worldsteel
ASSOCIATION

STEEL SOLUTIONS IN THE GREEN ECONOMY
Wind turbines

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The World Steel Association (worldsteel) is one of the largest and most dynamic industry associations in the world. worldsteel represents approximately 170 steel producers (including 17 of the world's 20 largest steel companies), national and regional steel industry associations, and steel research institutes. worldsteel members represent around 85% of world steel production.

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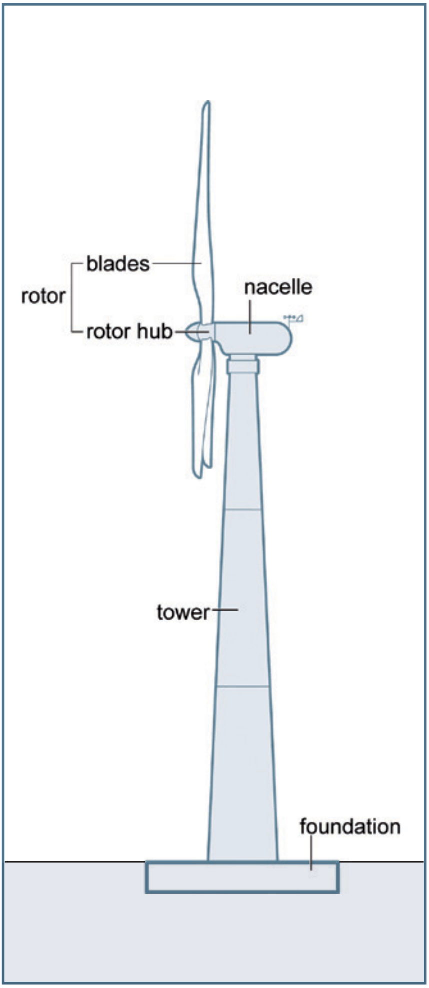
World demand for energy is increasing, driven by population growth and economic development. At the same time, climate change concerns require energy solutions that are sustainable.

The steel industry has an important role to play in clean production technologies. Wind energy is a good example. Unlike power generation based on fossil fuels, a wind farm does not emit any CO_2. Also, the energy used to build, operate and dismantle a typical turbine is recovered within the first few months of operation.

Every part of a wind turbine depends on iron and steel. The main components of a wind turbine are the tower, the nacelle, and the rotor. A foundation connects the turbine to the ground or seabed.

Whilst the blades are normally made of other materials, such as carbon fibre or alloys, steel holds the blades in place as they turn, using a cast iron or forged steel rotor hub.

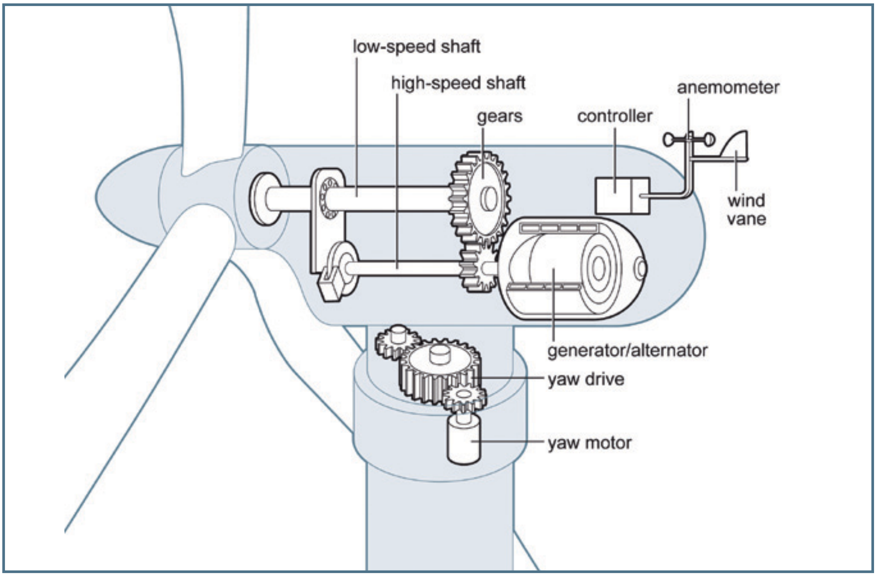


How wind energy is converted into electricity

At the top of the tower are the rotor and the nacelle. A nacelle can weigh as much as 300 tonnes, which is 14% of the weight of a large offshore turbine. Steel's strength makes it ideal for the nacelle's frame, housing and machinery.

