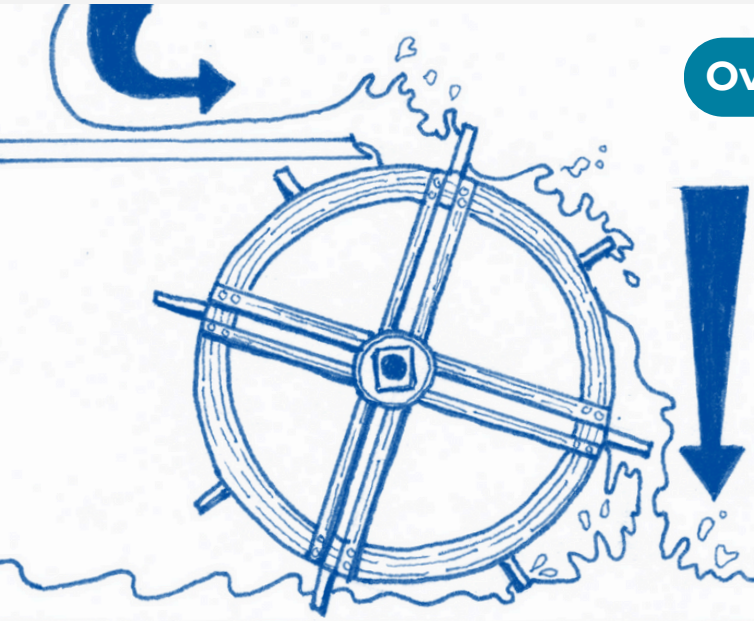
How Does A Waterwheel Work?

In 2023, only **1.8% of the UK's electricity generation mix came from hydropower.** Historically, waterpower from rivers and tides was widely used for mechanical tasks. **Over 6000 mills were recorded in the Domesday Book** (completed 1086), many of which are assumed to be watermills.

Early medieval waterwheels were set directly into rivers. The efficiency of watermills was increased by setting the wheel in a channel, called the "**Leat**". Millers could then use **sluice gates** to regulate the amount of water that arrived at the wheel.

