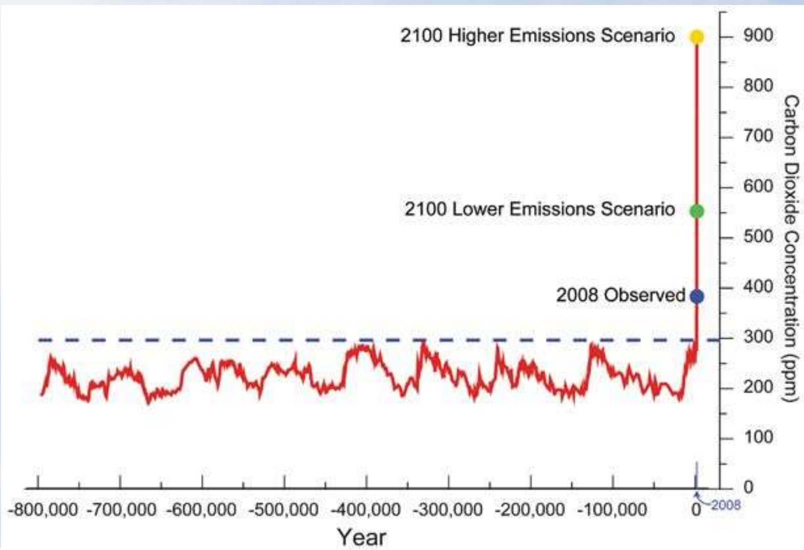
Project title: Educating the community on clean energy alternatives and a comprehensive, mathematically-backed analysis that compares various hydrogen production methods

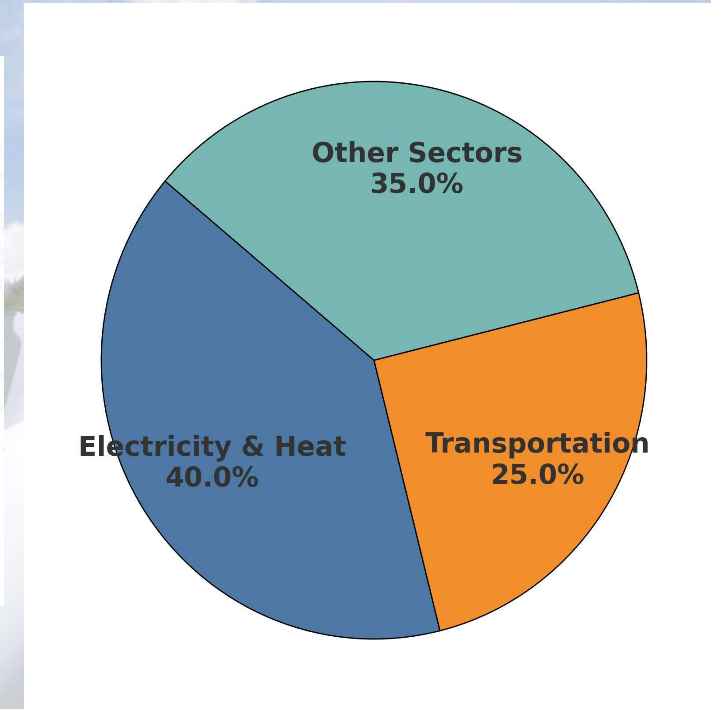
Project Advisors: Dr.Massiah Saad, Professor, Washington State University Tri-Cities,
Dennis Walters, Chief Of Staff, STARS Technology Corporation

Overview:

There are several different ways of producing energy in a renewable manner, but which one is best? We decided to explore. We ran a pilot-scale experiment for hydrogen production at the Washington State University with Dr. Messiah Saad to understand the process of electrolysis and researched about Steam Methane Reforming (SMR) for several months. After tens of hours of research, we were able to extract data from multiple papers that supported the energy used for hydrogen production and the energy density of hydrogen.Using the data on the energy used for hydrogen production and hydrogen energy density across many hydrogen production methods, we developed a comprehensive analysis that analyzes the energy consumption rates for different hydrogen production methods and how it impacts the energy outcomes. In addition, we educated different audiences across the community about the **hydrogen value chain** (as will be mentioned in following slides) and how the process lines up hydrogen production, storage, transportation, storage at end use site, and end use. Furthermore, we demonstrated CAD models and kid-friendly cartoons to demonstrate the function of the considered hydrogen production methods as well as the calculations that demonstrated energy efficiency.

