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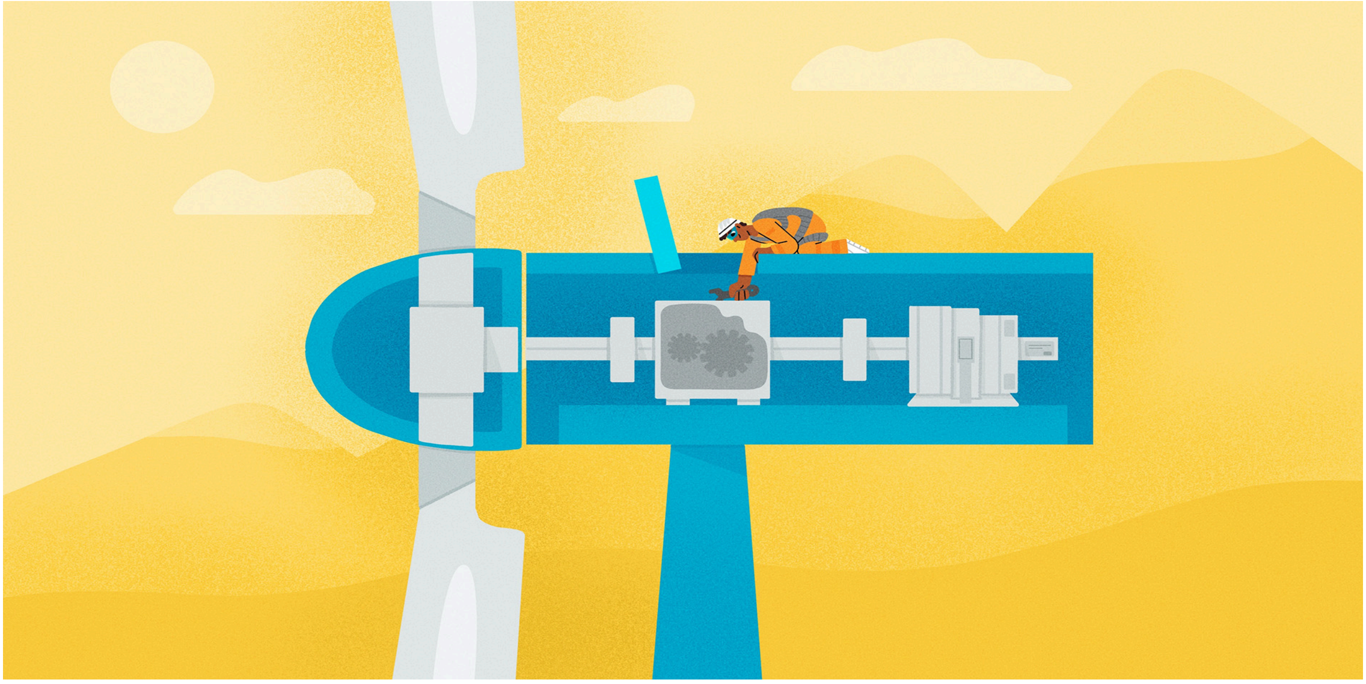

HOW CAN WIND TURN INTO ELECTRICITY?

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Wind generators, also known as wind turbines, turn wind into electricity. A wind turbine consists of several metal blades mounted on a metal pole and connected to an electrical generator. The wind rotates the blades, which turn a gear shaft connected to the generator, causing a coil of wires in the generator to move around a magnetic core. This generates an electric current that can be used for all our electrical needs, such as lights. Wind turbines should be placed in areas with strong winds, such as beaches, high mountain peaks, and wide-open mountain valleys. Wind turbines do not consume fuel, and therefore they are environmentally friendly because they do not emit the greenhouse gases that cause global warming.

HOW CAN MOTION BE CONVERTED TO ELECTRICITY?

Almost 200 years ago (1831–1832), English physicist and chemist Michael Faraday discovered that when a wire made of a metal that conducts electricity well, like copper, is passed near a magnet and the ends of the wire are connected, an **electric current** is created. Indeed,

ELECTRIC CURRENT

Movement of an electric charge; defined as the amount of electric charge passing through a given area in a unit of time.

it was established later that a changing magnetic influence will cause an Electric effect, but also that a changing electric influence causes a magnetic effect. Soon after, Faraday built a device made of a copper disc that could be spun between horseshoe-shaped magnets, using a handle. Through two electrical connections—one in the center of the disc and one on its rim—Faraday was able to produce a weak electric current. His method is still used in electrical **generators** today, to produce most of the world's electricity (see Figure 1).

