worldsteel ASSOCIATION

ENVIRONMENTAL CASE STUDY
Wind energy

The World Steel Association (worldsteel) case studies use a life cycle assessment (LCA) approach to measure the potential greenhouse gas impacts from all stages of manufacture, product use and end-of-life. worldsteel has developed this series of case studies to demonstrate the reduction of CO_2 emissions through the use of high-performance steels.

Wind energy: the fastest growing power source

As demand for energy increases, wind is seen as one of the key future sources of electricity generation. Installed capacity of wind power is growing rapidly. Electricity produced by wind turbines is generated with significantly lower lifetime CO_2 emissions than the global average for electricity production. This helps to mitigate our impact on climate change.

Steel plays a vital role in wind power generation. About 85% of the wind turbines around the world are installed on tubular steel structures. Steel represents on average 80% of all materials used to construct a wind turbine.

A wind farm emits no CO_2. The energy used to build, operate and dismantle a typical turbine is recovered within nine months of operation. The Horns Rev offshore wind farm in Denmark has 80 wind turbines and will generate almost 13,000 GWh over its lifetime. The entire wind farm will produce an estimated 650 GWh a year.

Meeting the climate change challenge with renewable energy

To meet the ambitious Intergovernmental Panel on Climate Change (IPCC) scenario of keeping worldwide temperature increases below 2.4°C, global CO_2 emissions need to be halved by 2050 compared to their current levels.[1] This case study shows how steel is contributing to the reduction of CO_2 emissions significantly, by reducing the CO_2 intensity of power generation and the dependency on fossil fuels, by being the most important material in wind energy production.[2]

The European Union Climate and Energy package includes a target that 20% of all energy production by 2020 will be by renewable means. Wind power will play a significant role in achieving this target.

Over 20 GW of wind power was installed globally in 2007, led by the US, China and Spain, bringing worldwide installed capacity to 94 GW, an increase of about 27%. The rate of installation is increasing, with the 2007 figure being 31% greater than the capacity installed in 2006. Wind energy now contributes to the energy mix in more than 70 countries. Germany is the largest producer of electricity from wind, with more than 22 GW installed capacity.[3]

Within Europe, the capacity of newly installed wind turbines was 8.7 GW in 2007. Total wind power capacity installed by the end of 2007 reached 57 GW. This is 2% of total electricity production in the region,[4] generating on average 119 TWh a year. This capacity results in a reduction in CO_2 emissions of about 60 million tonnes each year when compared to global average electricity (504 g CO_2/kWh - the figure used to calculate CO_2 savings throughout this case study[5]). The achieved CO_2 savings are equal to the annual CO_2 emissions of Hungary.[6]

Horns Rev offshore wind farm, Denmark (source: www.hornsrev.dk)

The Horns Rev offshore wind farm in Denmark

The Horns Rev offshore wind farm is one of the world's largest. It was installed in 2002 in the North Sea, 14 km west of the coast of Denmark. The location provides some of the best conditions for wind energy.

The wind farm has 80 2 MW wind turbines, which are 70 m tall and have an estimated lifetime of 20 years. These turbines are made primarily of steel, with high-strength steel foundations. The 28,000 tonnes of steel in the turbines accounts for 79% of all materials used in the wind farm.[7]

An estimated 13,000 GWh of electricity will be generated during the lifetime of the farm, equivalent to 650 GWh a year. This is comparable to the annual energy consumption of all the residents of Iceland[8] (population: 319,000). If this energy replaces global average electricity, the lifetime CO_2 saving provided by the wind farm is nearly 6.5 million tonnes. The wind farm's lifetime CO_2 emissions are only 7.6 g of CO_2/kWh.

Using LCA, it is estimated that 6,000 MWh of energy is required to construct, operate and dismantle one Horns Rev turbine. This means that the energy pay-back time for each turbine is only nine months.

Steel's vital role in the production of wind energy

Steel's contribution to the developments of wind energy is significant because steel is by far the most prevalent material used in turbine tower construction. Steel offers considerable advantages for the construction of wind turbine towers due to its strength and durability. The towers can be manufactured in sections of up to 30 m then fitted together and installed on site. Also, environmental impacts are minimised as steel can be infinitely recycled.

