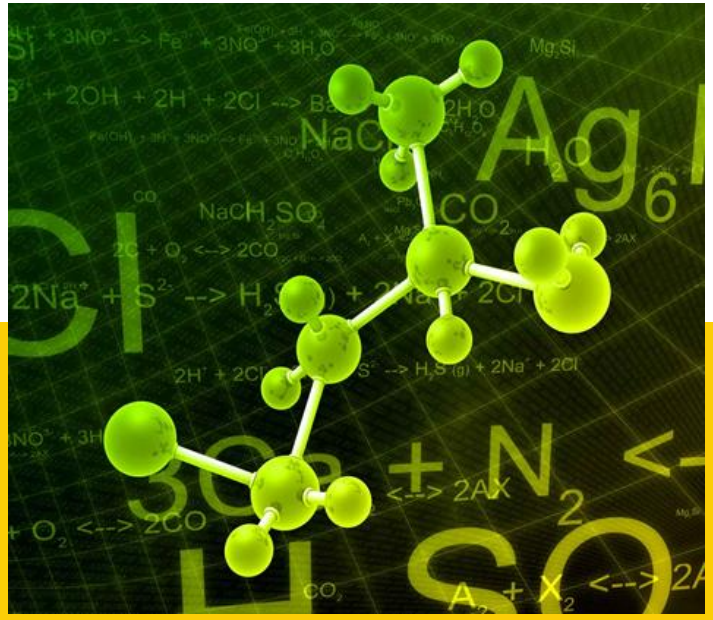
Shell Chemicals

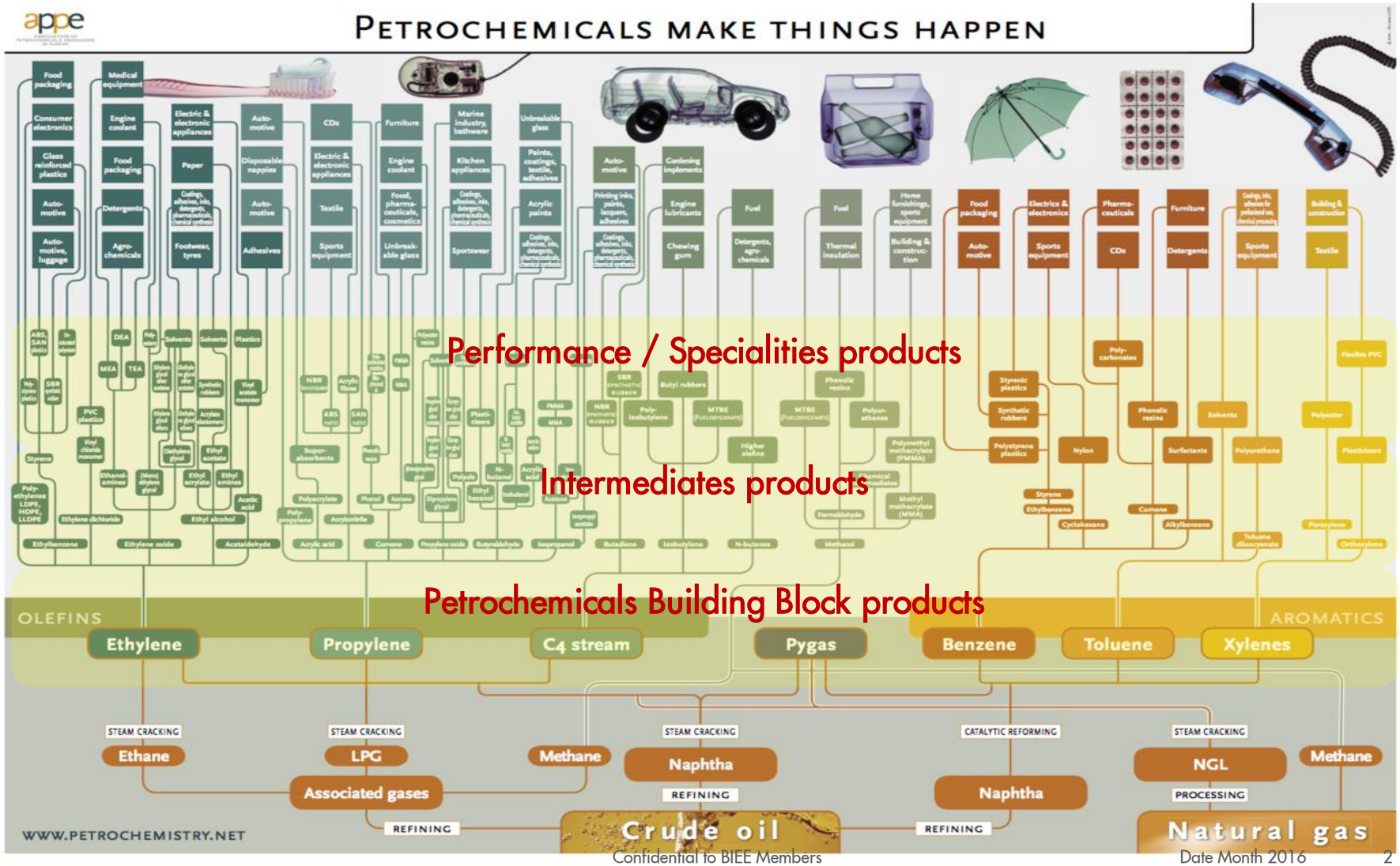
Chemicals' feedstock challenges – An opportunity for natural gas?

- Demand and Structure
- Feedstock – Current outlook
- Feedstock – What Next?