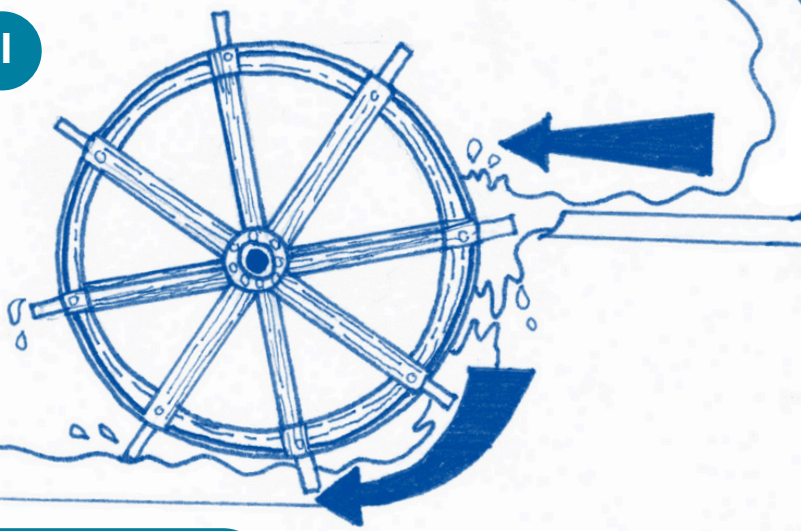


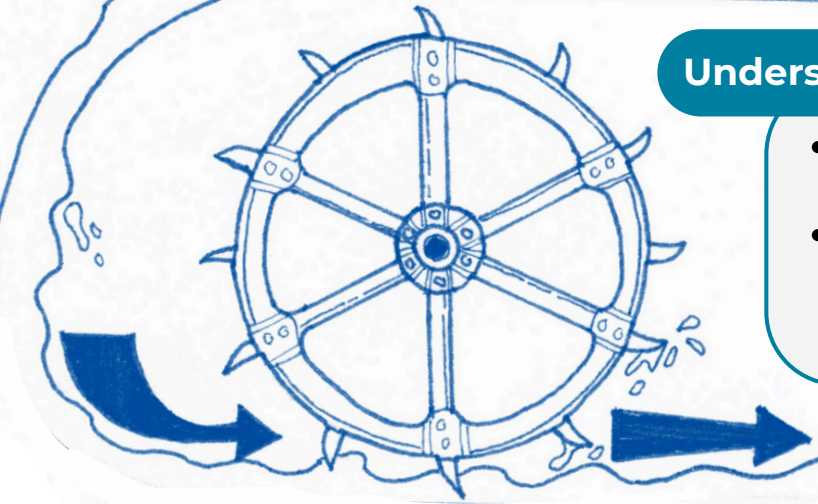
Overshot Wheel

- The power from a waterwheel is determined by the **fall of water** and its **rate of flow**.
- Overshot wheels are the most efficient.
- The water that pushes the wheel comes from above, increasing its gravitational force.

Breast Wheel

- This is a variation of the overshot wheel.
- Water arrives lower than on an overshot wheel. The lower fall means that less power is typically generated using a breast wheel.





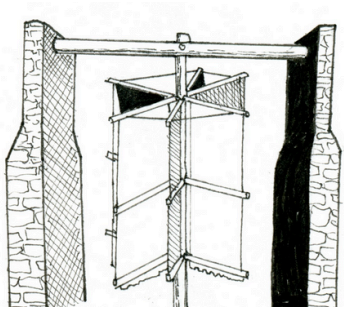
Undershot Wheel

- The least efficient type of waterwheel because there is little or no fall.
- This type of waterwheel is driven by the impulse of the water beneath it striking the lower floats/paddles.

From Windmill to Turbine

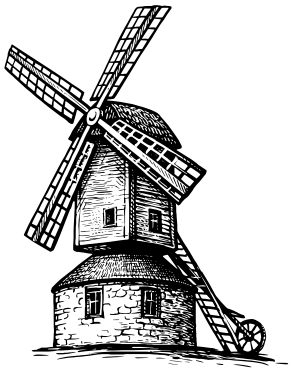
Did you know? Electricity-generating wind turbines are descended from the design and technology of traditional windmills.

Windmills work when the power of the wind turns the blades or sails around a rotor. In a traditional mill, this **rotational energy** drives a shaft or other machinery. In a turbine, the rotor spins a **generator**, which creates electricity. Getting to these simple sounding ideas, however, took centuries of engineering development and technical experimentation.



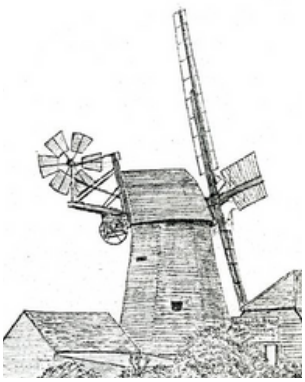
Horizontal Windmill

- The earliest extant examples of windmills were built in Persia (modern day Iran) as early as 7AD.
- These large wall-like structures were used to grind grain and buffer nearby villages from the force of the wind. The strong winds in Sistan compensated for the low efficiency of these drag-driven windmills.



Post Mill

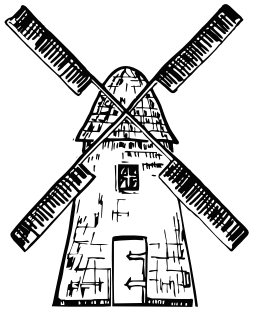
- The earliest form of European windmill.
- An upright timber post stood up from the ground. The body of the mill, including machinery and sails, could be rotated around this post to face the wind.
- The sails were angled for greater aerodynamic lift, which made them more efficient at converting wind energy into power.



Smock Mill

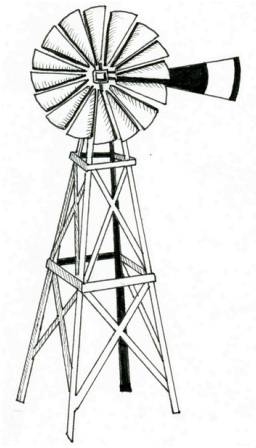
- A mill with a fixed timber body.
- The cap and sails at the top are moveable, and can be turned to face the wind.
- Smock mills were often bigger than post mills and could hold more bits machinery.

