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# Energy Arbitrage with Hydrogen: HTSE + Combustion Turbine

August 2023

Changing the World's Energy Future

Samuel Jacob Root, Amey Shigrekar, Michael McKellar, Todd Knighton

Idaho National Laboratory

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# Energy Arbitrage with Hydrogen: HTSE + Combustion Turbine

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## $H_2$ Energy Storage for LWRS

De-carbonizing our electrical grid is crucial to the health of our planet

- Renewables are insufficient at responding to changes to grid demand
- They regularly produce surplus energy that depresses the wholesale electricity price, and at other times under-generate, putting customers at risk of black-outs/brown-outs
- Energy Storage is critical for Energy Security

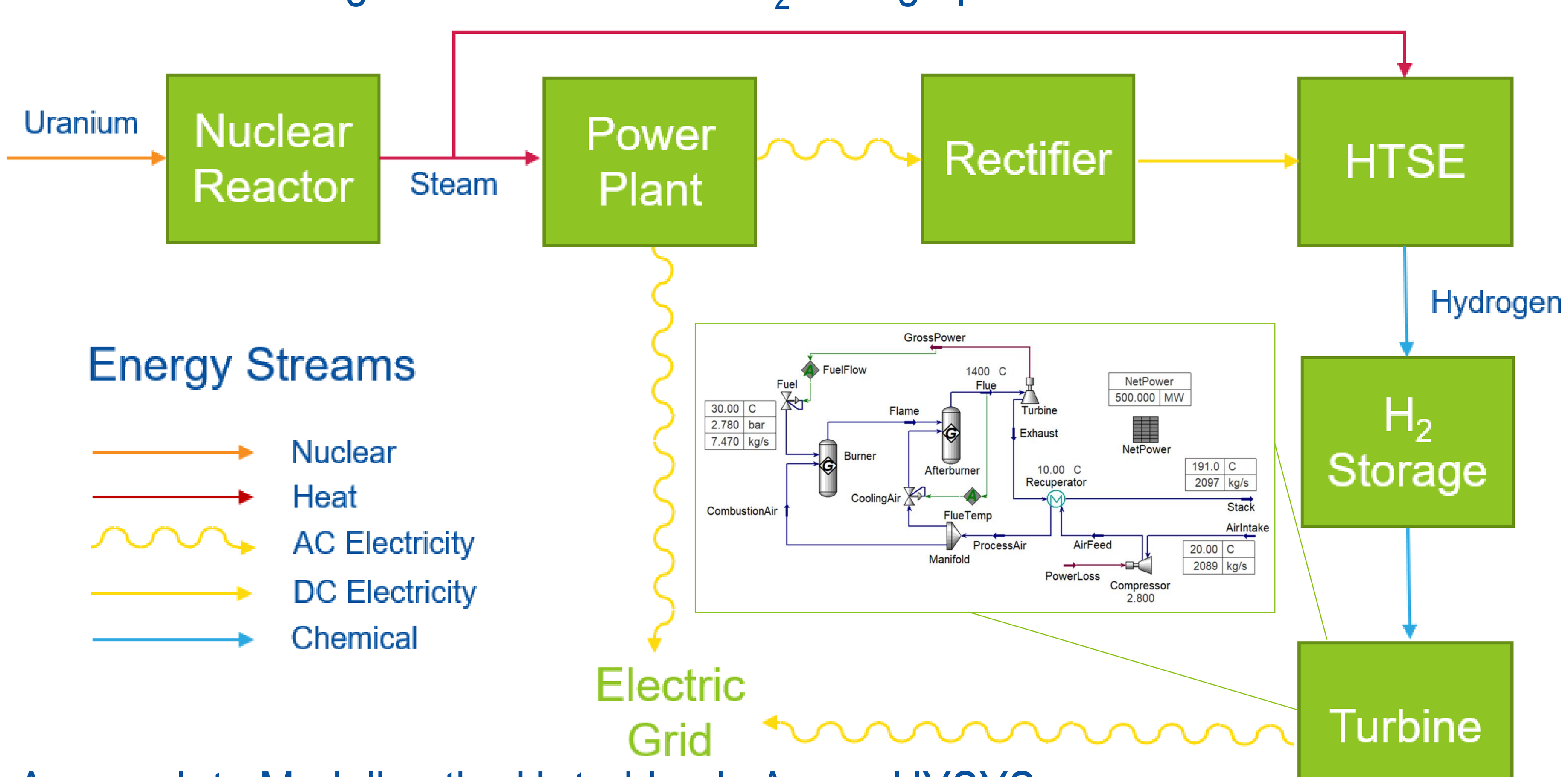
Divert Heat and Electricity to HTSE When Grid Demand is Low → Store Chemical Potential Energy as Hydrogen → Burn Hydrogen when Grid Demand is High to produce Zero-Emission Electricity

