One Small Step for Hydrogen

One Giant Leap for Humanity

John W. Sheffield

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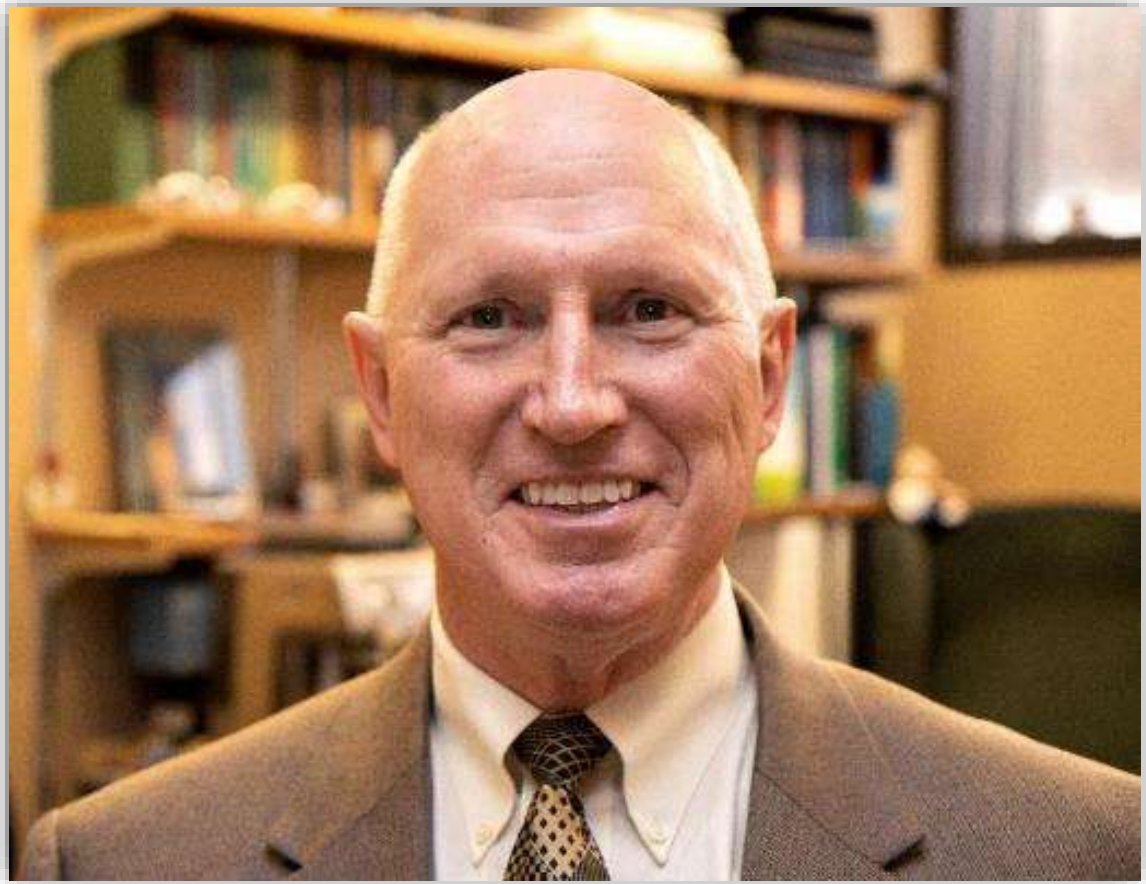


I am a professor from Purdue University in West Lafayette, Indiana. I also serve as the President of the International Association for Hydrogen Energy and the Senior Associate Editor of the International Journal of Hydrogen Energy published by Elsevier.

Purdue University is called the "*Cradle of Astronauts*" for good reason

Our 25 Purdue astronauts have flown in the Mercury, Gemini, Apollo, Space Shuttle, International Space Station, Commercial and In-Training missions. The most famous Purdue Astronaut was Neil Armstrong, who upon taking his first step onto the moon, uttered the words…

"That's one small step for man, one giant leap for mankind"

A Quick Flyover of Hydrogen Energy

Let's start with the "Race to the Moon"

The story begins in September 1944 when an American general and a professor met in a car parked at one end of a runway at LaGuardia airport. The general was Henry Harley Arnold, the only U.S. officer to hold a five-star rank in two different U.S. military services. The professor was Professor Theodore von Karman, a Hungarian-American aerodynamicist and jet propulsion pioneer at the California Institute of Technology in Pasadena. The General wanted the Professor to draw up plans for aeronautical research for the next 20 years and so began the Space Race with hydrogen propulsion.

