Electrification pathways for ethylene decarbonization and economic viability

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Introduction

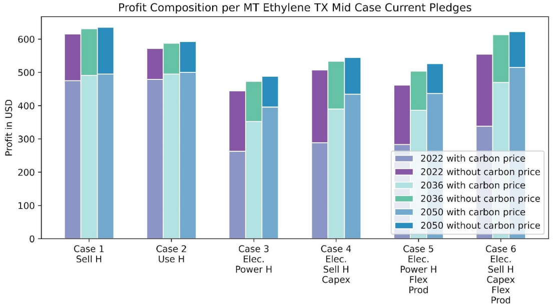
Case number	Power Source	Hydrogen use	Methane use	Plant production rate	Technology Readiness Level (TRL)	Investment needed (retrofit)
1	Natural gas	Sold as fuel	Recycled as heat	Constant	9	None
2	Natural gas	Recycled as heat	Recycled as heat	Constant	9	None
3	Electricity	Used as power	Used as power	Constant	7	Large
4	Electricity	Sold as fuel to a single customer	Sold as fuel to a single customer	Constant	8	Medium
5	Electricity	Used as power	Used as power	Variable	6	Large
6	Electricity	Sold as fuel to a single customer	Sold as fuel to a single customer	Variable	7	Large

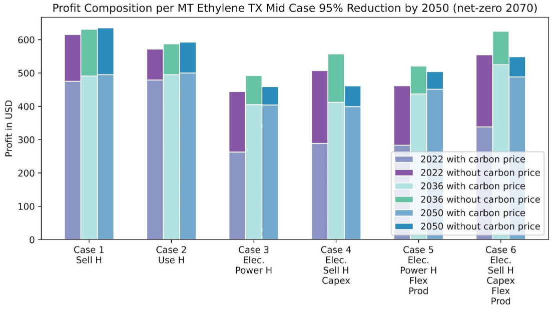
-Ethylene : LCA component of many plastics/chemicals
-Retrofit existing plants to replace natural gas with electricity
-Reduce emissions and use grid services to decrease costs
-Use projections of grid prices, marginal emissions, co-products, and capital investments under different scenarios to evaluate economic viability and carbon intensity of ethylene with mathematical programming and optimization

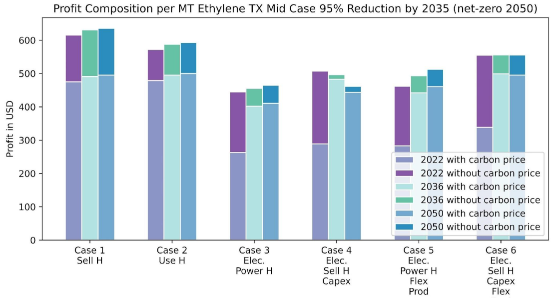
Materials And Methods

-Plants all use ethane feedstock and must take a week of downtime, operating at 93.5% capacity utilization
-Calculations are done using Julia programming language with JuMP wrapper and Gurobi solver (code will be made publicly available for open-source use)
-MIQP that solves for production rate (constant or variable), size of capital investment, energy storage per timestep, total profit, and carbon intensity per MT product

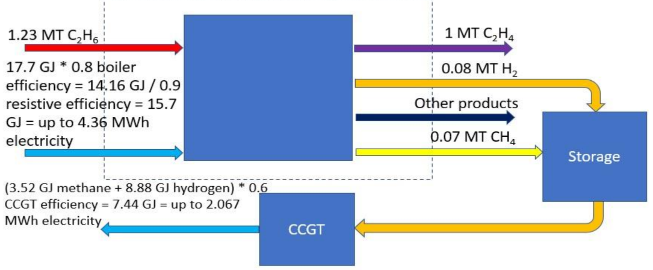
Case number	Capital Expenditures
1	None
2	None
3	Resistive Heater, CCGT, Hydrogen Storage
4	Resistive Heater, Pipelines (transmission and storage investment)
5	Resistive Heater, CCGT, Hydrogen Storage (assuming 0 cost flexibility which is the lower bound on flexibility cost)
6	Resistive Heater, Pipelines (transmission and storage investment) (assuming 0 cost flexibility which is the lower bound on flexibility cost)

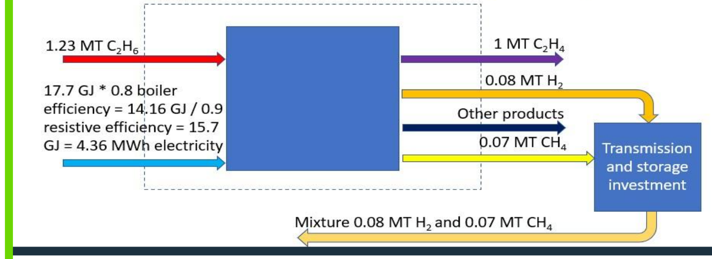

Profit Composition per MT Ethylene TX Mid Case Current Pledges


Profit Composition per MT Ethylene TX Mid Case 95% Reduction by 2050 (net-zero 2070)


Profit Composition per MT Ethylene TX Mid Case 95% Reduction by 2035 (net-zero 2050)

Cases 3 and 5: selling co-products as power using storage with constant or variable production rate





Cases 4 and 6: selling co-products as fuel using pipelines with constant or variable production rate

Discussion and Conclusion

-In 2022, electrified steam cracking plants would both lose money and increase total emissions
-Starting in 2036, plants become economically viable and reduce emissions
-The most profitable pathway is electrified steam cracking selling hydrogen and methane as fuel with a flexible rate of production
-Pathways for future work include plasma catalytic conversion, electrochemical CO2 reduction, and solid oxide electrolysis
-In future work, consider grid capacity expansion investments, network constraints, and modeling the plant as a market agent rather than a price taker