There's something in the air

For a long time, inventors have been promising to supply everyday devices with energy wirelessly. Why they failed and how they still hope to get there.

In September 1901, Nikola Tesla began building a mysterious tower in Long Island on America's East Coast. In the years before, the electrical pioneer had experimented with wireless power transmission. He generated high-frequency magnetic fields with one coil, which in turn excited currents in a second, distant coil. With the tower, he probably wanted to scale up such demonstrations. "That's at least a guess," says Bryan Field. The Farmingdale State College physicist is working at the "Tesla Science Center" to build a museum at the former site of the structure.

Tesla himself was secretive about exactly how the tower was supposed to work, Field says. The official version was that the wanted to transmit information with it. That's what Tesla led his backer, banker J. P. Morgan, to believe. But later interviews reveal that he intended to transmit electricity wirelessly with it. He believed he could pump electrical energy into the air or ground and get it out elsewhere with identical equipment, Field says. With small towers, Field explains, he wanted to power households. Later, Tesla even fantasized about powering electric planes that way. By 1902, the 57-meter-high wooden structure of the tower was ready. But J. P. Morgan turned off the money tap when he learned of the real plans. Never completed, the tower was demolished in 1917.

From a physics point of view, the idea was doomed to failure. But the desire to transmit energy wirelessly still drives inventors. In the seventies, NASA experimented with microwaves that bridged distances of more than a kilometer. Around the year 2006 the smartphone era dawned. Cell phones became constant companions, but their radius of movement is reduced to the length of the charging cable as soon as the battery runs out. Wouldn’t it be nice if the energy could be conducted through the air to the devices? Designers would then no longer have to worry about charging sockets. Smart watches would no longer have to be taken off for charging. Wireless energy transmission could enable spectacular developments, for example electronic contact lenses that project information into the field of vision or a world full of sensors that constantly measure the air quality in cities, the pesticide concentration in fields or the condition of roads and bridges. Bryan Field even dreams of microscopic robots that search our bodies for pollutants or signs of cancer. "You could load them from outside the body while sitting in front of the television", he says.

The technology to power all this seems to be on the verge of being ready for the market for years. The startup "uBeam", founded in 2011, promised to send energy through offices and living spaces by ultrasound. The company raised $ 26 million for this. In 2007 researchers from the Massachusetts Institute of Technology presented two copper coils in *Science*. They were so well tuned that the magnetic field of one induced enough current over a distance of two meters in the second to operate a 60-watt light bulb. The authors put the efficiency at 40 percent. This gave rise to the spin-off "Witricity". The CEO of this company supplied an iPhone with wireless power during a presentation some years later. In January 2016, the electrical engineering magazine *IEEE Spectrum* ran the headline: "Wireless energy sounds like the future, but it will happen this year".

It hasn't happened to this day. "UBeam" saw itself exposed to fraud allegations and fizzled out. "Witricity" now specializes in wireless charging of electric cars. You can supply cell phones without a cable, but you have to put them on a special charging station. In practice, wireless energy transfer overcomes some centimeters at maximum. There are two reasons for this.

First, the coils get out of step when you change their position. The efficiency drops. Axel Hoppe from the "Energietechnische Gesellschaft" knows how difficult it is to get a grip on this. He remembers how a mechanical engineering company tried to wirelessly supply sensors on the joints of an industrial robot with power. The system relied on gigantic control cabinets to operate the meter-wide coils. "That is the typical way that you have to go in order to transfer energy," says Hoppe.

The second reason are the electromagnetic fields. Markus Rehm from the Furtwangen University of Applied Sciences was once approached by a gentlemen's outfitter, who asked him to design a wireless showroom. “He wanted to equip the floor with coils and operate screens and lighting this way”, says Rehm, who is an electronics expert. He had to refuse the order because the electromagnetic fields of the systems would interfere with technical devices. Emission protection laws prohibit exposing people to excessive electromagnetic radiation anyway. "The advantage of wireless charging over short distances is that nobody can get between the sender and the receiver," says Rehm.