Fast forward thirty years…

On March 18, 1974 in Miami Beach, Professor T. Nejat Veziroglu opened "***The Hydrogen Economy Miami Energy***" (THEME) conference by proposing the "***Hydrogen Energy System***" as a permanent solution for the depletion of the fossil fuels and the significant environmental problems caused by their utilization. A small group of scientists and engineers commenced to establish the International Association for Hydrogen Energy. Today, we call those visionaries the "***Hydrogen Romantics.***" At 98 years old, Professor Veziroglu continues his unrelenting efforts for the advancement of the Hydrogen Energy System.

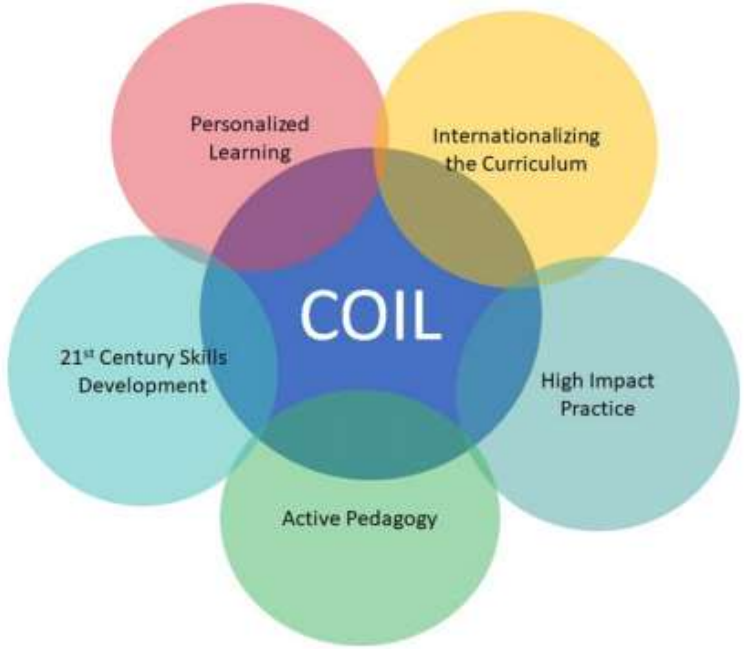
One Small Step for Hydrogen - One Giant Leap for Humanity

Meeting with Pope Francis on 7 Feb 2020 → Hydrogen Popemobile on 9 Oct 2020

Race To Zero is a global campaign to rally leadership and support from businesses, cities, regions, investors for a healthy, resilient, zero carbon recovery that prevents future threats, creates decent jobs, and unlocks inclusive, sustainable growth.

Collaborative Online International Learning (COIL) Projects

COIL is an innovative pedagogy that facilitates virtual international exchange by giving learners the skills to successfully link a course project at one educational institution with another in a different country with a different cultural setting



Virtual Experiential Intercultural Learning (VEIL) Projects

VEIL is a new innovative pedagogy initiated at Purdue University during the COVID-19 pandemic as an effort to create collaborative online opportunities. University students across the globe are staying put in their locations, but that doesn't mean that they should miss out on meaningful collaborative research projects.

A Race-to-Zero Student Design Project

For students who successfully completed optional training, they received a Global Competence Certificate (GEC)

global competence certificate

This is to certify that

Salvador Loayza Gonzales

has successfully completed our Global Competence Certificate, an educational program that explores intercultural theories and models through active experimentation in a new cultural environment and deep reflection with a facilitator. They are now more equipped with the knowledge, skills, and understanding needed to interact effectively in a global and cross cultural environment.

10 December 2020

Bert Vercamer
CEO, Sentio
Global Education Network

Qualified GCC Facilitator

sentio PURDUE CILMAR

The GCC content was designed to meet key educational goals to help learners develop global competence. These goals are organized into four core areas which support professional success in a diverse global setting:

SELF-AWARENESS

- Increase cultural self-awareness through reflecting on their own personal and cultural experience as citizens in local to global contexts.
- Identify and understand how cultural groups have shaped their characteristic ways of feeling, perceiving, thinking, and behaving.
- Analyze and reflect on power relations, privilege, and inequality.