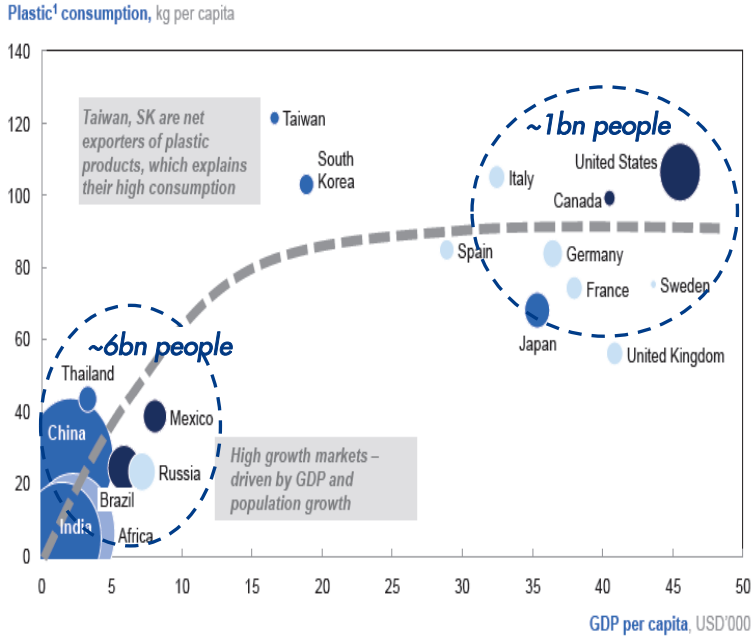
Stephen Kinder
Business Development

Wide range of chemical end products produced from oil / gas



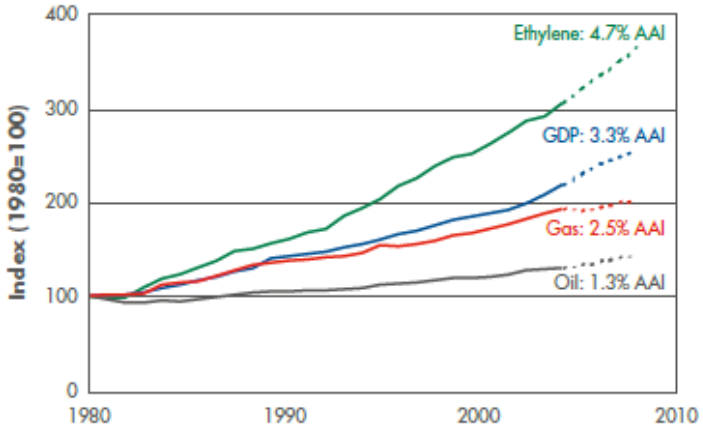
Demand for chemicals has been on a solid growth trajectory, backed by strong drivers

INCREASING STANDARDS DRIVING GROWTH

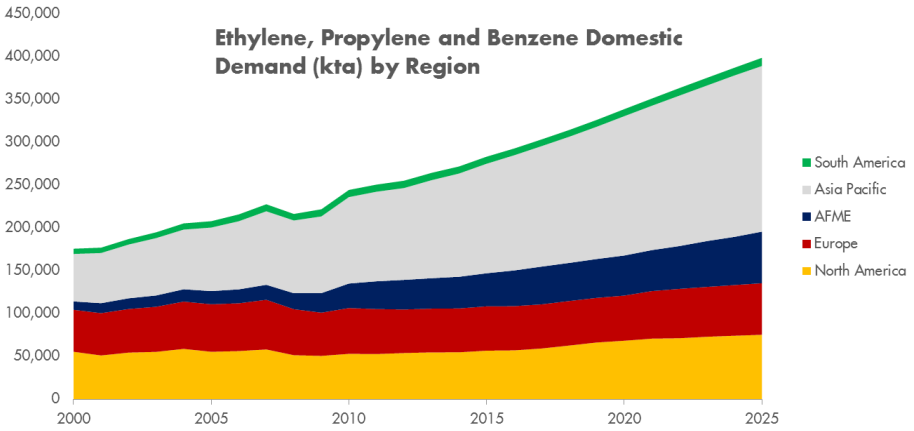


- Increasingly prosperous emerging economies with expanding populations driving demand for petrochemical-based products in order to meet needs in infrastructure, construction, automotive, and consumer product markets

