Green Hydrogen: Energy of the Future?

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Question and Hypothesis

Can green hydrogen become a major source of energy in Alberta?

- Green hydrogen is a clean fuel produced by splitting water into hydrogen and oxygen through a process called electrolysis (this process has to be powered by renewable sources).
- Based on the research I had done before starting my project, I hypothesize that green hydrogen could be used as an energy source; not only is it clean and doesn’t negatively affect the environment, but it's renewable unlike the source of energy we use today which are fossil fuels.
Background Information

- I chose this project because it focused on the environment and renewable energy which are topics I enjoy discussing about. This project was first thought of when I asked my science teacher on what project I should do that focused mostly on renewable energy and the environment. I was then introduced to an article that was about an Australian coal company wanting to bring coal back to Alberta and how it was protested against by civilians. The company decided to build a renewable energy complex on the site that will store and produce green hydrogen.

- Before I formed my question, I had to learn more about the process green hydrogen is made with and basic chemistry. After looking at a few other articles, I thought the topic was interesting and formed my question with it.

- In this project, I will be using the advantages and drawbacks of the production and use of green hydrogen, its environmental impact, and help from an expert in the field to answer my question.
Why Should We Care?

We are currently in a global crisis. The earth’s temperature is increasing due to global warming. Most of us know that global warming is mostly caused by the carbon emissions produced by burning fossil fuels. Green hydrogen is a clean fuel that releases zero carbon emissions when it is produced and used. We should care about this problem because if we find a way to switch from using fossil fuels to using clean energy, we could slow down global warming and Alberta could gain a profit from this industry.
Research Topics:

- What is hydrogen and how is it produced?
- How is hydrogen used as an energy source?
- Types of hydrogen and green hydrogen’s main competitors
  - Alberta current events on hydrogen
  - Advantages and drawbacks of producing and using green hydrogen.
- Cost of green hydrogen compared to its competitors.
- Asking an expert in the field.
What is Hydrogen and How is it Produced?

Hydrogen is a nonmetallic, odourless and colourless gas that is the simplest member of the periodic table of elements. Since our atmosphere is only 0.00005% hydrogen, the hydrogen we use is extracted from compounds using the following methods:

- **Electrolysis**: Electricity is used to separate water (H₂O) into hydrogen and oxygen.
  - Carried out in an electrolytic cell.
  - This process leaves water as a byproduct.
  - 4% of hydrogen used today is produced with this method.

- **Steam Methane Reforming**: In this process, methane (CH₄) from natural gas is heated with steam to produce a mixture of carbon monoxide, a small amount of carbon dioxide and pure hydrogen.
  - Usually in the presence of a catalyst.
  - 95% of hydrogen produced today is produced with this method.
Electrolysis Demonstration

Materials Used:
- 2 Wires (one positive, one negative)
- A beaker
- 5 D batteries
- A zinc rod (anode)
- A copper rod (cathode)
Electrolysis Demonstration

What happened and why did this happen?
- After leaving my demonstration out for 40 minutes, there were small hydrogen bubbles forming around the zinc rod and a few oxygen bubble forming around the copper rod.
- The hydrogen formed at the zinc because hydrogen is positively-charged and zinc is a negatively-charged electrode.
How is Hydrogen Used as an Energy Source?

Hydrogen is not an energy source but an energy carrier.

- Hydrogen can be used in fuel cells to generate electricity and heat through an electrochemical reaction.
- A fuel cell takes chemical energy and turns it into electricity that can power an electric motor.
  - Two electrodes:
    - Cathode (negative) - Oxygen
    - Anode (positive) - Hydrogen
- Fuel cells can be used to power homes and vehicles in the future.
- Fuel cells can continue to produce electricity as long as fuel and an oxidant is supplied.
Types of Hydrogen and Green Hydrogen’s Main Competitors

Color codes are used to describe how the hydrogen was produced and the process it went through. The most popular types of hydrogen and green hydrogen’s main competitors are gray and blue hydrogen.

- **Green hydrogen:**
  - Hydrogen that is produced by electrolysis (has to be powered by renewable sources)
  - Only leaves water as a by product.
  - Makes up 1% of all the hydrogen produced today.

- **Blue hydrogen:**
  - Steam methane reforming.
  - The carbon dioxide produced is safely and permanently stored underground.

- **Gray hydrogen**
  - Created from coal or methane and uses steam reformation.
  - Releases all the greenhouse gases produced when it is made
  - Most common form of hydrogen today.
Other Types of Hydrogen

- **Pink/Purple hydrogen**: Generated through electrolysis that is powered by nuclear energy.
- **Turquoise hydrogen**: Generated by the thermal splitting of methane.
- **Yellow hydrogen**: Hydrogen produced by electrolysis using grid electricity from various sources.
- **Brown/Black hydrogen**: Generated through the gasification of coal.
- **White Hydrogen**: Generated using a process called hydraulic fracturing where water, sand, and chemicals are injected underground at very high pressures to crack open rock layers and release the hydrogen trapped inside.
What Is Alberta’s Current Source of Hydrogen? How do we Plan to Use it?

