BORN GLOBAL FOUNDATION

AUGUST 2021

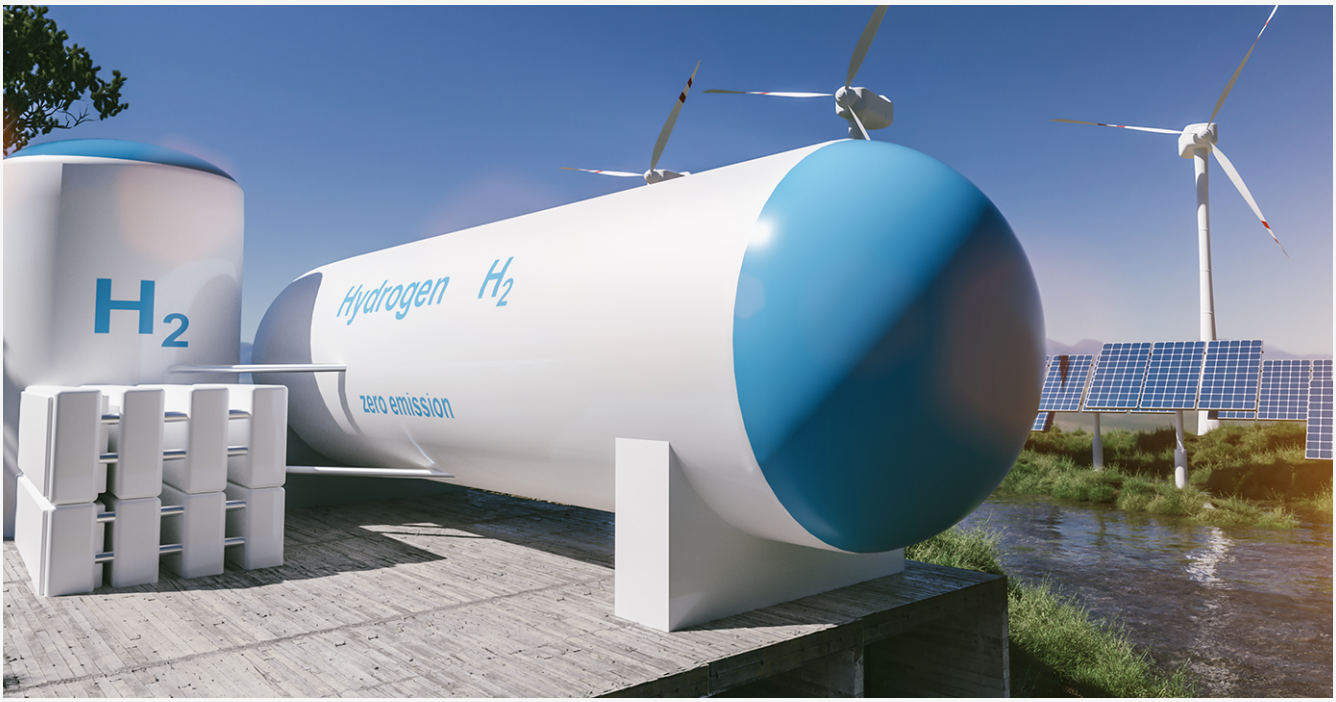
ARTIFICIAL LEAF

PREPARED AND PRESENTED BY

BELLE HE, EMILY DUNN, GAELLE CORM, ISABELLA SAMAHA, LYNN HADDAD, MARIA BEJJANI, AND ROBIN MCKEE
MENTORS: CATALINA BUSTILLO AND LAURA REGO

PROJECT OVERVIEW

Born Global Foundation interns began the Artificial Leaf project in Spring 2021. The aim of the project was to design a photoelectrochemical cell that would produce hydrogen gas when placed in water and exposed to sunlight. The design was inspired by the process of photosynthesis; specifically, it biomimics the thylakoid stacks inside a chloroplast. In Summer 2021, the team continued working on improvements to the leaf design and a bioinspired storage component.



WHY HYDROGEN?