FASTER GROWTH THAN GDP, OIL & GAS

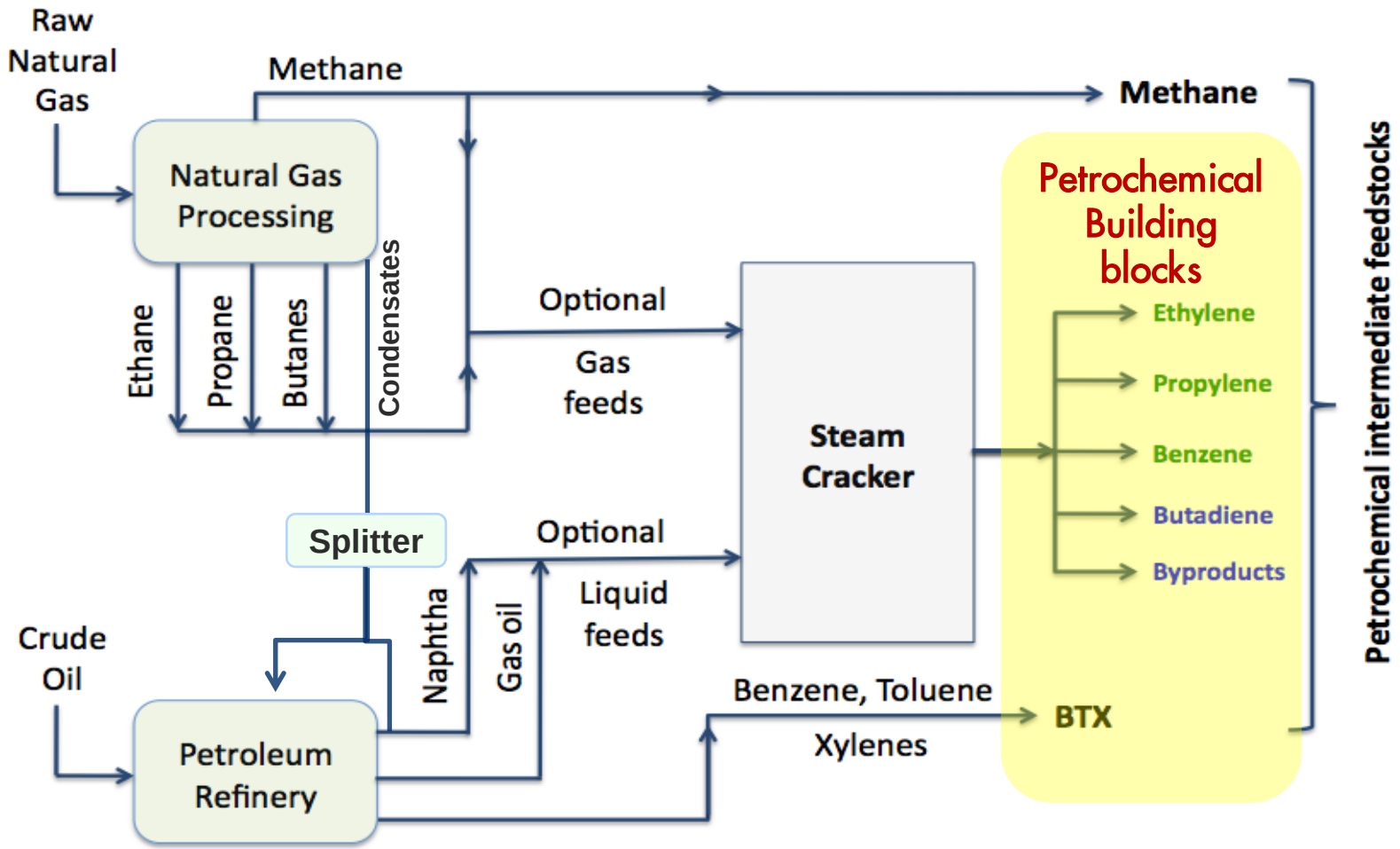


ASIA PACIFIC CONSUMPTION MAIN DRIVER



Sources: IHS, ICIS, McKinsey analysis

Chemicals are mainly produced from natural gas liquids and/or crude oil refined products

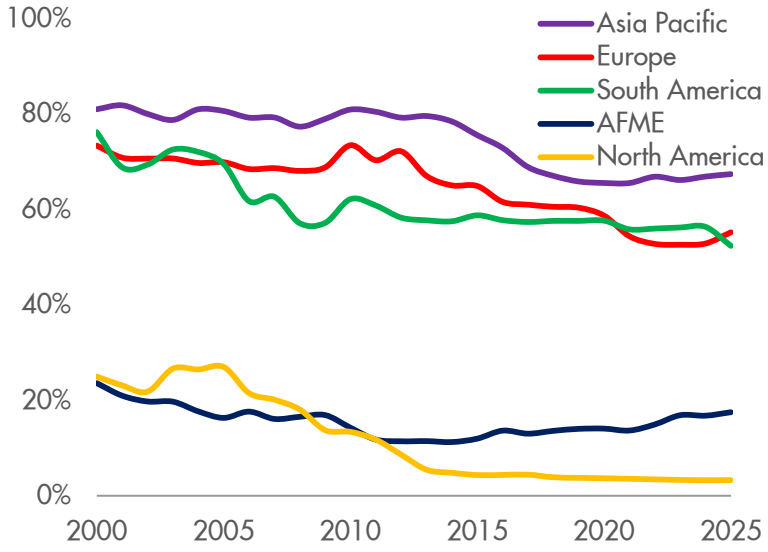


Methane already a major feedstock and growing Ammonia No1, Methanol 4th end Products by 2035

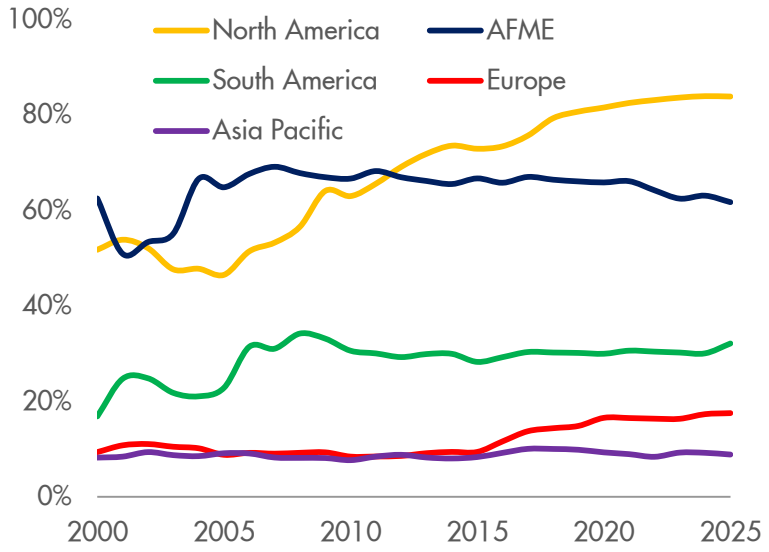
SOURCE: McKinsey Global Institute, IHS, end market demand model, team analysis

Ethane continues to grow as an important Cracker Feedstock – mainly driven by US Shale feedstock

