Photovoltaic Balloons: A Look into Mobile, Renewable Energy Technology

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Introduction

Climate change is occurring at an exponential rate. Floods, wildfires, and storms that can shut down an entire state have all occurred just this year in the United States due to climate change. Emergency preparedness and response teams know that these natural disasters will only increase in the coming decades, which is why developing mobile renewable energy technologies are so important today.

Solar energy is one of the fastest growing types of renewable energy technology. It's not uncommon for solar panels to be built into green housing or for solar farms to be built around the world. However important these panels are, they cannot be mobile, they can take up large areas of land, and the production of solar panels is expensive. Many researchers have developed ways to utilize solar technology separate from the panel. Solar cells can now be attached to almost anything — including mobile balloons like the Zephyr Photovoltaic Balloon.

Photovoltaic Balloons: What are they and how do they work?

Engineer Karen Assaraf and designers Julie Dautel and Cédric Tomissi saw the need for a sustainable and agile way to create electricity, so they developed the Zephyr Photovoltaic Balloon (aka "Zephyr").

Delivered by plane, the Zephyr is contained in a crate. Once it arrives at a relief site it is secured to the ground. The crate itself consists of a screen control, batteries, an electrolyzer, and a drawer that holds the balloon sail. To inflate the balloon, simply add water to the electrolyzer to start the production of hydrogen. The balloon will start to inflate and rise. Once risen the balloon is steerable so it can capture the maximum amount of sunlight. Once the balloon sail is unfolded, it immediately starts to collect solar energy. The balloon sail actually converts that energy into electricity by sending it to the crate via a grounding cable. That solar energy is gathered, and converted it is stored via batteries and can be used as needed.

> The team partnered with the Institute for Research and Development of Photovoltaic Energy (IRDEP) to develop the balloon. Constructed of a hydrogen plastic sail, it's covered with a thin film made of copper, indium, gallium and selenide (CIGS) that absorbs solar energy. The balloon can fly as high as 165 feet and has a steering mechanism, which ensures it receives maximum exposure to the sun. (Smithsonian Magazine, 2020)

The creators of the Zephyr claimed a Paris ArtScience Prize, won Challenge Humanitech 2014 and Entrepreneurial Pitch Day, hosted by HEC Paris.

How does an electrolyzer work?

The Zephyr sounds simple enough, but the technology was only theoretical until recently. What it's built *around* is far from new. An electrolyzer is a device that allows electrolysis to occur — using electricity to split water molecules into hydrogen and oxygen. According to Engergy.gov (2020), electrolyzers are similar to any fuel cell, meaning they have an anode and a cathode. There are a few different types of electrolyzers: alkaline and solid oxide, according to the Office of Energy Efficiency and Renewable Energy. Alkaline electrolyzers transport hydroxide ions through the cathode to the anode which produces hydrogen. Solid oxide electrolyzers allow water at the cathode to combine with electrons and form hydrogen gas and oxygen. At the anode, electrons react and are generated as electric current. It is unclear which form of electrolyzer the Zephyr uses.

What happens when it captures sunlight?

Solar energy is no longer limited to panels and expansive solar farms. Nanotechnology allows solar cells to be produced/printed as thin rigid or flexible sheets. The idea of a printed solar panel is something we will likely see more frequently in the future. This nanotech allows solar cells to be attached to anything from windows to cloth. The Zephyr is a prime example of how solar technology can evolve to meet the needs of nearly any environment.

Photovoltaic technology (solar cells) is extremely simple compared to other types of renewable energy. Photovoltaic cells produce electricity by allowing photons to stimulate electrons, causing them to jump back and forth, thus creating an electric current. That current is captured by a wire, and in the case of the Zephyr, bundled into a cable and sent to the ground to be stored in nine batteries.

Photovoltaic cells have their advantages and disadvantages though. They are fairly cheap to produce and have no direct emissions of air pollutants. On the other hand, photovoltaic cells currently have a low net energy (right now they only convert about 15-20 % of what they could in terms of energy) but that is predicted to improve as the technology progresses. A drawback of photovoltaic technologies is that they require sunlight, which isn't always available. As Jean-François Guillemoles explains:

> The main problem with photovoltaic energy is that sunlight can be obscured by clouds, which makes electrical production intermittent and uncertain. But above the cloud cover, the sun shines all day, every day. Anywhere above the planet, there are very few clouds at an altitude of 6 km—and none at all at 20 km. At those heights, the light comes directly from the Sun, as there are no shadows and hardly any diffusion by the atmosphere. As the sky loses its blue color, direct illumination becomes more intense: the concentration of solar energy results in more effective conversion, and hence higher yields. (2015)

This is where balloon technology is really interesting. Theoretically, large atmosphere-level balloons could be raised into higher altitudes where there is more sunlight and the solar energy is more concentrated. These types of balloons would be able to capture solar energy day or night.

Current State of Zephyr Technology

In some sense the design of Zephyr balloons can be found all around the world already. The technology and concepts behind the Zephyr balloon are similar to Makani wind kites (essentially giant plane-like kites that use wind to produce electricity and are tethered to the ground like a Zephyr balloon) and floating photovoltaic systems which sit on lakes or bodies of water instead of taking up land space. Finding new ways to implement and effectively harness solar power is the pathway of the future.

