Electrochemistry and Systems Approaches to Methane Conversion

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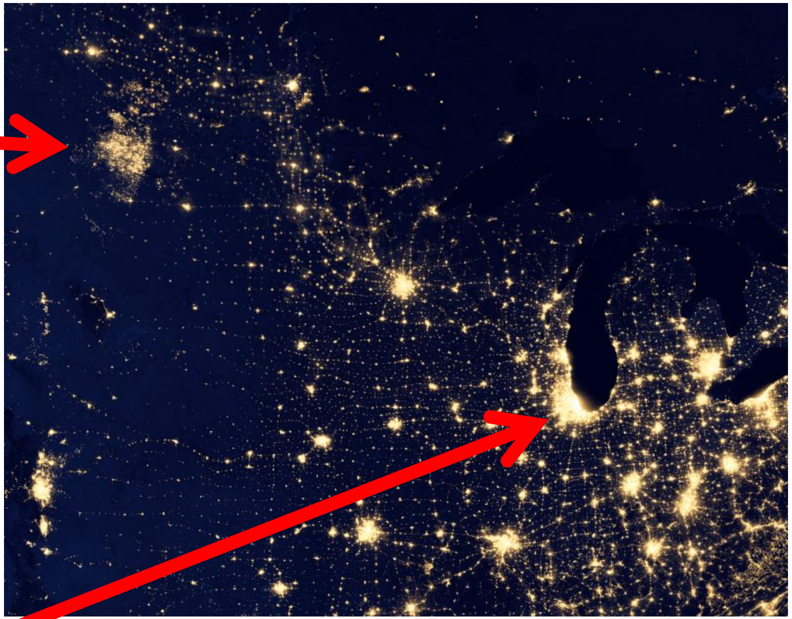
Background: Conventional Shale Gas Conversion

- Natural gas must be converted to be transported
- Current technology not scalable to the small size of individual wells
- large CAPEX costs for methane coupling, Fischer-Tropsch and methanol to gasoline



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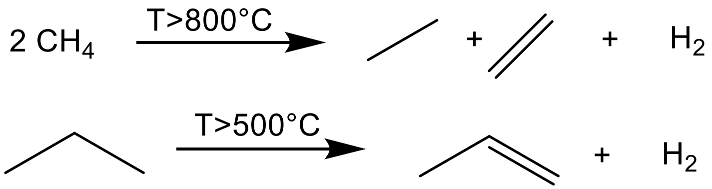
How do you transport gas?

- Make C-C bonds
- Make valuable products



These reactions are attractive but unfavorable at low temperature.

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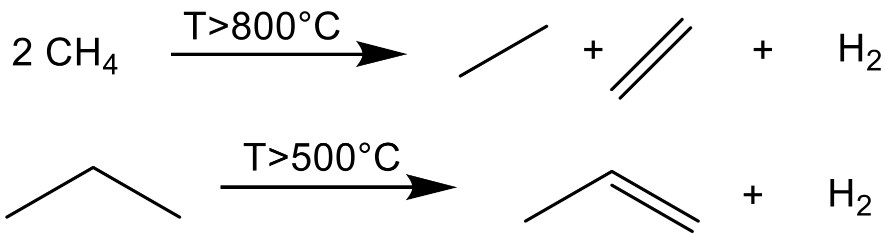
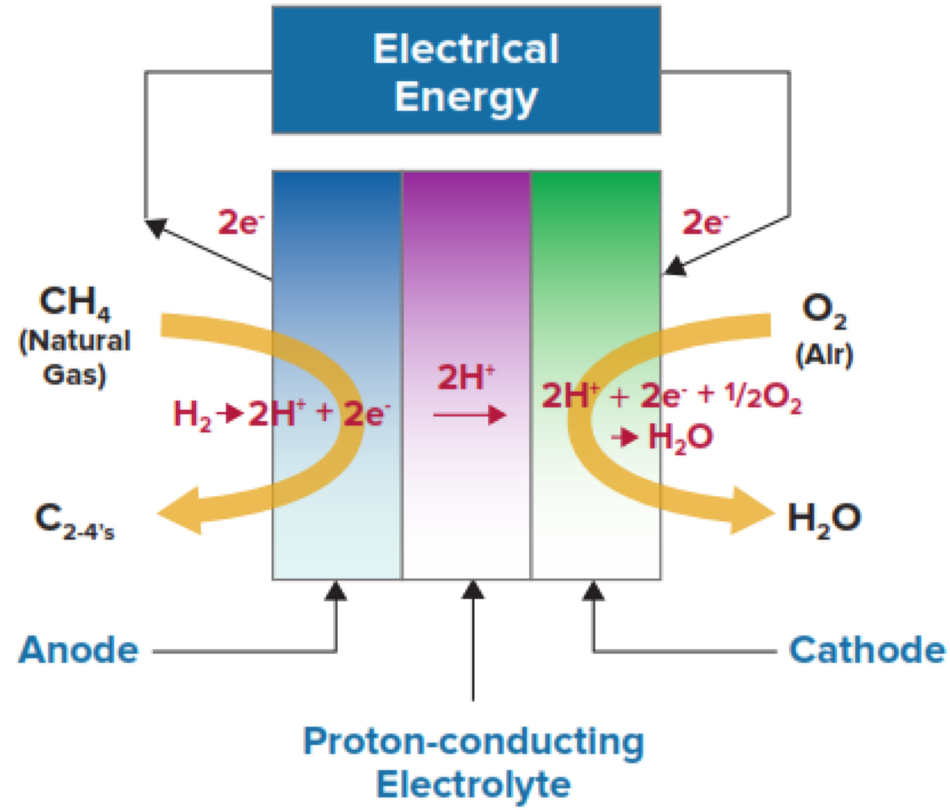
Specific Example: Cogeneration of electricity and chemicals





