Pink Hydrogen Feasibility

This project aims to test the feasibility of solid-oxide electrolysis to produce 170 metric tons of hydrogen per day. The heat generated by a nuclear power plant will be converted into electricity using a Supercritical CO_2 Brayton Cycle to power the electrolysis.

Hydrogen Fuel

The objective of our process is to produce 170 metric tons of hydrogen per day by using the heat of a nuclear reactor for electrolysis of water. In recent days, the most common method to obtain hydrogen fuel is Steam Methane Reforming (SMR) but the major drawback is that **~10 kg of CO and CO_2 is produced per kg of H_2**. In this case, the electrolysis of water using reactor heat, a negligible amount of carbon is produced which allows for a much cleaner production for the environment.

Nuclear Reactor

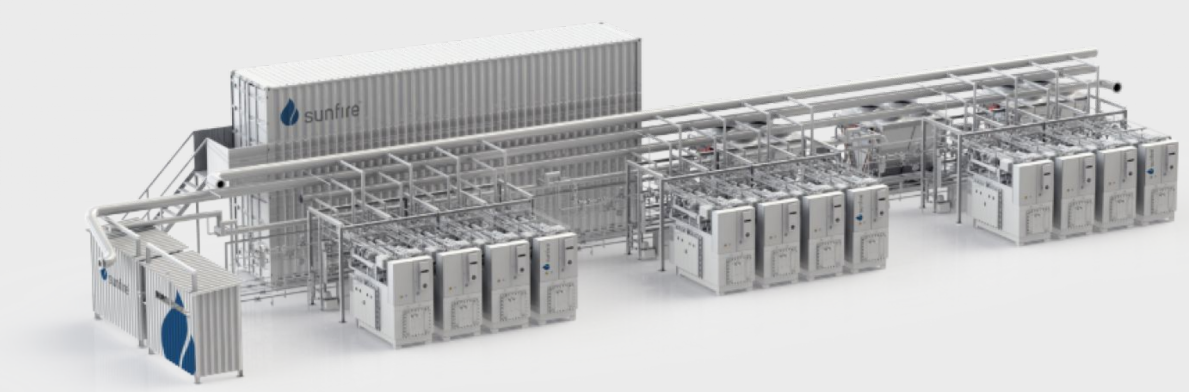
The USA is one of the biggest nuclear nations in the world and it has the second highest number of nuclear assets in the world. The US Department of Energy (DOE) has decided to invest 9.5 billion USD into technology to improve the infrastructure and promote clean hydrogen. The carbon tax credits by using this technology will help to allow for the clean technology to catch up and compete with the current market.

Why not use renewable energy?

Our proposal produces what is known as 'pink' hydrogen. It utilizes surplus heat from a nuclear reactor to vaporize water and separate it into hydrogen and oxygen gas. Green hydrogen, made from renewable energy, is more expensive to produce and the amount of energy can be highly variable as well as area inefficient. Pink hydrogen increases the efficiency of an already-existing energy source that, where in use, makes up a large percentage of the area's energy. That makes it a more cost-effective and high-volume hydrogen source.

170 metric tons of hydrogen can produce 5661 MWh of energy. This takes 6 football fields of space to produce.

