Experimenting Close to the Wind

Wind energy is a technology with a future – and with origins that can be traced far back into the past. One of its pioneers was **Albert Betz**, who was a Director at the **Max Planck Institute for Fluid Dynamics** in Göttingen from 1947 to 1956.

TEXT **MICHAEL GLOBIG**

"When, after the war, our economy was suffering acutely from the general shortage of coal, attention once again turned more eagerly to other sources of energy. In addition to the development of hydropower, it was primarily recommended to make greater use of wind energy. This interest continued even after the coal shortage was overcome." Albert Betz, who wrote these lines, was himself one of the pioneers of wind power. It was he who postulated a law, now named after him, that no engineer can afford to ignore.

Betz' law states that a wind turbine can convert a maximum of 59 percent of the kinetic energy of the wind into mechanical energy. Betz arrived at this theorem mathematically, but it can also be explained thus: if an attempt were made to extract all of the energy from the wind with a turbine, the air speed behind the rotor would be zero – in other words, it would never pass the wind turbine. In this case, there would be no energy to extract from the wind, as no more air could flow into the rotor. At the other extreme, the wind could be allowed to flow through without reducing the air speed at all – in which case, once again, no energy would be "tapped."

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It can thus be assumed that, between these two extremes, there must be an area in which mechanical energy can be extracted by slowing the wind down. Upon closer examination, it becomes apparent that there is a very simple solution: the ideal wind turbine slows the wind by two thirds of its original speed.

Albert Betz was born in Schweinfurt on Christmas Day 1885. He studied philosophy in Eichstätt, and later mechanical engineering at the Technical University Munich. In 1905 and 1906, he worked at a shipyard, the Germaniawerft Kiel, after which he studied shipbuilding at the TU Berlin-Charlottenburg, earning his degree in 1910. From 1911 until 1918, he was an assistant at the Institute of Applied Mechanics at the University of Göttingen – a position that left him time to pursue his mathematics and physics studies. In 1918, Betz took charge of the model trials department at the Göttingen aerodynamics laboratory. He received his doctorate from the university in 1919 and qualified three years later as a professor of physics. In 1935, Albert Betz was appointed professor at Göttingen University. From 1924 to 1937 he was a Scientific Member, and from 1938, Director of the Kaiser Wilhelm Institute for Fluid Dynamics, which was established in Göttingen in 1925.

Inspired by the sophisticated criteria for aircraft propellers, in the mid-1920s Betz turned his attention to windmill sails and discovered that these are subject to the same laws as propellers: a propeller driven by an engine creates air pressure, whereas windmills rotate in response to natural air pressure. Exactly the same aerodynamic laws apply to both and can be calculated using the same equations. However, windmills with sails that exhibit an exact propeller shape have a very low starting torque: they do not attain their high efficiency until they reach nominal speed.

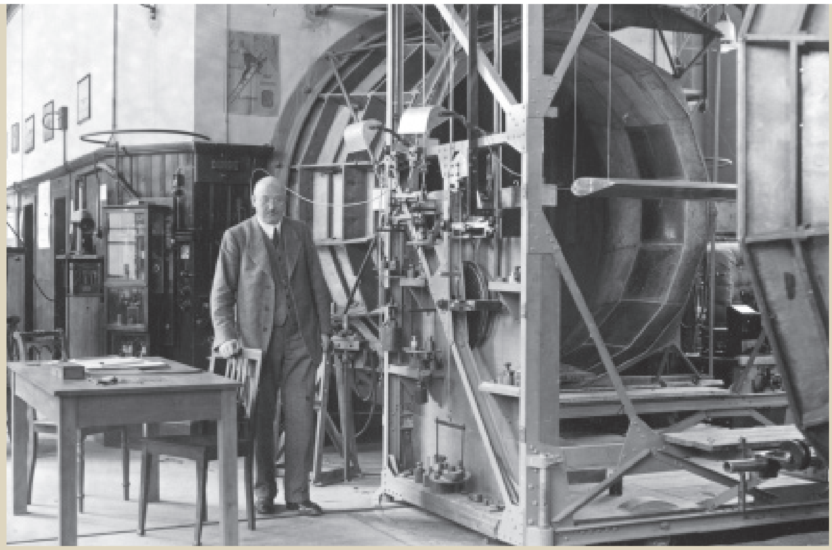
As the successor to renowned expert in fluid mechanics Ludwig Prandtl, from 1937 to 1945, Betz headed the Aerodynamics Laboratory, which belonged to the Kaiser Wilhelm Society at the time and was later taken over by the Max Planck Society. From 1947 to 1956, Albert Betz was a Director at the Max Planck Institute for Fluid Dynamics (which was renamed the Max Planck Institute for Dynamics and Self-Organization in 2004). In the early 1930s, Betz had also learned to fly a glider and qualified for his license in 1934 – a very practical way of coming to grips with the subject of his research.