Illustration: James Venn, Smock Mill drawing, Cranleigh [Mills Archive, VENN-25600]



Tower Mill

- Like smock mills, these mills have a fixed body and are fitted with a revolving cap.
- Unlike smock mills, tower mills (hence their name) are made of stone or brickwork.
- These building materials meant mills could be built taller.



Multiblade Windmill

- Commonly used to pump water in rural areas in North America and Europe.
- They are automatically self-regulating and can furl their own rotors to avoid damage from in dangerous winds.
- A recent archival discovery by windmill authority **Philippe Bruyerre** suggests that the first documented electric wind turbine was built by **Josef Friedländer**.
- Friedländer used an American Halladay windmill to drive a dynamo at the Vienna International Electrical Exhibition in **1883**.

Early Electricity Generation

Windmills fell into decline during the **Industrial Revolution**, when wind power was superseded by steam power. In the **19th century**, various small-scale experiments began to test the potential for windmills to generate electricity.

France, 1887 - Charles de Goyon

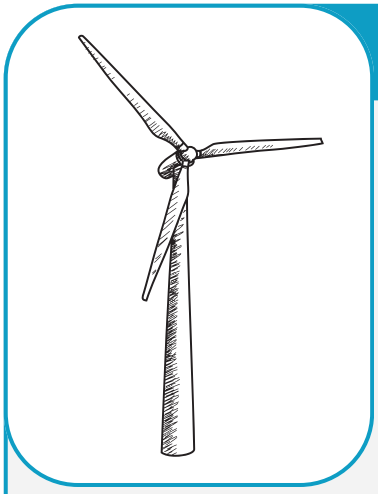
- De Goyon and his collaborators invented an electricity generating windmill. It was used to charge batteries for commercial sale.

Ohio, 1888 - Charles Brush

- When it came to the generating capacity of windmills, it appeared that **bigger was better**. Brush's windmill had 144 blades measuring 17m in diameter. The rotor and dynamo sat atop an 18.3m tower.
- Like the smaller multiblade windmills it was based on, Brush's windmill was self-regulating and could furl its rotor in high winds.

Edinburgh, 1897 - James Blyth

- Blyth designed an electricity generating turbine to light his summer home



20th Century Breakthroughs

- Lasting commercial breakthroughs occurred in **Denmark**. In **1891, Poul la Cour** installed his first electricity-generating wind turbine at Askov.
- La Cour's wind-tunnel experiments in 1897 corroborated the established knowledge of millwrights: **four blades were better than six.**
- La Cour was part of a broader social movement to raise living standards through education. He made his work public domain through scientific publications.

An abundance of wind and the ability of communities to understand, access, and own wind power technologies laid the groundwork for a **greater turn towards wind energy in the 1970s.**

- The three-blade turbines we see on hillsides and offshore windfarms today derive from the inventions of **Johannes Juul**, a disciple of la Cour's. Juul was motivated to research the potential of wind power by the high-cost and low availability of fuel in post-war Denmark.
- Juul's innovative combination of **stall regulation** and **pitchable blade tips** became cornerstones of subsequent turbine designs. These blades are more aerodynamic than traditional canvas or wood windmill sails.

Environmental Impact of Wind Turbines

Wind is a clean and renewable source of energy, but what about wind turbines?

According to the National Grid, wind power contributed **29.4% of the UK's total electricity generation in 2023**. If wind power continues to grow, it is important to consider how the use and construction of wind turbines can be made more sustainable.

Once running, wind turbines produce almost no pollution. Most of the carbon pollution from wind turbines is released during manufacture.

A 3MW wind turbine needs **1200 tonnes of concrete** to be built. On top of that, the Northwestern Mining Association calculates that a single wind turbine requires **335 tonnes of steel, 4.7 tonnes of copper, 3 tonnes of aluminium,** and another **2 tonnes of rare earth elements.**

Irresponsible mining activity can leave behind cavernous **legacy mines**, where the surrounding area has not been rehabilitated or rewilded after the damage of excavation. Attempts to meet demand by mining polymetallic nodules on the sea-floor have been met with condemnation by many environmental groups and scientists, who object to disturbing these untouched regions.

The lifespan of a wind turbine ranges from **20 to 30 years.** The question of how to best to recycle wind turbines within a **circular economy** is a pressing one.