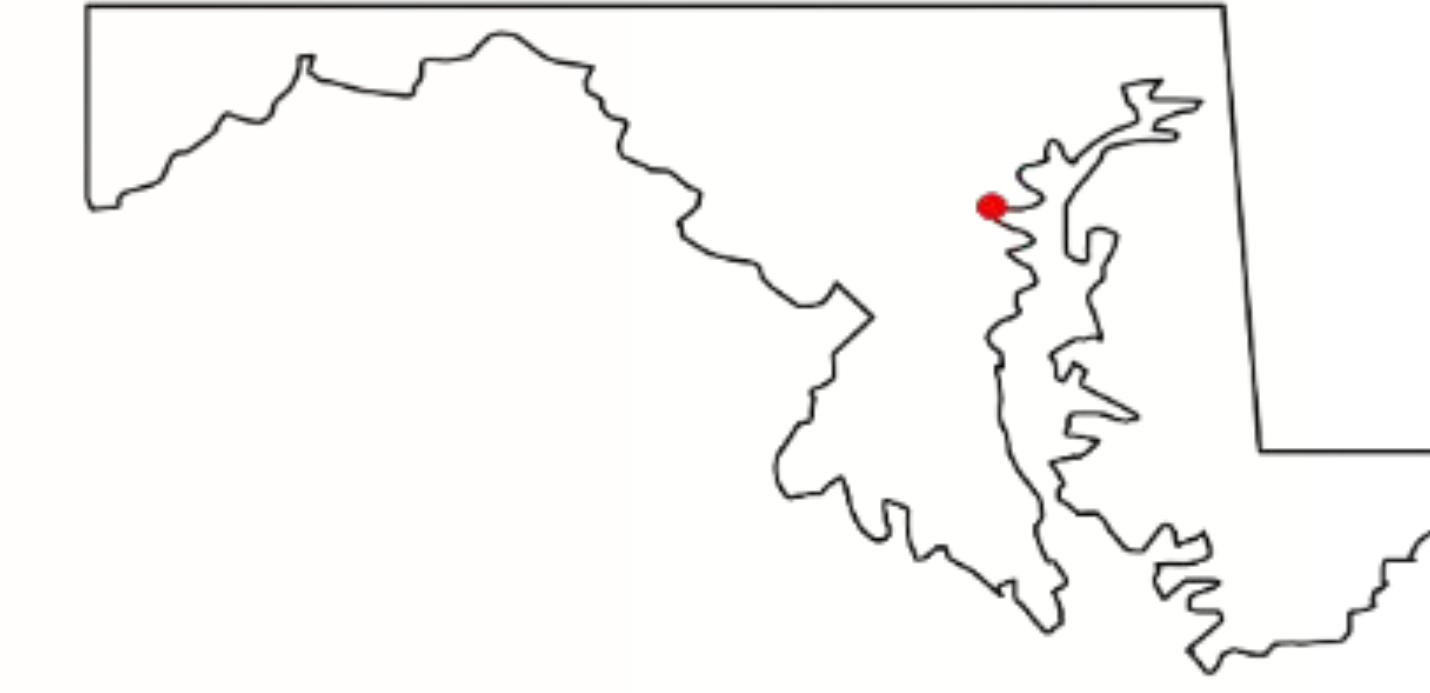
