Project #3: Solar fuels on Mars

Scene from the movie "The Martian".

Scenario: NASA has recently stated their intention to land human beings on and asteroid by 2025 and the planet Mars in the 2030s.[1] The Martian atmosphere is ~95% CO_2, ~0.2% O_2, with the balance predominantly Ar and N_2, which is unable to support human life. Therefore, in order for a human outpost on Mars to be successful, they must either bring the necessary life-supporting gases (i.e. O_2) and energy supplies with them, or make them *in situ* on the surface of Mars. Due to the limited space and high expense of shipping supplies to Mars, *in situ* production of fuels (H_2 + O_2) and life-sustaining chemicals (O_2) is highly desirable. One such solution for the production of O_2, which will be tested on the 2020 mission, is to use PV-powered PEM electrolyzers to electrochemically convert CO_2 in the Martian atmosphere into solid carbon and O_2 for breathing and as a liquid fuel to return to Earth.[2] Another option is to use PEM electrolyzers to convert Martian water ice into oxygen and hydrogen through electrolysis driven by electricity from solar PV panels.[3] Your job is to design and evaluate a system for solar hydrogen and oxygen production from Martian CO_2 and/or ice as a possible route forward for providing fuels and oxygen for a colony of 5 astronauts on Mars. **The major question that NASA wants you to answer is the following: should it generate fuels and life-sustaining O_2 starting from H_2O, CO_2, or a combination of both?** You should assume that the only energy input is from sunlight harvested through PV panels, and that back-up energy storage comes from converting stored H_2 back into electricity with fuel cells.

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

i.) What are the respiration needs of 5 astronauts (O_2 generation, CO_2 removal)? What are the energetic needs besides respiration? How large of electrolysis systems (in kW) would be needed?

ii.) What is the average light intensity on mars, and how would the output and efficiency of a given solar panel on earth's surface compare to when it's on Mars? How large must the array of solar panels be to meet the electrolysis needs?

iii.) Approximately how much will the combination of solar panels, electrolyzers, and fuel cells weigh (on earth)? Is it practical to carry that much weight to Mars?

iv.) How will H_2 and O_2 be stored? If using liquid H_2, how much energy is required for liquefaction? If H_2 is not stored as a liquid, how large must the storage tanks be to sustain five astronauts for 3 days? (e.g. in the event of a failure to the solar panels)

References

[1] https://www.nasa.gov/content/nasas-journey-to-mars

[2] http://mars.nasa.gov/mars2020/mission/science/for-scientists/instruments/moxie/

[3] L. Ojha, et al. *Nature Geoscience* **2015**, *8*, 829-832, http://www.nature.com/ngeo/journal/v8/n11/full/ngeo2546.html