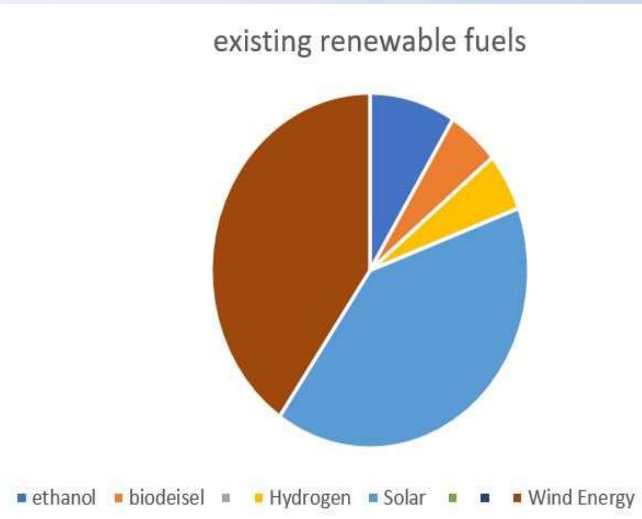
Our learnings about the need for Clean and Sustainable Energy Sources





As a first step in our project, we researched and learnt the need for Green and sustainable energy sources.We researched several articles and found that significant CO_2 emission in recent and future years attributed to fossil fuel and energy use. Besides, transportation and electric generation contribute about 65% of Greenhouse gas emissions. We found that using green and sustainable energy sources will be alternate energy forms and we narrowed our research to finding better ways for producing Hydrogen.

Defined a problem , Researched various hydrogen production methods, made comparative analysis, and Did Outreach



Energy efficiency	Life Cycle emissions
High heat is key for the implementation of combining TWSCs and solar reactors. Energy is obtained by reflecting the sun's irradiance to achieve efficiencies of 60%. The following solves for x, the energy that was needed to produce 1 kg hydrogen. $\frac{39.4}{x} = \frac{60}{100}$ $39.4 = \frac{60}{100}x$ $x = 65.67$ kWh $\frac{39.4}{x}x = \frac{60}{100}x$ $39.4/0.6 = 0.6x/0.6$ $x = 39.4/0.6$ Therefore, to produce 39.5 kWh, 65.67 kWh will be needed.	There is no carbon input or output in this process and is therefore carbon neutral.

Energy efficency	Lifecycle emissions
• The energy density of hydrogen is 39.4 kWh/kg • The energy density of methane is 14.5 kWh/kg • Since 4 molecules of hydrogen has a weight of 8 and methane has a weight of 16, 2.2 molecules of methane will be needed to make 1 molecule of hydrogen. • 15 kWh electrical energy will be needed. $\frac{E_{out}}{E_{in}} * 100 = \eta$ $\frac{39.4}{46.5} * 100 = \eta$ $\frac{39.4}{(14.5 \times 2.2) + 15} * 100 = \eta$ $\eta = 84.7\%$ $\frac{39.4}{31.9 + 15} * 100 = \eta$	Biomethane in compost is 28 times more contributive to global warming than Co_2. Steam methane reforming converts biomethane into Co_2. Therefore, SMR is carbon negative and produces hydrogen at the same time. $M = 28C$ $f(M) = \frac{f\ (M+1)}{28}$

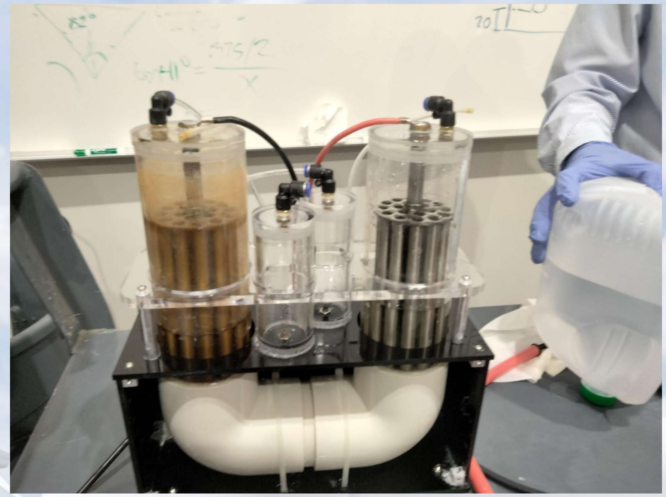
Our Inquiry: Of our global energy demand, only 20% is satisfied by renewables. Only about 1 percent of renewable energy is met by hydrogen, which is the most energy dense fuel (Journal of Renewable and Sustainable Energy Reviews). But what is the best hydrogen production method?

Industry-based knowledge transfer: We learned about 3 major hydrogen production methods experimentally with Dr. Massiah Saad and many research articles.

Answering inquiry through our knowledge: We highlighted specific parts of the papers we read to formulate several equations that solve for the efficiency of each H2 production method

