3774,9 |
| 12,0 | 3832,2 |
| 12,5 | 3872,1 |
| 13,0 | 3868,8 |
| 13,5 | 3872,7 |
| 14,0 | 3866,6 |
| 14,5 | 3862,9 |
| 15,0 | 3859,7 |
| 15,5 | 3857,6 |
| 16,0 | 3857,8 |
| 16,5 | 3856,0 |
| 17,0 | 3856,0 |
| 17,5 | 3856,0 |
| 18,0 | 3856,0 |
| 18,5 | 3856,0 |
| 19,0 | 3856,0 |
| 19,5 | 3856,0 |
| 20,0 | 3856,0 |
| 20,5 | 3856,0 |
| 21,0 | 3856,0 |
| 21,5 | 3856,0 |
| 22,0 | 3856,0 |
| 22,5 | 3856,0 |
| 23,0 | 3856,0 |
| 23,5 | 3856,0 |
| 24,0 | 3856,0 |
| 24,5 | 3856,0 |
| 25,0 | 3856,0 |

Hinweis: Werte für wind bins von 17,5m/s bis 25,0m/s sind extrapoliert und nicht vermessen

| $v_{Nabe}$ [m/s] | $c_t$ [-] |
|---|---|
| 3,0 | 1,22 |
| 3,5 | 1,08 |
| 4,0 | 0,97 |
| 4,5 | 0,88 |
| 5,0 | 0,87 |
| 5,5 | 0,87 |
| 6,0 | 0,87 |
| 6,5 | 0,87 |
| 7,0 | 0,87 |
| 7,5 | 0,87 |
| 8,0 | 0,87 |
| 8,5 | 0,84 |
| 9,0 | 0,80 |
| 9,5 | 0,76 |
| 10,0 | 0,73 |
| 10,5 | 0,69 |
| 11,0 | 0,55 |
| 11,5 | 0,46 |
| 12,0 | 0,39 |
| 12,5 | 0,34 |
| 13,0 | 0,30 |
| 13,5 | 0,26 |
| 14,0 | 0,23 |
| 14,5 | 0,21 |
| 15,0 | 0,19 |
| 15,5 | 0,17 |
| 16,0 | 0,16 |
| 16,5 | 0,14 |
| 17,0 | 0,13 |
| 17,5 | 0,12 |
| 18,0 | 0,11 |
| 18,5 | 0,10 |
| 19,0 | 0,09 |
| 19,5 | 0,09 |
| 20,0 | 0,08 |
| 20,5 | 0,08 |
| 21,0 | 0,07 |
| 21,5 | 0,07 |
| 22,0 | 0,06 |
| 22,5 | 0,06 |
| 23,0 | 0,06 |
| 23,5 | 0,05 |
| 24,0 | 0,05 |
| 24,5 | 0,05 |
| 25,0 | 0,04 |