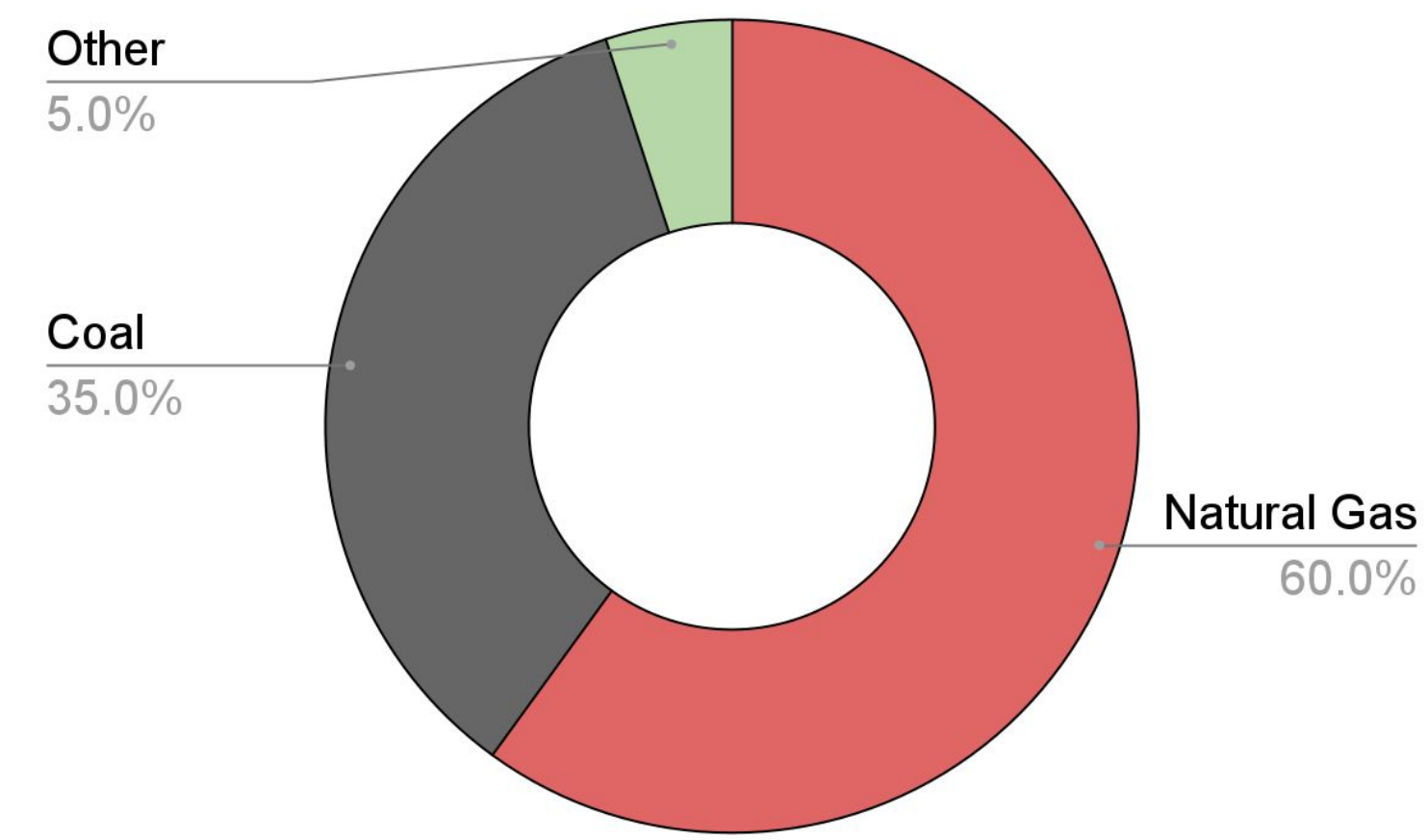