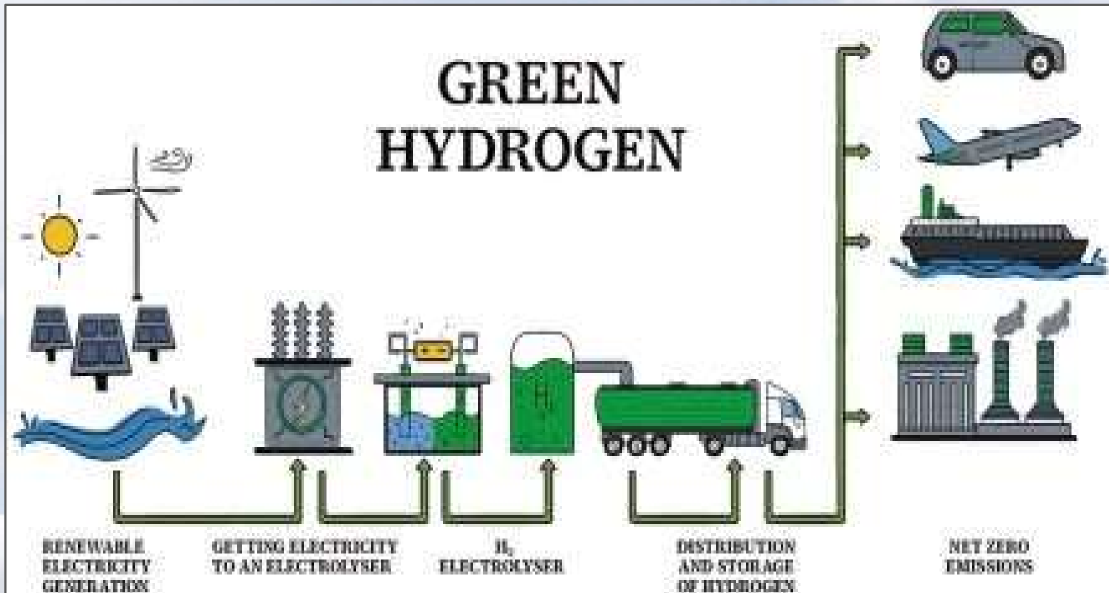
Community outreach: We did community outreach to the Columbia Basin College, West Richland Public Library, Richland Public Library, our school, and our scouting troop. They gave excellent feedback and remarks in handwritten letters.

Research: Learning about Electrolysis from experts at Washington State University (WSU), Tri-Cities



We approached Professor Messiha Saad,Mechanical Engineering, WSU After meeting with Professor Messiha we learned the basics of electrolysis such as how it uses electrodes to split water and the electrodes needed to make electrolysis with water happen. We also did a hands on experiment with electrolysis using an electrolysis module. He helped us really understand and appreciate the concept of electrolysis and taught information through experiments. The two day field trip was worthy and we appreciate his time for educating and inspiring us.

Our further research: Chemical Equations and sources for powering electrolysis



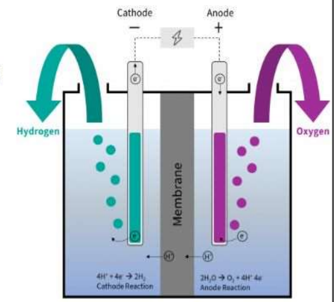
Electrolysis of water is a process that uses electricity to split water to hydrogen and oxygen.

Electrolysis = Water + Conductance + Power Sources

$$2H_2O \rightarrow 2H_2 + O_2$$

$2H_2O$	$2H_2 + O_2$
H = 4	H = 4
O = 2	O = 2

Conductance speeds up the process



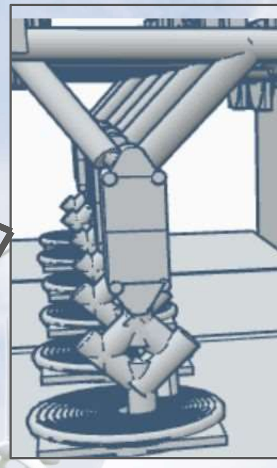
Water contain 11% of hydrogen and 89% Oxygen (1 kg hydrogen per 2 gallons of water)

\We learned from our research more about how the process works and why we use electrodes like salt to make electrolysis happen. We also researched the chemical equations for electrolysis and various energy sources for electrolysis.

Our research about the steam methane reformer

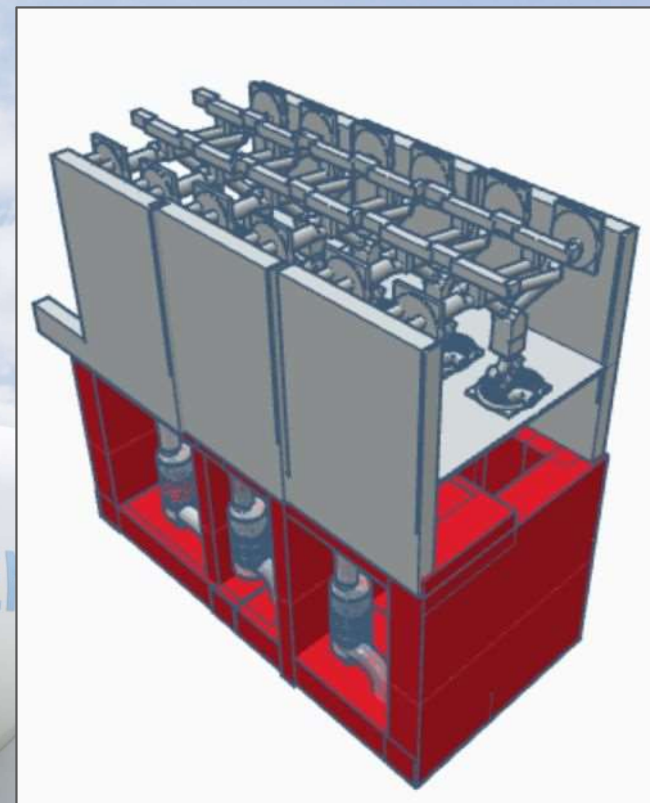
Water is boiled to 220 °C because system operates at 10 atmospheres

Biomass conversion to Biomethane: Various sources of biomass can be converted into sludge, stored in an airtight tank that will be fed on by bacteria, creating biogas, which can be processed to create biomethane



The steam methane reforming: Steam methane reforming has 2 processes.