AWARENESS ABOUT OTHERS

- Recognize and understand patterns of behavior and values of people from different cultural contexts.
- Empathize with culturally different others.

EMOTIONAL INTELLIGENCE

- Suspend judgment and be flexible in new and different cultural contexts.
- Apply effective and appropriate strategies to deal with ambiguous situations.
- Describe and manage responses to their own cultural biases and emotional triggers.
- Be aware of personal limits and be open to seek support.

BRIDGES TO OTHERS

- Initiate and develop relationships with culturally different others.
- Communicate and interact effectively and appropriately in different cultural contexts.

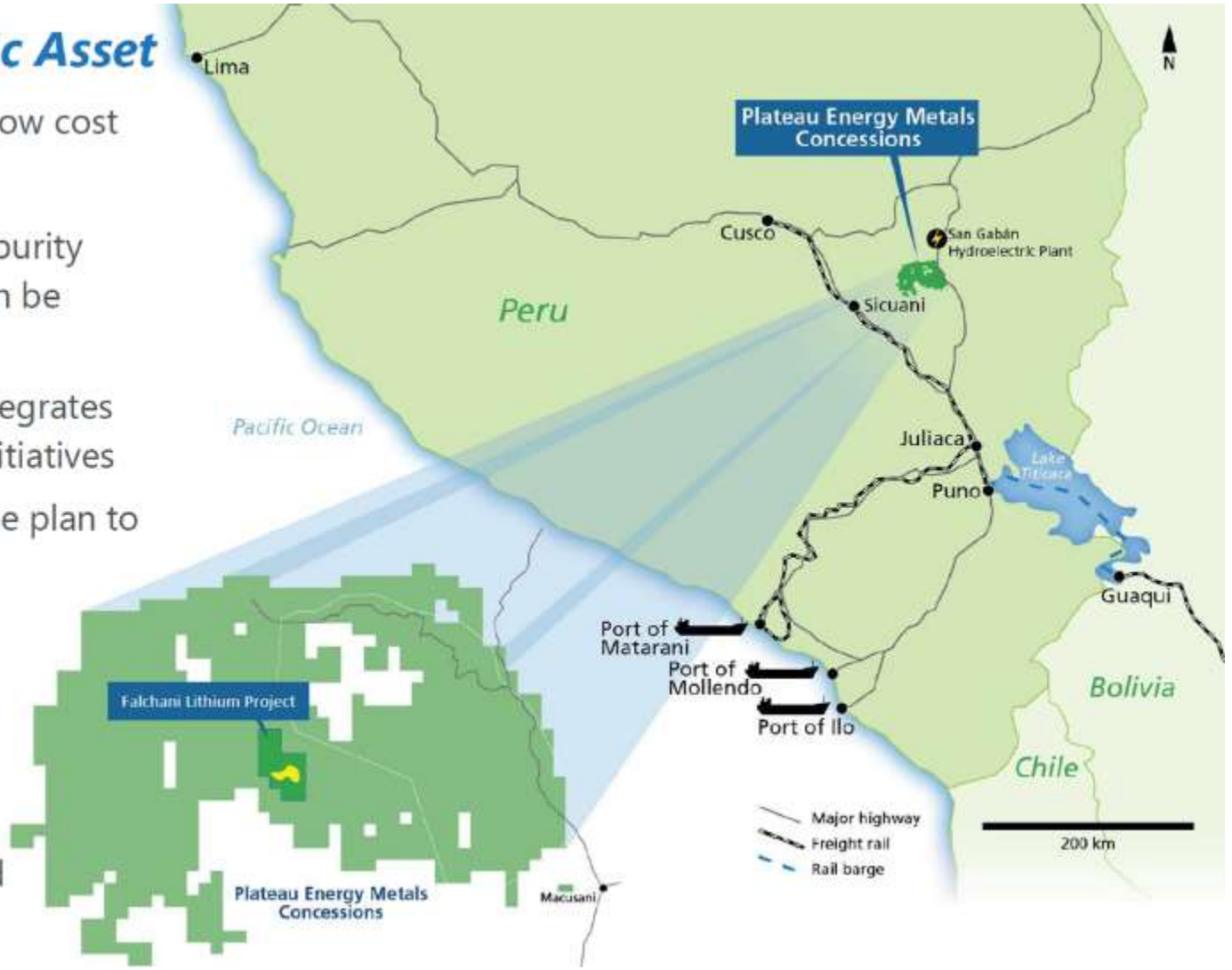
sentio | global competence certificate

A Race-to-Zero Student Design Project

Falchani Lithium

A Clean Tech Strategic Asset

- **Strong Project Economics** – low cost
- **100% Controlled**
- **High quality product** – high purity (99.74%) lithium carbonate can be produced onsite
- **Green** – development plan integrates multiple sustainable mining initiatives
- **Scalable –** long life with a mine plan to grow as demand grows
- **Size – sixth largest** hard rock lithium deposit in the world*
  - 0.96 Mt LCE indicated