# Carbon Hydrogen Advanced Reaction to Methanol (CHARM)

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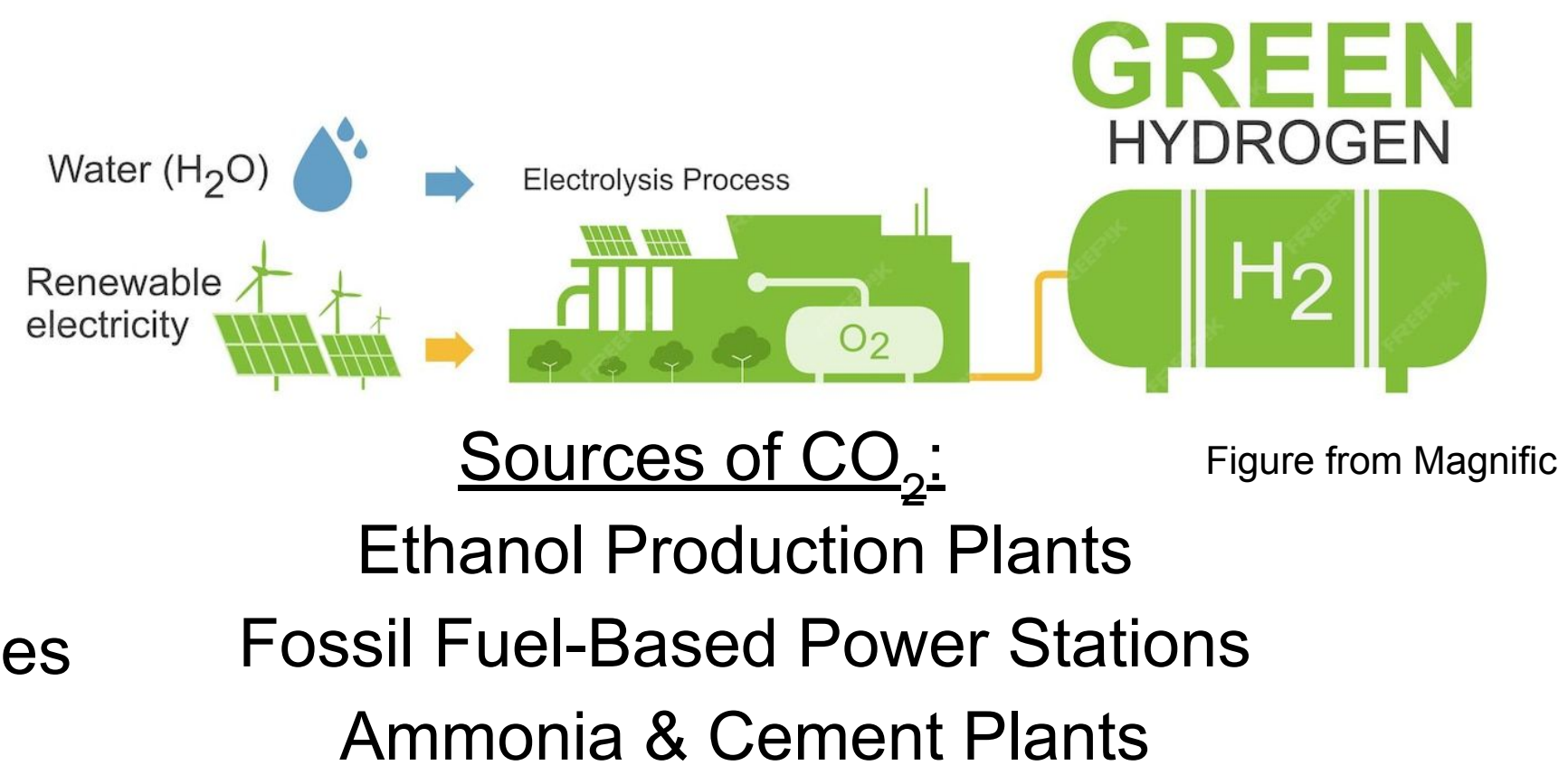
## Background