The nacelle contains key components and some of the highest-value steels. These include electrical steels (also known as lamination, silicon or transformer steels) that help save energy.

Electrical steels are a specialty steel tailored to producing the specific magnetic properties that make wind energy possible.



Behind the blades, a low-speed shaft transfers the rotational force of the rotor to the gearbox. The gears of the gearbox were machined using precision tools and special hardened steel components. The gears increase the low rotational speed of the rotor shaft to the high speed needed to drive the generator.

The generator converts the mechanical energy captured by the blades into electric energy, much like a bicycle dynamo, and directs it to the transformer. The generator is made of 65% steel and 35% copper. An alternator is sometimes used instead.

The difference between an alternator and a generator is what is fixed and what spins. In an alternator, a magnetic field is spun inside windings of wire called a stator. This generates electricity.

A transformer, usually on the ground, converts the electricity from the turbine to the higher voltage required by the electricity grid.

Various bearings are applied. All have to withstand the varying forces and loads generated by the wind.

Screws and studs are needed to hold the main components in place and must be designed for extreme loads.

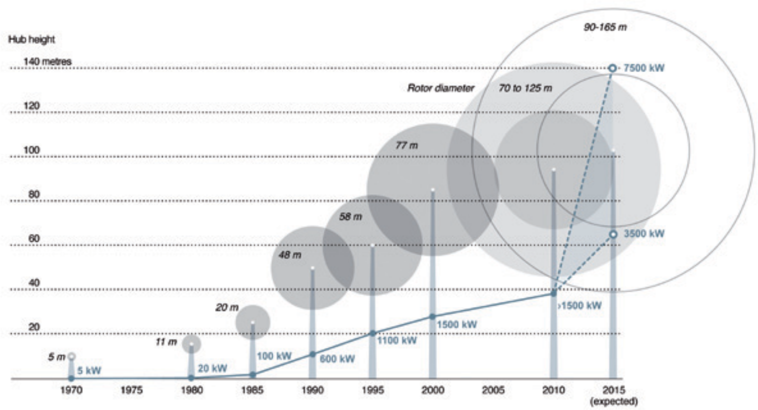
All of these components depend on steel.

The tower

Most of the steel in a wind turbine is the tower. About 90% of all wind turbine towers are tubular steel towers. They are called tapered tubular towers because they gradually narrow towards the top.

To construct a tower, fan-shaped plate segments are cut from rectangular parent steel plates and roll-formed and welded into cone sections. A section's thickness may vary from 8 mm at the top to 65 mm at the base, depending on loads and steel grades used. Offshore installations usually use thicker or stronger plates.

Longer blades increase the energy yield of a turbine. They sweep a larger area and so capture more wind. The tower and the foundation have to be adjusted to carry these heavier blades and the bigger rotor that they require. Also, to maximise yield, longer blades mean taller towers.

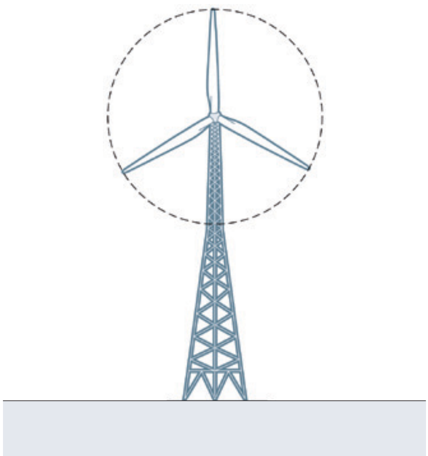


For speed and cost-efficiency, steel towers are transported to site as complete tubes. This limits the maximum tower diameter to roughly 4.3 m. For offshore developments the tower can be lifted onto a barge and shipped out whole. Taller towers are segmented for transport.

Higher steel grades can be applied to achieve lighter and taller towers. For example, by upgrading the steel of a wind tower structure from grade S355 to S500, a weight saving of 30% can be achieved. Even with a cost increase of 20-25% per tonne for the higher strength steel, the balance is positive since 30% less material is needed. More savings result from lower transport and construction costs.

Sometimes, steel-concrete hybrid towers are used to overcome transport restrictions associated with taller towers. Concrete sections are constructed and combined with steel tubes on site. However, on-site concrete solutions are heavily dependent on good weather, and require a lot of skilled labour and extended construction times. Other turbine manufacturers have installed steel-concrete hybrid prototypes using pre-cast concrete.

In forested areas, steel truss (lattice) towers are used to lift turbines above the tree-line without disturbing vegetation. They are proving a cost efficient solution for very tall towers. The world's tallest wind tower, known as the Fuhrländer Wind Turbine Laasow, is a steel lattice tower with a hub height of 160 m.