% Ethylene Produced Using Naphtha Feed

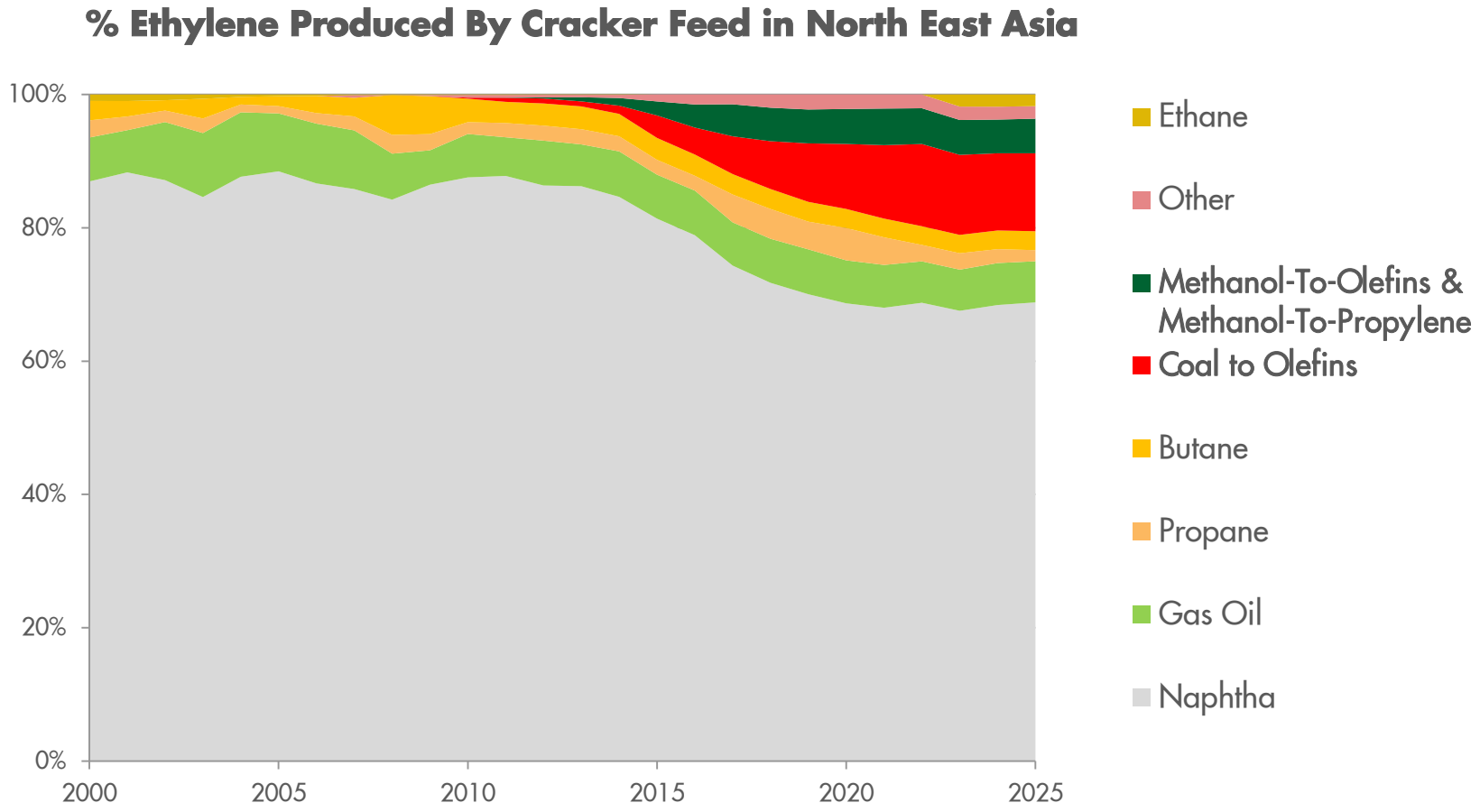


% Ethylene Produced Using Ethane Feed



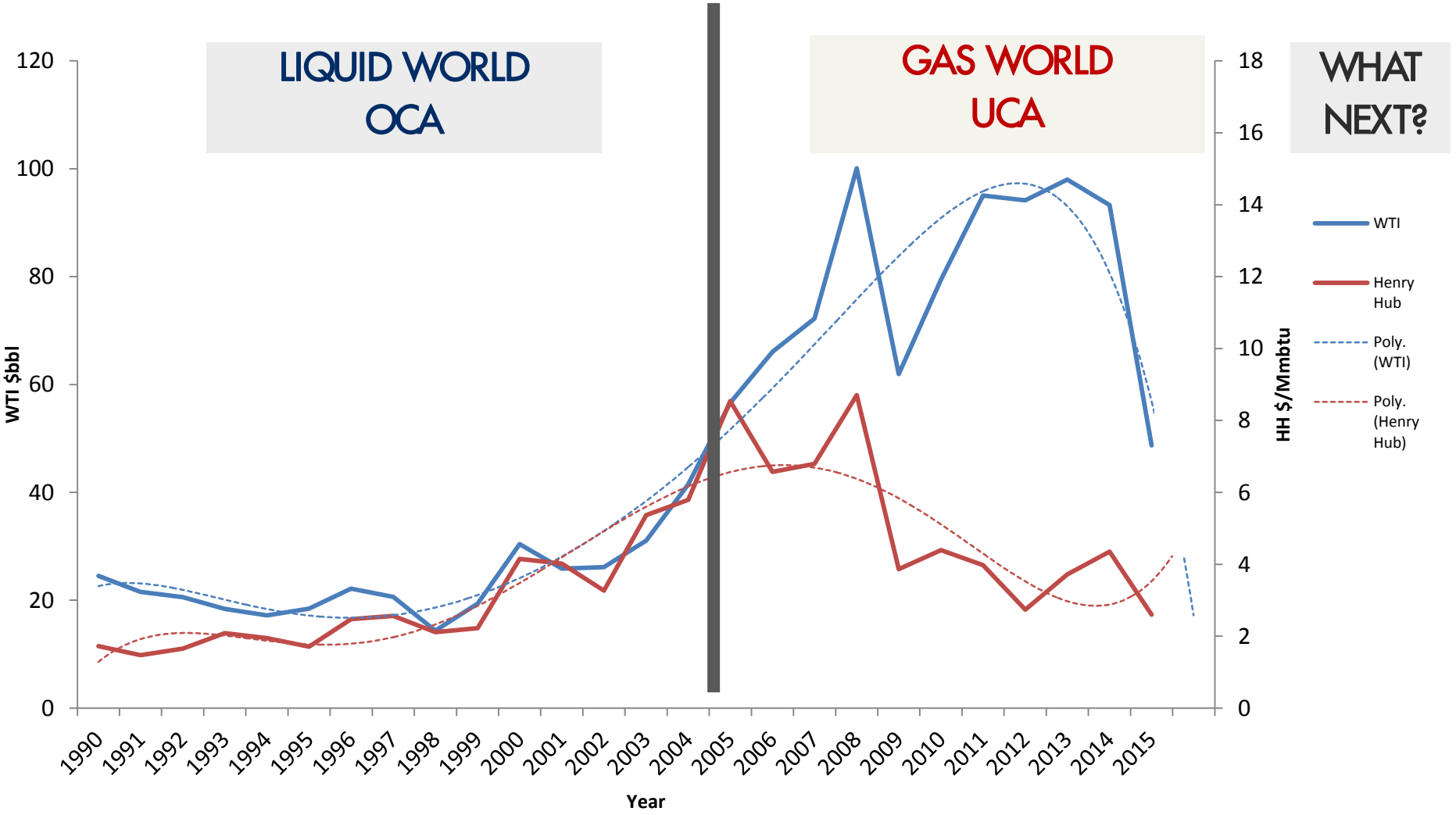
SOURCE: IHS Connect October 2016
Europe = Western Europe, Central Europe and CIS & Baltic States

