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# LOW-CARBON FUELS WITH CSP

## *How concentrated sunlight can address challenges with Green Hydrogen*


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*Concentrating Solar Technologies*


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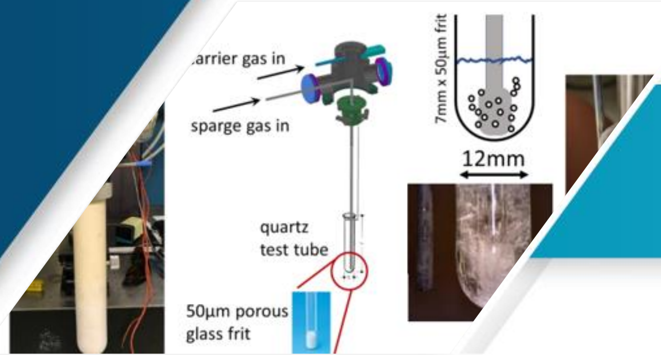



U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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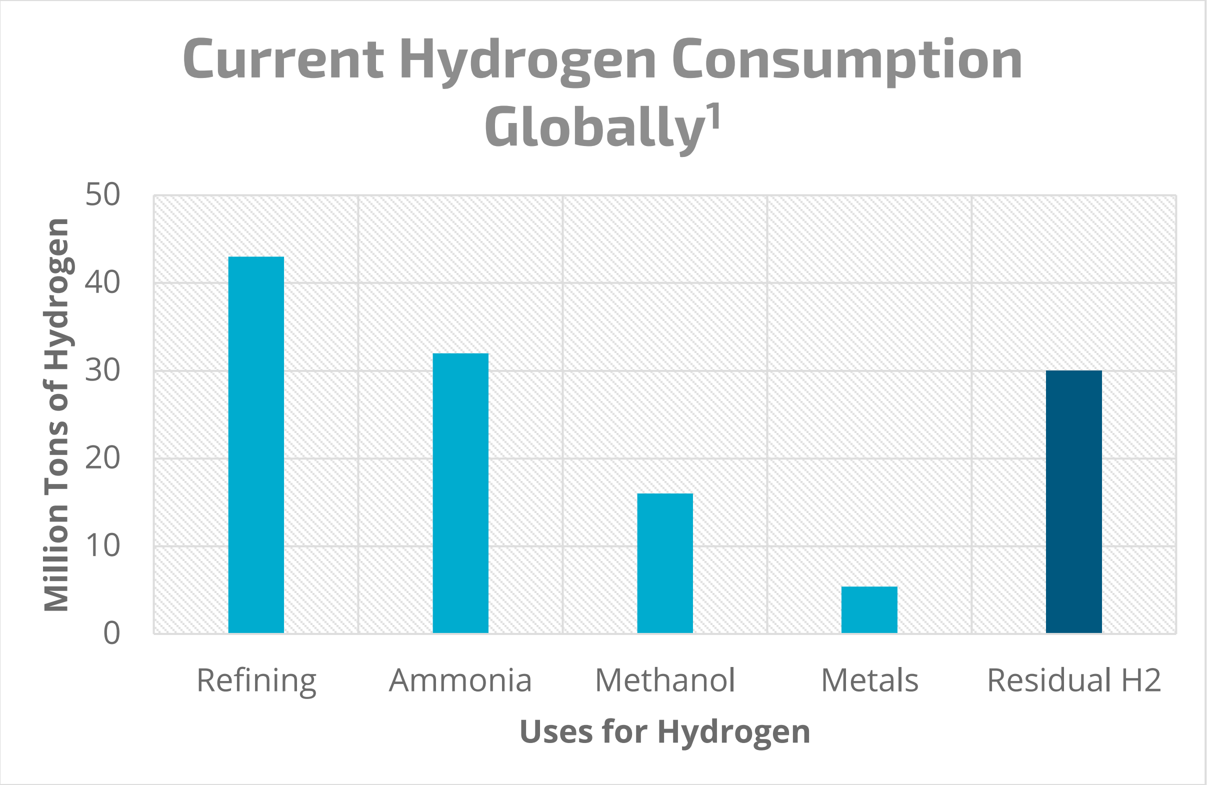
# OPPORTUNITY SPACE FOR HYDROGEN ($H_2$)

FAQ: What is hydrogen used for and why develop green hydrogen technologies?