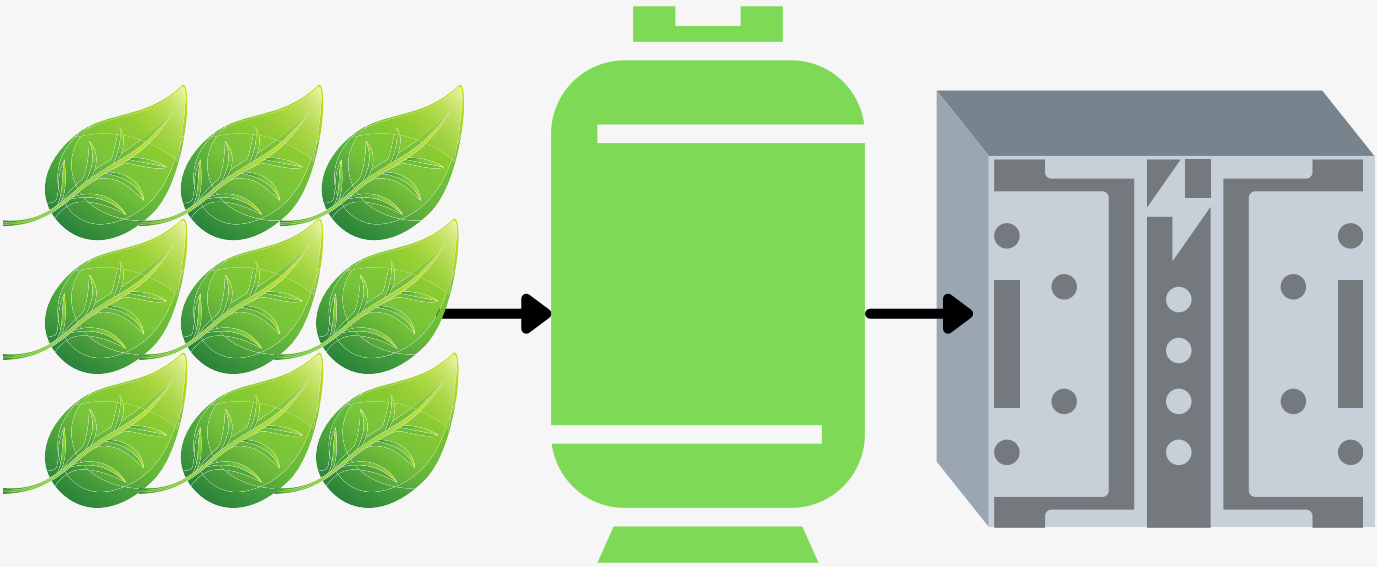
Strategies for moving towards cleaner energy often incorporate variable renewable energy (VRE) technologies, such as solar and wind energy. However, hydrogen has often been touted as another promising energy alternative. In fact, the market for green hydrogen is expected to grow exponentially in the coming decade. Carbon-free "green" hydrogen can be made using electrolytic or solar-driven processes. The only byproduct after hydrogen combustion is water. Because cost and storage are two current limitations of using hydrogen on a large scale, residential energy systems may be a more feasible means of utilizing hydrogen as fuel, while helping households reduce their carbon footprint.

PROJECT TIMELINE

TASK	START DATE	END DATE
PHASE 01 IDEA GENERATION, RESEARCH, AND INITIAL DESIGN	JAN 2021	MAY 2021
PHASE 02 DESIGN IMPROVEMENT (BIOMIMICRY FOCUS)	JUN 2021	AUG 2021
PHASE 03 DESIGN IMPROVEMENT (TECHNICAL/ENGINEERING FOCUS)	SEP 2021	DEC 2021
PHASE 04 DESIGN FINALIZATION AND PREPARATION FOR WORLD BIODIVERSITY FORUM (JUN 26-JUL 1 2022)	JAN 2022	MAY 2022

HOUSEHOLD HYDROGEN SYSTEM

SHOWN BELOW IS A DIAGRAM OF THE RESIDENTIAL ENERGY SYSTEM AND DESCRIPTIONS OF ITS THREE MAJOR COMPONENTS:



PRODUCTION

The artificial leaf captures sunlight in order to produce hydrogen through the process of photoelectrolysis. Several leaves can be incorporated into the system to produce enough hydrogen to meet household needs.

STORAGE

Hydrogen produced by the artificial leaf can be stored for a short period of time in a separate part of the system. The storage container will allow hydrogen to be transported quickly from the production phase to the use phase.