Coal- and Methanol-to-Olefins increasing in importance – mainly driven by China

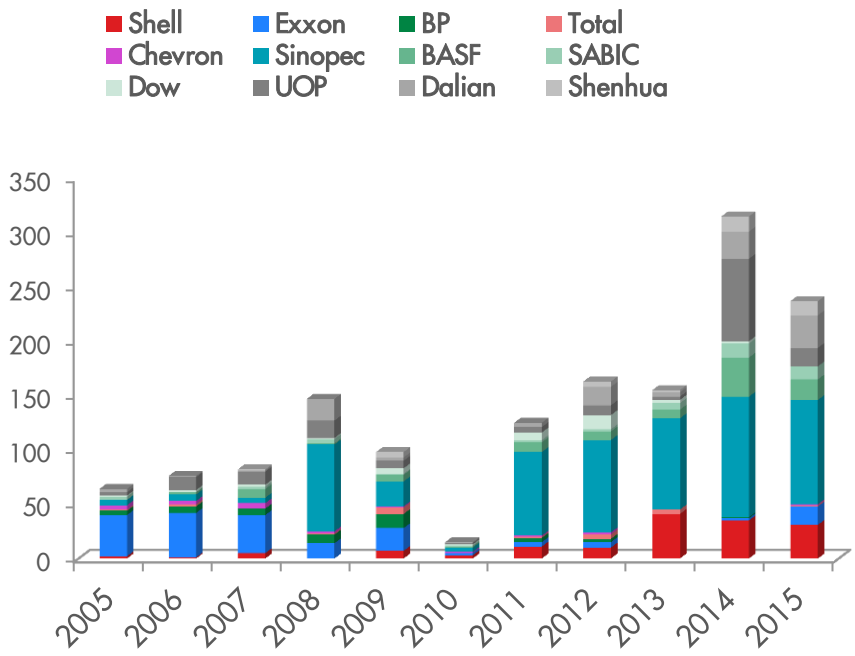


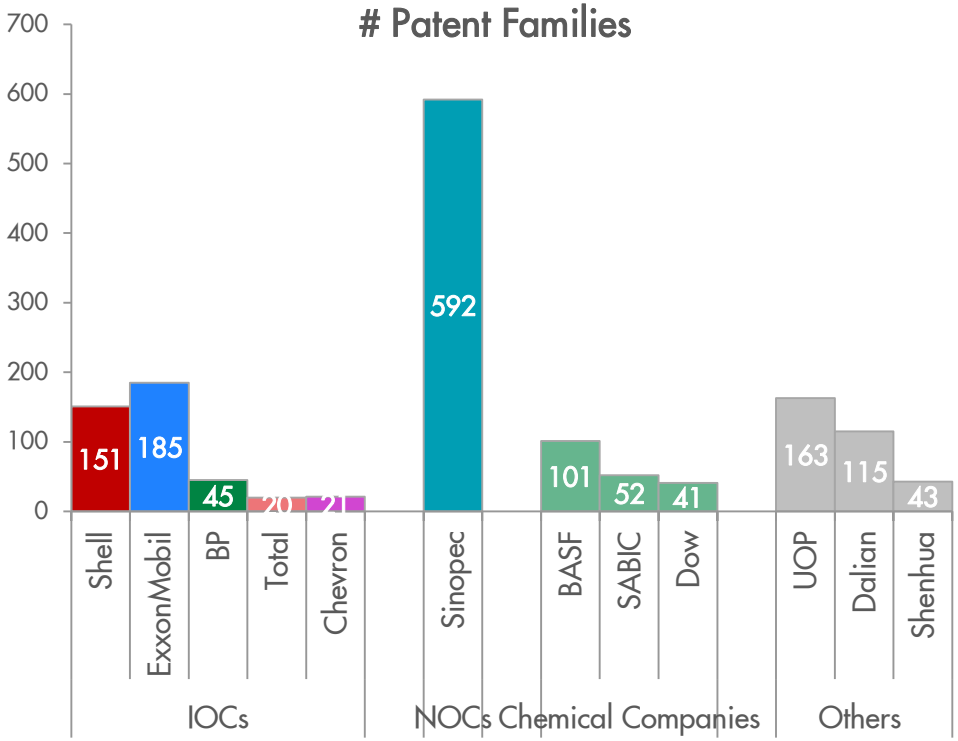
SOURCE: IHS Connect October 2016
Europe = Western Europe, Central Europe and CIS & Baltic States

Divergence of oil & gas prices incentivized chemical producers to adopt a gas-based feed strategy



Gas to Chemicals – Publications trend Top 12 players
Significant growth of R&D activity as oil increased