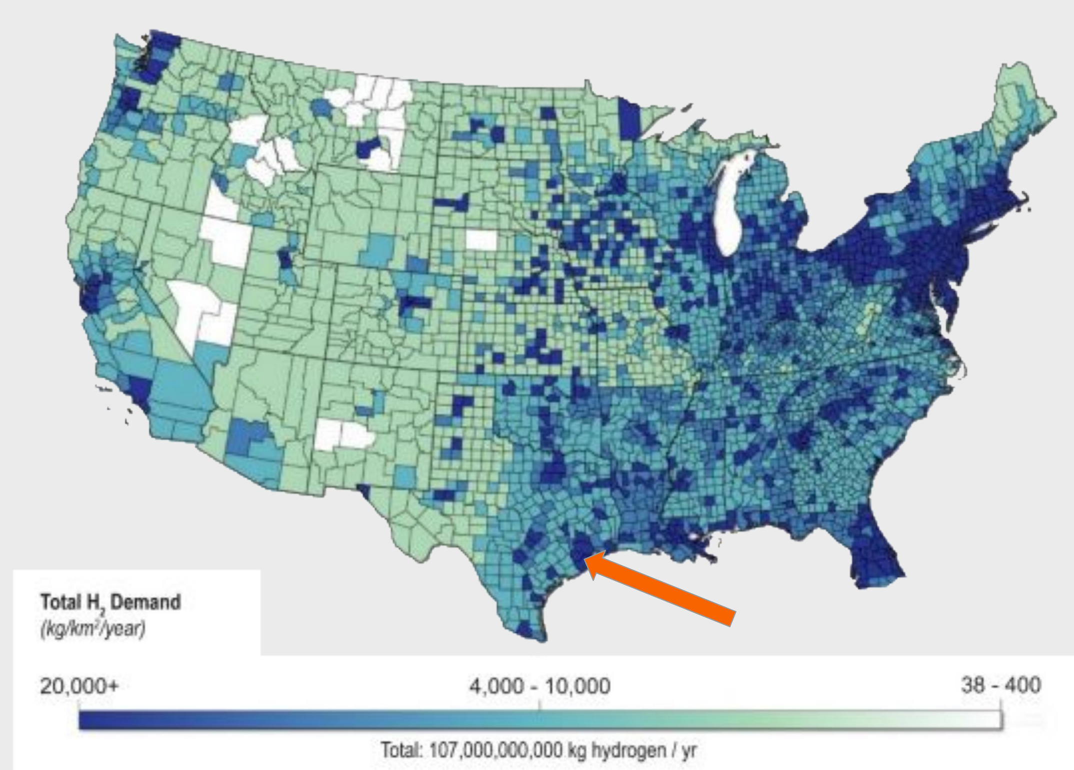
The same amount of solar energy takes 591 football fields of space to produce.



https://www.sunfire.de/en/

Location

Existing operating nuclear reactor sites in the US are a primary location indicator for this project. Operating reactor sites greatly vary in size and MW output capacity. The average nuclear plant generates 1 GW of power, which fits our demands. The demand of hydrogen, as well as its consumption, is the main driving force for our desired location. The team has decided on the **South Texas Nuclear Generating Station** (STNGT), which has two reactors, each of **1354 MW** gross capacity, located in Matagorda County. A fertilizer facility is present here, and the nuclear site is planning to add two additional reactors.