GENERATOR

Device that converts energy from one form to another. A wind generator converts the kinetic energy of wind into electrical energy.

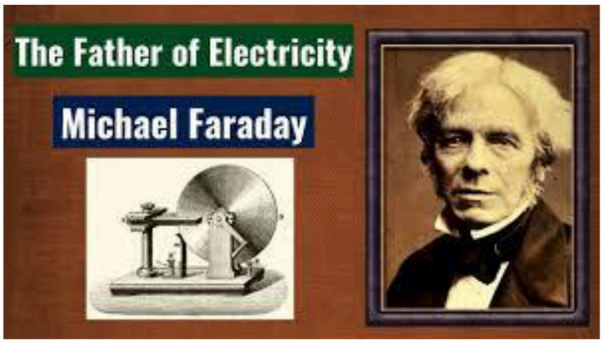

Figure 1

Figure 1

Michael Faraday was a British scientist and is considered the father of the theory of electricity. He invented the generator pictured on the left. To watch a video about his life, click here (Image credit: Flourishing Exams).

Later, the generator was refined so that the permanent magnet was replaced by an electromagnet, consisting of coils of wire wrapped around an iron core. When a current flows through the wires, it creates a magnetic field. The basic structure of any generator consists of two parts: the fixed part, called the stator, and the moving or rotating part, called the rotor (Figure 2). The question is how to make the rotor turn.

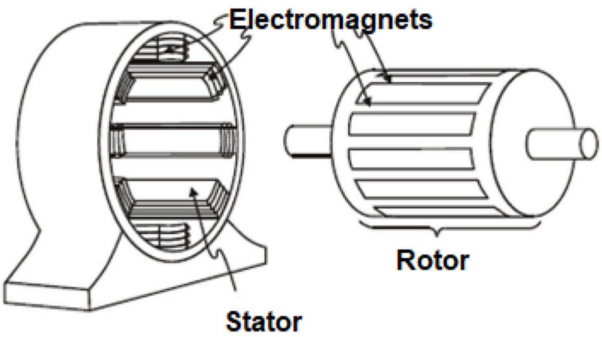

Figure 2

Figure 2

The basic structure of a generator includes a non-moving part (the stator) and a rotating part (the rotor). Both parts include coils of metal wires (electromagnets). The electromagnets are used to create both a magnetic field and an electrical current (Image credit: https://www.polytechnichub.com/construction-3-phase-induction-motor/stator-and-rotor/).

SINCE THEN, GENERATORS HAVE CHARGED AHEAD...

Faraday's generator was powered by the arm strength of the operator who turned the handle, and it provided very little electricity. Today, we need a lot of electricity to run the many devices found in our homes: lights, air conditioning, refrigerators, washing machines, ovens, televisions, computers, and more. We also need electricity to charge our mobile phones, and soon we will need to charge our electric cars. And of course, we are talking about *millions* of houses in *hundreds* of countries around the world. We need a whole lot of electricity—a lot more than can be generated by hand.

So, instead of turning rotors by hand, we use motors. Motors can provide more rotational force than a human can, and they can rotate much faster. However, motors have a big disadvantage: they require fuel. The various materials that can be used as fuels, including coal, natural gas, and oil, all cost money [1]. Furthermore, these fuels are finite, meaning they will run out one day. On top of that, these fuels must be burned to release the energy to power the motor.

All fuels pollute the air, but not to the same extent: coal pollutes more than natural gas does, for example. The pollution produced by burning contributes to climate change, primarily due to one of the pollutants called carbon dioxide. When this gas is emitted into the atmosphere, it prevents heat from leaving the Earth, creating what is called the greenhouse effect, and making the Earth progressively warmer. Warmer temperatures are causing glaciers to melt and sea levels to rise, which will lead to flooding of cities close to the sea. Additionally, global warming causes extreme and unusual weather, as we have experienced in recent years.

So, what can we do? We cannot give up the electricity we need for so many things, yet we cannot continue to pollute the atmosphere. The answer lies in **clean electricity**, meaning electricity that is produced without polluting the atmosphere.

