Article

Sustainable wind power plant modernization

Robert Kasner 1, Weronika Kruszelnicka 1, Patrycja Bałdowska-Witos 1, Józef Flizikowski 1,and Andrzej Tomporowski 1,\*

1 Department of Manufacturing Technology, Faculty of Mechanical Engineering, University of Science and Technology in Bydgoszcz, 85-796 Bydgoszcz, Poland; weronika.kruszelnicka@utp.edu.pl (W.K.), robert.kasner@gmail.com (R.K.), patrycja.baldowska-witos@utp.edu.pl (P.B.-W.), fliz@utp.edu.pl (J.F.), a.tomporowski@utp.edu.pl (A.T.),

**\*** Correspondence: weronika.kruszelnicka@utp.edu.pl (W.K.)

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**Table S1.** Lifetime-extension methods and operations (the authors; own work based [34])

|  |  |  |  |
| --- | --- | --- | --- |
| End-of-life pathways | | Range of activities | Impact on WPP productivity |
| Decommissioning | | Disassembly of the wind turbine and recycling or landfilling its elements | No |
| Lifetime-extension | Upgrade | Improving system elements or replacing them with new ones | Yes (+) |
| Retrofit | Modernizing particular elements by replacing them or by adding new elements to already existing ones | Yes (+) |
| Recondition/refurbish | Replacing worn out components and assemblies to restore their original functionality | No |
| Overhaul | Complete inspection of the turbine often combined with the disassembly and repair of components and assemblies | Yes (+) |
| Modernization | Includes upgrades, retrofitting, replacements, and inspections of elements and assemblies | Yes (+) |
| Repowering | | Replacing a wind power plant with a new one | Yes (+) |

**Table S2.** Materials and elements used to construct a wind power plant

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Lp.** | **Element** | **Material** | **mass [kg]** | **% share in WPP** |
| **1** | **NACELLE** | | | |
| 1.1 | Generator with the radiator | copper | 1,430 | 0.08 |
| cast iron | 3,920 | 0.22 |
| steel | 2,090 | 0.12 |
| other | 60 | 0.00 |
| **Generator total** | **7,500** | 0.43 |
| 1.2 | Gearbox | upgraded steel | 2,620 | 0.15 |
| cast iron | 14,060 | 0.80 |
| oil | 280 | 0.02 |
| other | 40 | 0.00 |
| **Gearbox total** | **17,000** | 0.97 |
| 1.3 | Transformer | steel | 4,150 | 0.24 |
| aluminum | 860 | 0.05 |
| other | 80 | 0.00 |
| **Transformer total** | **5,090** | 0.29 |
| 1.4 | Main body shaft | upgraded steel | 9,520 | 0.54 |
| cast iron | 1,795 | 0.10 |
| other | 20 | 0.00 |
| **Main body shaft total** | **11,335** | 0.65 |
| 1.5 | Radiators | aluminum | **960** | 0.05 |
| 1.6 | Hydraulic system | oil | 360 | 0.02 |
| steel | 2,660 | 0.15 |
| aluminum | 420 | 0.02 |
| other | 200 | 0.01 |
| **Hydraulic system total** | **3,640** | 0.21 |
| 1.7 | Switchgears, inverters, connections | steel | 340 | 0.02 |
| copper | 240 | 0.01 |
| aluminum | 180 | 0.01 |
| other | 120 | 0.01 |
| **Switchgears. inverters total** | **880** | 0.05 |
| 1.8 | Nacelle platform | Polymer materials | 14,590 | 0.83 |
| steel | 3,750 | 0.21 |
| **Nacelle platform total** | **18,340** | 1.04 |
| 1.9 | Nacelle housing | steel | 1,100 | 0.06 |
| polymer materials | 1,815 | 0.10 |
| other | 340 | 0.02 |
| **Nacelle housing total** | **3,255** | 0.19 |
| **Nacelle total** | | | **68,000** | **3.87** |
| **2** | **Rotor** | | | |
| 2.1 | Blades | steel | 1,750 | 0.10 |
| Polymer materials reinforced with carbon fiber and glass fiber | 18,250 | 1.04 |
| **Blades total** | **20,000** | 1.14 |
| 2.2 | Hub | cast iron | 17,650 | 1.00 |
| polymer materials | 200 | 0.01 |
| other | 150 | 0.01 |
| **Hub total** | **18,000** | 1.02 |
| **Rotor total** | | | **38,000** | **2.16** |
| **3** | **Tower** | | | |
| 3.1 | Tower rings | steel | 253,775 | 14.45 |
| aluminum | 1,295 | 0.07 |
| copper | 380 | 0.02 |
| other | 550 | 0.03 |
| **Tower total** | | | **256,000** | **14.57** |
| **4** | **Foundation** | | | |
| 4.1 | reinforcement | steel | 54,545 | 3.10 |
| 4.2 | concrete | cement | 209,050 | 11.90 |
| aggregate | 1,036,775 | 59.01 |
| water | 90,400 | 5.15 |
| other | 3,390 | 0.19 |
| Concrete total | 1,339,615 | 76.25 |
| 4.3 | other | | 650 | 0.04 |
| **Foundation total** | | | **1,394,810** | **79.39** |
| **WIND POWER PLANT TOTAL** | | | **1,756,810** | **100.00** |