1. Takes place when Steam and methane reacts under high temperature of 740 °C, leading to carbon monoxide and hydrogen.
2. Takes place when carbon monoxide is supplemented with more steam, leading to carbon dioxide and hydrogen.



Above: *Our 3D model of both parts of the steam methane reformer*

Our Research: Steam Methane Reforming (SMR) efficiency and carbon negativity calculation

Energy efficency

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$$\frac{E_{out}}{E_{in}} * 100 = \eta$$

$$\frac{39.4}{(14.5 \times 2.2) + 15} * 100 = \eta$$

$$\frac{39.4}{31.9 + 15} * 100 = \eta$$

$$\frac{39.4}{46.5} * 100 = \eta$$

$$\eta = 84.7\%$$

Lifecycle emissions

Biomethane in compost is 28 times more contributive to global warming than Co_2. Steam methane reforming converts biomethane into Co_2. Therefore, SMR is carbon negative and produces hydrogen at the same time.

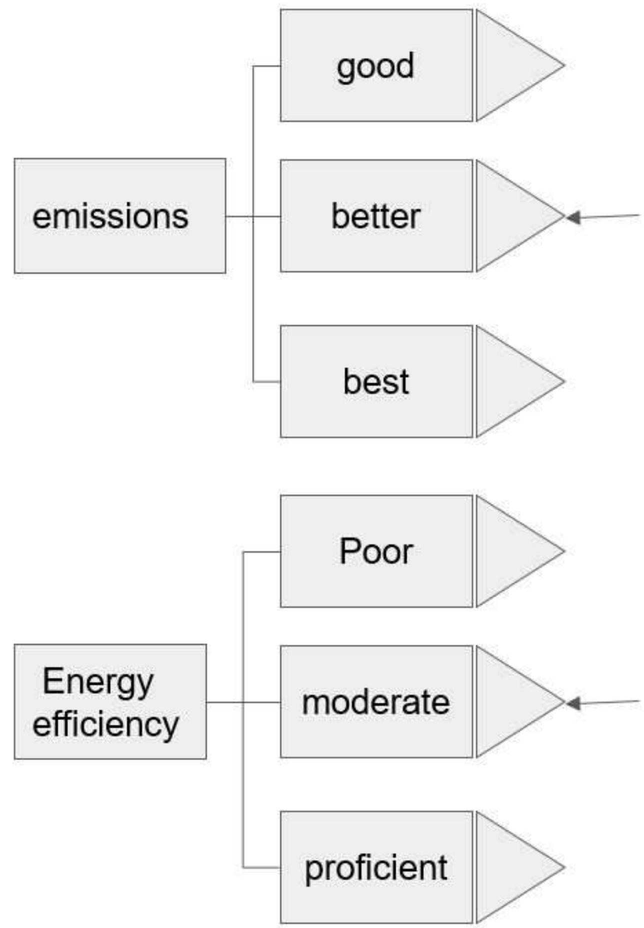
$$M = 28C$$

$$f(M) = \frac{f\,(M+1)}{28}$$

Our Research: Electrolysis efficiency and carbon negativity

Electrolysis efficiency

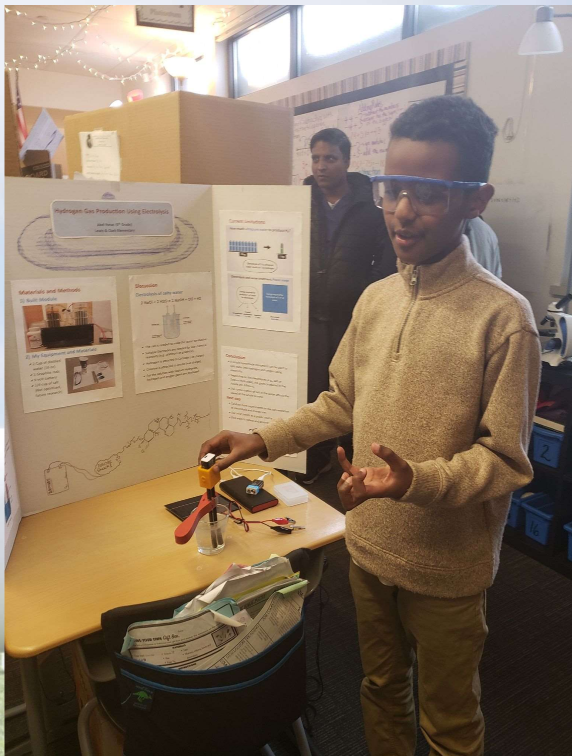
Energy efficiency	Lifecycle emissions
• Energy needed to produce 1 kg H_2 with electrolysis is 50-55 kw (52.5 avg.). • 1 kg H_2= 20 kw energy $E_{in}= 50$ $E_{out} = 39.4\ kw.$ $\frac{E_{out}}{E_{in}} \times 100 = 78.8\%$	• $2H_2O$ converts into $2H_2+O_2$ with the help of anode, cathode, and Sodium Hydroxide (NaOH) • No emissions are involved in any part of the Electrolysis process and is therefore carbon neutral.