Steel lattice tower solutions were popular in the past and may see a revival. Using mainly standardised steel solutions they compare well with other tower concepts when looking at life cycle cost.

Lattice towers are constructed of pre-assembled steel sections which are hot-dip galvanised for corrosion protection and bolted together on site. The tower is then lifted by a crane.

Excessively cold environments, such as the Arctic, present specific challenges. Although a standard wind turbine can operate to -20ºC or even down to -30ºC and remain structurally sound, below -40ºC, low temperature steels are needed, as well as synthetic lubricants and heating systems in the nacelle or elsewhere.

Types of foundations

Offshore wind farms were traditionally placed in maximum water depths of 30 m and depended mainly on a gravity base (relying on spread rather than depth) and monopile foundations. Future projects could be installed in waters of up to 60 m as new foundation concepts emerge for offshore and deep water installations. In the future, foundations are likely to change from monopile to jacket-type. Both are almost completely made of steel.

Monopile

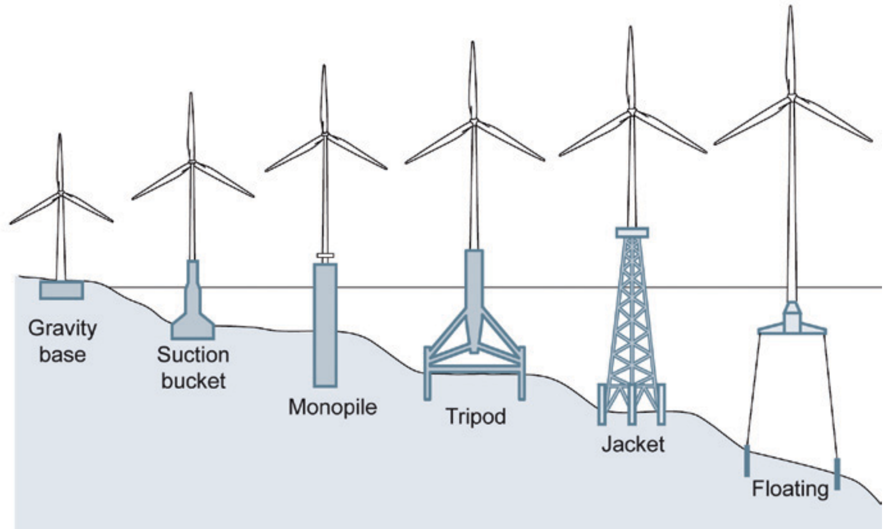
A monopile is a steel pipe pile of up to six metres in diameter with a wall thickness of 150 mm. Depending on seabed conditions, the pile is plunged far down by pile-driving or drilling, or the piles are grounded into sockets that have been drilled into rock. Compared to the gravity base foundation, the monopile has minimal and localised environmental impacts. The technique is relatively simple and does not usually require any pre-processing of the sea bed.

Tri- or tetrapod

A tripod foundation consists of a monopile divided at its bottom into a frame of steel rods. This is attached to the sea bed with piles of smaller diameter (compared to a monopile foundation or a suction bucket foundation). It can be used at greater depths than the gravity base and monopile foundations.

Jacket

The jacket foundation is similar to a lattice tower. It is a squared network of steel rods. It is anchored at four anchorage points and the whole steel construction can be mounted in one piece. Using a three-dimensional truss like the jacket foundation substantially increases rigidity. Although it is more expensive than a monopile or gravity base foundation, the jacket foundation is cost-efficient at greater depths.