  - 3.74 Mt LCE inferred
- **Exploration upside** ~30% of mineralization footprint drilled to-date + regional targets



A Race-to-Zero Student Design Project

Falchani Lithium

US$1.5 billion NPV(8%)[1]	**19.7%** IRR, after-tax[1]	**4.7 years** Payback[1] undiscounted	**US$8,977M** LOM **US$430M** average annual LOM Cash Flow[1] after-tax
US$3,958 per tonne Li_2CO_3 OPEX[2]	**US$587M** Initial CAPEX[3]	**33 years** Mine Life	**Production** 23,000 tpa Li_2CO_3 years 1 to 7; 44,000 tpa Li_2CO_3 years 8 to 12; 85,000 tpa Li_2CO_3 years 13 to 33 Battery Grade[4]

Green Project Attributes

Falchani Lithium

- Filtered tailings enables recycling of up to 90% of process water
- Dry stacking technology in order to handle safely and more securely the tailings disposal – an environmentally responsible choice
- Sulfuric acid plant on site will be self-sufficient to power entire process plant
- Access to hydro power grid available nearby
- Future development work to evaluate opportunities such as:
  - Electric mine fleet,
  - Wastewater recycling,
  - Rainwater run off storage, and
  - Low CO_2 transport and logistics for consumables

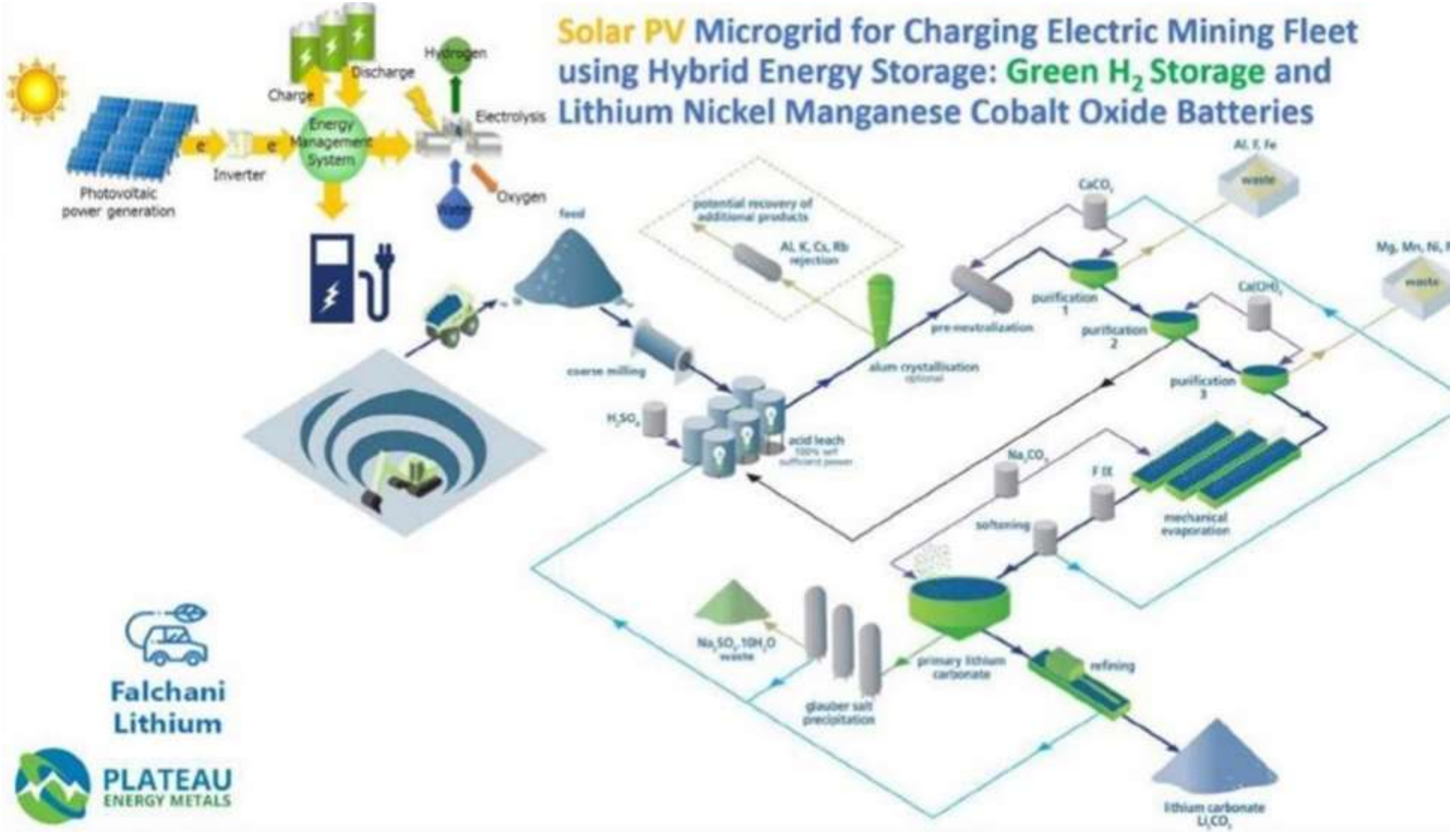
A Race-to-Zero Student Design Project - Greening of Mining Fleets