- Alberta is Canada's largest hydrogen producer (2.4 million tonnes annually).
- Currently have 5 important markets for the growth of clean hydrogen:
  - Residential and commercial heating: Powering appliances.
  - Transportation: Creating vehicles powered by clean hydrogen.
  - Industrial processes: Using hydrogen to refine fossil fuels and upgrade bitumen and oil.
  - Power generation and energy storage: Producing electricity and fuel cell generators.
  - Export market: Creating more hydrogen and selling it around the world.
Alberta’s Current Events on Hydrogen

Tent Mountain Redevelopment Project
- In October of 2021, Montem Resources Ltd proposed to bring back coal mining in Alberta's Rocky Mountains.
- When people protested, they decided to build a green hydrogen facility on the site instead.
  - If all goes as planned, Tent Mountain will become Canada's first large scale green hydrogen production facility (producing 13000 tones of green hydrogen/ year).
  - It is estimated that it could power 200,000 homes through the night.

Alberta's Natural Gas and Vision Strategy
- In October 2020, Premier Jason Kenney announced a strategy to grow and expand the natural gas sector (included expanding the use of hydrogen).
- He plans for hydrogen to be produced at a larger scale and for it to be deployed in many places across Alberta by 2030.
- By 2040, He plans for clean hydrogen to be exported around the globe.
- This document focuses on blue hydrogen.
Advantages of Using and Producing Green hydrogen

- Hydrogen in general can move a lot of energy for every pound of fuel. This means that a car that runs on a liter of hydrogen will go farther than one which runs on a liter of gasoline since hydrogen fuel is 3 times more powerful than gasoline.
- It is a renewable energy source and is plentiful in supply (in water)
- Green hydrogen only leaves water as a byproduct after it is produced
- It is non-toxic (it doesn't negatively affect the environment)
- It's production process is sustainable since electrolysis can be powered by renewable energy
- Green hydrogen is versatile and it can be used in many different industries
Disadvantages of Using and Producing Green Hydrogen

- It is hard to store since it has an extremely low density. This means that it needs to be compressed to a liquid state and stored at a lower temperature.
- Hydrogen is flammable and if it is not handled correctly, it could be very dangerous. It also lacks smell so any leak detection is impossible.
- It cannot easily replace today's most used energy sources (fossil fuels) since it is more costly and time consuming to produce.
- Green hydrogen energy is expensive to extract and produce.
- Has a low efficiency (30-40%)
Cost of Green Hydrogen Compared to its Competitors

- In Alberta, the cost of producing hydrogen in general is very low compared to other provinces.
  - Green hydrogen can cost about $2.50 to $5.00 per kilogram.
  - Blue hydrogen can be produced at a cost of $1.50 to $2.00 per kilogram.
  - Gray hydrogen can cost about $1.00 to $2.00 per kilogram.
- Researchers estimate that the cost of producing green hydrogen will drop by up to 64% by 2040. Blue hydrogen's production cost will see an increase in price by 59% during the same time period. Researchers believe that the hydrogen industry will switch its interest from blue to green hydrogen.
Asking an Expert in the Field

Professor Blake Shaffer from the Economics department, University of Calgary

I asked him two questions:

- Considering the cost of producing it, in your opinion can green hydrogen become the fuel of the future in Alberta?
- If so, how would it impact Alberta's economy since this province is known for its oil?

Professor Blake Shaffer told me that green hydrogen will eventually compete with blue hydrogen. He says that it will eventually happen because generating electricity from renewables gets really cheap and building electrolyzers will start to reduce in price as more innovation occurs. He then states that blue hydrogen has a lot of promise because of our abundance of natural gas and that for it to work, we need to work on capturing as much emissions that are generated from steam reforming.

For my second question, he told me that though Alberta is mainly known for its oil, it is also extremely rich in all forms of energy. Apparently, we have the most abundant onshore wind resource in Canada and also have the most hours of sunlight in the country. This makes our renewable resources much cheaper than the rest of Canada. He finally closed off by telling me that we should take advantage of this cheap renewable energy when we produce hydrogen.
Analysis

- In my opinion, green hydrogen can be a source of energy because:
  - It is renewable.
  - It only leaves water and air as byproducts after it is produced through electrolysis.
  - It’s versatile.
  - It doesn’t negatively affect the environment.
  - It could positively affect our province as well since we are known for our abundant source of renewable energy (this makes our renewable resources cheaper).
- I think we should take advantage of all of our resources to produce even more hydrogen.
- I think that the only reason companies are hesitating when it comes to moving forwards in this is because of the cost of green hydrogen and its low efficiency. Though the price might be high now, it is estimated to decrease greatly by 2040 and technology is being developed to maximize its efficiency.
Conclusion and What’s Next

- In this project, I tried to find out whether green hydrogen can be used as a major source of energy in Alberta. Based on the research I have conducted, green hydrogen could become a source of energy in Alberta. However, as it currently has a 30% efficiency, technological advancements would be needed in order for it to be a major source of energy.

If I could spend more time on my project, I would try to improve my conclusion and analysis by really going in depth why I think green hydrogen could be a source of energy in Alberta and why it cannot currently become a major source of energy. I would also try to expand my knowledge in chemistry a bit further by maybe finding a mentor that could teach me more. I would do this because we do not learn chemistry in grade 8 and for this project, experience in chemistry is needed to really understand it.

If I could take my project to the next level, I would explain what could happen in the future if we do switch from fossil fuels to green hydrogen (challenges, opportunities green hydrogen could bring). I would try to incorporate how green hydrogen could be essential for the world to reach its “Net-zero 2050” goal. I would lastly talk about how green hydrogen can be used in different industries.
Bibliography (Pictures)

Alberta Hydrogen Road Map [PDF]
https://montem-resources.com/projects/tent-mountain/
https://www.crunchbase.com/organization/montem-resources
Natural Gas And Vision Strategy [PDF]

Sites used for information is on the platform
THANK YOU