# Anhang

# Auszüge aus original Messbericht

# LK20008B2

### 8.3.1 Tabular power performance evaluation

Table 14 Power curve bin values

| IEC relevant bin range: 5-31 | | | | Power curve - bin values | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Bin No. | Wind Speed From [m/s] | Wind Speed To [m/s] | Number of Data Sets [-] | Wind Speed * Bin Avg. [m/s] | Power Output Bin Avg. [kW] | Cp Bin Avg. [-] | Power St. - Dev. Bin Avg. [kW] | Power Min. Bin Min [kW] | Power Max Bin Max [kW] | TI Bin Avg. [%] | Air Density ** Bin Avg. [kg/m3] |
| 1 | [0 | 0.25] | 0 | - | - | - | - | - | - | - | - |
| 2 | [0.25 | 0.75] | 0 | - | - | - | - | - | - | - | - |
| 3 | ]0.75 | 1.25] | 0 | - | - | - | - | - | - | - | - |
| 4 | ]1.25 | 1.75] | 0 | - | - | - | - | - | - | - | - |
| 5 | ]1.75 | 2.25] | 2 | 2.13 | 2.45 | 0.03 | 42.55 | -38.23 | 132.78 | 15.60 | 1.23 |
| 6 | ]2.25 | 2.75] | 33 | 2.60 | -13.82 | -0.10 | 18.93 | -44.88 | 165.62 | 11.11 | 1.24 |
| 7 | ]2.75 | 3.25] | 78 | 2.99 | 7.26 | 0.04 | 28.91 | -44.75 | 209.47 | 8.02 | 1.23 |
| 8 | ]3.25 | 3.75] | 137 | 3.52 | 90.04 | 0.27 | 52.26 | -46.34 | 437.97 | 7.63 | 1.23 |
| 9 | ]3.75 | 4.25] | 113 | 3.98 | 169.56 | 0.35 | 56.04 | -34.18 | 676.73 | 8.42 | 1.22 |
| 10 | ]4.25 | 4.75] | 87 | 4.48 | 279.41 | 0.41 | 75.28 | -52.05 | 1716.69 | 7.50 | 1.22 |
| 11 | ]4.75 | 5.25] | 49 | 5.02 | 423.00 | 0.44 | 122.47 | 111.64 | 1041.51 | 7.46 | 1.22 |
| 12 | ]5.25 | 5.75] | 59 | 5.49 | 597.15 | 0.47 | 135.18 | 184.63 | 1175.28 | 7.82 | 1.22 |
| 13 | ]5.75 | 6.25] | 104 | 6.00 | 804.04 | 0.49 | 195.78 | 277.74 | 2846.43 | 8.28 | 1.22 |
| 14 | ]6.25 | 6.75] | 113 | 6.50 | 1011.05 | 0.48 | 193.27 | 311.05 | 2516.85 | 8.34 | 1.22 |
| 15 | ]6.75 | 7.25] | 167 | 7.02 | 1263.52 | 0.48 | 213.71 | 496.81 | 2408.84 | 8.27 | 1.22 |
| 16 | ]7.25 | 7.75] | 210 | 7.50 | 1540.61 | 0.48 | 228.44 | 602.15 | 3383.98 | 8.07 | 1.22 |
| 17 | ]7.75 | 8.25] | 138 | 7.99 | 1836.16 | 0.47 | 274.25 | 717.45 | 3825.55 | 8.78 | 1.22 |