Mining companies are increasingly operating in remote locations as resources become scarce. Mines in these remote locations are faced with high energy costs. Renewable energy microgrids can offer benefits including energy storage systems.

A Race-to-Zero Student Design Project - Greening of Mining Fleets

In Phase 1 of the project, the students evaluated the new trolley assist system for electric-drive mining trucks lowers both fuel and engine costs while boosting *speed-on-grade* for greater productivity. The "CAT 795F AC equipped with the trolley assist system" has become the most powerful mining truck in the world.

A Race-to-Zero Student Design Project - Greening of Mining Fleets



Falchani Lithium

PLATEAU ENERGY METALS

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HOMER Energy by UL

The HOMER Pro® microgrid software by HOMER Energy is the global standard for optimizing microgrid design and was developed at the U.S. Department of Energy National Renewable Energy Laboratory.

Simulation - At its core, HOMER Pro is a tool used to simulate a viable system for all possible combinations of the equipment that you wish to consider.

Optimization - HOMER Pro can examine all possible combinations of microgrids in a single run, and then sorts the systems according to the optimization variable of choice.

Sensitivity Analysis – HOMER Pro lets you ask as "What if?" questions.

Hydrogen Module – Lets you model systems that generate, store, and consume hydrogen.

A Race-to-Zero Student Design Project - Greening of Mining Fleets

CASE STUDY

A solar PV stand-alone microgrid system using a hybrid hydrogen and battery energy storage system to stabilize the variable and intermittent solar energy for a 24 hours/day demand in a remote area of Australia.

 **SOLAR PV** Picture credit: https://etap.com/product/photovoltaic-array-solar-panel	Panel Type: Flat Plate PV Peak month: July Efficiency: 18.7% Temp. Coefficient: -0.39 Operating Temp.: 45° C Life time: 25 Years	MPPT lifetime = 15 years Ground reflectance = 20% No Tracking system Capex: $1000/kW Installed Opex: $5/kW/yr.
 **Battery Bank** Picture credit: https://www.greentechmedia.com/articles/read/tesvolt-breaks-new-ground-with-lithium-ionllgs.d50tQaw	Type: Lithium-Ion Nominal Voltage: 600 Volts/string Roundtrip Efficiency: 90%	Capex: $700 /kWh (installed) Opex: $10/kWh/yr Life time: 15 Years
Electrolyser & Fuel Cell  Proton Exchange Membrane (PEM)	Type: PEM electrolyser Life time: 15 years Efficiency: 80% Water consumption: 10 l/Kg H_2 Capex: $2500/kW (Installed) Opex: $80 kW/yr	Type: PEM Fuel Cell (PEMFC) Life time: 60,000 hours Efficiency: 75% Water consumption: 10 l/Kg H_2 Capex: $2500/kW (Installed) Opex: $0.02 op hr
H2 Storage Tank  Picture credit:	Life time: 15 years Capex: $1000/Kg H_2 Installed plus peripherals Opex: $10/kg H_2 Compressed gas (350 bar)	**Economics** [Homer Pro] Project lifetime= 25 years Discount rate= 8% Inflation rate= 2% Currency= US Dollars ($)