The Light Water Reactor Sustainability (LWRS) program seeks to keep Nuclear Power Plants (NPPs) competitive in the changing market

- The Flexible Plant Operation and Generation (FPOG) pathway investigates Energy Storage System (ESS)
- ESSs can be used for Energy Arbitrage to give an alternative to curtailment or paying to put power on the grid
- High Temperature Steam Electrolysis (HTSE) connected to $H_2$ storage is one of the most promising energy arbitrage technologies due to scalability

## Process Modeling

This work is focused on regenerating electricity by burning stored $H_2$ in a recuperated simple cycle combustion turbine. Previous and concurrent work at INL have investigated the HTSE and $H_2$ storage processes in more detail[1].




Approach to Modeling the $H_2$ turbine in Aspen HYSYS

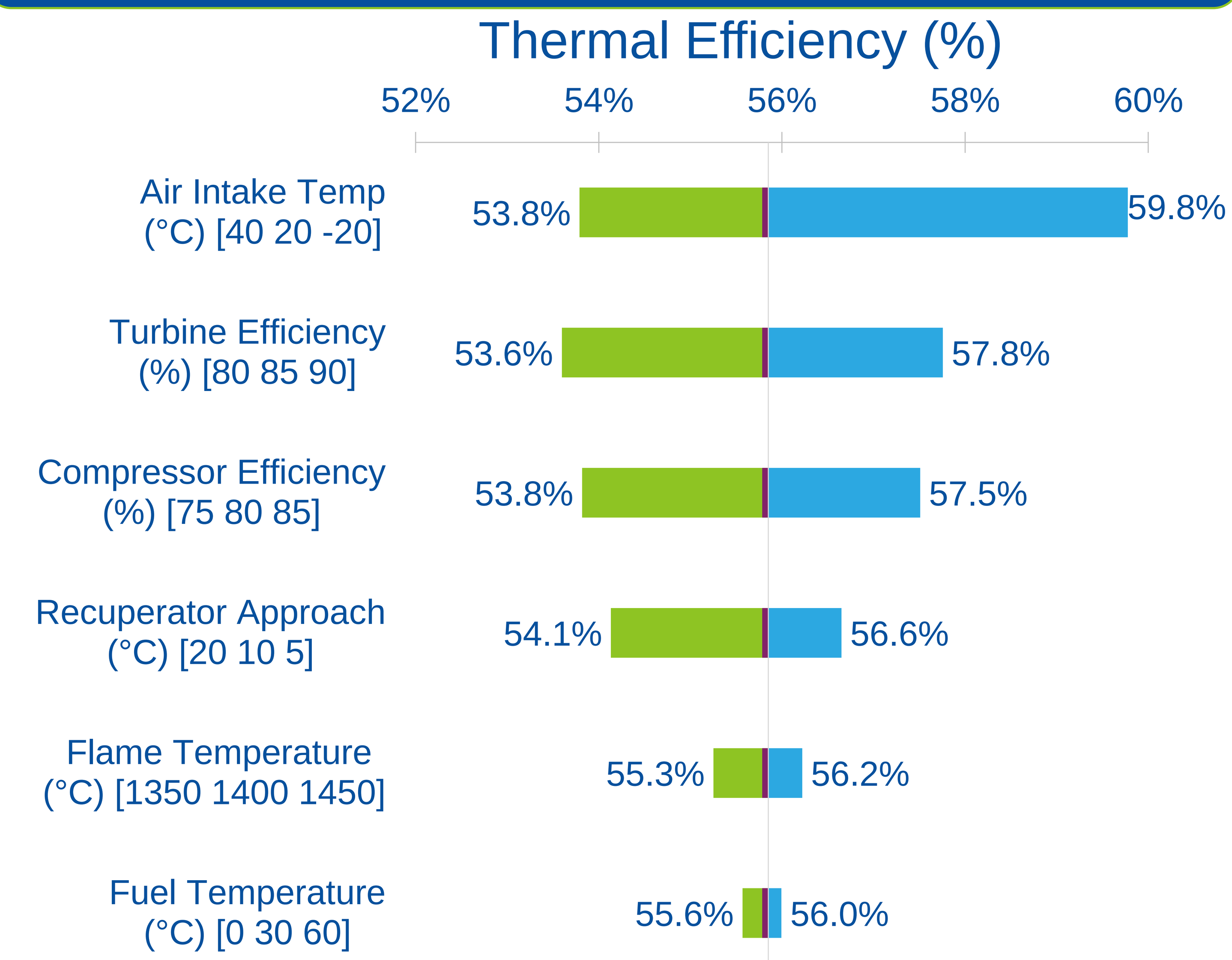
- Fuel flow rate adjusted to yield 500 MWe net power
- Air flow rate adjusted to provide 20 percent excess air and cool adiabatic flame temperature to 1400°C
- 2.8:1 Pressure Ratio
- Recuperator with 10°C minimum approach
- Burner and Afterburner modeled as Gibbs Reactors