- Green hydrogen technologies must be scaled up to meet zero-carbon emission goals
  - ~100 million tons of $H_2$ were produced Globally[1]
  - Less than 1% of this demand was low-emissions "Green" in 2023[1]
  - 900 million tons of $CO_{2\_eq}$ was emitted in 2022 to meet current demand[1]
- Future Uses for Hydrogen
  - Heavy Transportation (Aviation, Ships, Trucks)
  - High-Temperature Industrial Heating




2023 transportation was ~0.01% of total $H_2$ demand

# HYDROGEN PRODUCTION PROCESSES

FAQ: What part of the hydrogen process does Concentrating Solar Power (CSP) technology address?

## Steam Methane Reformation (SMR)

"Grey" Hydrogen

Natural Gas (2 ton) + Water (4.5 ton) + 3,000 kWh electricity[3], 50,000 kWh heat[4] → Hydrogen (1 ton)

Fugitive emissions (½ ton $CO_{2\_eq}$)[2]

Purification (negligible)

New Mexico grid (1 tons $CO_{2\_eq}$)[4]

Gas combustion (5 tons $CO_{2\_eq}$)[5]

Process (5.5 tons $CO_2$)

Composite Tank[6] (1.5 ton $CO_{2\_e}$)

Note: DOE Hydrogen Hubs target 100 tons/day

Turquoise dash indicates targeted areas for technology development

## Electrolysis

"Green" Hydrogen

Water (9 ton) + 56,000 kWh Electricity[7] → Hydrogen (1 ton)

PV Lifecycle (1 tons $CO_{2\_e}$)[8]

Composite Tank (1.5 tons $CO_{2\_e}$)[6]

# CONCENTRATING SOLAR POWER (CSP) FOR HYDROGEN PRODUCTION

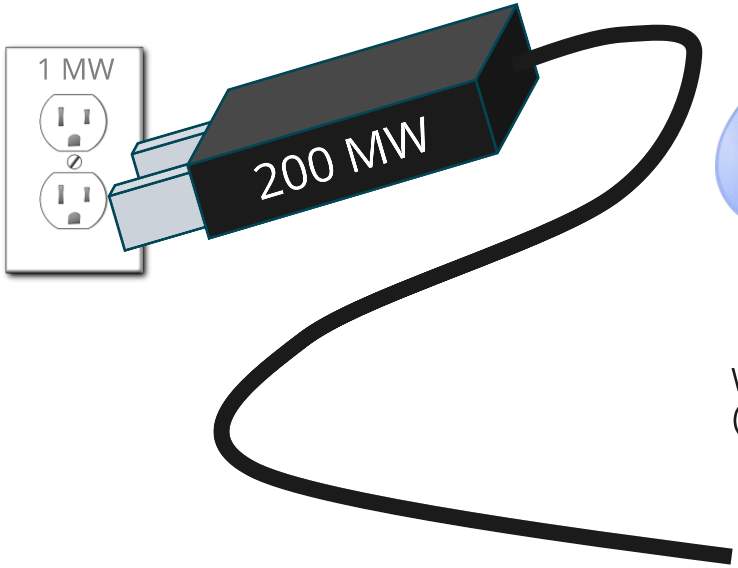
## FAQ: How can Green Hydrogen help with stretched grid infrastructure?

A green hydrogen hub that makes 100 tons/day could require a 200 MW transmission line (122 kV). High-voltage lines are hard to permit and may have to compete with other users.