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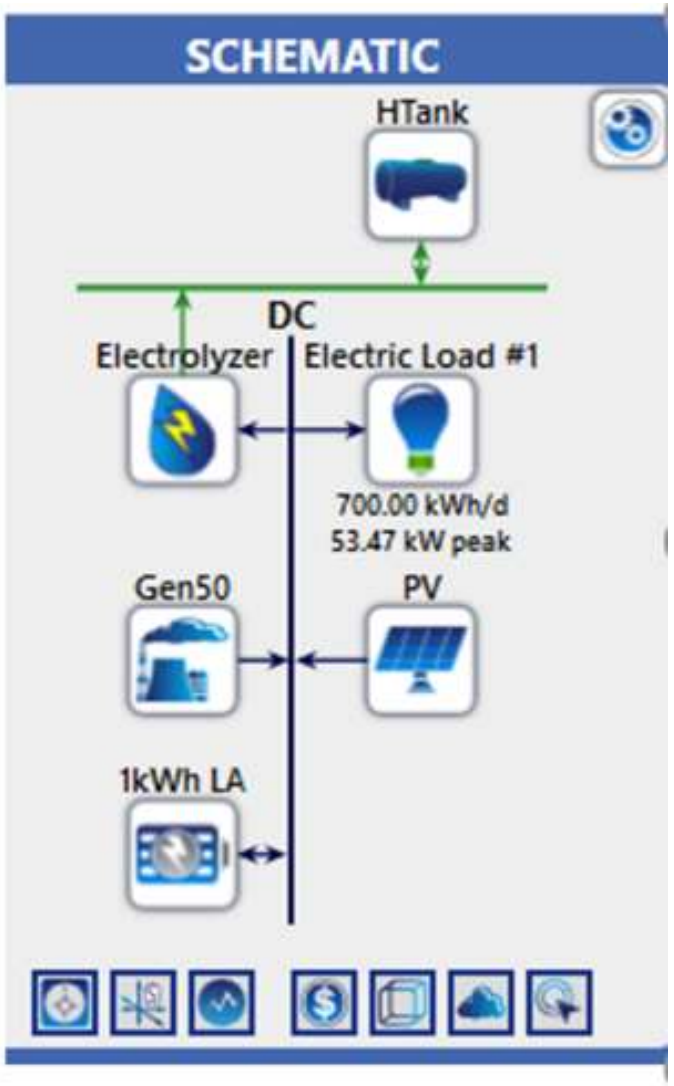
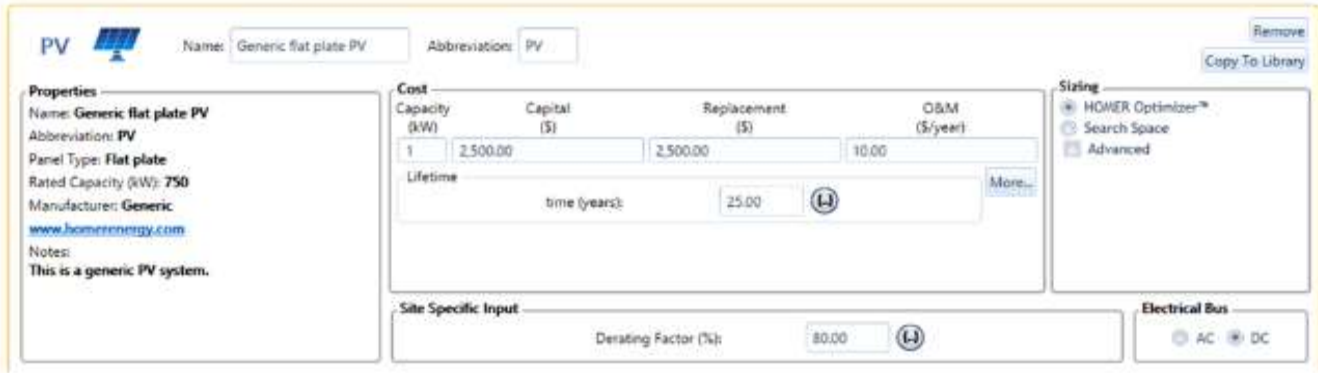
A Race-to-Zero Student Design Project - Greening of Mining Fleets