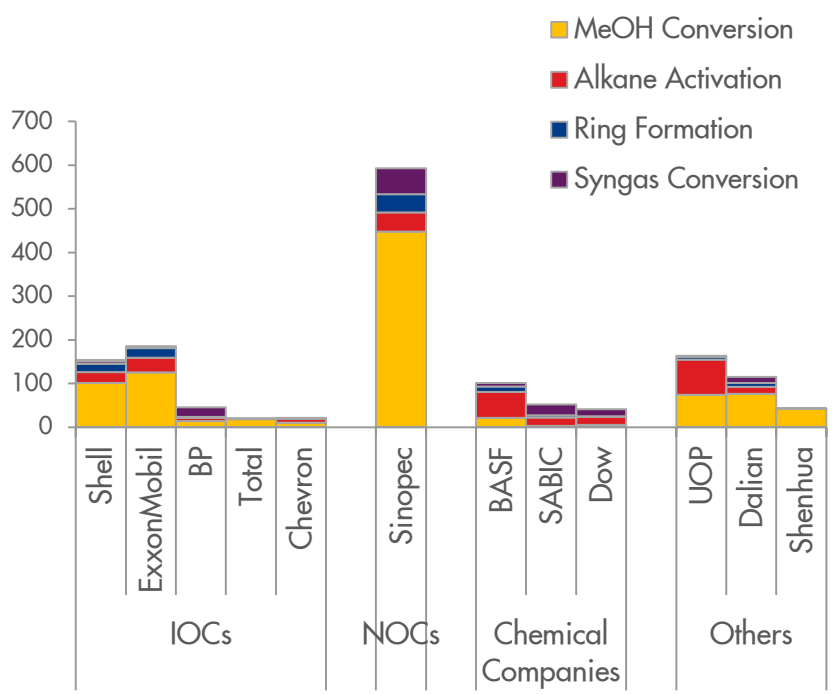
Observations

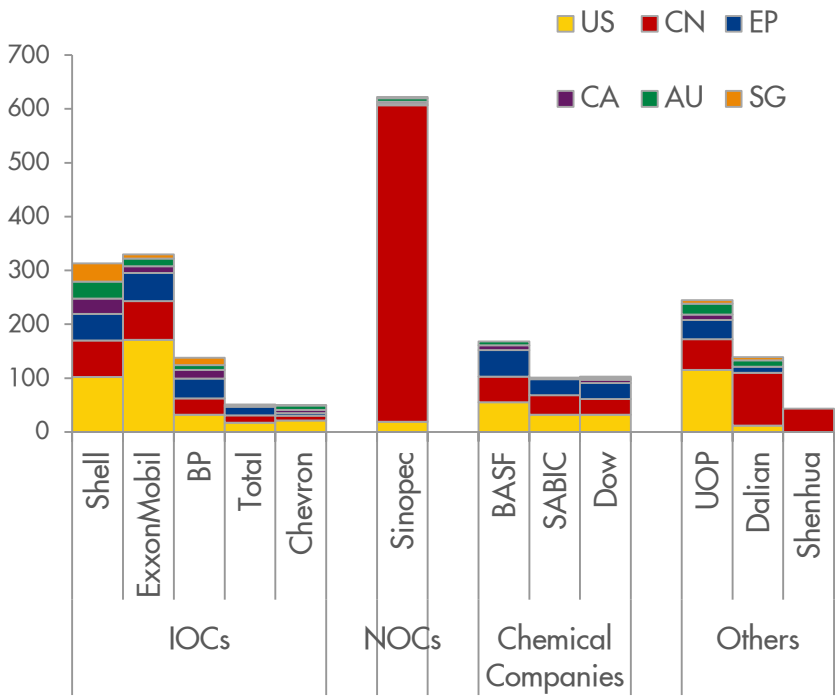
- >50% - MTO , 25% - alkane activation
- Exxon was very active till 2009 in Ring formation and MTO then dormant; since 2015 Exxon is back with focus on Methane to Products

Observations

- Sinopec is the leader but with major focus in China
- Exxon is the leader amongst IOC's
- SABIC is active in alkane activation whereas BASF is active in butane to butadiene

G2C: Technology Categories & Major Countries





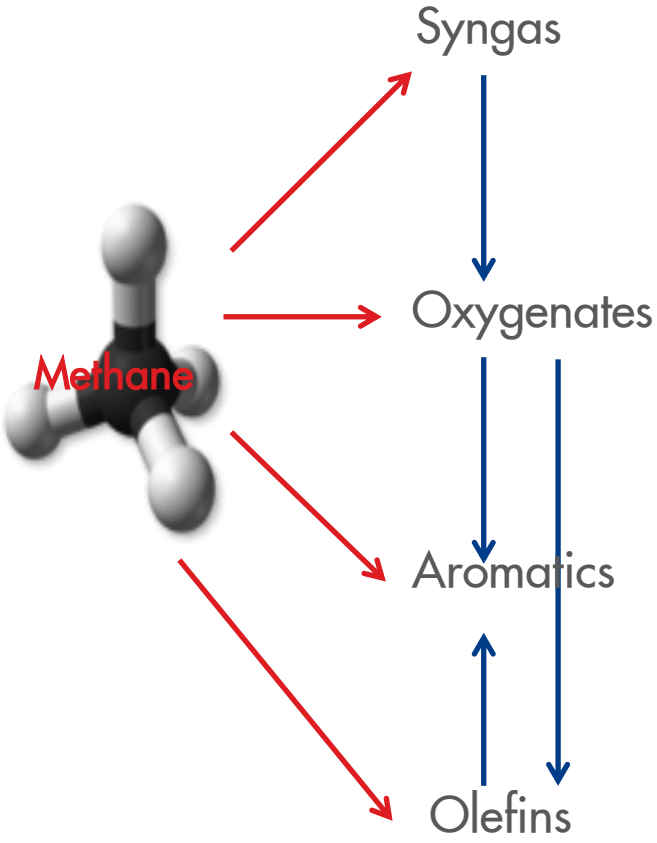
Observations

- Sinopec, Shell, Exxon major focus is on MeOH conversion, whereas BASF, SABIC, UOP is on Alkane activation

