Sustainable Ethylene via Chemical Looping – Oxidative Dehydrogenation

Fanxing Li
NC State University
In collaboration with SABIC

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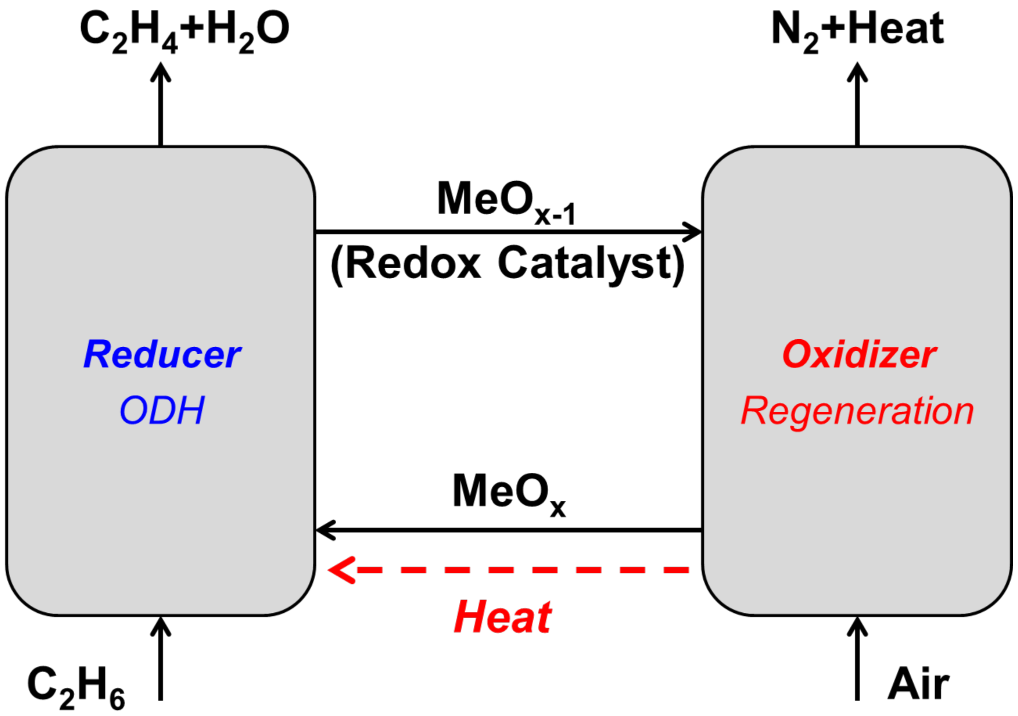
Technology Characteristics

Key Challenges to Address:

- Ethylene production accounts for ~300 million tons of CO_2 emission each year, even though the commercial process, i.e. steam cracking, is already ***~90%*** efficient from a first law standpoint;
- The key challenges resides in the low second law efficiency stemmed from high endothermicity and low single-pass conversion for the cracking reaction and the complex product separation;
- Oxidative dehydrogenation can address these limitations, but air separation is expensive and existing catalysts show limited selectivity and yield;



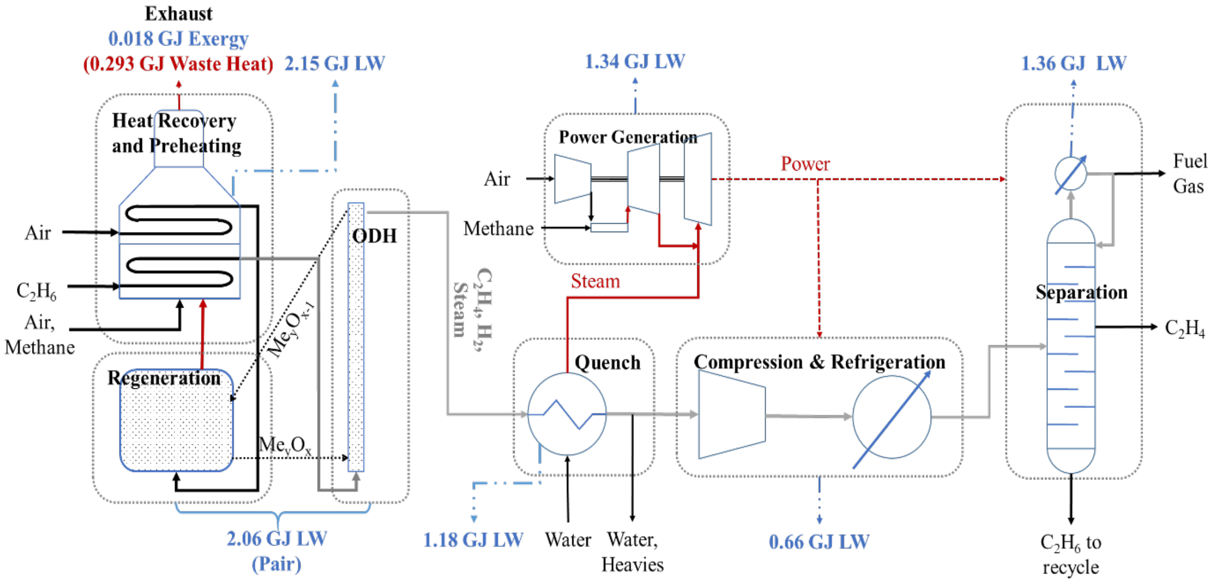
ODH Step: $C_2H_6 + MeO_x \rightarrow C_2H_4 + MeO_{x-1} + H_2O$