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

Results from the HYSYS Model

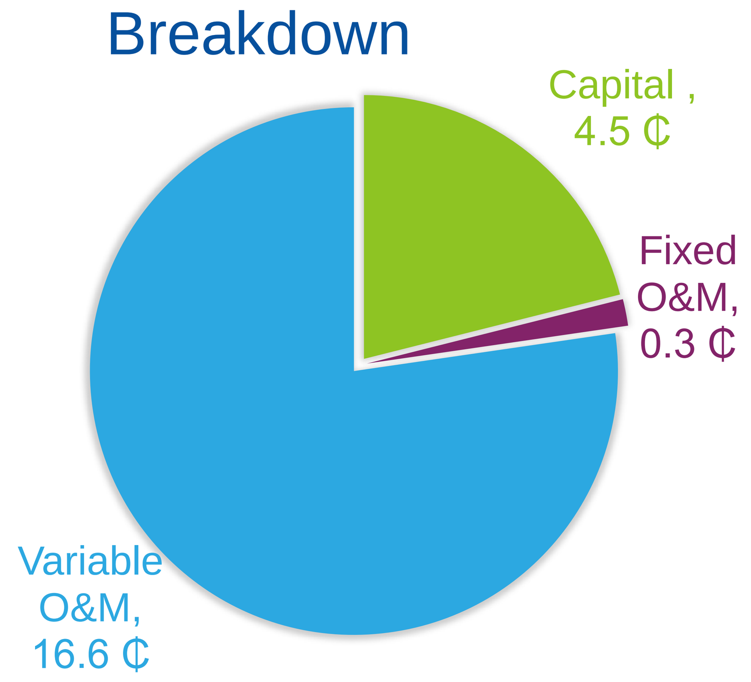
- 18.59 $kWh_e/kg\text{-}H_2$
- 55.8% Thermal Efficiency
- 191°C stack gas can provide 200 $MW_{th}$ for district heating when cooled to 100°C and an additional 150 $MW_{th}$ at its dewpoint of 33°C