| 18 | ]8.25 | 8.75] | 86 | 8.46 | 2111.71 | 0.46 | 272.85 | 902.59 | 3930.37 | 9.41 | 1.22 |
| 19 | ]8.75 | 9.25] | 64 | 9.00 | 2609.74 | 0.47 | 327.81 | 1097.29 | 3945.91 | 10.57 | 1.21 |
| 20 | ]9.25 | 9.75] | 60 | 9.50 | 2868.01 | 0.44 | 314.97 | 1346.15 | 3937.08 | 10.88 | 1.22 |
| 21 | ]9.75 | 10.25] | 65 | 9.99 | 3183.50 | 0.42 | 267.39 | 1748.35 | 3939.28 | 10.85 | 1.21 |
| 22 | ]10.25 | 10.75] | 58 | 10.45 | 3437.40 | 0.39 | 209.39 | 1821.64 | 3945.55 | 10.80 | 1.21 |
| 23 | ]10.75 | 11.25] | 65 | 11.00 | 3658.53 | 0.36 | 186.01 | 1708.52 | 3957.88 | 10.62 | 1.21 |
| 24 | ]11.25 | 11.75] | 61 | 11.49 | 3755.24 | 0.32 | 117.54 | 2037.93 | 3951.77 | 10.52 | 1.20 |
| 25 | ]11.75 | 12.25] | 56 | 12.00 | 3810.08 | 0.29 | 61.65 | 2383.13 | 3946.64 | 10.96 | 1.21 |
| 26 | ]12.25 | 12.75] | 55 | 12.51 | 3846.47 | 0.26 | 29.75 | 2663.93 | 3944.18 | 11.53 | 1.21 |
| 27 | ]12.75 | 13.25] | 55 | 12.99 | 3849.08 | 0.23 | 17.11 | 2742.76 | 3950.97 | 11.75 | 1.21 |
| 28 | ]13.25 | 13.75] | 58 | 13.47 | 3854.40 | 0.21 | 7.16 | 2790.86 | 3947.99 | 12.26 | 1.21 |
| 29 | ]13.75 | 14.25] | 57 | 14.00 | 3856.83 | 0.18 | 4.91 | 2786.33 | 3937.43 | 12.06 | 1.21 |
| 30 | ]14.25 | 14.75] | 61 | 14.50 | 3856.07 | 0.17 | 3.27 | 3397.51 | 3939.86 | 12.25 | 1.20 |
| 31 | ]14.75 | 15.25] | 38 | 15.03 | 3855.44 | 0.15 | 3.83 | 2979.82 | 3932.08 | 12.51 | 1.20 |
| 32 | ]15.25 | 15.75] | 31 | 15.48 | 3854.94 | 0.14 | 4.73 | 2953.54 | 3932.80 | 12.60 | 1.20 |
| 33 | ]15.75 | 16.25] | 21 | 16.02 | 3856.76 | 0.12 | 2.89 | 3567.60 | 3920.48 | 12.53 | 1.21 |
| 34 | ]16.25 | 16.75] | 18 | 16.48 | 3855.98 | 0.11 | 2.34 | 3546.86 | 3917.77 | 12.22 | 1.20 |
| 35 | ]16.75 | 17.25] | 10 | 16.98 | 3856.08 | 0.10 | 3.95 | 3643.65 | 3921.69 | 12.08 | 1.20 |
| 36 | ]17.25 | 17.75] | 2 | 17.48 | 3859.54 | 0.09 | 0.83 | 3681.79 | 3916.58 | 10.62 | 1.21 |
| 37 | ]17.75 | 18.25] | 0 | - | - | - | - | - | - | - | - |
| 38 | ]18.25 | 18.75] | 1 | 18.25 | 3866.99 | 0.08 | 0.00 | 2470.44 | 4004.43 | 11.52 | 1.17 |
| 39 | ]18.75 | 19.25] | 0 | - | - | - | - | - | - | - | - |