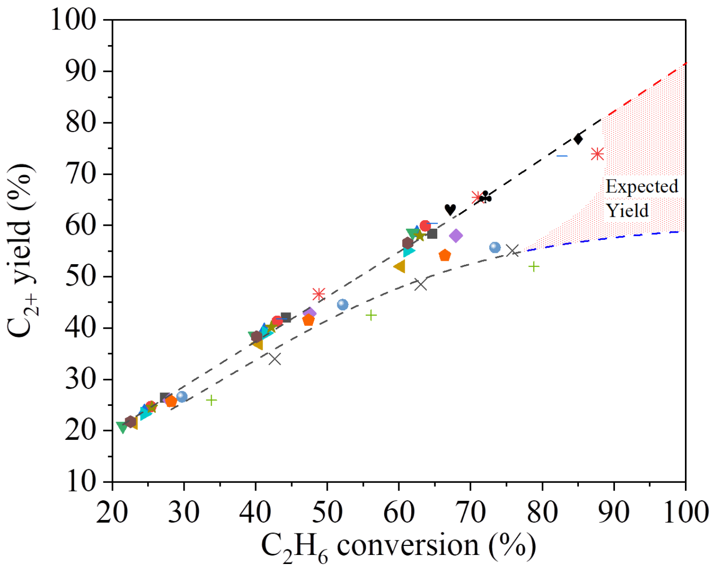
Regeneration Step: $MeO_{x-1} + 1/2O_2(air) \rightarrow MeO_x + Heat$

Chemical Looping Oxidative Dehydrogenation (CL-ODH)

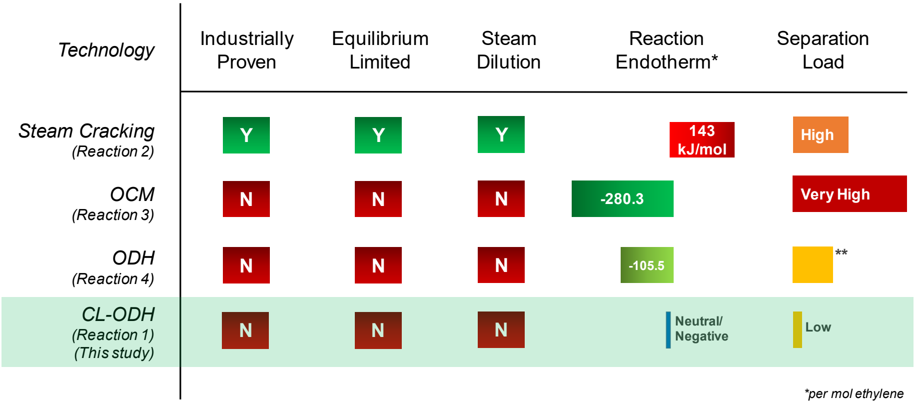
- Two step cyclic process facilitated by oxide based redox catalyst particles in a circulating fluidized bed;
- The ODH step occurs under an O_2-free environment, with the redox catalyst donating its lattice oxygen;
- The spent redox catalyst particle is circulated to a regenerator for re-oxidation with air for in-situ air separation.

Technology advantages





1. Integrated air separation: a safer process with cost and energy savings;
2. Autothermal operation: significantly lower exergy loss for the ethane conversion step;
3. Excellent single-pass yield: up to 77% single pass olefin yield demonstrated experimentally. With simultaneous combustion of the hydrogen byproduct, the downstream compression and separation loads are greatly reduced;
4. Potential for near an order of magnitude reduction in energy consumption and CO_2 emissions.



Technology	Industrially Proven	Equilibrium Limited	Steam Dilution	Reaction Endotherm*	Separation Load
Steam Cracking *(Reaction 2)*	Y	Y	Y	143 kJ/mol	High
OCM *(Reaction 3)*	N	N	N	-280.3	Very High
ODH *(Reaction 4)*	N	N	N	-105.5	**
CL-ODH *(Reaction 1)* *(This study)*	N	N	N	Neutral/ Negative	Low

**per mol ethylene*
***Air separation can induce large parasitic losses, and limited single pass conversion at low dilution*

Planned project approach

- **Updated Process Modeling, Techno Economic Analysis (TEA), and Life Cycle Analysis (LCA)**
  - Our existing ASPEN Plus model will be evaluated and refined, particularly taking advantage of SABIC's ample experience in commercial cracker operation. Key TEA and LCA assumptions will be developed in collaboration with SABIC to ensure the accuracy of the analyses;
  - The environmental and economic advantages of CL-ODH relative to ethane cracking will be quantified, along with detailed sensitivity analysis to quantify the uncertainty;
- **TEA Driven Experimental Testing of an Advanced Redox Catalyst**
  - Advanced promoters will be applied to the metal oxides to further suppress CO_x selectivity;
  - Redox catalyst formulation and operating conditions will be optimized based on the TEA findings to obtain more favorable economic and environmental attractiveness;
- **Detailed TEA and LCA**
  - In collaboration with SABIC, the team will develop a commercially viable design of the CFB based CL-ODH system and obtain accurate cost estimation;
  - The TEA and LCA models will be updated with the experimental data. Updated process economics and LCA impacts will be obtained with significantly tighter uncertainties;
- **EH&S Risk Assessment, Gap Analysis, and Phase II Planning**
  - An updated process data table, EH&S risk assessment and mitigation strategies, and technology gap analysis will be completed;
  - The mitigation strategies and gaps identified will be integrated into the Phase II work.