Observations

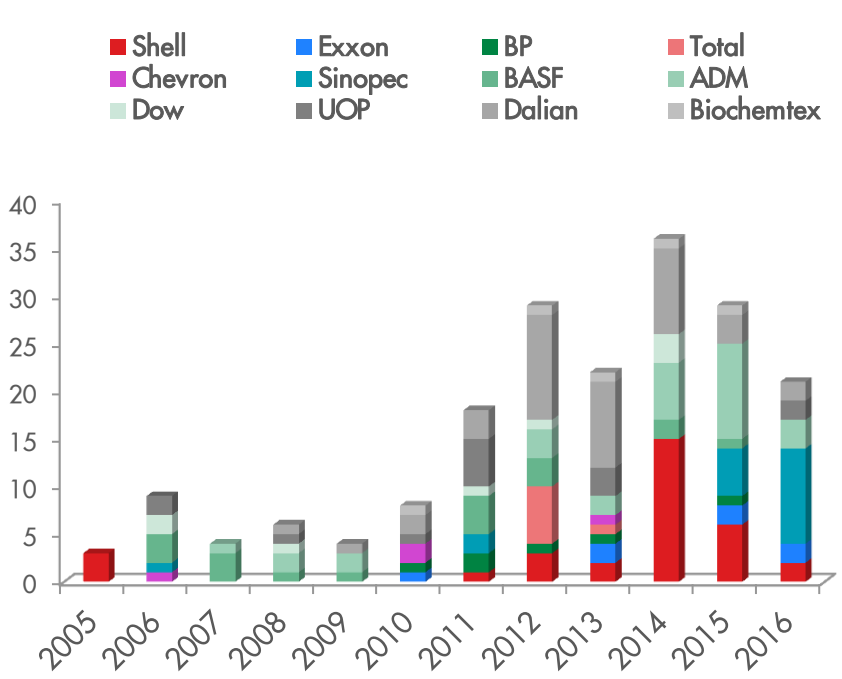
- US and China are the dominant countries as these are the regions with strong growth prospects for Chemicals

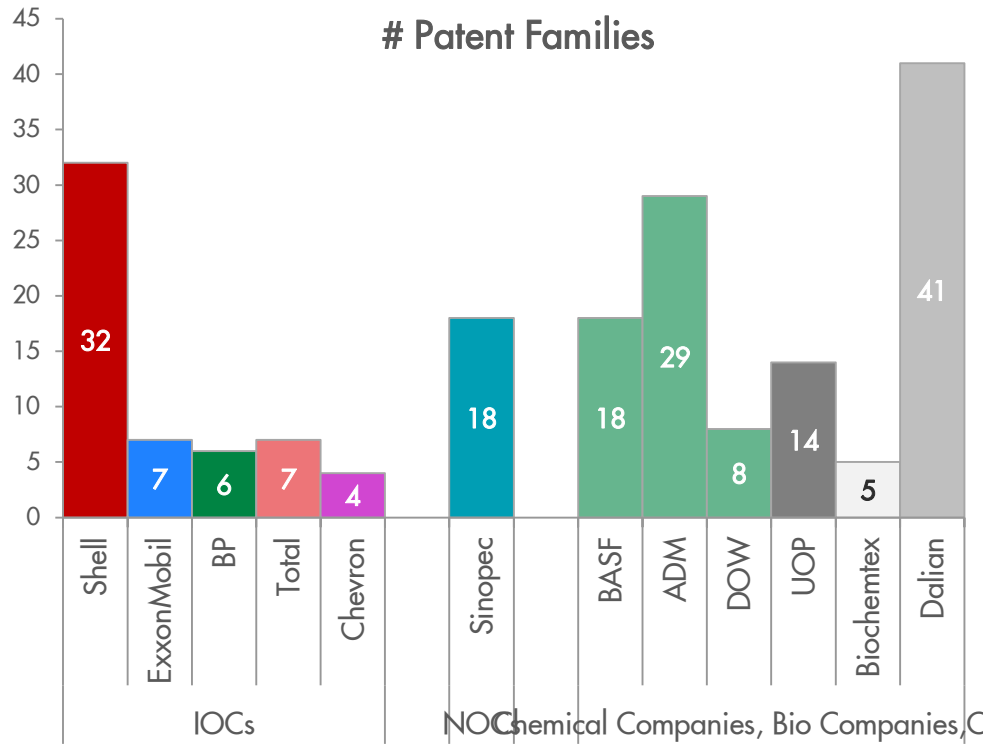
Methane to Chemicals technology focus broadening with focus on main building blocks



- Methane traditionally used for NH3, H2, MeOH, fuels via GTL
- Methane direct to the key building blocks of ethylene and aromatics is being investigated
- Historically Methane is disadvantaged due to capital and variable cost economies and mainly due to easy access to Ethane
- However as single molecule readily available in large concentrated volumes creating a potentially attractive feedstock source

Bio to Chemicals – Publications trend Top 12 players **COP15 in 2009 a trigger event**