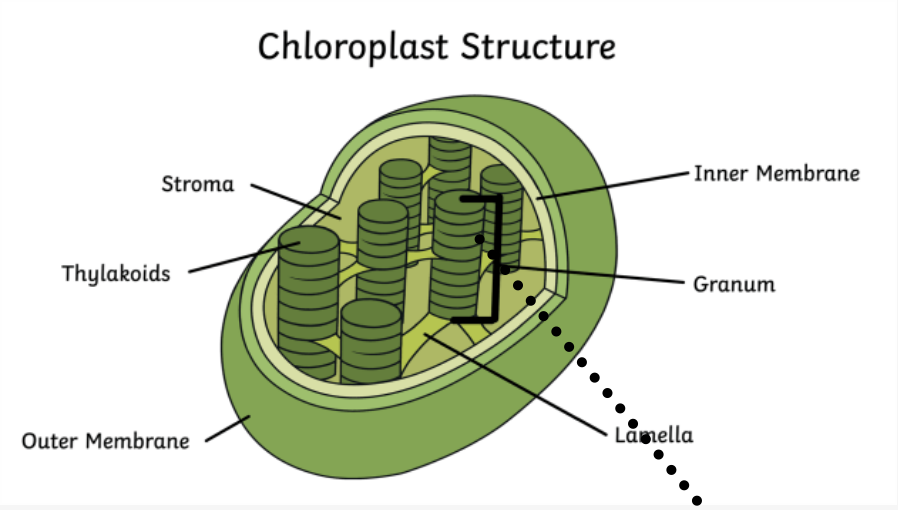
CONVERSION/USE

In order for hydrogen to power most household devices, it must first be converted to electrical energy. This can be achieved with a small fuel cell that generates an electrical current when fed hydrogen and oxygen.

HYDROGEN PRODUCTION

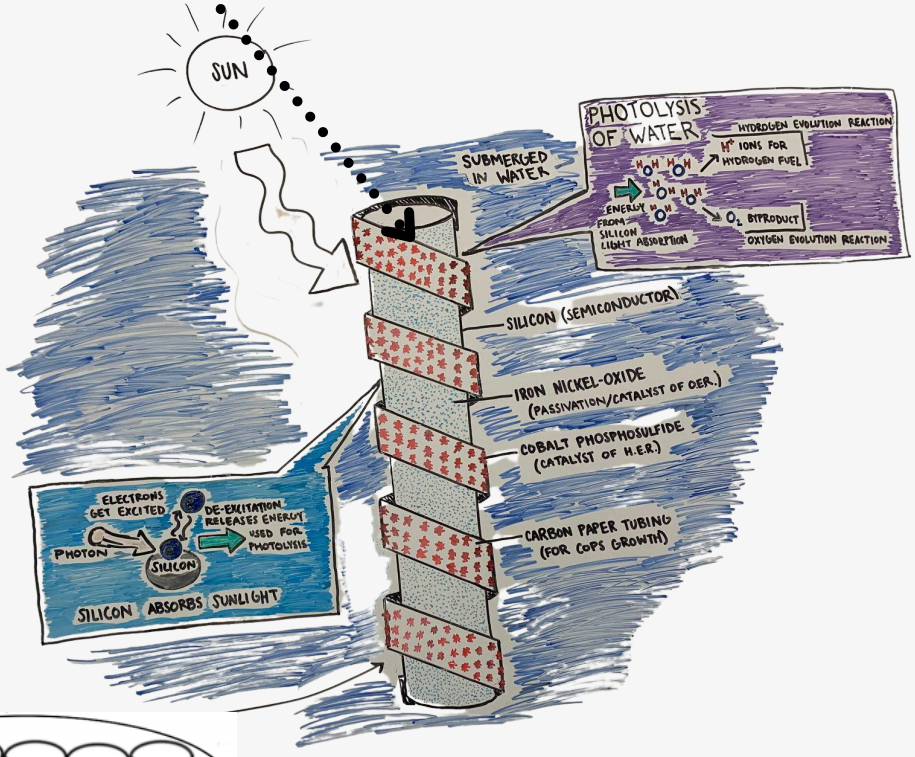
THIS SECTION INCLUDES A LOOK AT THE DESIGN OF THE HYDROGEN PRODUCTION COMPONENT--THE ARTIFICIAL LEAF.

