ADVANCES IN CATALYSIS FOR HYDROCARBONS

RESULTS FROM ZEOCAT-3D, C123 & BIZEOLCAT EU RESEARCH PROJECTS

ZEOCAT-3D

C123
VALORISING METHANE RESOURCES

BiZeolCat

Funded by
the European Union

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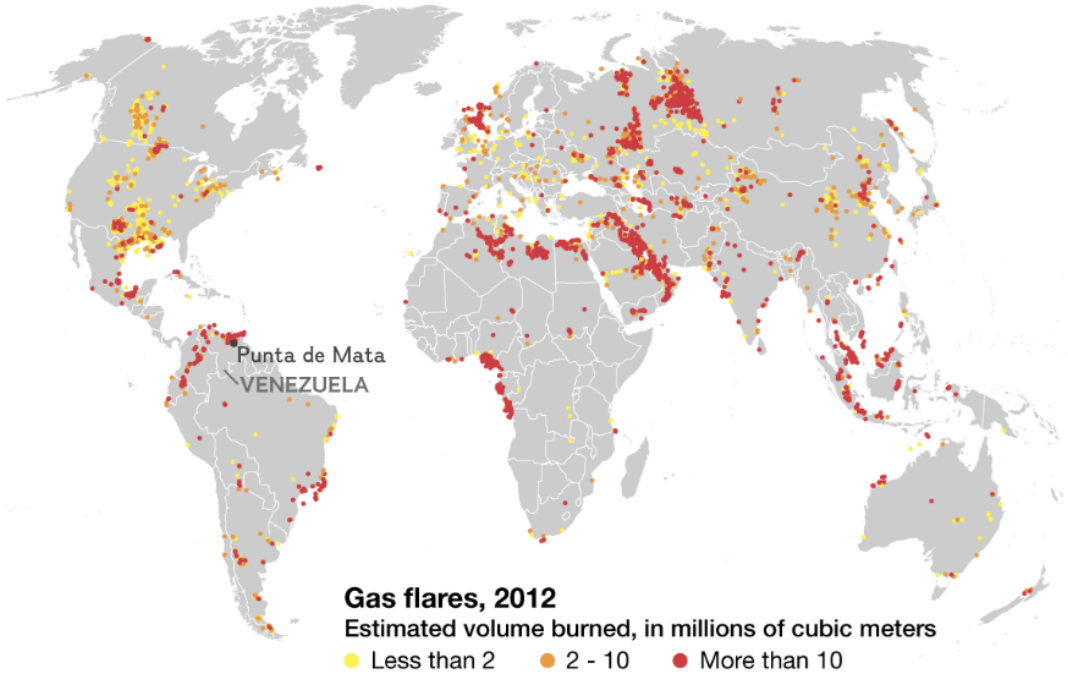
C123
Methane oxidative conversion and hydroformylation to propylene
Project overview

Richard H. Heyn (SINTEF), Project coordinator

Joris Thybaut (Univ. Gent), Scientific coordinator

Today's reality



A waste is a terrible thing to mind

- Converting CH_4 to CO_2 is better for the environment! 😱
- Simply a waste of natural resources 😢

- Why?
  - Cheaper and easier to simply burn CH_4 than convert it to something useful
  - Location, location, location!
    - "Stranded gas"

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The C123 solution

- 2 stage process

Oxidative Conversion of Methane (OCoM): $CH_4 + O_2 \rightarrow H_2C{=}CH_2 + CO\ (+ H_2)$

Hydroformylation (HF): $H_2C{=}CH_2 + CO + H_2 \rightarrow$ propanal $\rightarrow$ other C_3 products

- Easier transportation of liquid C_3 products from remote locations

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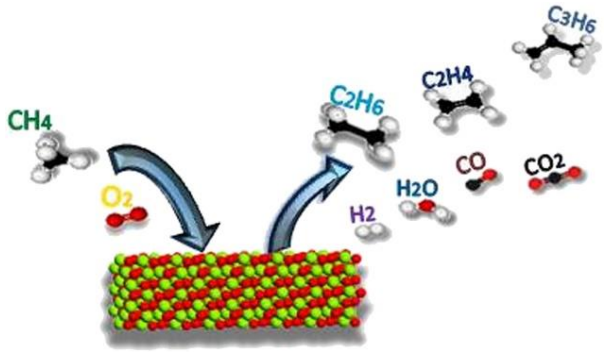
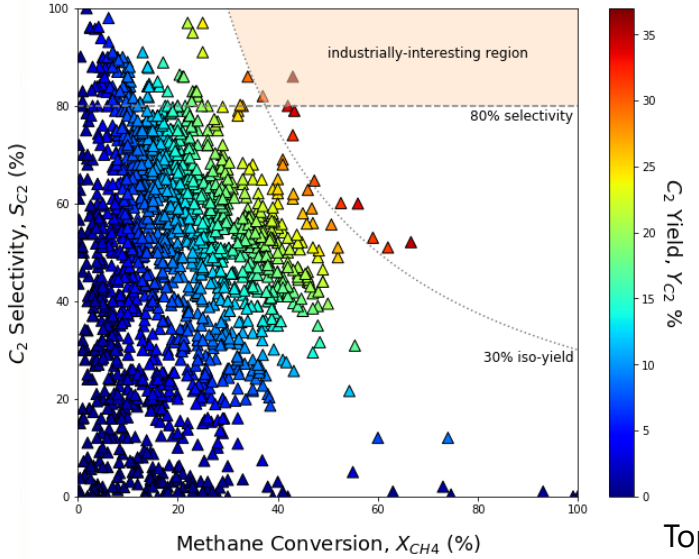
Oxidative Conversion of Methane (OCoM)
Like Oxidative Coupling of Methane, but different