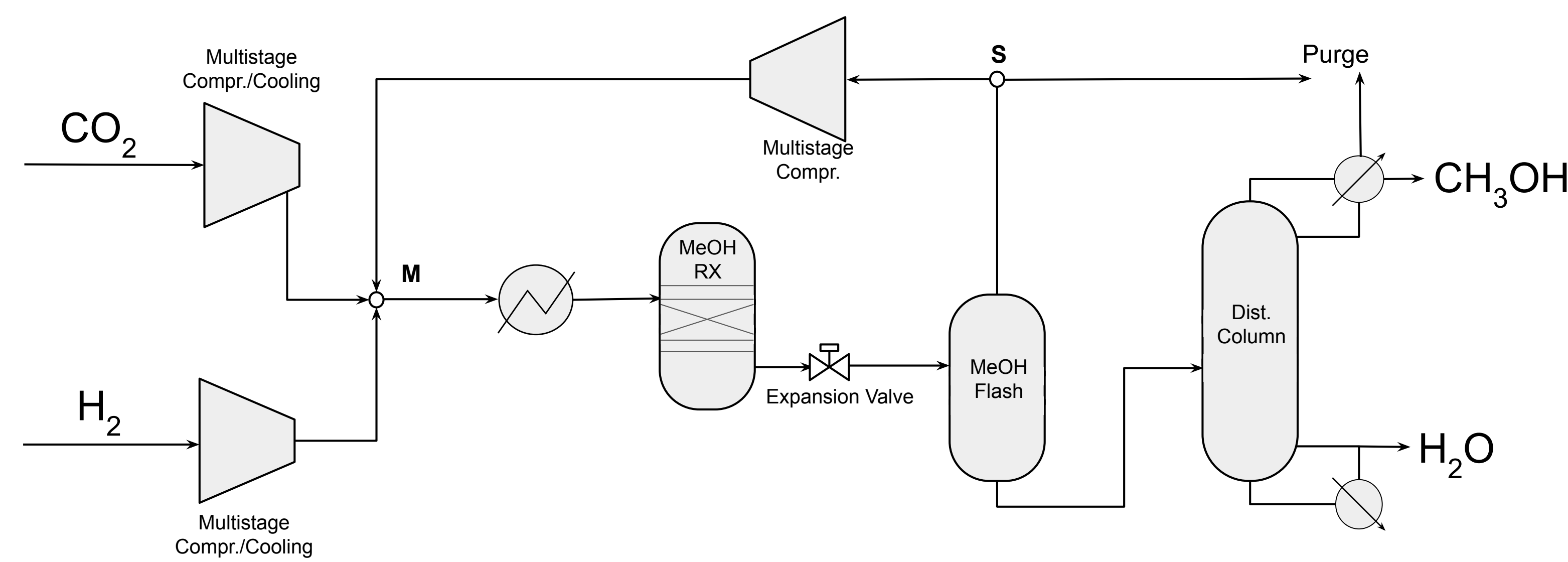
- On a global scale, about 60% of methanol is produced by natural gas, and 35% is produced by coal
- Only a small percentage of methanol produced is "green" and not reliant on fossil fuels
- Growing push towards decarbonizing methanol production

Methanol usage in Maryland:

- Pharmaceutical synthesis**
    - AstraZeneca in Frederick
    - John's Hopkins in Baltimore
  - Building material synthesis**
    - GAF Roofing
  - Antifreeze & De-Icing**
    - Important for industrial vehicles/airplanes
      - BWI, Dulles, Joint Base Andrews
- \* Global market exists for methanol



## Design Concepts



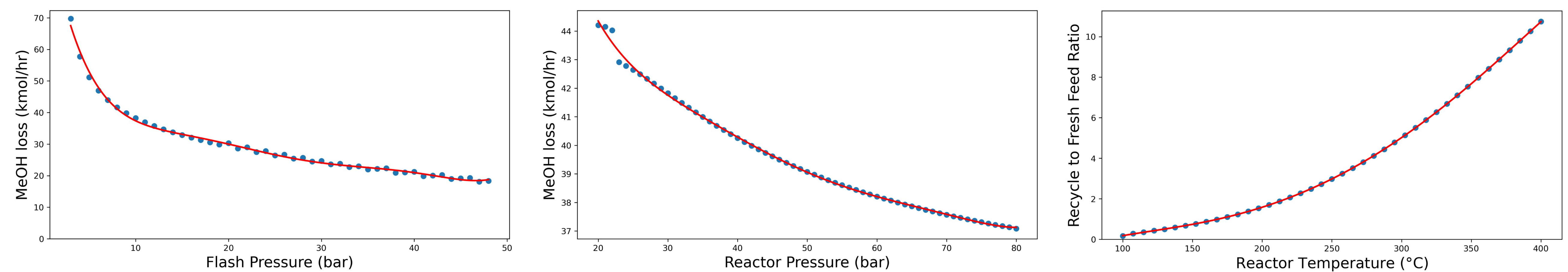
Tradeoffs	
Significant reduction in CO <sub>2</sub> emissions	Green hydrogen from electrolysis is highly energy-intensive
Utilizes captured CO <sub>2</sub> and carbon recycling	Requires reliable CO <sub>2</sub> capture systems, some methods are expensive
Reduces reliance on fossil fuels	Requires large-scale renewable energy infrastructure
Growing demand for sustainable fuel	Requires a steady supply of purified CO <sub>2</sub>