CLEAN ELECTRICITY

An electricity generation process that does not pollute the environment.

PRODUCING CLEAN ENERGY

How can we produce enough electricity for our needs without burning polluting, expensive fuels? We can do so through the use of other types of energy, such as solar energy from the sun. Solar energy is the main way clean electricity is produced in Israel.

Today, there are **photovoltaic cells**, also called solar panels, that can convert sunlight into electricity, and this technology is constantly improving. Individuals and business owners alike cover their homes and businesses with photovoltaic cells. By doing so, they save on their electricity bills, and even receive money back from the electricity company for the electricity they produce.

PHOTOVOLTAIC CELL

A device that generates electricity using sunlight.

There are also several possible ways to turn the rotor of a generator without using fuel, to produce clean electricity. A waterfall, for example, can turn a wheel that rotates a generator. At Niagara Falls, a huge waterfall located on the border between the USA and Canada, there is a power station powered only by the falls. In Israel, there is a project planned called the Mediterranean–Dead Sea Canal, based on a similar idea. The project involves digging a canal between the Mediterranean Sea, which is at sea level, and the Dead Sea, which is 436 meters lower, to create a waterfall that will rotate an electricity generator.

A GENERATOR POWERED BY WIND? IT IS A BREEZE!

Wind is another way to create clean electricity. A wind generator, also known as a wind turbine, consists of blades mounted on a long pole, called an axis. It essentially an updated version of the old windmills that were once used to grind wheat into flour.

There are two main types of wind turbines, both based on **kinetic energy**. The first type is a horizontal axis wind turbine (HAWT; Figure 3B). In a HAWT, the mechanical movement created by the rotation of the blades is directly connected to a generator. This is similar to an electric fan, but an electric fan *uses* electricity to rotate the motor that turns the blades to create wind, while in a HAWT, the wind turns the propellers that rotate the rotor to *create* electricity.

KINETIC ENERGY

The energy of motion, which is the simplest type of energy.

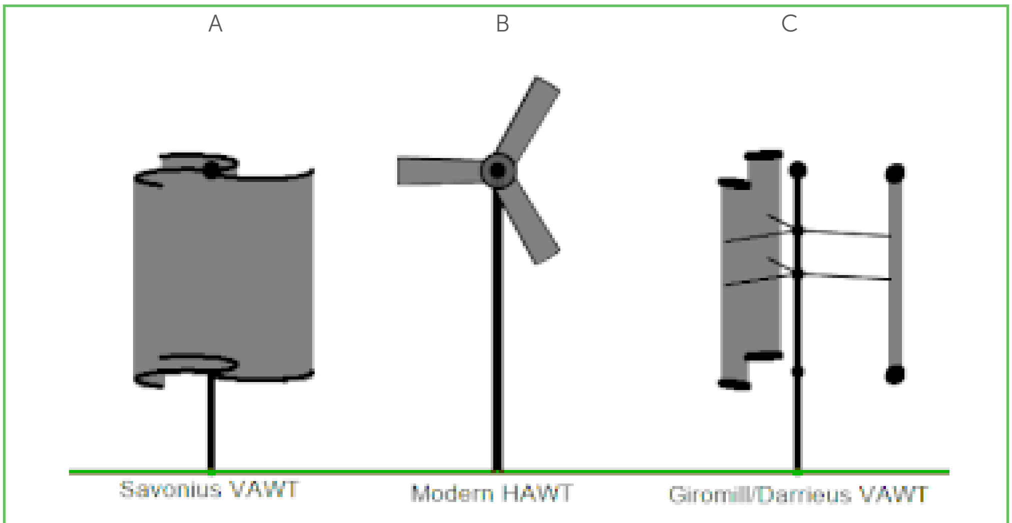

Figure 3

Figure 3

Three common types of wind generators. **(A)** In a Savonius VAWT, this is vertical axis wind turbine with two (or more) scoops. **(B)** A modern HAWT, horizontal axis wind turbine. **(C)** A Darrieus VAWT (this is vertical axis wind turbine which one or more blades), the Giromill subtype of Darrieus turbine has straight, as opposed to curved, blades (Animation credit: Ssgxnh, and is copyrighted in the public domain).