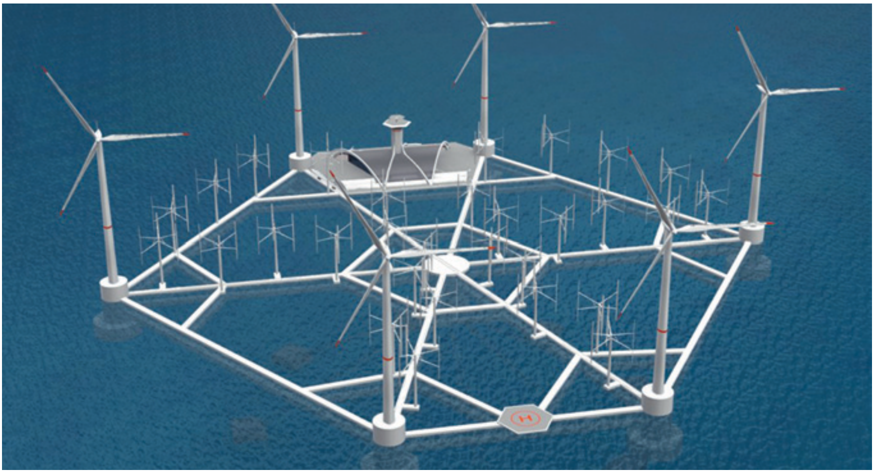


Floating

Many proposed floating concepts use designs borrowed from the oil and gas industry. One example is the HyWind concept, installed in June 2009 by Siemens and StatoilHydro. It is the first megawatt-scale floating turbine. Designed for depths of 120-700 m, it has a capacity of 2.3 MW. The structure consists of a steel floater filled with ballast of water and rocks. Extending 100 m beneath the surface, it is fastened to the seabed by three steel anchor wires.

Other floating concepts, such as the Hexicon, hold multiple turbines (see illustration below).

The Hexicon concept offers maintenance advantages. It is constantly manned and has an on-site crane. Also, it can be moved into a better wind profile position. The 25,000 to 30,000 tonnes of steel needed for the 480 m diameter platform holding 54 MW of turbine capacity would be relatively easy to recuperate at the end of its useful life.



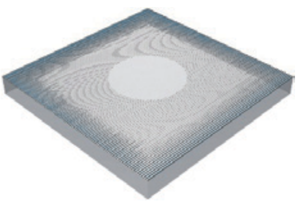
The turbines can be replaced while the steel platform itself should last for 50 years or more.

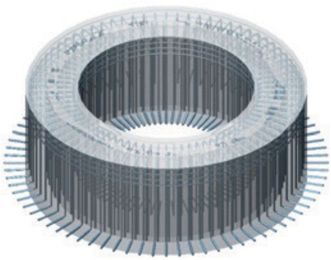
The Hexicon project is being evaluated. If successful, it will quickly increase the share of offshore wind in the energy mix.

In and around the concrete

The foundation is an unseen and yet critical part of the structure. Gravity base foundations are the most commonly used onshore foundations. Most gravity base foundations are made of steel-reinforced concrete slabs.

Steel 'carpets' are reinforcement bars (rebars) welded to flexible steel straps. The carpets are simply lifted into place and unrolled on site. Their use not only saves steel by minimising cuttings, but also means that the reinforcing steel for one wind tower foundation can be placed in less than one quarter of the time and using half the manpower compared to if using loose rebar. This offers additional cost savings.





In towers and foundations, there is much scope to work with the cement and concrete industries to spur the development of 'steel in concrete' or 'steel around concrete' solutions for wind energy.

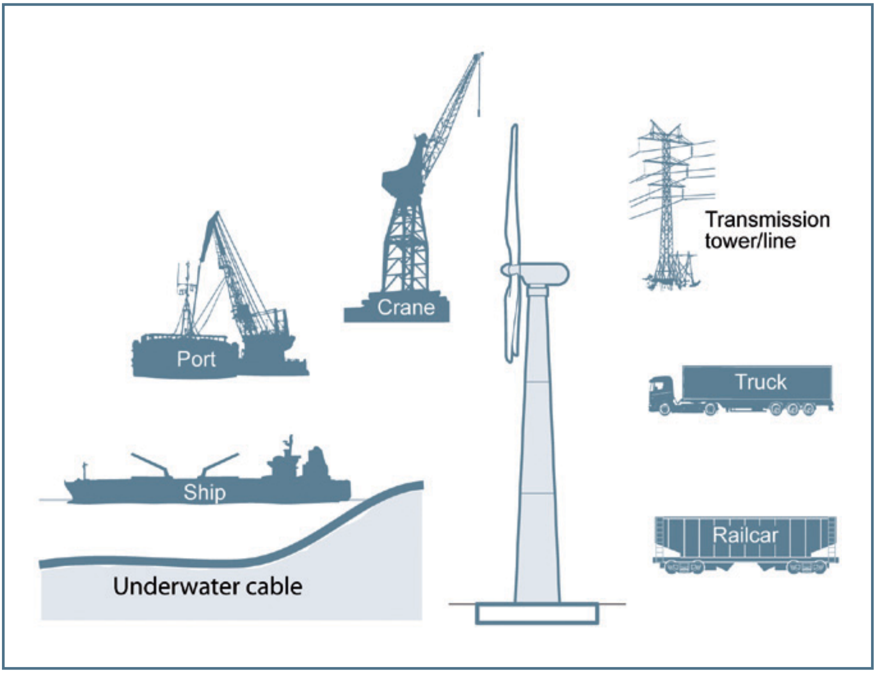
To improve durability and achieve longer-term strength, 70% of the cement in a concrete foundation can be replaced with ground granulated blast furnace slag (GGBS), a by-product from the steel industry. In many cement or concrete applications, this is the most cost-effective method for strengthening foundations because it adds no overall cost. Furthermore, compared to a foundation that does not use GGBS, it saves an average of 92 tonnes of CO_2 per foundation manufactured.