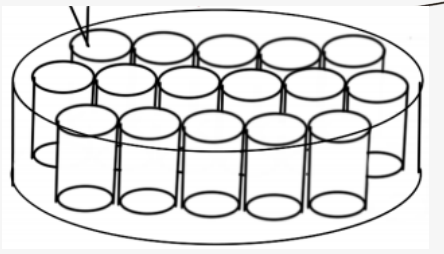
SPRING 2021



OUR DESIGN BIOMIMICS THE STACKING OF THYLAKOIDS AND ARRANGEMENTS OF LAMELLA IN CHLOROPLASTS

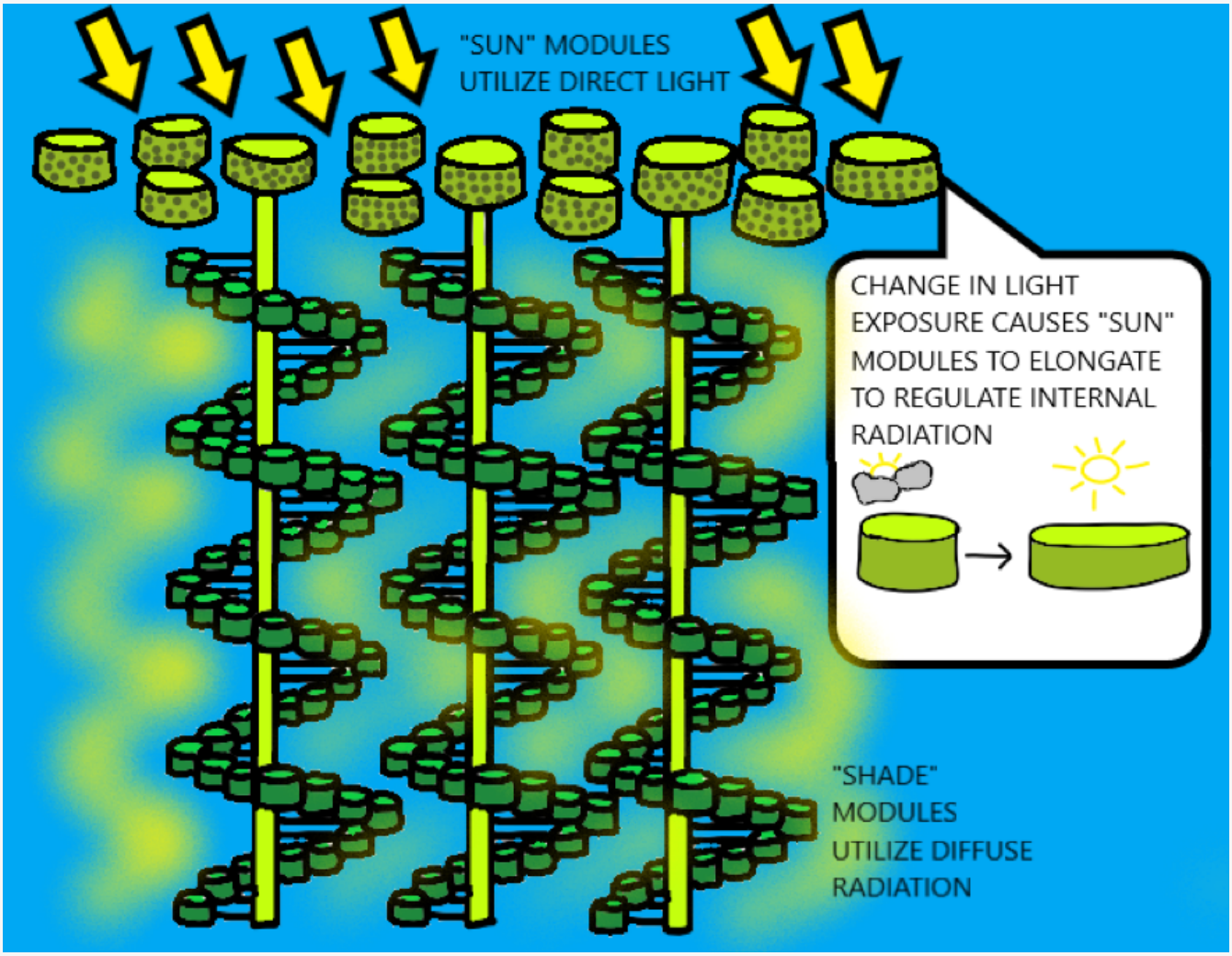
IDEA:
EACH TUBE AS AN INDEPENDENT PHOTOELECTRODE AND EACH LEAF UNIT AS A PHOTOCHEMICAL CELL CONSISTING OF MULTIPLE TUBES