The European wind energy sector consumes 700,000 tonnes of steel a year. About 85% of the wind turbines around the world are installed on tubular steel structures.[9] Steel represents on average 80% of all materials used to construct a wind turbine, including steel foundations. Due to the high steel content in a 3 MW 80 m high wind turbine, at least 80% of all materials are recyclable.[10]

As a global average, at least 90% of the steel from wind turbines can be recovered for recycling.[11] When the turbines reach the end of their life, recycling 90% of the steel from Horns Rev wind farm will save 47,000 tonnes of CO_2 in primary steel production.

Without the recycling scenario, the environmental impacts of a wind turbine production phase would be significantly higher, highlighting the importance of using and recycling steel. For example, a 6% increase in recovery from 90% to 96% results in a reduction of greenhouse gas emissions of approximately 3%, based on LCA studies.[12]

The lifetime energy production of wind turbines

The Horns Rev wind farm generates electricity for over 192,500 households. The energy embodied in the materials used in the construction of the each turbine, together with the energy required to operate, maintain and dismantle it is estimated at 6,000 MWh.

An onshore wind farm with 100 3 MW turbines would deliver 15,780 GWh over the course of its 20 year life and is comparable to the annual energy consumption of 235,000 Danish households. As the total energy required during the full life cycle of a 3 MW onshore turbine is about 4,300 MWh, the energy pay-back time is calculated to be 6.6 months.

Wind turbine CO_2 emissions are minimal

Electricity generated by wind power is regarded as sustainable energy because no CO_2 is emitted during the production of the electricity. Forecasts show that the global wind power market will grow by over 155% to reach 240 GW of installed capacity and over 500 TWh generated energy by 2012.[13] This will result in CO_2 emission savings of 250 million tonnes.

Also, when taking the whole life cycle into account, minimal CO_2 emissions are generated. 1 kWh of electricity generated by a 1.65 MW onshore turbine generates 6.59 g of CO_2/kWh during its 20 year life, mainly from the production of raw materials and manufacturing processes.

As wind turbine technology improves and larger turbines are used, the lifetime CO_2 emissions per kWh generated are reduced. For example, 1 kWh of electricity generated by a 3 MW offshore turbine generates 5.23 g of CO_2/kWh during the life cycle of 20 years. For an onshore 3 MW turbine, the figure is 4.64 g of CO_2/kWh. These values are much lower than the 504 g of CO_2/kWh global average emission factor for electricity.

Steel is crucial for the manufacture of wind turbines and is part of the solution to climate change.

Did you know?

- Steel is by far the most widely used material in the construction of wind power turbines.
- The energy used in the construction of a wind turbine is typically recovered within 6 to 9 months of the turbine operating.
- The first urban wind farm in the US is Steel Winds, built on a 445 hectare site donated by ArcelorMittal. This farm in New York state generates over 50 GWh of electricity a year, powering about 6,000 homes and saving 25,000 tonnes of CO_2 a year.

Footnotes

1. International Energy Agency, 2008, Energy technology Perspectives 2008: Fact Sheet: The Blue Scenario
2. Based on Vestas Wind Systems LCA calculations (http://www.vestas.com/en/about-vestas/sustainability/wind-turbines-and-the-environment/life-cycle-assessment-(lca).aspx)
3. Global Wind Energy Council, Global Wind 2007 Report, Second Edition, May 2008
4. European Commission, Directorate-General for Energy and Transport, 2007, Renewables make the difference
5. World Steel CO_2 Emissions Data Collection User Guide, Version 3: World average emission factor for electricity is 0.504 tCO_2/MWh
6. Eurostat, Country specific CO2 emissions 2006
7. Vestas Wind Systems, 2004, LCA of offshore and onshore wind farms
8. International Energy Agency, Statistics 2005
9. ArcelorMittal, 2007, Client Magazine September 2007
10. Vestas Wind Systems, 2006, LCA of offshore and onshore sited wind power plants based on Vestas V90-3.0 MW turbines
11. Based on Vestas Wind Systems LCA calculations
12. Vestas Wind Systems, 2006, Life cycle assessment of electricity produced from onshore sited wind power plants based on Vestas V82-1.65 MW turbines
13. Global Wind Energy Council, Global Wind 2007 Report, Second Edition, May 2008