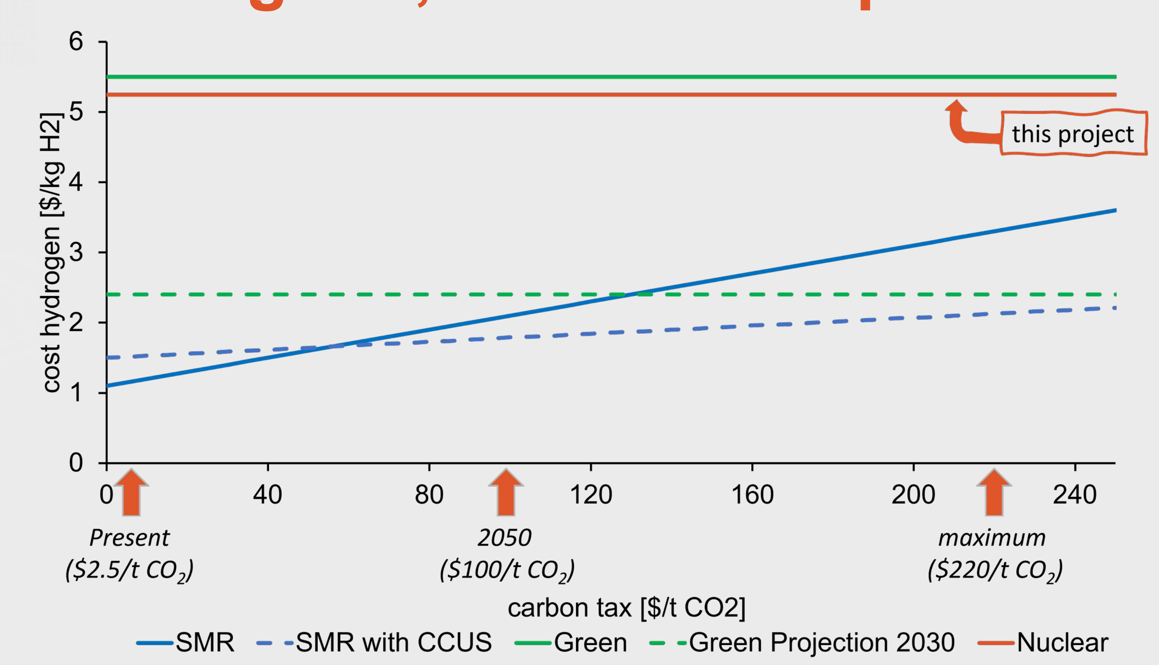


https://www.iea.org/reports/world-energy-outlook-2021

Safety

As with all flammable fuels, safety needs to be prioritized. According to the Office of Energy Efficiency and Renewable Energy, some handling differences of hydrogen provide safety benefits compared to gasoline. Hydrogen's safety record, according to the Department of Energy, can continue to grow and build confidence that hydrogen can be as safe as the fuels in widespread use today. Moreover, "**U.S. plants are among the safest and most secure industrial facilities in the country**", says the Nuclear Energy Institute - the policy organization of the nuclear technologies industry.

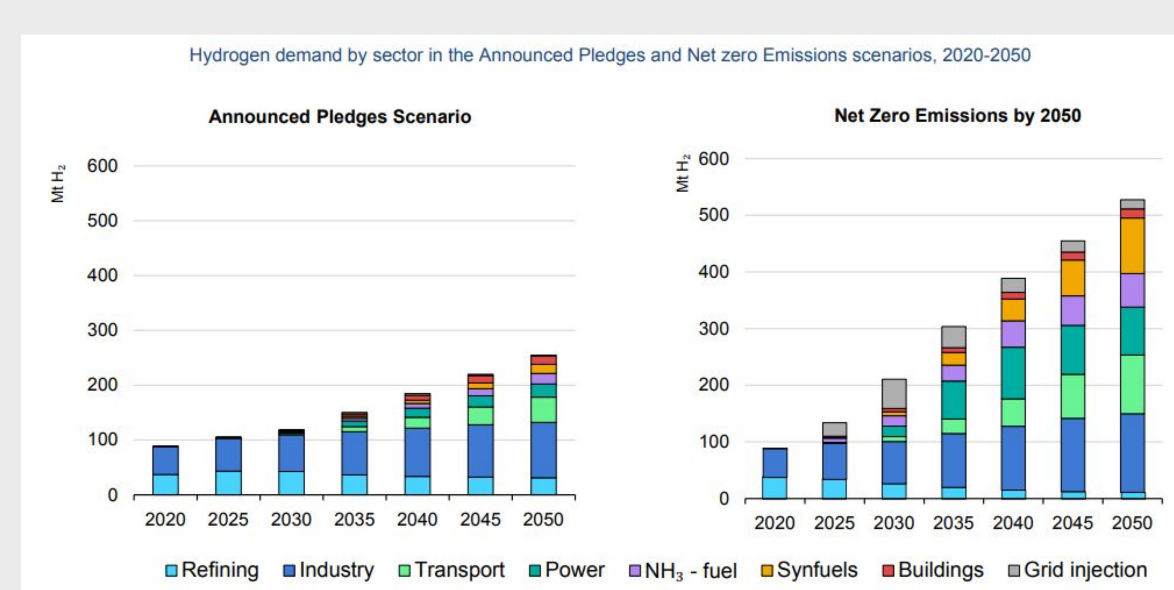
Looks good, but is it competitive?