HYDROGEN PRODUCTION

SUMMER 2021

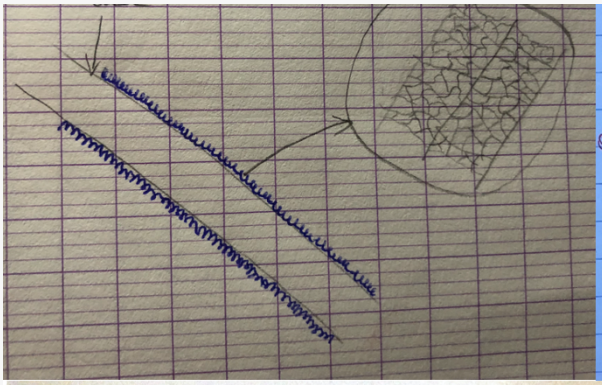


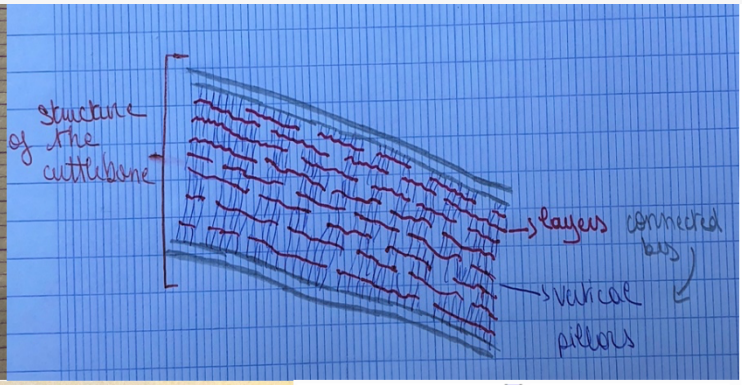
Our redesign mimics two strategies from olive tree leaves. The first is having separate functions for outer and inner modules respectively. The second is the plasticity in the outer modules in response to changes in light conditions.

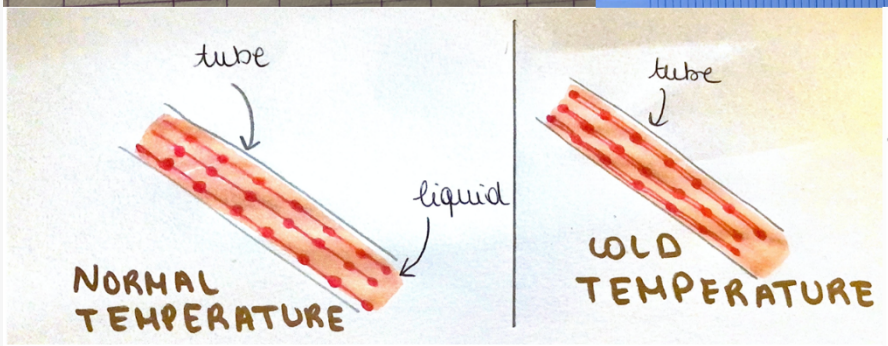
ONE, OUTER MODULE OF A SYSTEM SHOWS PLASTICITY IN RESPONSE TO DIRECT LIGHT WHILE THE SECOND, LOWER MODULE UTILIZES DIFFUSE RADIATION TO OPTIMIZE THE WHOLE SYSTEM'S USE OF LIGHT ENERGY. ENHANCED LIGHT EXPOSURE TRIGGERS ELONGATION, INCREASE IN SPECIFIC AREA, AND CHEMICAL RESPONSE.