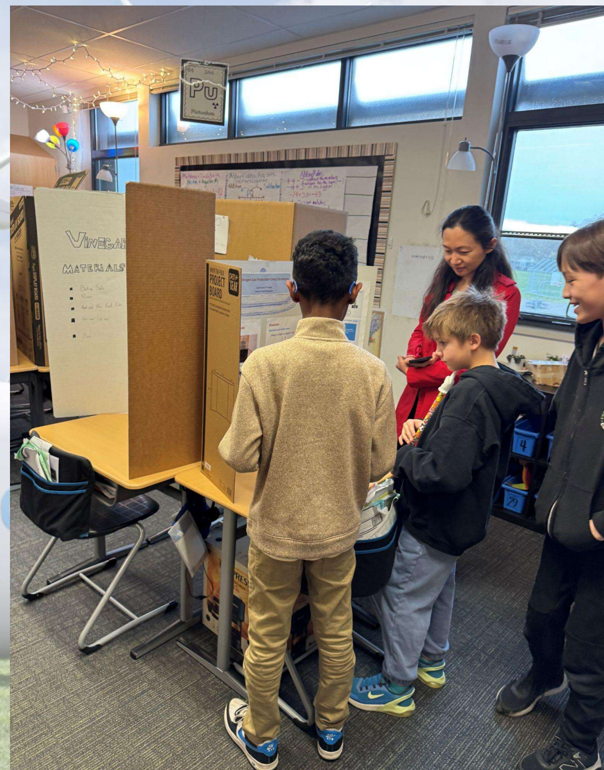


Outreach : Kids Engineering Day, STEM event supported by Energy Northwest

We presented the basics electrolysis to kids attending the kids engineering day. To do this we developed CAD designs and 3d printed items for a module that would help us more clearly and conveniently demonstrate Electrolysis to attendees of Kids engineering day. Roughy 50 kids came to our presentation and the audience varied widely from little kids to adults who knew a lot in this area and even told us some useful information We think the kids learned about the basics of how electrolysis works and could help them see that hydrogen could be a good solution for reducing greenhouse emissions.

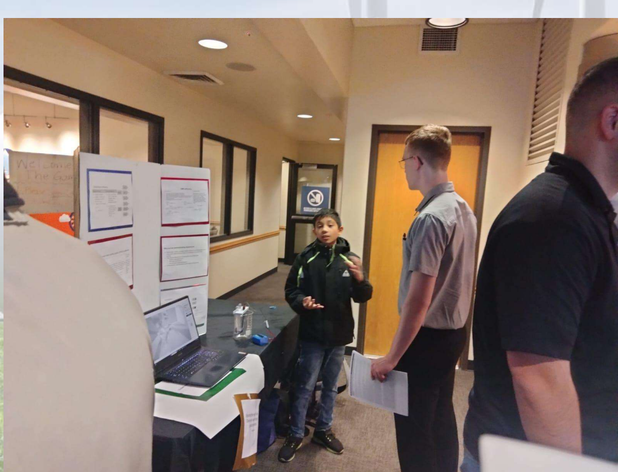
Outreach at our school science fair : Science Fair, Lewis and Clark Elementary School, Richland, WA

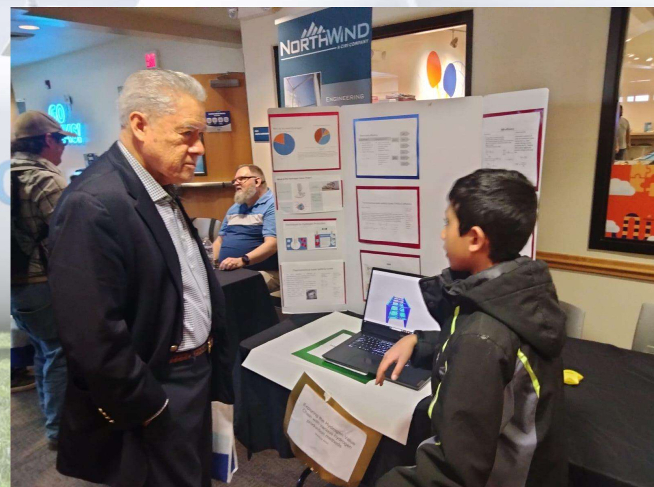




The Science Fair at our school, Lewis and Clark Elementary is an annual event where we our showcase a science project . This year we showcased electrolysis and demonstrated the same. About 30 people visited and the audience included parents, engineers from various energy companies, scientists from Pacific Northwest National Laboratory (PNNL) and Professors from WSU, Tri-Cities. Through this we were able to educate parents on electrolysis and get feedback from experts in this field. This outreach was valuable as we were able to reach the scientific community at large, and seek ideas to extend our project. Besides, this opportunity helped us practice our own presenting skills and gave scope for improvement.

