# High Energy Systems for Transforming $CO_2$ to Valuable Products

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## BACKGROUND

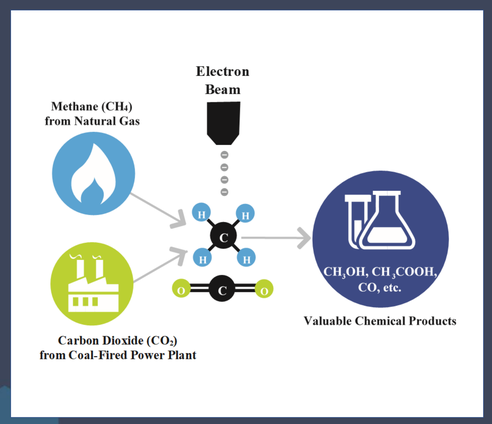
Current technology for the commercial production of acetic acid, methanol, and carbon monoxide requires:

- High temperatures and pressures
- Expensive catalysts in multiple process steps
- High capital and operating costs

Creating valuable products will offset the cost of carbon capture and storage

## INNOVATION

Using high-energy electron beams to break bonds, allowing production of desired chemicals at near-ambient pressure and temperatures




## OBJECTIVE

Develop a direct electron beam (E-Beam) synthesis (DEBS) process to produce valuable chemicals using $CO_2$ captured from a coal-fired power plant and methane (natural gas)

## MODEL DEVELOPMENT

### Model Reactions

**Radiolysis Reactions:**

$CH_4 \rightarrow CH_3^+ + H + eh^-$
$CO_2 \rightarrow CO_2^+ + eh^-$
$CO_2 \rightarrow C^+ + 2O + eh^-$

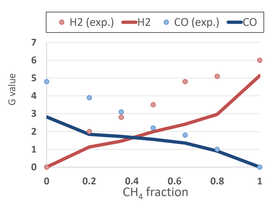
$eh^-$ : high-energy electrons
et- : thermal electrons

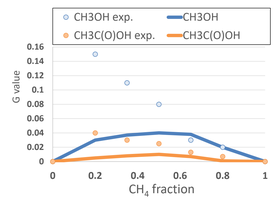
$eh^- + X \rightarrow et^- + X$

**Gas-phase reactions:**

1. Electron attachment:
   $(et^- + H + M \rightarrow H^- + M)$
2. Ion-neutral reaction:
   $(CH^+ + CH_4 \rightarrow C_2H_3^+ + H_2;\ C^+ + CO_2 \rightarrow CO_2^+ + C)$
3. Neutral-neutral reaction:
   $(H + CH_4 \rightarrow CH_3 + H_2;\ OH + CH_4 \rightarrow H_2O + CH_3)$
4. Cation-anion reaction:
   $(C^- + O^+ \rightarrow C + O;\ O^- + H_3O^+ \rightarrow H + O + H_2O)$

### Model Predictions

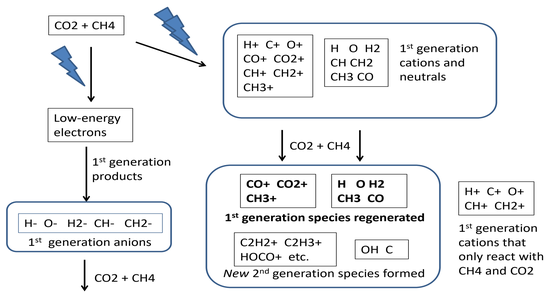



- **Initial gas composition influences G value**
- **Model discrepancy at low $CH_4$ fraction**
- *** Experimental values are from *Arai H et al. 1982***

*Ref: Arai, H. et al., "Electron Beam Radiolysis of $CH_4/CO_2$ Mixtures,", Zeitschrift fur Physikalische Chemie Neue Folge, Bd. 131, S. 69-78 (1982)

### Reaction Pathways




Initial experiments confirm CO and $H_2$ as the major products

## E-BEAM REACTOR DESIGN

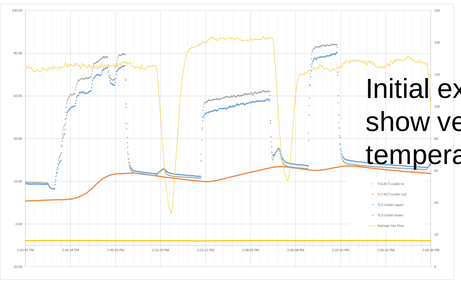
Sealed lamp electron accelerator
200 keV, 20 mA

Reactor enclosure designed and provided by PCT E-Beam and Integration

## GTI'S ACCELERATOR LAB


- First set of experiments performed in February 2020
- Currently updating reactor design
- Experiments will resume at GTI after reactor update

## E-BEAM REACTION PERFORMANCE



Initial experiments show very fast gas temperature change

Product gas composition measured is mostly CO and $H_2$

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