He investigated numerous wing profiles and described in mathematical terms the optimum width at any given point along the wing.

Using the latest discoveries in aerodynamics, he then went on to develop the optimum sails for windmills together with his colleague Kurt Bilau: they proved their superiority when tested and measured in

This photo, taken in July 1950, shows the pioneers of aerodynamics, Ludwig Prandtl (left) and Albert Betz, by the shallow water tank at the Max Planck Institute for Fluid Dynamics, watching eddies form behind objects as water flows around them.

Photo: MPI for Fluid Dynamics



Albert Betz in 1930 standing beside a three-component balance. The object being measured is a rectangular wing.

the wind tunnel. Betz also carried out wind tunnel research together with another prominent engineer, Ludwig Bölkow, who was working for Messerschmitt.

These trials demonstrated that the flat sails propagated by the Dane Poul La Cour in 1890 as the ideal solution were in fact no match for streamlined profiles. Once the rear section of such sails was streamlined, the performance almost doubled. This was because turbulence ceased, air resistance fell and lift increased. By 1940, sails of this shape had been successfully fitted to 130 mills in place of the originals.

Göttinger Presse, June 14, 1955

» A wish long cherished by the Director of the Max Planck Institute for Fluid Dynamics, Prof. Betz, is set to come true with the construction of a "flying wind tunnel."

These and other improvements came at a time when a public electricity grid was just being developed, and wind energy technology was in danger of being sidelined. The successes achieved in theory and in practice were all the more important in that they laid the foundations in physics and technology on which the refinement of wind energy systems would later be based.

The Second World War brought development to an abrupt halt: during the War, plans for new windmills were abandoned the world over, and the few installations that were under construction were not completed. When the War was over, wind energy projects remained on the back burner – oil was plentiful and cheap. It was not until the oil crisis of 1973 that numerous industrialized countries began to seek ways to reduce their dependence on oil. Here, at last, wind energy offered one possible alternative.

ENERGY FROM ALTERNATIVE SOURCES – THANKS TO THE OIL CRISIS

In parts of Europe, America and Asia, windmills were the principal sources of energy until well into the 19th century. They were never quite forgotten, but it took the oil crisis to revive interest in wind energy. The governments of a number of industrialized countries encouraged the development of wind energy converters (wind-powered turbines for electricity generation). This would soon bear fruit, for example in the US, where wind energy converters with a capacity of up to several hundred kilowatts were grouped together in wind farms. Some mega-installations were also built, with output running into thousands of kilowatts.

Such projects were undertaken in Germany, too: in 1982 the 100-meter tall Growian (*Grosse Windanlage*, or Large Converter) with a design capacity of up to three megawatts was built at the mouth of the River Elbe. Growian, however, didn't measure up to the stress and strain. Cracks soon appeared, as winds are stronger by half at a height of one hundred meters than they are at ground level, where their speed is slowed by a variety of obstacles. That, and the fact that the wind aloft is more constant, is why wind turbines are always erected on tall masts.

The design of such wind power installations generally follows a basic pattern: the rotor is shaped like a propeller and is combined with a gearbox and generator to form a single module. The module sits on top of a tubular or lattice mast and is turned into the wind with a fixed rudder. Windmills like this are a competitive option wherever there is plenty of wind and few other energy sources available. However, using the windmill to produce electricity can be problematic: when demand is high – in the evenings, for example, when the wind drops – the windmill is unable to supply enough energy. Conversely, when the wind is strong, there is insufficient use for the power.

Albert Betz died on April 16, 1968 in Göttingen. Three years prior to this, he was awarded the Carl Friedrich Gauß Medal in honor of, among other things, his meritorious achievements in formulating the basic principles of aerofoil theory. Betz did not live to see the boom in wind energy in Germany. In 1976, the author Felix von König came to the following conclusion in his book "*Windenergie in praktischer Nutzung*" (Wind energy in practical use): If, apart from water power, wind energy should one day be the only source available, wind power would certainly be inadequate to guarantee a regular power supply in today's sense, since the wind is too irregular. However, for a pre-industrial standard of living it should suffice – thanks to wind energy and our knowledge of physics and technology, there will be no return to the Stone Age. Albert Betz surely would not have disagreed. ◂

Photo: DLR-Archiv Göttingen