- Oxidative Coupling of Methane (OCM)
  - decades of research
  - entire periodic table investigated
  - awaiting successful commercialization
- Oxidative Conversion of Methane
  - Focus on maximizing both C_2 and CO as equimolar products
  - Better atom efficiency
  - Incorporation of CO_2 into products

Top left: Noon et al. J. Nat. Gas Sci. Eng. 18 (2014) 406; Bottom left: Pirro et al. Reac. Chem. Eng. 5 (2020) 584

OCoM results

- Most suitable OCoM catalyst
- Kinetic model for the OCoM reaction stage
- Optimal reaction conditions for C_2H_4 production
- 10:25 Alejandro Romero Limones (U Gent)

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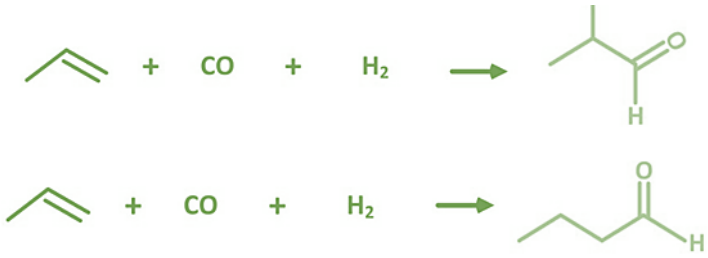
Hydroformylation

- One of the world's largest homogeneously catalysed industrial processes
- Couples an alkene and syngas (CO + H_2) into an aldehyde
  - High yield and selectivities
- Primarily catalysed by organometallic Rh complexes
  - Co also used
  - Separation issues
  - Complex ligand systems to control selectivity
    - Can get both linear and branched aldehydes



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Hydroformylation results

- Three new heterogeneous HF catalysts
  - PolyPhos
  - Metal-organic frameworks (MOFs)
- Successful testing in gas-phase hydroformylation of ethene
- 11:40 Alvaro Amieiro (Johnson-Matthey)

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C123 Scenarios

- 5 scenarios based on 3 gas sources and 2 process sizes
  - Biogas (Germany)
  - Marginal gas (Russia)
    - 15 % of proven gas reserves
    - Not economically viable with state-of-the-art technology
    - Unfavorable crude characteristics
    - High gas and low oil reserves
  - Associated gas (USA)
    - 25 % of proven natural gas reserves
    - Natural gas found in association with oil in an oil reservoir
  - Modular route
    - 10-30 kton/yr product propanal or propanol
  - Add-on route
    - 200-300 kton/yr product propene

C123 Scenarios: TEA/LCA

- Process design, TEA and LCA of all 5 scenarios
  - Scenario A: Biogas, modular (Germany)
  - Scenario B1: Marginal gas, modular (Russia)
  - Scenario B2: Associated gas, modular (USA)
  - Scenario C1: Marginal gas, add-on (Azerbaijan)
  - Scenario C2: Associated gas, add-on (Iraq)
- Scenario B2 is considered the most promising industrial application

- 15:20 Mohamed Mahmoud (PDC) and Jordy Motte (U. Gent)

Continued relevance of the C123 project

- Given the current conflict in Ukrania and the weaponisation and increased price of natural gas supplies, how relevant is the C123 project?
- Natural gas prices will affect primarily its large production and consumption
- Natural gas prices do not change the current situation of natural gas flaring in remote locations, thus C123 is still relevant.

Conclusions

- C123 offers a technical solution for the conversion of stranded natural gas reserves to transportable C_3 chemicals
  - OCoM catalysts and process for conversion of $CH_4/CO_2/O_2$ to an equimolar mixture of C_2 hydrocarbons and CO
  - Synthesis of heterogenous catalysts for gas-phase hydroformylation
  - Processes and techno-economic and life cycle assessments of 5 different scenarios for the conversion of CH_4 to C_3 products

- 6.5 M€ (EU contribution) project
- 01.01.2019 – 30.06.2023

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THANK YOU

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