Fresh Feed		Unit Conditions		Recycle/Purge Info			Distillation				Product			MeOH Losses	Energy		
H <sub>2</sub> Feed Rate	CO <sub>2</sub> Feed Rate	H <sub>2</sub> /CO <sub>2</sub> Ratio	Reactor Conditions	Flash Conditions	Recycle Split	Recycle Flow	Recycle/Feed Ratio	Column Setup	Reflux Ratio	Distillate Rate	Top/Bot Temp	MeOH Product Flow	MeOH Purity	MeOH Recovery	MeOH in purge, bottoms, column vapor	Total Heating Duty	Total Cooling Duty
3948 kmol/hr	1310 kmol/hr	3.014	250°C, 5 bar	30°C, 10 bar	95%	15,653 kmol/hr	2.98	30 stages, 1.2bar	3	1095.6 kmol/hr	62.4°C/103.8°C	1072.1 kmol/hr	99.86%	96.59%	37.84 kmol/h	58,996 kW	149,095 kW

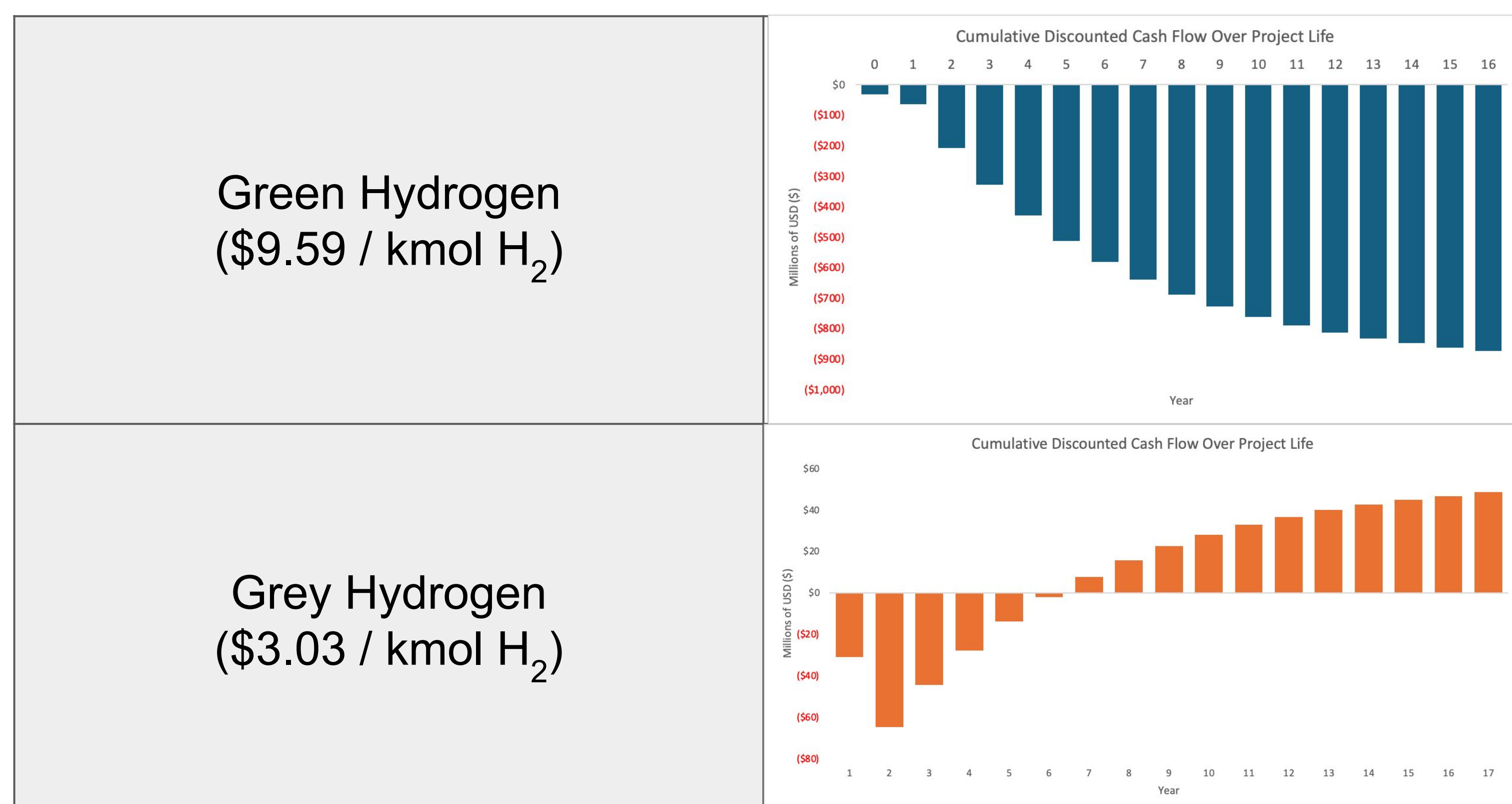
## Environmental Sustainability

Metric	Grey vs Green Hydrogen	Syngas vs CO <sub>2</sub> Captured MeOH Synthesis
Carbon	Grey: 7.33 kg CO <sub>2</sub> / kg H <sub>2</sub> Green: <b>0.97</b> kg CO <sub>2e</sub> / kg H <sub>2</sub>	Syngas: 1.6kg CO <sub>2</sub> /kg MeOH CO <sub>2</sub> Capture: 0.8kg CO <sub>2</sub> /kg MeOH
Energy	Our process uses <b>193.34 MW</b> for synthesizing MeOH from grey hydrogen and captured CO <sub>2</sub>	
Water	Our process requires an estimated <b>0.05 MMGal/hr</b> of evaporated makeup water (estimation found with Q/H <sub>vap</sub> )	

## Sensitivity Analysis



## Economic Sustainability



## Stakeholder Considerations

Stakeholders	Needs	Process Impact
Process Engineers	Safe, controllable systems that are highly efficient and stable	Greater reliance on monitoring, need to manage intermittent renewable energy inputs
Plant Administrators	Profitable process that complies with regulatory requirements	Higher upfront investment but potential benefits from carbon credits/subsidies
Plant Neighbors	Safe process that supports local economic activity and is environmentally friendly	Improved local air quality, job creation and local economic activity
Wider Society	Reduction in GHG emissions while being sustainable long-term	Climate change mitigation through carbon recycling and acceleration of renewable energy infrastructure
Environmental Organizations	A transparent and environmentally minimal harmful process	Potential support if process meets strict environmental standards

## Conclusions

- Further process optimization is needed to maximize methanol recovery and recycle to feed ratio
- Current infrastructure for green hydrogen production is not sustainable due to economic constraints
- Methanol production process utilizes carbon recycling, but requires reliable storage and capture methods

## References

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- Harris, K.; Grim, R.; Huang, Z.; Tao, L. A comparative techno-economic analysis of renewable methanol synthesis from biomass and CO<sub>2</sub>: Opportunities and barriers to commercialization. *Applied Energy*. 2021.
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