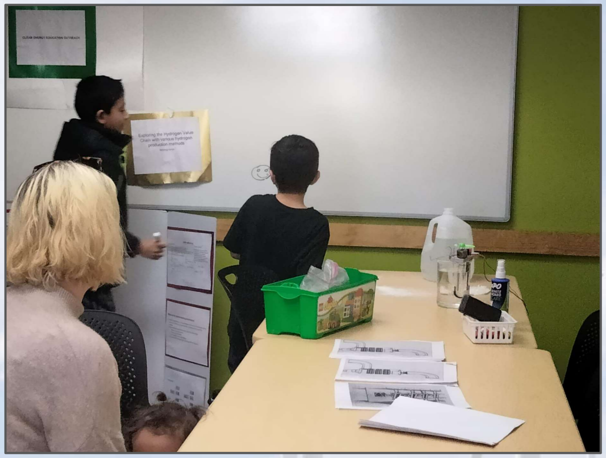
Outreach: Our Community College–The Columbia Basin Hawks

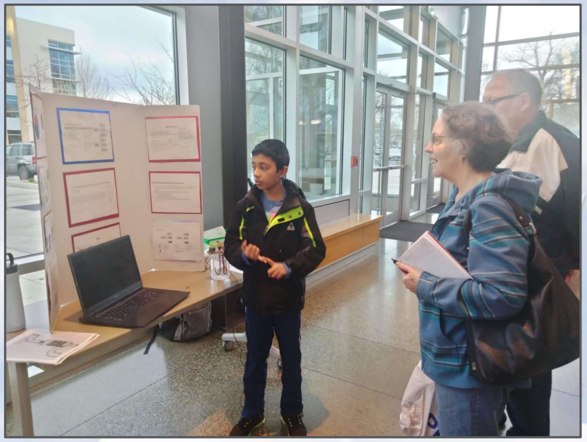


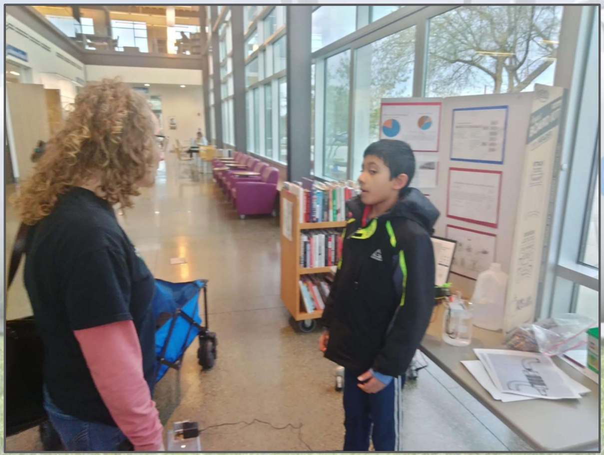


We hosted a booth in a Career & Internship fair at the columbia basin college, a major community college in our city. This outreach event came to become one of the most popular events in this year's NEED outreach booths. About 40 to 50 people arrived in long lines to hear about our project. The audience range of the people who came to visit our booth was vast; Everyone from families who were interested to come and learn about clean energy to retired U.S. Army Colonels who were familiar about each and every part of our project came to our stall. We learned about how the future was headed towards using hydrogen and hydrogen missiles, inspiring us towards a new found interest. We also were introduced to speaking in simple terms so anyone can understand complex information by breaking it into simple parts, that helped us make other presentations to basic audiences much more fun and engaging.