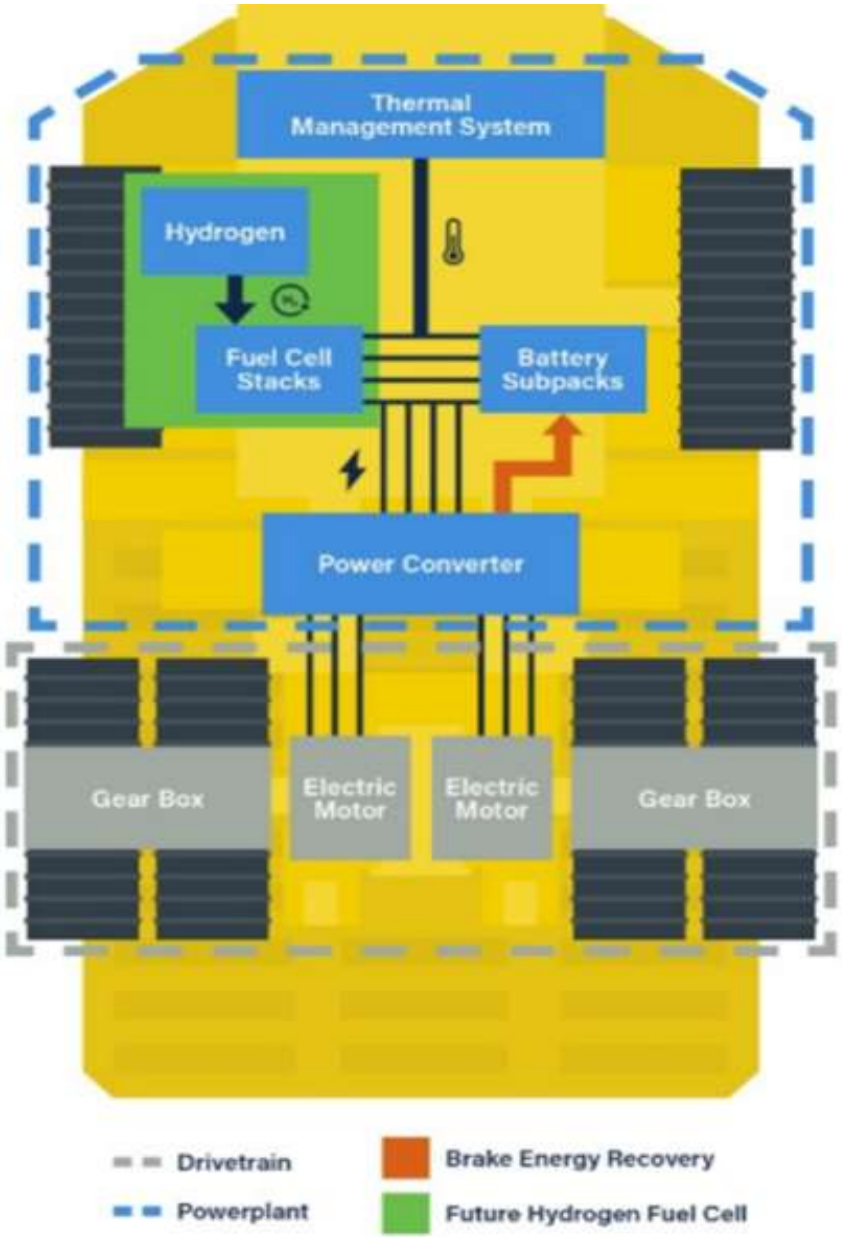
NASA database is used for estimation of solar resource at site (Puno, PERÚ).



Solar PV system considered for modeling purposes, using HOMER Optimizer (sizing) feature.

A Race-to-Zero Student Design Project - Greening of Mining Fleets

Phase 2 is focused on replacing the diesel engine with a hydrogen fuel cell.



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TRUCKS

What is the Mining Fleet for Open Pit Mining

EXCAVATOR/SHOVELS

FRONT LOADERS

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