Life Cycle Assessment of Four 100 m Wind Turbines With Different Tower Designs

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Introduction

An increase of hub height from the standard 80 m (262 t) to 100 m (328 ft) would result in a 4.6% higher wind speed, which could have up to a 14% increase in power output for the wind turbine. To reach hub heights of 100 m, it becomes more economical to look at tower designs other than the commonly used tubular steel design; these include concrete towers, hybrid concrete-steel towers, and ultra high performance concrete (UHPC) towers.

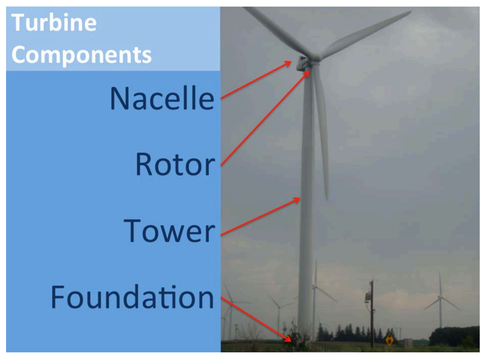
One of the most significant differences between steel towers and concrete towers is that a concrete tower can outlast the typical 20 year lifetime of turbine, and would remain in place to be fitted with a new nacelle and rotor for an additional 20 years of use. This also applies to the concrete base of the hybrid tower.

Objective

Perform two life cycle assessments (LCA) of four 3 MW wind turbines each placed on a different kind of 100 m tower: steel, concrete, concrete-steel hybrid and UHPC. One LCA will cover a 20 year time span, the other will cover a 40 year time span.

Methods

The software SimaPro 7.3.2 was used to perform the LCA. The analysis method used was EcoIndicator99.



Results

Due to the high efficiency of steel recycling and the low efficiency of concrete recycling, in the short term the turbine with the steel tower has the smallest environmental impact.

However, due to the durability of concrete towers, the turbine with the standard strength concrete tower has the lowest overall impact when looked at over 40 years.

In the production of each turbine, the nacelle and rotor (not including the blades) comprised 40-47% of the total impact, followed by the tower which made up 20-30% of the impact, while the foundation and blades tied for smallest portion of the overall impact.

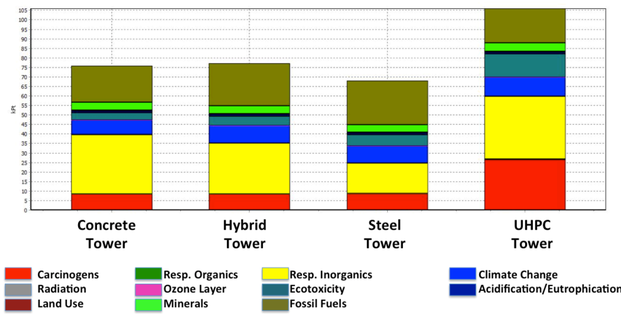


Figure 1. Single score comparison of turbines over 20 years. Results given in kilo-ecopoints (kpt).

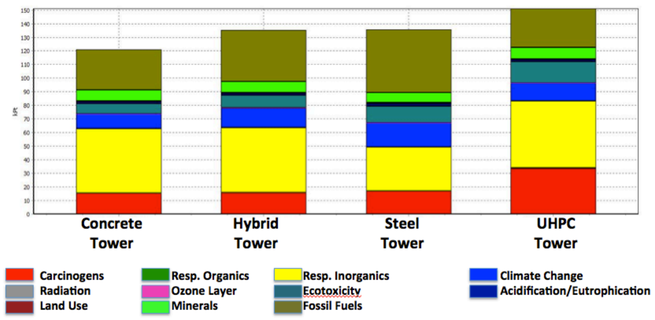


Figure 2. Single score comparison of turbines over 40 years. Results given in kilo-ecopoints (kpt).

Discussion

Though the production of each turbine does produce a significant environmental impact, the production of energy without emissions means that this impact pales in comparison to the impact of energy generated by burning fossil fuels.

Table 1. Payback times for each turbine compared to energy produced from coal, assuming that each turbine produces 9,881,000 kWh per year.

	Concrete	Hybrid	Steel	UHPC
Respiratory Inorganics	44.3 days	37.9 days	22.9 days	47.2 days
Fossil Fuel Consumption	137.4 days	160.3 days	164.6 days	129.5 days
Carcinogens	23.7 days	24.1 days	24.3 days	75.9 days
Climate Change	24.6 days	29.4 days	28.7 days	32.0 days

Table 2. Payback times for each turbine compared to energy produced from natural gas, assuming that each turbine produces 9,881,000 kWh per year.

	Concrete	Hybrid	Steel	UHPC
Respiratory Inorganics	70.7 days	60.5 days	36.5 days	75.3 days
Fossil Fuel Consumption	17.0 days	19.8 days	20.3 days	16.0 days
Carcinogens	321.3 days	326.8 days	329.5 days	1027.4 days
Climate Change	43.3 days	51.8 days	50.5 days	56.3 days

Conclusion

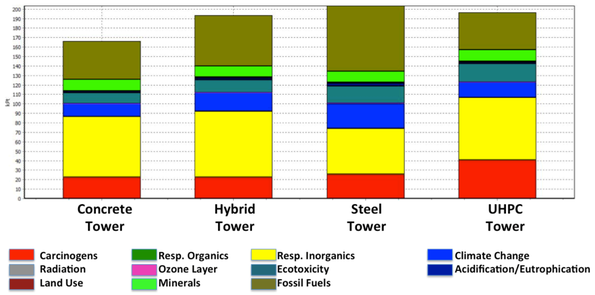


Figure 3. Projected impact of turbines over 60 years. Results given in kilo-ecopoints (kpt).

The concrete tower has the smallest environmental impact when looked at in the long term. The difference in impact between this turbine and the turbine with the steel tower becomes more prominent if viewed over an even longer time span. Optimistic views suggest that concrete towers could endure for lifetimes of over 50 years. If this were the case, the steel tower would have the greatest environmental impact of all four designs examined.

Over the 20 year life span of one of these taller turbines, 197.62 GWh of energy could be produced, avoiding 226,000 metric tons of carbon dioxide emissions from fossil fuels. This is approximately equivalent to planting 130 square miles of forest over the turbine's life span.

References

PRé Consultants. SimaPro 7.3.2. Amersfoot, the Netherlands. Available from <http://www.pre.nl/>; 2010 [accessed 23.06.12].

Acknowledgements

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