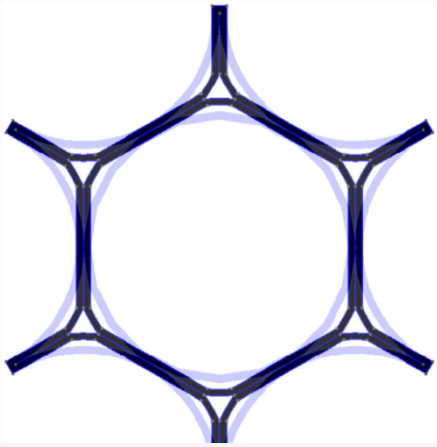
HYDROGEN STORAGE

THIS SECTION INCLUDES A LOOK AT THE DESIGN OF THE HYDROGEN STORAGE COMPONENT.







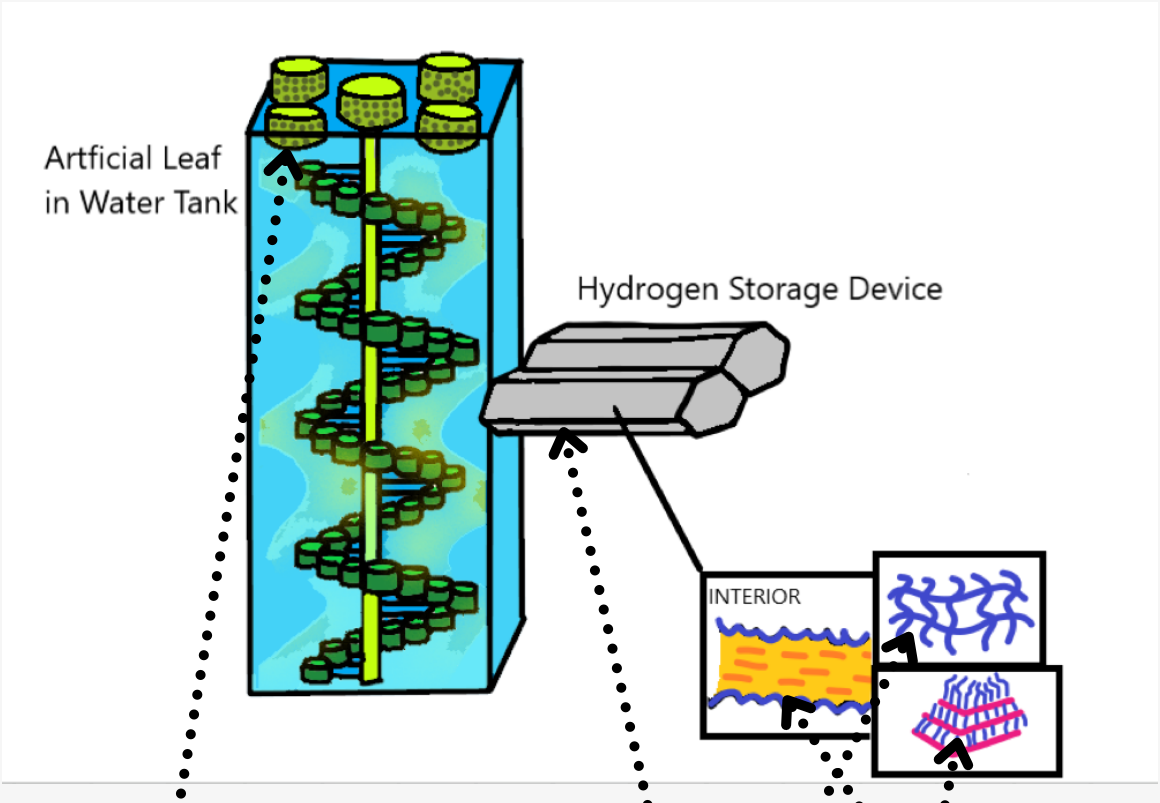


Our hydrogen storage unit was bioinspired by several organisms. Each one of them has a different function that tackles different aspects of hydrogen storage.