* Wind speed is normalized with sea level air density (1.225 kg/m³).

** Measured air density that was not used for normalization.

Incomplete wind speed BINs, less than 3 data sets.

Table 15 TI normalised power curve bin values

| IEC relevant bin range: 5-31 | | | | **Power curve - bin values** | | | | |
|---|---|---|---|---|---|---|---|---|
| Bin No. | Wind Speed From [m/s] | Wind Speed To [m/s] | Number of Data Sets [-] | Wind Speed Bin Mean [m/s] | Power Output Bin Mean [kW] | Cp Bin Mean [-] | TI Bin Mean [%] | Air Density Bin Mean [kg/m3] |
| 1 | [0 | 0.25] | 0 | - | - | - | - | - |
| 2 | [0.25 | 0.75] | 0 | - | - | - | - | - |
| 3 | ]0.75 | 1.25] | 0 | - | - | - | - | - |
| 4 | ]1.25 | 1.75] | 0 | - | - | - | - | - |
| 5 | ]1.75 | 2.25] | 2 | 2.13 | 3.31 | 0.05 | 15.60 | 1.23 |
| 6 | ]2.25 | 2.75] | 33 | 2.60 | -14.94 | -0.11 | 11.11 | 1.24 |
| 7 | ]2.75 | 3.25] | 78 | 2.99 | 10.59 | 0.05 | 8.02 | 1.23 |
| 8 | ]3.25 | 3.75] | 137 | 3.52 | 90.52 | 0.27 | 7.63 | 1.23 |
| 9 | ]3.75 | 4.25] | 113 | 3.98 | 170.31 | 0.35 | 8.42 | 1.22 |
| 10 | ]4.25 | 4.75] | 87 | 4.48 | 283.49 | 0.41 | 7.50 | 1.22 |
| 11 | ]4.75 | 5.25] | 49 | 5.02 | 429.76 | 0.44 | 7.46 | 1.22 |
| 12 | ]5.25 | 5.75] | 59 | 5.49 | 601.20 | 0.47 | 7.82 | 1.22 |
| 13 | ]5.75 | 6.25] | 104 | 6.00 | 806.84 | 0.49 | 8.28 | 1.22 |
| 14 | ]6.25 | 6.75] | 113 | 6.50 | 1015.93 | 0.48 | 8.34 | 1.22 |
| 15 | ]6.75 | 7.25] | 167 | 7.02 | 1270.86 | 0.48 | 8.27 | 1.22 |
| 16 | ]7.25 | 7.75] | 210 | 7.50 | 1550.36 | 0.48 | 8.07 | 1.22 |
| 17 | ]7.75 | 8.25] | 138 | 7.99 | 1846.70 | 0.47 | 8.78 | 1.22 |
| 18 | ]8.25 | 8.75] | 86 | 8.46 | 2119.09 | 0.46 | 9.41 | 1.22 |
| 19 | ]8.75 | 9.25] | 64 | 9.00 | 2615.97 | 0.47 | 10.57 | 1.21 |
| 20 | ]9.25 | 9.75] | 60 | 9.50 | 2884.74 | 0.44 | 10.88 | 1.22 |
| 21 | ]9.75 | 10.25] | 65 | 9.99 | 3205.73 | 0.42 | 10.85 | 1.21 |
| 22 | ]10.25 | 10.75] | 58 | 10.45 | 3461.70 | 0.40 | 10.80 | 1.21 |
| 23 | ]10.75 | 11.25] | 65 | 11.00 | 3679.30 | 0.36 | 10.62 | 1.21 |
| 24 | ]11.25 | 11.75] | 61 | 11.49 | 3774.93 | 0.33 | 10.52 | 1.20 |
| 25 | ]11.75 | 12.25] | 56 | 12.00 | 3832.17 | 0.29 | 10.96 | 1.21 |
| 26 | ]12.25 | 12.75] | 55 | 12.51 | 3872.13 | 0.26 | 11.53 | 1.21 |
| 27 | ]12.75 | 13.25] | 55 | 12.99 | 3868.82 | 0.23 | 11.75 | 1.21 |
| 28 | ]13.25 | 13.75] | 58 | 13.47 | 3872.74 | 0.21 | 12.26 | 1.21 |
| 29 | ]13.75 | 14.25] | 57 | 14.00 | 3866.58 | 0.18 | 12.06 | 1.21 |
| 30 | ]14.25 | 14.75] | 61 | 14.50 | 3862.94 | 0.17 | 12.25 | 1.20 |
| 31 | ]14.75 | 15.25] | 38 | 15.03 | 3859.65 | 0.15 | 12.51 | 1.20 |
| 32 | ]15.25 | 15.75] | 31 | 15.48 | 3857.63 | 0.14 | 12.60 | 1.20 |
| 33 | ]15.75 | 16.25] | 21 | 16.02 | 3857.78 | 0.12 | 12.53 | 1.21 |
| 34 | ]16.25 | 16.75] | 18 | 16.48 | 3856.01 | 0.11 | 12.22 | 1.20 |
| 35 | ]16.75 | 17.25] | 10 | 16.98 | 3856.02 | 0.10 | 12.08 | 1.20 |
| 36 | ]17.25 | 17.75] | 2 | 17.48 | 3859.43 | 0.09 | 10.62 | 1.21 |
| 37 | ]17.75 | 18.25] | 0 | - | - | - | - | - |
| 38 | ]18.25 | 18.75] | 1 | 18.25 | 3867.03 | 0.08 | 11.52 | 1.17 |
| 39 | ]18.75 | 19.25] | 0 | - | - | - | - | - |