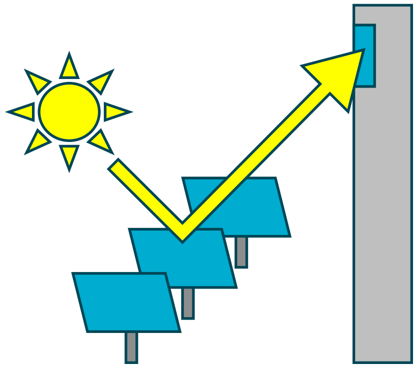
Sandia is developing technologies that could reduce required electrical loads and potentially accelerate green hydrogen production by using solar heat.

Mirrors focus sunlight to heat up metal materials that can split $H_2O$ molecules into $H_2$+O and $CO_2$ into CO+O

Concentrating solar plants can be installed in remote locations isolated from other infrastructure and improve efficiency by 30%. CSP alone reduces land area need by 20%.

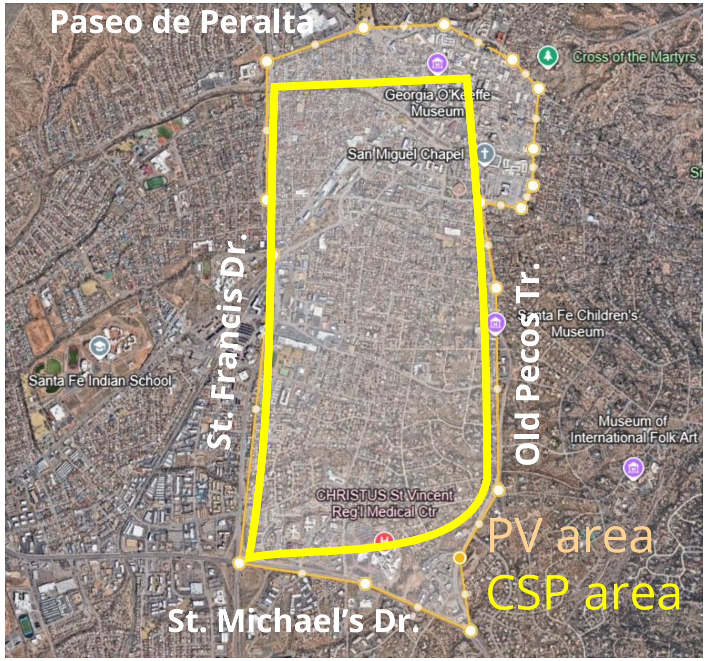



Water (9 ton)



13,000 kWh of solar heat[10]

CSP Lifecycle Emissions (0.2 tons $CO_{2\_eq}$)[9]




PV array needed to power 100 ton/day $H_2$ plant

Overlay on Santa Fe map

# SYNTHETIC FUELS "SYNFUEL"

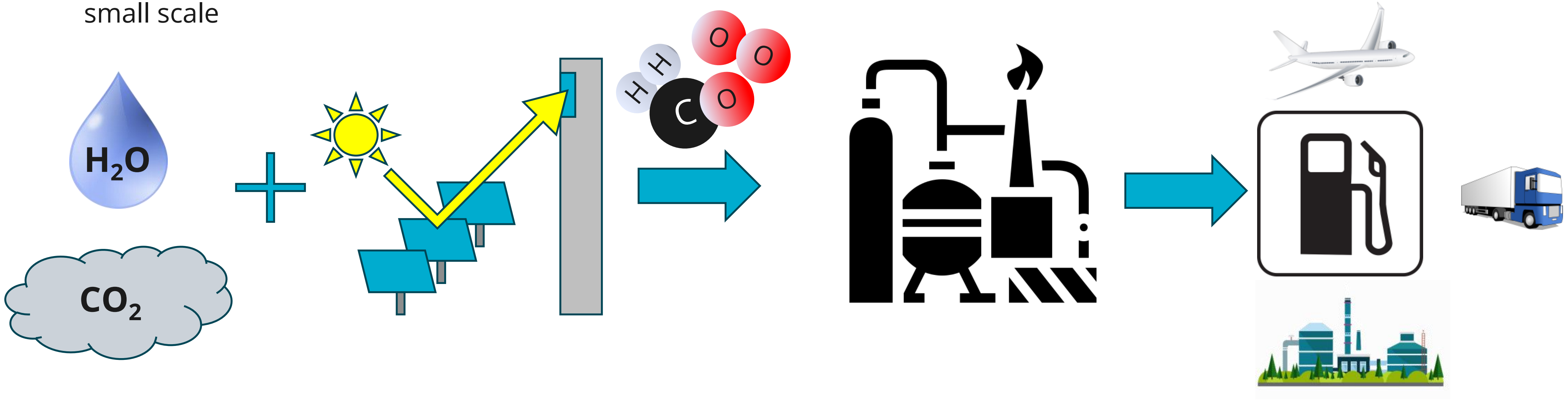
## FAQ: How can hydrogen be more accessible?