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- Shale gas to transportable products
  - C2, C3 hydrocarbons
- Physical separation of alkane and O_2
  - *Avoids burning*
  - Net favorable reaction: ODH thermodynamics
- Challenges and lessons for REMEDY:
  - Catalyst development – high TOF, selectivity, stability
  - Fuel cell performance – H^+ or O^{2-} conducting oxide, anode development
  - *Catalyst integration/cell fabrication – material compatibility, processing*

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Traditional Electrochemical Research

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Focused on:

- **Maximum electrical energy/power**

  H_2 and alkane fuel cells

- **Extremely challenging reactions**
  - H_2O splitting
  - $CO_2 \rightarrow$ useful products

- **Fine chemicals and biomass**

What are the challenges and opportunities for dilute methane streams?

Potential Impact of Electrical Approaches

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Lowering Operating Temperatures

- High T combustion results in large amounts of NOx
- Low concentration feeds require additional heating

Increasing active oxygen surface concentrations

- Use overpotential to drive O^{2-} concentration
  - Improved combustion performance $CH_4 + O_2 \rightarrow CO_2 + H_2O$

Integration with concentration(?)

- dilute streams present significant challenges to all catalytic conversion technology
- Integration of separations/concentration with abatement?

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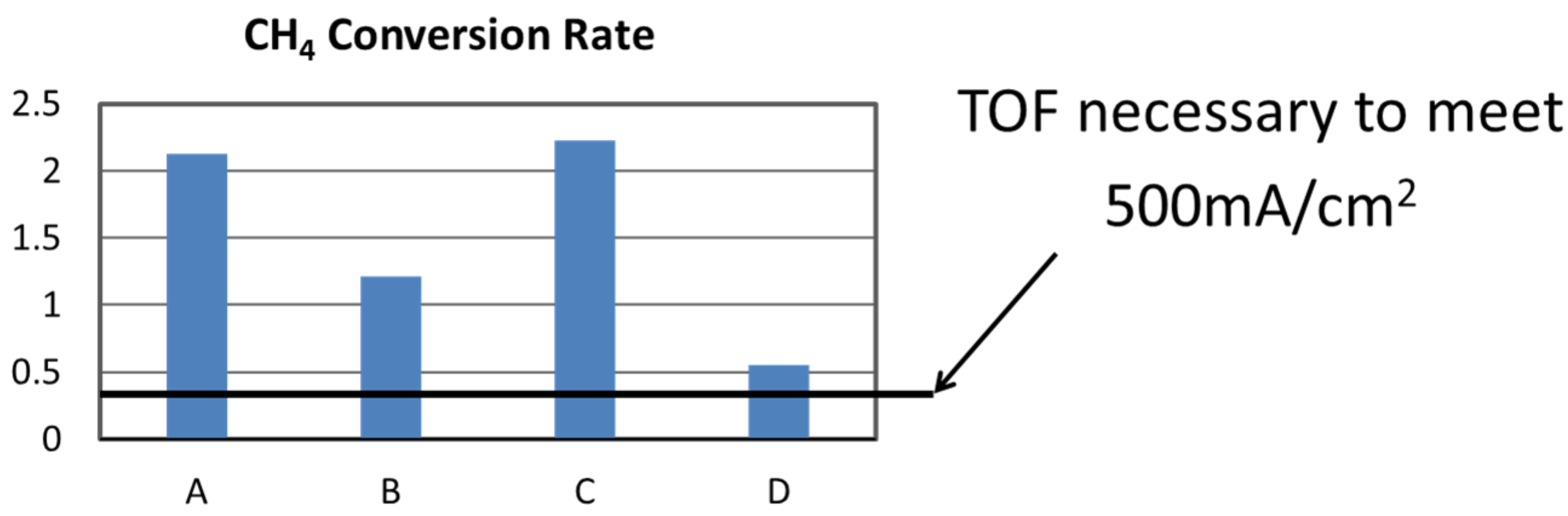
Benchmarking TOF vs Electrical Performance