Anyone aiming for greater distances has to come up with something. The American company Ossia relies on targeted radio waves. Their system consists of a transmitter and several receivers. The receivers constantly emit weak radio signals. As soon as they arrive at the transmitter, it knows that it has a clear field of vision on the receiver and sends the radio waves towards it. Since the system is only activated when the view is clear, it does not bombard the environment unnecessarily with electromagnetic radiation, the company promises. It also points out that the system is approved in Europe.

While it can transmit up to three watts at a distance of one meter and thus keep a smartphone running, the power drops to 50 thousandths of a watt at ten meters. The efficiency also drops to a few percent. Regarding this numbers, Ossia points out that the system makes cables and non-chargeable batteries obsolete after all. The company does not manufacture products itself, but is currently working on marketing the technology to other manufacturers.

At the experimental stage of the development spectrum, you find a kind of charging room, which researchers from Japan and the USA recently described in *Nature Electronics*. It is surrounded by metal plates on which alternating currents flow. These plates are connected with capacitors. An electric field oscillates in these. The magnetic field on the other hand forms waves throughout the room, where it supplies the coils of receiving devices with energy. Depending on the frequency, two different magnetic field patterns are formed - one that better covers the center of the room and one in the corners. So you can get up to 50 watts of energy anywhere in the room, which is enough to run a typical laptop.

"The difficult thing was to design the room in such a way that it works at certain frequencies that we had previously determined," says one of the inventors, Takuya Sasatani from the University of Tokyo. This enabled them to choose frequencies that did not interfere with electrical appliances. Sasatani promises that there is even cell phone reception. According to a simulation, the energy absorbed by people in the room remains below the limits applicable in the US. For Axel Hoppe however, this is only half the story. The magnetic field oscillates at a frequency with which it generates small currents in the body that stimulate the nerves. The researchers ignored that, says Hoppe. Sasatani replies that the requirements for the absorbed energy are stricter, so that was the focus.

In order to translate the concept into reality, one would have to build metal plates into the walls during the construction of buildings. Sasatani therefore believes that the system will initially be used in laboratories. The magnetic field could drive electronics implanted in test rats while they move freely.

A team from the Georgia Institute of Technology, on the other hand, wants to use infrastructure: the 5G mobile network. The new standard relies on antennas every 100 to 180 meters. It also allows signals to be sent specifically in the direction of the device for which they are intended. Energy can be extracted from these signals. For this purpose, the researchers built receivers the size of a credit card, which they recently described in *Scientific Reports*. There are mini antennas on the receiver that convert the radio waves into electricity. They are coupled in such a way that they can absorb the energy from all sides. Since the transmitters use the standard to send their signals and thus energy to the receivers in a targeted manner, a business model for the mobile network operator could be developed from this. They could ask for money for sending energy to small devices like sensors. "We are working with mobile operators to explore these possibilities," says study author Manos Tentzeris.

So far, these possibilities seem to be limited. In an experiment, the researchers showed that the idea works. However, they have also calculated that at a distance of 180 meters, at best, a few microwatts will reach the receiver. You could only operate simple sensors with it. Nevertheless, co-author Aline Eid believes that the 5G signals can even be used to power drones in flight. “We're working on that right now,” she says, but doesn't want to reveal any details. Only this much: "It depends very much on the size of the recipient".

This 5G power grid has parallels to Nikola Tesla's visions. When asked how this man would look at today's technical developments, Bryan Field replies that he might feel vindicated. “He might think about us: ‘They almost got it.’”

Images:

Nikola Tesla in 1899 in his laboratory in Colorado Springs. The picture, however, is a double exposure. In reality, the inventor was not sitting next to the high-voltage discharge from his Tesla transformer, which could bring 300 kilowatts to 12 million volts and send sparks 41 meters long.

Takuya Sasatani in a metal-lined room in which a lamp, fan and smartphone are supplied with energy via inductive coupling. The researcher assures us that the similarity between this press photo and the one above from Nikola Tesla's laboratory is purely coincidental.