Atmospheric humidity and carbon dioxide is being captured at small scale

Specific metal materials split $H_20$ and $CO_2$ when heated by concentrated sunlight

Syngas is processed using standard oil refinery

Drop-in Synfuels can be used with current infrastructure (1 ton)




Direct Air Capture energy (0.3 ton $CO_{2\_eq}$)

CSP Lifetime Emissions (1 ton $CO_{2\_eq}$)

Refining energy (1.1 ton $CO_{2\_eq}$)

# RAW MATERIALS FOR MAKING HYDROGEN

FAQ: Is Concentrating Solar Power (CSP) compatible with all types of feedstocks?

## Natural Gas (99%)

- Mature at market scale
- Fugitive well emissions

## Ground water (1%)

- No carbon emissions. Used in Sunshine to Petrol project
- Competes with societal use

## Biomass (Mid TRL)

- Carbon neutral, used in pre-commercial CSP plants
- Seasonal supply chain

## Direct Air Capture (Early TRL)

- Available everywhere. Used in Swiss demonstrations.
- Not at market scale for several years

## Produced/Waste Water (Early TRL)

- Does not compete for drinking water
- CSP technologies are being used for water purification and desalination

# CONCLUSIONS

- ~100 million tons of $H_2$ per year emitting 900 million tons of $CO_{2\_eq}$. **Green hydrogen technologies could reduce emissions if scaled.**
- Concentrating solar heat could produce green hydrogen without overtaxing the grid by using heat from sunlight instead of electricity.
- Concentrating solar can split water and carbon dioxide into the basic building blocks of fuels.
- Existing refineries can reform "syncrude" into accessible liquid fuels that utilize existing infrastructure.
- Sandia has dedicated experts who focus on safety and distribution for the hydrogen infrastructure.

# THANK YOU

# CITATIONS AND NOTES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    - Uses of hydrogen globally. Residual hydrogen is produced from coke ovens and steam crackers and is typically captured and used for heat. This is not considered in the 97 Million tons of $H_2$ production.
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    - The mean leak rate for CBM and natural gas operations in the San Juan Basin in April 2015 are 2% in NM.
    - 2 tons of methane would expect to see 20 kg emitted. Methane is 25 x more heat trapping than CO2 so the CO2 equivalent emission is 20*25=500 kg rounded to ½ metric ton.
3. This estimate includes the electricity used for compressors, pumps, control systems, cooling systems, hydrogen purification, and auxiliary equipment.
4. https://www.eia.gov/electricity/state/newmexico/
    - New Mexico Electricity emissions per MWh
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6. Agostini, A., et al., *Role of hydrogen tanks in the life cycle assessment of fuel cell-based auxiliary power units. Applied Energy, 2018.* ***215: p. 1-12.***
7. Petronilla, F. and G. Matteo, *Numerical simulations of the energy performance of a PEM water electrolysis based high-pressure hydrogen refueling station. International Journal of Hydrogen Energy, 2020.* ***45(51): p. 27457-27470.***
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