The electrolysis technology is still being developed and is projected to reduce its costs low enough for both green and pink hydrogen to be competitive with SMR methods. The future for Steam Methane Reforming (SMR) is dwindling as carbon tax credits are a market that penalizes products which have carbon emissions. As the world moves towards a greener future, products which emit less carbon are desired. Economists predict that by 2050, carbon tax credits will have risen to **$100/ton** of CO_2.

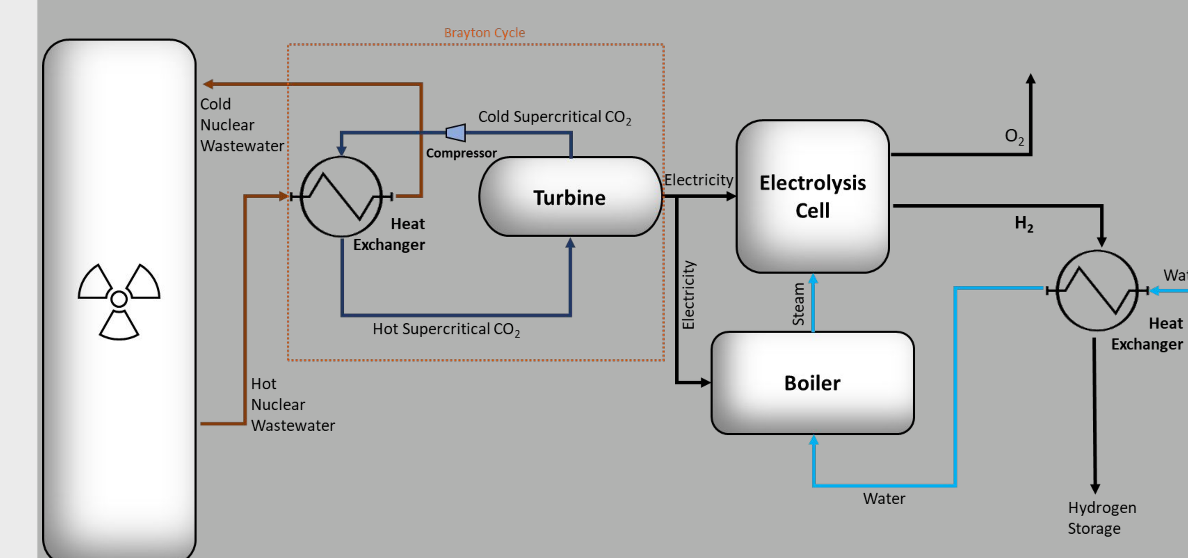
Where is Hydrogen needed?

In the United States, there are many industrial processes that utilize hydrogen. According to the US Energy Information Administration, most of Hydrogen is used for **"refining petroleum, treating metals, producing fertilizer, and processing foods."** Several power plants in the US have also announced plans to operate by burning hydrogen for electricity generation through a natural gas-hydrogen fuel mixture in combustion gas turbines, yet burning hydrogen results in nitrogen oxides emissions and is less efficient than use in fuel cells. Hydrogen has also been utilized in rocket ships for outer space exploration since the 1950s. Since the Energy Policy Act of 1992, hydrogen vehicles powered with zero-emission fuel cells have been growing in interest, and may also be 2-3 times more efficient than an internal combustion engine running on gasoline.