Catalyst and cell electrical performance must be compatible



Catalysts can be tested conventionally

TOF converted to electrical current density

Both optimized and cell integrated

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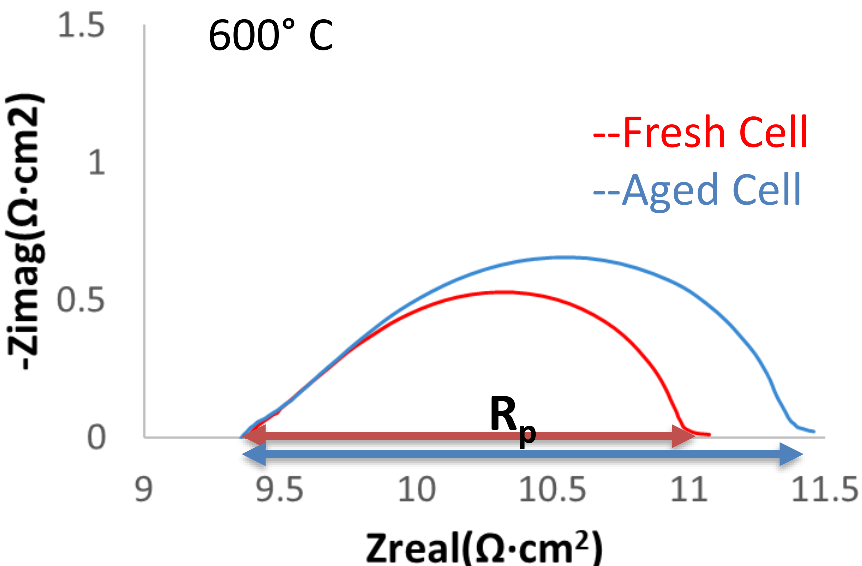
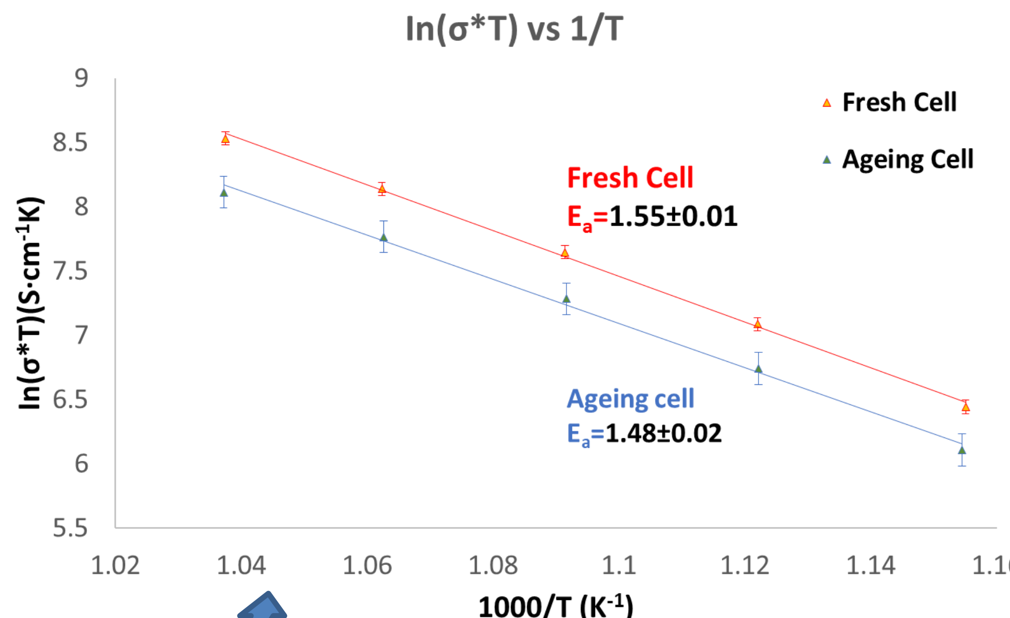
Accelerated Aging of Working Cells

Quickly identify *which part* of the system is weak point

Example: aging reveals but overall performance is *down,* catalytic performance goes *up*





R_p → Polarization Resistance
Cell performance

Ea → *catalyst* performance

Systems approach is ***critical***

T2M and Economic Outlook

CAPEX vs OPEX

- Remote sites may involve significant OPEX, depending on systems reliability, autonomy, etc.

Fuel Cells benchmarked per kw hr (electricity production);

- DOE targets $2000 /kW or better for fuel cells
- Direct comparisons challenging; inc. uncertainty for mass/energy balance
    - E.g. CO_2 capture? Heat balance (electrical vs combustion)?

Dilute streams challenge for economic modeling

- Effectiveness to get to market? 99.9%? ppb?
- Real-world performance, durability must be robustly benchmarked *and* tracked post-install

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