## Parametric Analysis




## Techno-Economic Analysis

Levelized Cost Breakdown



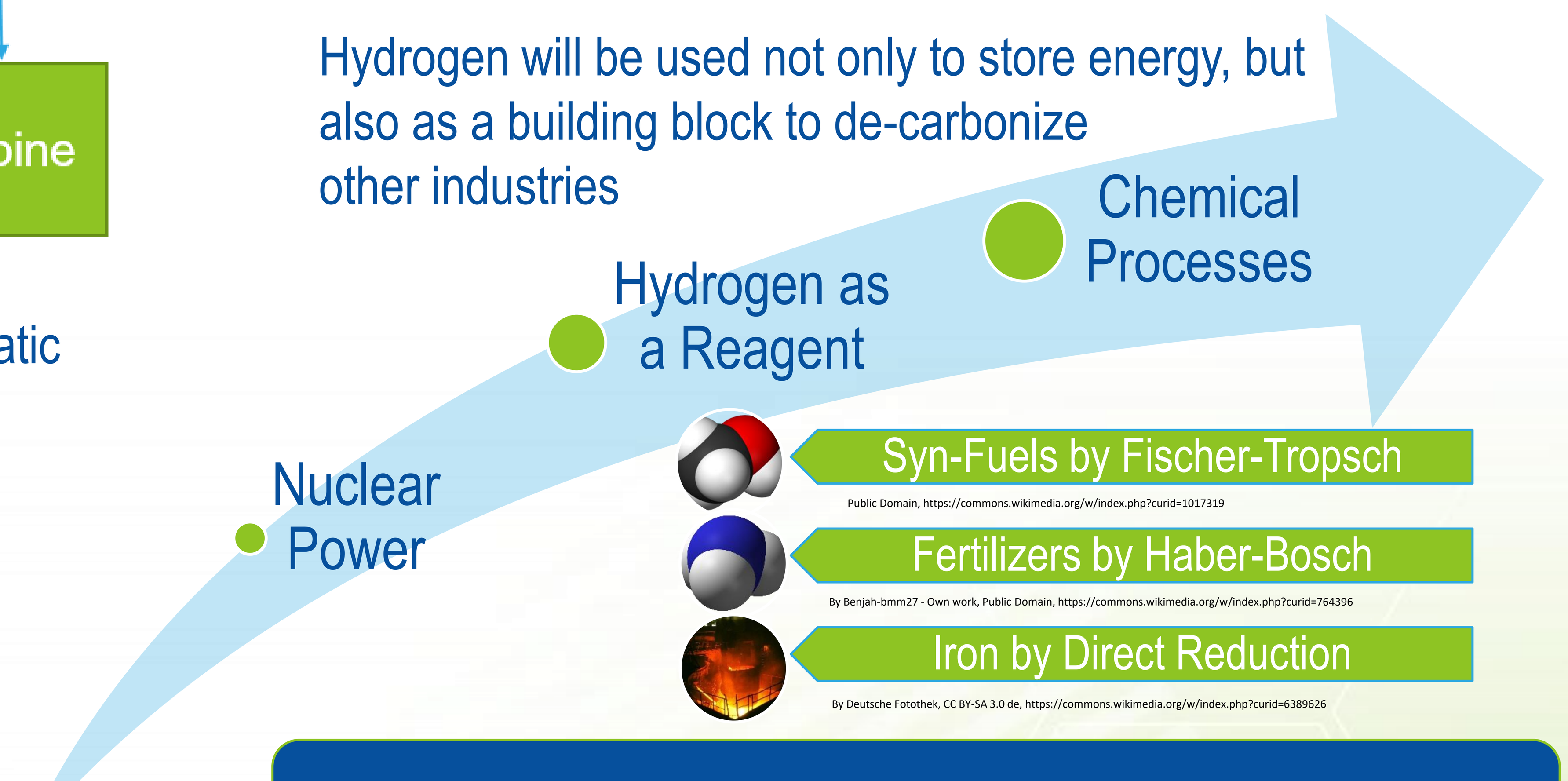

Assumptions

- $473MM CAPEX
- $3/kg $H_2$ from HTSE, stored in pressurized tube trailers
- 8 full power hours/day
- 12% WACC
- 25-year project life

Levelized Cost of Storage (LCOS) – 21.5 ₵/kWh-e

## Future of Clean Hydrogen

Hydrogen will be used not only to store energy, but also as a building block to de-carbonize other industries




## Acknowledgements

[1] Knighton, Lane T, Shigrekar, Amey, Wendt, Daniel S, Frick, Konor L, Boardman, Richard D, Elgowainy, Amgad A., Bafana, Adarsh, Tun, Hla, and Reddi, Krishna R. *Energy Arbitrage: Comparison of Options for use with LWR Nuclear Power Plants*. United States: N. p., 2021.

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