Project #1: Solar hydrogen high-altitude balloons for continuous electricity production

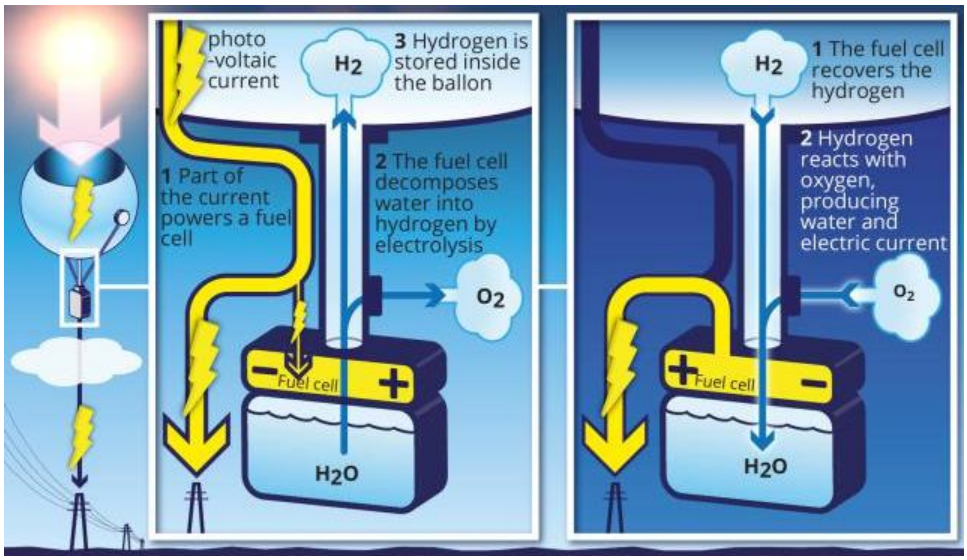

Figure: Schematic describing the basic idea of a solar-hydrogen high altitude balloon.[1]

Scenario: Researchers at a joint French-Japanese laboratory called NextPV recently described their vision for 24/7 hour production of electricity from sunlight using high altitude, solar-powered hydrogen balloons.[1] As describe in [1] and [2], they propose harvesting sunlight with solar PV panels on the surface of high altitude balloons that are tethered to the earth's surface by a large cable that simultaneously holds the balloon in place and allows electricity to be sent down to earth. During the day, some of the electricity from the PV panels is sent down to earth, while another portion of it is used to electrochemically split water into O_2 and H_2 with a regenerative electrolyzer / fuel cell [3.],[4.] that is attached to the base of the balloon (middle panel). The gaseous H_2 is then stored in the balloon while helping to keep it afloat. During the nighttime, H_2 stored in the balloon is sent to the regenerative fuel cell (operated in fuel cell mode), where it is converted back into electricity that is sent down to earth. By this means, electricity may be produced 24/7. A major benefit of harvesting sunlight at high altitudes is that the intensity of solar radiation is far greater than it is on the earth's surface and extremely predictable because it operates above the clouds. Your job is to figure out if these benefits are likely to outweigh the costs and inconveniences of putting solar panels miles up in the sky.

In order to arrive at your final recommendation, you should address the following questions:

i.) How does the yearly electrical output of solar panels vary as a function of altitude, and at what altitude would you position your balloon? For identical PV panels, how would the amount of solar power harvested per m^2 per year by the balloon compare to that of a ground-mounted solar panel located in Phoenix AZ?

ii.) What size would you make the balloon, solar panels, and regenerative fuel cell in order to provide 24/7 electricity through conversion of hydrogen into electricity during the nighttime hours? Keep in mind that you cannot deplete 100% of the hydrogen in your balloon, but must keep a certain minimum amount of hydrogen to keep the balloon afloat.

iii.) For optimized conditions, what is an expected levelized cost of electricity?

References

[1.] J. Guillemoles,"Renewable Energy aims for the sky", article available online here, (2015).

[2.] A. Epstein, "Are these futuristic high-altitude balloons the brave new world of solar energy?", article on qz.com, available here, Dec. 16th, 2015.

[3.] C. Mittelsteadt, "Regenerative fuel cells for energy storage", presentation, available online here. (2011)

[4.] "Regenerative Fuel Cells" Wikipedia page and associated references. Available online here.