Steel in supporting applications

Increasing turbine sizes threatens to outpace the capabilities of ports, lifting equipment, trucks, trailers and rail cars. Installation capacity is one of the biggest barriers to the development of the offshore wind farms.

For example, in the ship-building industry tailor-made jack up platforms are being developed for the new types of wind turbine foundations. Crane booms made of ultra-high-strength steel are needed to hoist the heights and weights of larger turbines.

Transmission and distribution lines also require steel, and probably more of it, as installations move further offshore. Demand is growing for electrical steels to serve this market.


Crane
Transmission tower/line
Port
Truck
Ship
Railcar
Underwater cable

LIFE CYCLE THINKING

Life cycle assessment (LCA) studies have shown that there is an energy payback time of three to five months of operation. This is the time it takes for the energy savings of a project to equal the amount of energy expended since the project's inception.

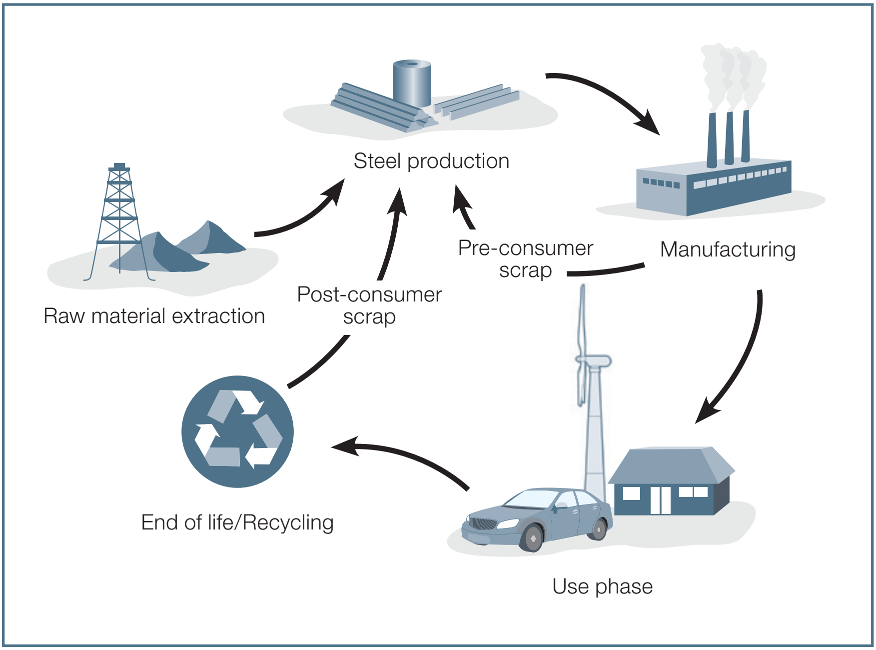
Steel is infinitely recyclable. It also has a limited environmental impact. Recovery of the material at the end of its useful life also helps to recover upfront cost, due to the value of steel scrap. If parts are not given an extended life or reused elsewhere, they return to the steelmaking process.

The life span of a wind turbine is 20 to 30 years. As turbines age, replacements are needed. Denmark and Germany are mature wind energy markets. Here, fewer opportunities for new onshore sites exist whilst offshore developments are still in their infancy. As wind farms reach the end-of-life phase of the life cycle, new solutions are being explored to extend that life.

For example, in Germany in 2010, 116 wind turbines with a total rated capacity of 56 MW were dismantled and replaced by 80 turbines with a total rated capacity of 183 MW. It is estimated that by 2015, 9,500 wind turbines will reach re-powering age. This equates to an investment of €40 billion.

From a climate change and sustainability perspective, it is important to take into account the life cycle of products. Part of the application process for permits to build wind farms often requires an explanation of how the developer plans to manage the site into the future. Consequently, re-use and recycling are of great importance.

The application of steel in most of the key compoments of wind turbines makes it possible for the wind energy industry to meet the technical requirements of the turbines and climate change demands at the same time.


Steel production
Manufacturing
Pre-consumer scrap
Post-consumer scrap
Raw material extraction
End of life/Recycling
Use phase

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