## 8.3.16 Tabular power performance evaluation with uncertainties

Table19 Combined uncertainties

| Wind Speed Bin Center [m/s] | Average Wind Speed [m/s] | Power Output [kW] | Cp [-] | No. of Data Sets [-] | Category A Standard Uncertainty Si [kW] | Category B Standard Uncertainty Ui [kW] | Combined Standard Uncertainty UCi [kW] |
|---|---|---|---|---|---|---|---|
| 2.5 | 2.599 | -14.936 | -0.111 | 33 | 3.302 | 16.197 | 16.530 |
| 3 | 2.988 | 10.594 | 0.052 | 78 | 3.296 | 30.338 | 30.516 |
| 3.5 | 3.517 | 90.516 | 0.272 | 137 | 4.465 | 47.840 | 48.048 |
| 4 | 3.984 | 170.305 | 0.353 | 113 | 5.273 | 65.380 | 65.592 |
| 4.5 | 4.478 | 283.486 | 0.413 | 87 | 8.083 | 89.965 | 90.327 |
| 5 | 5.024 | 429.755 | 0.444 | 49 | 17.523 | 127.545 | 128.743 |
| 5.5 | 5.493 | 601.201 | 0.475 | 59 | 17.607 | 168.645 | 169.561 |
| 6 | 6.000 | 806.842 | 0.489 | 104 | 19.200 | 195.328 | 196.269 |
| 6.5 | 6.505 | 1015.927 | 0.483 | 113 | 18.187 | 234.736 | 235.439 |
| 7 | 7.019 | 1270.858 | 0.481 | 167 | 16.547 | 300.615 | 301.070 |
| 7.5 | 7.495 | 1550.363 | 0.482 | 210 | 15.778 | 351.443 | 351.797 |
| 8 | 7.990 | 1846.698 | 0.474 | 138 | 23.363 | 371.054 | 371.789 |
| 8.5 | 8.463 | 2119.094 | 0.458 | 86 | 29.433 | 498.789 | 499.657 |
| 9 | 9.004 | 2615.970 | 0.469 | 64 | 40.983 | 519.642 | 521.256 |
| 9.5 | 9.497 | 2884.744 | 0.441 | 60 | 40.721 | 450.089 | 451.927 |
| 10 | 9.987 | 3205.726 | 0.421 | 65 | 33.282 | 475.081 | 476.246 |
| 10.5 | 10.453 | 3461.704 | 0.397 | 58 | 27.682 | 392.778 | 393.752 |
| 11 | 10.996 | 3679.302 | 0.362 | 65 | 23.217 | 258.702 | 259.742 |
| 11.5 | 11.494 | 3774.926 | 0.326 | 61 | 15.263 | 141.400 | 142.221 |
| 12 | 12.002 | 3832.170 | 0.290 | 56 | 8.760 | 96.855 | 97.250 |
| 12.5 | 12.505 | 3872.126 | 0.259 | 55 | 5.318 | 51.548 | 51.822 |
| 13 | 12.992 | 3868.824 | 0.231 | 55 | 3.541 | 31.956 | 32.152 |
| 13.5 | 13.471 | 3872.741 | 0.207 | 58 | 2.605 | 30.881 | 30.990 |
| 14 | 13.996 | 3866.577 | 0.185 | 57 | 1.456 | 27.156 | 27.195 |
| 14.5 | 14.495 | 3862.938 | 0.166 | 61 | 0.980 | 24.933 | 24.952 |
| 15 | 15.033 | 3859.648 | 0.149 | 38 | 0.930 | 23.727 | 23.746 |
| 15.5 | 15.480 | 3857.633 | 0.136 | 31 | 0.982 | 22.713 | 22.734 |
| 16 | 16.017 | 3857.783 | 0.123 | 21 | 0.670 | 22.491 | 22.501 |
| 16.5 | 16.484 | 3856.013 | 0.113 | 18 | 0.552 | 22.479 | 22.486 |
| 17 | 16.976 | 3856.021 | 0.103 | 10 | 1.249 | 22.345 | 22.380 |

### 8.3.17 Annual energy production

Table 20 AEP results

| Reference air density: 1.2250 kg/m3<br>Cut-in wind speed: 3 m/s<br>Cut-out wind speed: 25 m/s<br>(Extrapolated by constant power from last bin) | | | | | |
|---|---|---|---|---|---|
| **Hub Height Annual Average Wind Speed (Rayleigh) [m/s]** | **AEP – Measured (Measured Power Curve) [MWh]** | **Standard Uncertainty in AEP [MWh]** | **Standard Uncertainty in AEP [%]** | **AEP – Extrapolated (Extrapolated Power Curve) [MWh]** | **Notes*** |
| 4 | 3520.205 | 902.760 | 25.65 | 3520.229 | Complete |
| 5 | 6571.106 | 1365.698 | 20.78 | 6575.056 | Complete |
| 6 | 9890.436 | 1664.171 | 16.83 | 9953.203 | Complete |
| 7 | 12874.849 | 1780.872 | 13.83 | 13206.361 | Complete |
| 8 | 15126.987 | 1767.980 | 11.69 | 16094.477 | Incomplete |
| 9 | 16530.443 | 1681.519 | 10.17 | 18517.132 | Incomplete |
| 10 | 17171.575 | 1560.966 | 9.09 | 20434.737 | Incomplete |
| 11 | 17222.388 | 1429.831 | 8.30 | 21840.534 | Incomplete |

* incomplete: if any annual average wind speed AEP – Measured is less than 95 % of AEP - Extrapolated