An exciting finding is the effectiveness of photovoltaic systems is increased in mountainous areas. It was discovered that photovoltaic systems actually work better at a higher altitude because of the colder temperature, with an increased efficiency of 42% (Chitturi, 2018). This increased efficiency is another vote cast in favor of high altitude balloons as mentioned earlier.

Potential Applications

The primary application for pop-up photovoltaic balloons like the Zephyr is disaster relief or refugee zones. The need for mobile response teams and systems will only increase over time. The United Nations released a report in 2020 saying that the last 20 years have produced a "staggering" rise in climate related disasters. (Roughly 40 percent of those were floods.) "Despite the fact that extreme weather events have become so regular in the last 20 years, only 93 countries have implemented disaster risk strategies at a national level ahead of the end-of-year deadline" (United Nations, 2020). Having photovoltaic balloons or other portable and renewable energy resources could be a valuable resource when responding to these ever-increasing climate emergencies.

Today, it is unclear if the Zephyr is being widely used for emergency response, but its uses are very promising. "Zephyr's creators estimate each unit can provide enough energy to light and heat up to 15 tents in a disaster area, as well as set up a telecommunications network. The concept is still in the development stages, but it’s getting a lot of recognition” (Smithsonian, 2014). There are other emergency uses as well. The designers of the project started a company called EONEF that provides a version of the Zephyr with a specific focus on telecommunication and surveillance, used to find survivors after a natural disaster.

The design of Zephyrs is rather new--it was only developed in 2017. However, the idea of electricity-producing balloons has been discussed well before, specifically with the intention of using them on Mars. Professor Viorel Badescu, of the Candida Oancea Institute at Polytechnic University of Bucharest, gathered information regarding energy and resources that could be used for Mars missions and colonies. In his book he suggests that balloons like the Zephyr design would be ideal for collecting and storing energy on Mars:

> The main disadvantage of using solar electricity on the Mars surface is its limited power density, due to seasonal dust storms… we propose to mitigate this deficiency by designing a balloon system for collecting solar electricity in the dust-free part of the atmosphere. This concept may be used to backup planned Martian power plants or as a primary energy source where possible. (2009)

The chapter goes on to say that at the time of publication, there were no balloons with embedded solar cells that could do this. He went on to discuss three concepts to mitigate the technology that still needed to catch up on earth:

> Three concepts are developed: (i) a simple, helium-filled spherical balloon containing a PVA on the outer skin surface; (ii) a specialized paraboloidal balloon with a transparent upper part and an opaque lower part containing paraboloid-shaped photovoltaic cells on the inner surface, thus increasing the solar energy conversion efficiency; and (iii) the same balloon wherein the inner collectors are replaced by flexible thin mirrors, and the upper transparent part contains a PVA at the focus of the inner paraboloid-shaped mirror, thus augmenting the incoming solar energy flux. (2009)

Finding renewable energy sources that can travel with us, and sustain us, is vital to space exploration.

Conclusion

Renewable energy is a rapidly growing field. Every year, new ways to harness renewable energy are developed. The technology in these areas is constantly building off of itself. Versatile solar cells, that can be attached to nearly anything, are now being connected to balloons to quickly capture sunlight. Those balloons can be used to bring energy to natural disaster relief locations or packed into a spaceship and sent to Mars. Creating mobile technologies that can harness renewable energy is paramount to our future of surviving on this planet or planning for survival on others.

References

Badescu, V. (2009). *Mars : prospective energy and material resources*. Springer. https://link-springer-com.antioch.idm.oclc.org/content/pdf/10.1007%2F978-3-642-03629-3.pdf

Chitturi, S. R. P., Sharma, E., Elmenreich, W., & 2018 IEEE International Energy Conference (ENERGYCON) Limassol, Cyprus 2018 June 3 - 2018 June 7. (2018). 2018 ieee international energy conference (energycon). In *Efficiency of photovoltaic systems in mountainous areas* (pp. 1–6). essay, IEEE. https://doi.org/10.1109/ENERGYCON.2018.8398766

Goetzberger, A., & Hoffmann, V. U. (2005). *Photovoltaic solar energy generation* (Ser. Springer series in optical sciences, 112). Springer. https://link-springer-com.antioch.idm.oclc.org/content/pdf/10.1007%2Fb137803.pdf

Guillemoles, J.-F. (0AD). Solar Energy Aims for the Sky. CNRS News.

https://news.cnrs.fr/opinions/solar-energy-aims-for-the-sky-0

Hydrogen Production: Electrolysis. Energy.gov. (0AD). https://www.energy.gov/eere/fuelcells/hydrogen-production-electrolysis

Pimentel Da Silva, Gardenio Diogo, & Branco, D. A. C. (2018). Is floating photovoltaic better than conventional photovoltaic? assessing environmental impacts. *Impact Assessment and Project Appraisal, 36*(5), 390-400. doi:http://dx.doi.org.antioch.idm.oclc.org/10.1080/14615517.2018.1477498

United Nations. (0AD). *'Staggering' rise in climate emergencies in last 20 years, new disaster research shows | | UN News*. United Nations. https://news.un.org/en/story/2020/10/1075142