The second type of turbine is a vertical axis wind turbine (VAWT; Figure 3C). Most VAWTs look a little like the flame of a candle, formed by 2–3 curved blades connected at the top and bottom to a vertical axis whose spinning powers the generator located at the base of the turbine. Another type of VAWT, which is sometimes placed vertically next to a wall or laid horizontally on the ground, is the cross-flow turbine, also known as a "Savonius" (Figure 3A).

BUT WHICH WIND TURBINE IS BETTER?

A study conducted in the European Union on wind turbines in Asia found that the efficiency of cross-flow turbines is higher than that of turbines with blades.

To determine how efficient a wind turbine is, we use what is called an **efficiency index**. This is the ratio between the amount of electricity produced in a given period of time and the amount of wind that passes through the "swept area" of the turbine—the circle created by the propellers as they sweep through the air. Both the amount of wind and the amount of electricity are expressed in terms of energy. The maximum efficiency of a wind turbine theoretically stands at about 59.3%. This is known as the **Betz limit**, according to which 16/27 of the initial energy of the wind is converted to electricity—but this percentage is not actually achievable. Manufacturers and operators of wind turbines report that their actual efficiency is 15%–35%.

EFFICIENCY INDEX

A measure of how much of the wind kinetic energy is converted to electrical energy (electricity).

BETZ LIMIT

A theoretical maximum on how good a turbine can be in converting wind to electricity, this is an upper limit of the efficiency index.

Experience and research in this field have shown that VAWTs have a higher efficiency rate than HAWTs. Despite this, VAWTs are less common due to high design and construction costs.

WHAT HAVE LEARNED SO FAR?

Wind turbines are one of the cheapest ways to produce electricity. The potential of generating electricity from wind is proportional to the wind speed. This means that, to generate the most electricity possible, wind turbines must be placed in very windy places. In Israel, for example, a wind turbine facing the direction of the wind in the Golan Heights produces, on average, eight times more electricity than a turbine in the coastal plain [2]. This is because the wind speed in the Golan Heights is approximately double the wind speed in the coastal plain. Placing turbines at higher elevations (the higher you go, the faster the wind) and using windbreaks, such as rows of trees or bushes that buffer and direct the wind, are other ways to obtain higher wind speeds [3, 4].

In most of the world, wind turbines are generally found on wind farms, which are complexes where several wind turbines operate together. Denmark is one of the first countries in the world to use wind energy to produce most of its electricity. On certain days, Denmark manages to fill all its electricity needs with wind generators, and even transfer some of the electricity produced to its neighbors!

Overall wind energy can be used to satisfy at list part of humanity energy needs, it is clean and cheap. We hope that more countries will follow the footsteps of Denmark and make optimal use of their wind energy resources and mitigate carbon emission and global warming.

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CONFLICT OF INTEREST: The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

AVIV, AGE: 8

Hello, I am Aviv. I like to read and draw. I was born and raised in Israel, but I moved to England for a few years. I live there with my parents, my little sister and my baby brother, with whom I love to play. My cat George had to stay in Israel with my grandmother. When I grow up, I want to be an actress or an artist. I am interested in science because it is related to many subjects that I like.

CENTER FOR GIFTED AND TALENTED STUDENTS, EAST JERUSALEM, AGE: 13

We are 7th grade students studying at the Center for Gifted and Talented Students in East Jerusalem. We are curious, highly motivated students, imbued with a spirit of exploration and adventure. We also love to laugh and play sports.

AUTHORS

ASHER YAHALOM

Born in Jerusalem in 1968, he received his B.Sc. in physics and mathematics at the Hebrew University, and later his master's and doctorate in physics at the same university, completing his doctorate thesis in 1996. During his post-doctorate at Tel Aviv University, he was invited to join the faculty of Ariel University, and, in 1999, became the fourth faculty member in Ariel University's Department of Electrical and Electronics Engineering. In 2006, he was appointed an associate professor, and in 2013 he was made full professor. From 2014 to 2017 he served as head of the department, and from 2018 to 2021 served as the vice dean. He has more than 270 publications under his name, including several patents. He is a nine-time winner of the Gravity Research Foundation award. Professor Yahalom is married to Judge Hadas Yahalom, president of the Regional Labor Court in Tel Aviv, and they have three children. In his spare time, he likes to swim and play basketball. *asya@ariel.ac.il