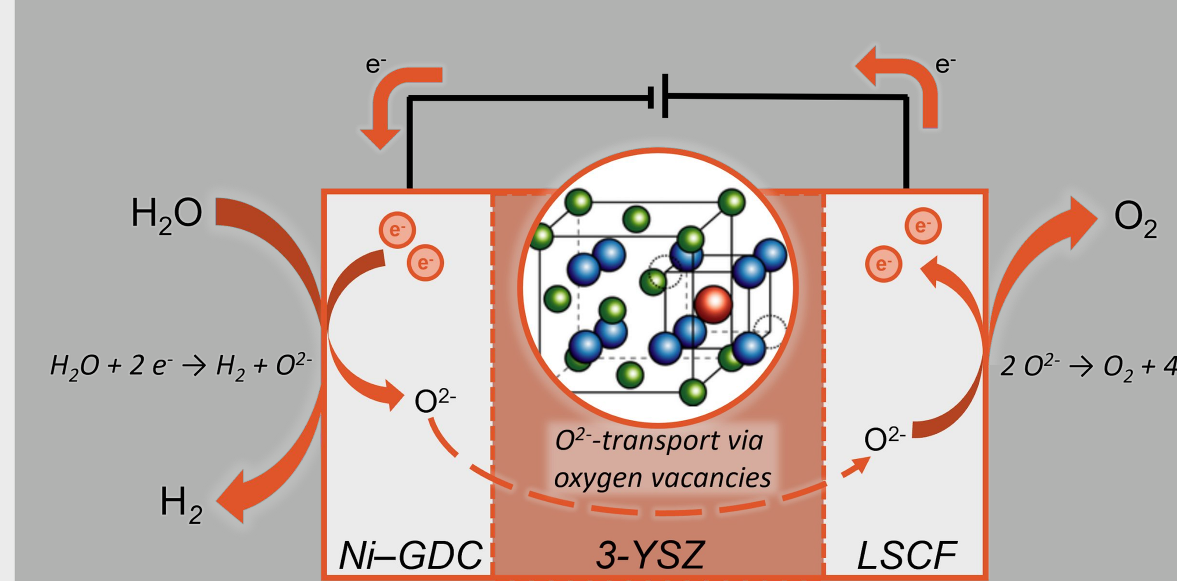
Brayton Cycle

The Brayton Cycle is a method of high efficiency electricity production from heat using Supercritical CO_2. In our project, we will be heating CO_2 to 680ºC in order to turn a turbine to produce electricity and then recompress the CO_2 to 8 MPa in order to repeat the cycle. At these conditions, we are able to obtain a theoretical 53% net efficiency.



Electrolysis

In general, electrolysis converts electrical energy into chemical energy and is therefore the reversal of the more well-known fuel cell. The electrolyzer cell consists of three parts: cathode, anode, and electrolyte. These can be used to split **water** into **hydrogen** and **oxygen**. In this project, a **solid-oxide electrolyzer cell** (SOEC) was chosen. Here, a solid oxygen-ion-conducting electrolyte is used, replacing the usual liquid electrolyte which leads to the opportunity of working at harsher conditions. **Yttria-stabilized zirconia** (YSZ) is capable of conducting O^{2-}-ions due to its oxygen vacancies in its structure. The water gets reduced to hydrogen and oxygen-anions at the **cathode,** which consists out of highly porous nickel oxide/gadolinia-doped ceria (Ni-GDC). The oxygen-anions then get transported through the electrolyte and to the lanthanum strontium cobaltite ferrite **anode** (LSCF) where they get oxidized to oxygen. In the proposed facility, each electrode has a surface of 128 cm². 25 of these systems will be combined into a stack, and **84,000 stacks** (which are grouped in different modules) will be used. The current density will be **0.7 A·cm⁻²** leading to a cell potential of **1.22 V,** which corresponds to an output of at least **230 MW**. The working temperature and pressure of the systems are **850 °C** and 8 bar to optimize degradation and performance of the electrolysis. Still, the different stacks have to be replaced approximately every 10 years in order to maintain the desired production rates.



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