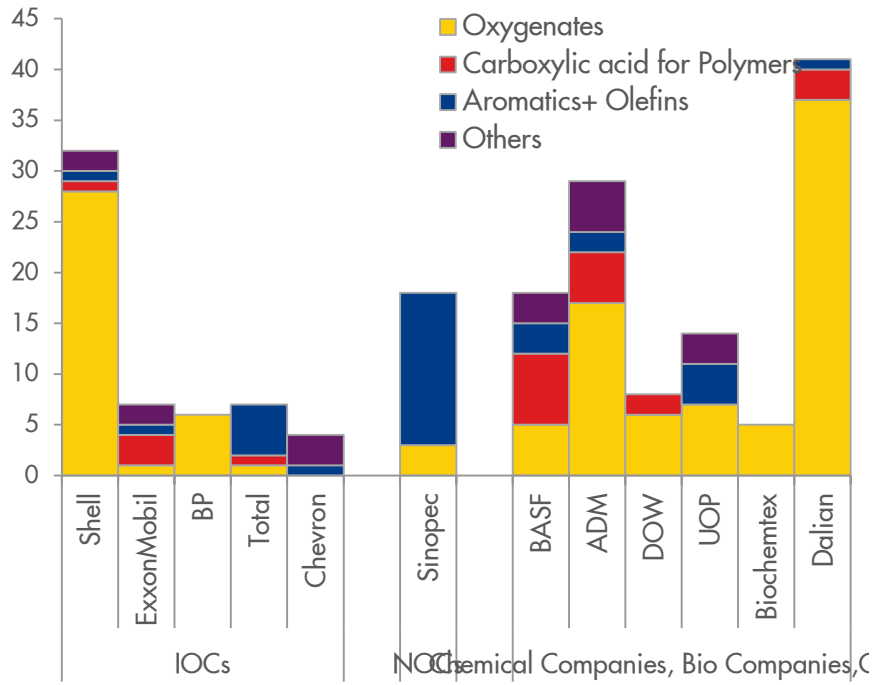
Observations

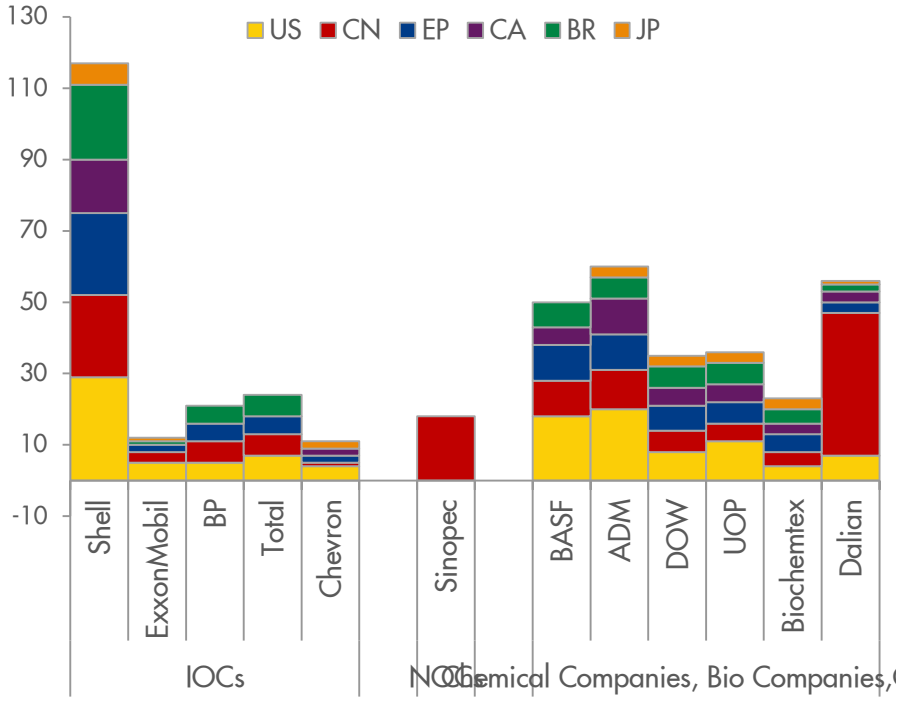
- Distinct activity is from 2010
- 2016 Data is up to August 2016 so may be by year end the number maybe "40"

Observations

- Shell is a leader amongst IOC's
- BASF has significant publications amongst the chemical companies along with Archer Daniels (agroindustry)
- Dalian is one of the leading University/Institutes in this space

Bio based Chemicals: Technology Categories & Major Countries





Observations

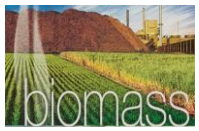
- Oxygenates predominantly glycols is the major focus followed by carboxylic acid used for polymers
- Olefins like ethylene and isoprene rubbers too have few publications

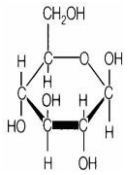
Observations

- US and China are the dominant countries as these are the regions with strong growth prospects for Chemicals

Bio based Chemicals – Complex feedstock base with wider range of end products targetted

Complex Feed Stock





- Syngas
- Olefins
- Oxygenates
- Polymers
- Aromatics
- Acids

Why bio based chemicals?

- Fossil fuel depletion concerns
- Diversification of feedstock
- Kyoto Protocol / COP15
- Integrated development of agriculture and chemical industry
- Marketing / Brand positioning "Renewable, Bio-Based"

Opportunities and Challenges

- Growing Market
- Oleo-chemicals well established from plant oils
- Potential green house gas emission savings
- Co-production of bio based chemicals with biofuels
- Difficult to target single product; multiple products stream similar to petroleum refineries

Methane vs Bio

Methane to Chemicals

- **Availability** – Easy / Single source / consistent long term annual supply
- **Unique** feedstock
- **Unreactive** feedstock;
- **Simple** chemicals platform; production selectivity is better ; base chemicals /building block focussed
- **Chemical & Catalytic technical expertise** required is broadly existing

Bio based Chemicals

- **Availability** – Cumbersome / extensive logistics / seasonal
- **Dynamic** Feedstock
- **Reactive** feedstock;
- **Complex** multifunctional oxidised chemicals; wide variety of products / intermediates & speciality focussed
- **Broader spectrum of technical expertise** required / to be developed

What Next remains the key question?

Note: In the year 2014 – Methane to chemicals had 532 publications of which ~300 publications are from the top 12 players indicated in the graph; similarly for bio-based chemicals in 2014 there are ~200 publications but the top 12 players only account for 35 publications this also indicates in methane to chemicals there is focused efforts by top 12 players where as in bio-based Chemicals there are many players, with single publications indicating one time effort but only a focused few.
In Methane to chemicals publications are twice that of bio-based publications; but if we compare top 12 players it is 10 times.

References

IEA Bioenergy report (link)
Future of biobased Chemicals(link)
SRI biobased Chemical Report(link)
Biobased economy (link)
Lux Research report(link)
Challenges and opportunities(link)
World Congress on industrial biotech.(link)
Overview of biobased chemical building block(link)
Some presentations(link1, link2)
Biobased chemicals: the convergence of green chemistry with industrial biotechnology(link)

Shale gas revolution – methane to chemicals(link1, link2)
Natural gas market analysis(link)
Natural gas as Industry feedstock(link)
Methanol to aromatic(link)

- IOC: International Oil Companies; NOC: National Oil Companies; ISC: International Service Providers
- Country Codes – US , EP –European Patent, CA- Canada, AU- Australia, SG- Singapore

Questions and Answers