Outreach: We conducted Outreach at public libraries

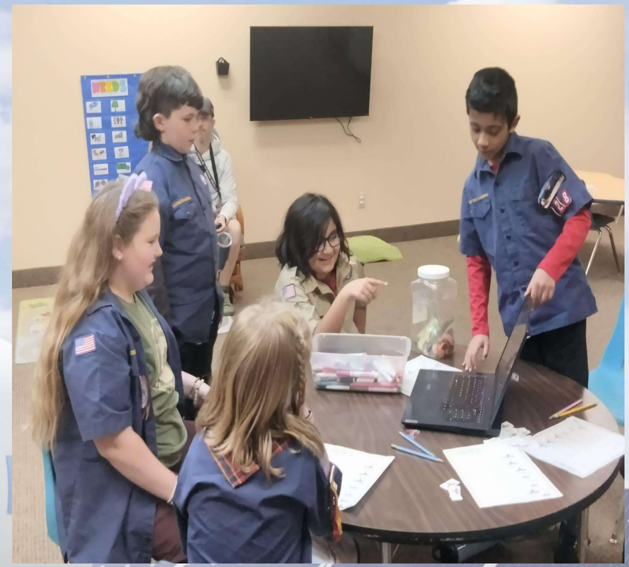






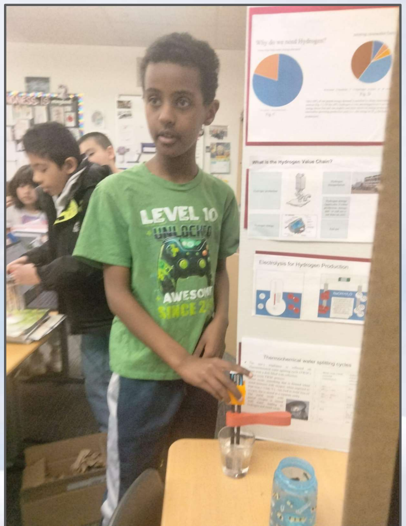
Our outreach event at our local libraries had about 20 people. The audience range was vast as well; The audience ranged from families wanting to see the homemade conversion of water into hydrogen to environmental engineers and people in affiliation with proton exchange membrane and electrolysis. The audience gave lots of handwritten letters of appreciation and how surprised they were to here the presentation. We also had lots of fun drawing cartoons to represent the function of hydrogen production methods, especially when there were kids, who were very engaged and entertained with our presentation.

Outreach: Sharing knowledge about effective ways of producing Hydrogen to our cub scouts.



Our audience were cubs and their parents. We found out that our audience were very interested and inquisitive about the 3D modeling designs. This helped us streamline our presentation style for our school audience, which was simple and engaging.

Outreach: We educated 3rd students at our school, Lewis and Clark Elementary, Richland, WA



The 3rd grade audience in our school were very motivated to learn. They never feared to participate, had great team spirit, and were very enthusiastic to learn. The really liked our 3D model and boldly took guesses when they were asked a question. This reflected the importance of simple explanation and interactive Q&A during a presentation to keep the audience engaged.

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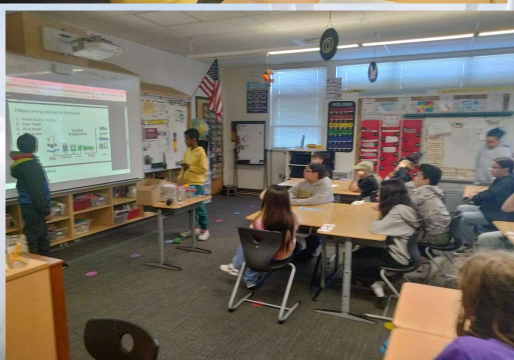

We reached out to a big fifth grade classroom. The kids were very interested and were able to understand and appreciate about hydrogen production methods. They were very curious and had several questions. They appreciated the simple version of our electrolysis unit and as well the third dimensional models of the Steam Methane Reformer (SMR). We used TINKAR CAD software and kids had so excited to watch them. We explained both electrolysis and SMR process in detail. The teacher was very supportive and wanted to showcase our project to other parents in the school

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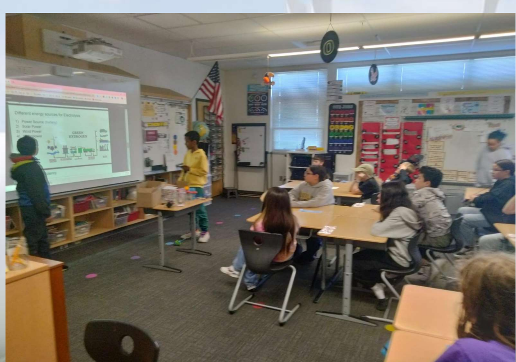