THE FOUR FUCNTIONS WE FOCUSED ON ARE "MODIFY DENSITY", "ABSORB LIGHT", "STORE GASES", AND "SPACE EFFICIENCY"

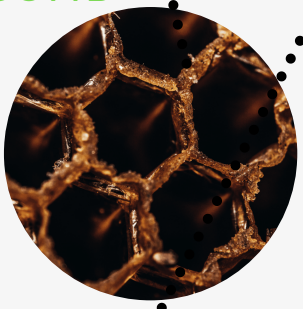
OVERALL DESIGN

SHOWN BELOW IS AN ILLUSTRATION OF THE COMBINED DESIGN OF THE ARTIFICIAL LEAF AND HYDROGEN STORAGE COMPONENTS:



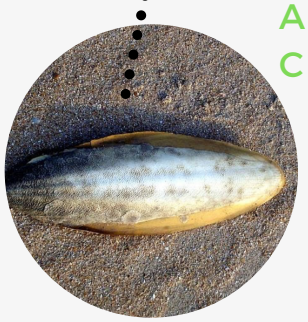
HONEYCOMB

OLIVE TREE



ANTARCTIC
CRUSTACEAN

BUTTERFLY



CUTTLEFISH

TEAM MEMBERS

THE AWESOME PEOPLE BEHIND THIS PROJECT

BELLE HE
TEAM LEAD
M.S. MATERIALS SCI. & ENGINEERING, BOSTON UNIVERSITY

EMILY DUNN
TEAM MEMBER
SENIOR HIGH SCHOOL
HOUSTON, TEXAS

GAELLE CORM
TEAM MEMBER
JUNIOR HIGH SCHOOL STUDENT
LEBANON

ISABELLA SAMAHA
TEAM MEMBER
JUNIOR HIGH SCHOOL STUDENT
LEBANON

LYNN HADDAD
TEAM MEMBER
JUNIOR HIGH SCHOOL STUDENT
LEBANON

MARIA BEJJANI
TEAM MEMBER
JUNIOR HIGH SCHOOL STUDENT
LEBANON

ROBIN MCKEE
TEAM MEMBER
FRESHMAN AT PENN STATE UNIVERSITY

CATALINA BUSTILLO
BIOMIMICRY MENTOR
M.S. BIOMIMICRY, ARIZONA STATE UNIVERSITY

LAURA REGO
BIOMIMICRY MENTOR
M.S. BIOMIMICRY, ARIZONA STATE UNIVERSITY

REFERENCES

1. ABC News Network. (n.d.). ABC news. https://abcnews.go.com/Technology/green-hydrogen-renewable-energy-source-watch-2021/story?id=74128340.
2. Casas, R. R. de, Vargas, P., Pérez-Corona, E., Manrique, E., García-Verdugo, C., & Balaguer, L. (2011, March 25). Sun and Shade leaves of Olea europaea respond differently to plant Size, light availability and genetic variation. besjournals. https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/j.1365-2435.2011.01851.x.
3. Castle, S. (2017, February 7). *9.4 the Phytochrome System*. YouTube. https://youtu.be/tf3avaZCCQo.
4. Chen, A. (2017, October 19). Butterfly wings inspire a better way to absorb light in solar panels. The Verge. https://www.theverge.com/2017/10/19/16503258/butterfly-wings-engineering-solar-cell-energy-biomimicry.
5. *Gas-holding structure aids buoyancy*. AskNature. (n.d.). https://asknature.org/strategy/gas-holding-structure-aids-buoyancy-2/.
6. *Honeycomb structure is space-efficient and strong*. AskNature. (n.d.). https://asknature.org/strategy/honeycomb-structure-is-space-efficient-and-strong/#the-strategy.
7. *Hydrogen for transport*. Hydrogen for Transport. (n.d.). https://ricardo.com/hydrogen.
8. Learning, L. (n.d.). Biology for majors ii. Lumen. https://courses.lumenlearning.com/wm-biology2/chapter/plant-responses-to-light/.
9. Liao, H., Du, T., Zhang, Y., Shi, L., Huai, X., Zhou, C., & Deng, J. (2019). Capacity for heat absorption by the wings of the butterfly Tirumala limniace (Cramer). PeerJ, 7, e6648. https://doi.org/10.7717/peerj.6648
10. National Geographic Society. (2019, September 5). Photosynthesis. National Geographic Society. https://www.nationalgeographic.org/encyclopedia/photosynthesis/.
11. *Wax changes density to help sink or float*. AskNature. (n.d.). https://asknature.org/strategy/antarctic-crustaceans-use-wax-to-sink-in-water/.
12. *World Biodiversity Forum*. bioDISCOVERY. (2019, April 23). https://biodiscovery.earth/2019/01/14/world-biodiversity-forum/.