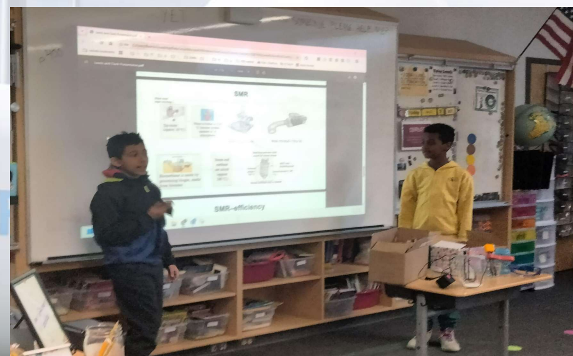

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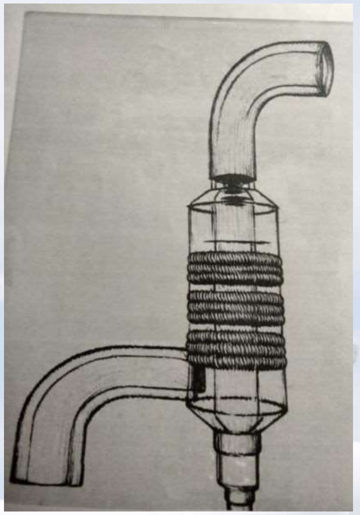
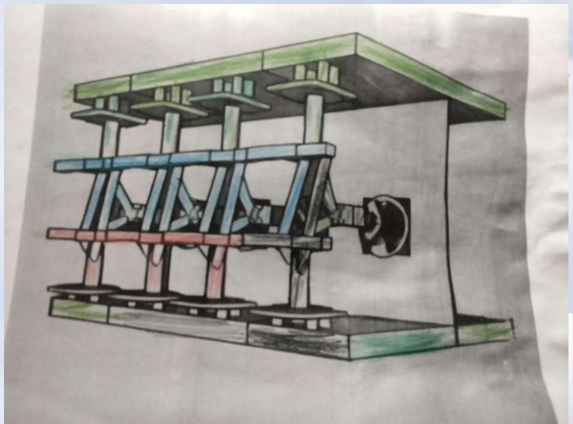
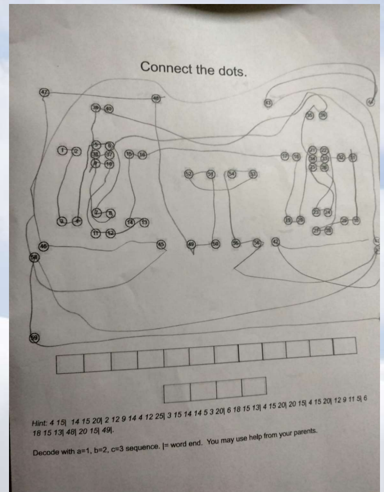
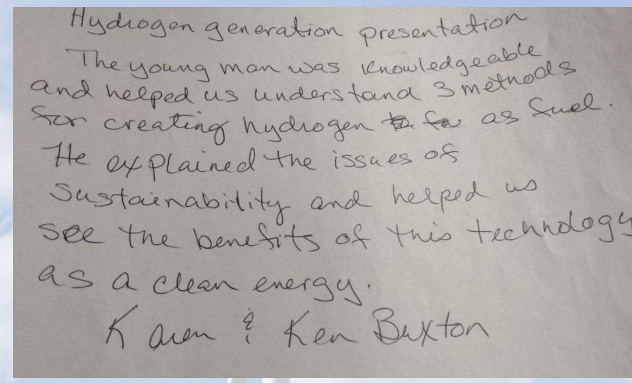
Outreach: We prepared coloring sheets and educational puzzles for our school students and community kids to understand and appreciate hydrogen production methods

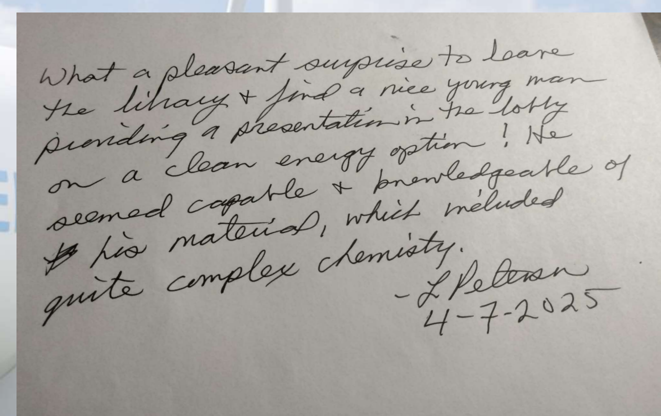








Hydrogen generation presentation
The young man was knowledgeable and helped us understand 3 methods for creating hydrogen ~~to~~ ~~for~~ as fuel. He explained the issues of sustainability and helped us see the benefits of this technology as a clean energy.
Karen & Ken Buxton



What a pleasant surprise to leave the library + find a nice young man providing a presentation in the lobby on a clean energy option! He seemed capable + knowledgeable of ~~h~~ his material, which included quite complex chemistry.
- L Peterson
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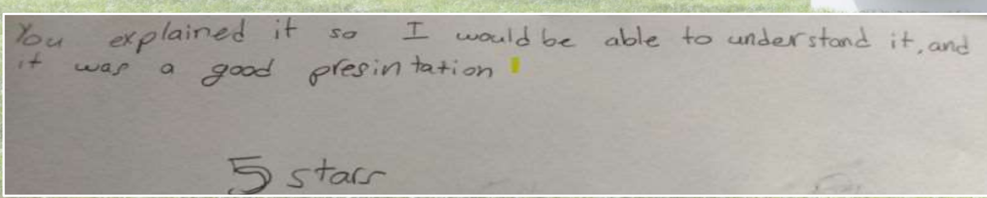
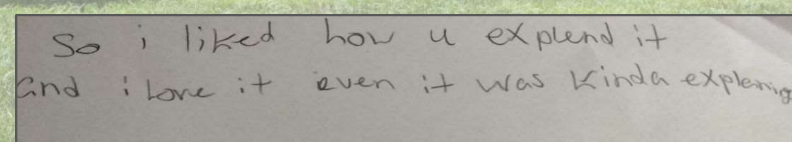
We created graphics of parts of Steam Methane Reformer and as well fun puzzles that would turn into electrolysis unit. Besides, we got great feedback from kids as well from community members who participated in our outreach.



You explained it so I would be able to understand it, and it was a good presintation!
5 stars



So i liked how u explend it and i love it even it was kinda explening!

Next Steps and Future Steps of our project

- Improving current fuel cells towards complex systems and presenting our idea to hydrogen agencies as well as to kids who love to learn in our community
- Finding and explaining where entropy plays a role in both Steam Methane Reforming
- Make modular design kits for kids from across many states and countries and lessons to understand the complexity of some hydrogen production technologies with ease

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