NOVEL ROUTES IN CO$_2$ UTILIZATION: A SUSTAINABLE APPROACH

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SABIC AT-A-GLANCE

1976
Company established

34,000
Employees around the world

50
Countries of operations

3rd
Largest global chemical company*

120th
Largest public company in the world*

4
Core businesses

86
US$ B**
Total assets

4.9
US$ B**
Net income

39.9
US$ B**
Annual revenue

≈ 150
New products each year

11,534
Global patent filings

64
World-class plants worldwide

*Forbes 2018  **Billion
OUR BUSINESSES

BUSINESS PORTFOLIO

PETROCHEMICALS
- Polyolefins, Polycarbonates and Blends, PVC, Polyester and Polystyrene
- Synthetic Rubbers
- Specialty Polymers & Polymer Additives
- Glycols, Olefins, Oxygenates and Aromatics
- Chemical Intermediates & Industrial Gases

SPECIALTIES
- Engineered Thermoplastics
- Specialty Compounds
- Sheet & Film
- Composites
- Additive Manufacturing
- Fluids
- Thermosets and Additives

AGRI-NUTRIENTS
- Nitrogen Prilled Urea
- Granular Urea
- Ammonia
- Phosphate DAP and Dark DAP MAP
- Specialty NPK
- TGU

METALS*
- Long Steel
- Rebar
- Wire Rod
- Rebar in Coil
- Flat Steel
- Hot Rolled Coils
- Cold Rolled Coils
- Galvanized Rolled Coils
- Pre-painted Rolled Coils

* Supplied under SABIC brand through Hadeed, a fully-owned SABIC Affiliate
OUR SUSTAINABILITY STRATEGY:
MAIN FOCUS AREAS AND ACHIEVEMENTS IN 2017

Innovation and Sustainability Solutions
- Total Sustainability Solutions: 82

EHSS and Product Safety
- Decrease in Total Recordable Incident Rate: 14%

Resource and Energy Efficiency*
- GHG Emissions Intensity: 9.3%
- Energy Intensity: 7.6%

Human Capital Development
- Training program participants: +24,900

Supply Chain
- Safety and Quality Assessment System (SQAS)
- Material-loss Intensity: 93% solids 100% liquids

Resource and Energy Efficiency*
- Reduction in Flaring Emissions: 43%
- Water Intensity: 8.8%
- Total Current CO₂ Utilization: 3.5 million MT

* Assured by KPMG
- We are currently refreshing our materiality priorities and have linked SDG’s to the current sustainability priorities
SABIC GLOBAL T&I NETWORK

- Research Centers
- Application Centers
- SABIC Plastic Application Center at KSU, Riyadh
- SABIC Corporate Research & Development Center at KAUST

Five key geographies with innovation hubs in Middle East, USA, Europe, South East Asia, North East Asia
SABIC GOALS FOR CO₂ EMISSION REDUCTION

In KSA, SABIC plants vent a total volume of 5.2 Million Tons/year of “High Concentration” CO₂ as waste streams from all MEGs, ammonia and steel plants. From this total vented CO₂, around 3.4 Million tons/year will be utilized by 2025.

TECHNICAL OPTIONS FOR CONTROLLING CO₂ EMISSIONS:

• Energy efficiency
• CO₂ purification
• CO₂ utilization

CURRENT FOCUS

• Broaden the utilization of CO₂ as a feedstock for chemicals and polymers production, which includes methanol, acrylic acid, MEG, aromatics and special grades of polymers

SABIC COPYRIGHT 2018
• The top three assignees are, Sabic, BASF and Covestro.
• Other assignees active in this field include, Sinopec, Shell, Casale, LG etc.
• Sabic, Casale, Bayer, Ekokap found active and make entry to the top assignee list in this quarter; whereas Chinese Academy of science found as less active player in this quarter.
HP METHANOL CATALYST DEVELOPMENT
SABIC is developing a catalytic technology to reduce the poisoning effect of CO$_2$ on the methanol catalyst, thereby increasing the potential use of CO$_2$ as feedstock in the process.

3 times higher CO$_2$ captivated per ton of Methanol

17% less CH$_4$ intake
DRIVE AND VALUE PROPOSITION

TECHNOLOGY GAP/ BUSINESS DRIVE

- Development of high performance catalyst for methanol production
- Enhancement of catalyst stability under CO2-rich syngas feed (up to 14%)

APPROACH

- High dispersion of active metals (Cu) to increase activity
- Enhance the interaction of metals and support to increase selectivity of methanol

Assembling Preparation method

Activity Stability Selectivity
CO₂ INJECTION INTO H₂/CO

- Feed gas: 55% H₂/11% CO/x% CO₂/ Ar
- Reaction conditions: 240 °C, 40 bar, and 5000 h⁻¹

- Feed gas: 55% H₂/11% CO/x% CO₂/ Ar
- Reaction conditions: 220 °C, 40 bar, and 5000 h⁻¹
PRODUCTION OF HYDROGEN FROM S, CO$_2$/H$_2$O
CO₂ REDUCTION BY ELEMENTAL SULPHUR

SABIC developed a process for hydrogen and CO production from Sulphur, water and CO₂. Catalyst development for ‘S₂+CO₂’ chemistry was demonstrated in a labscale reactor. The performance and stability of the catalyst were demonstrated up to 250 hours. Several catalyst found to be able to split CO₂ to produce CO in presence of elemental sulfur.

BENEFITS

- Both Sulphur and CO₂ are inexpensive raw materials and easily available
- Energy intensity = 25 MMBTU/ton H₂
PROJECT HIGHLIGHTS

TECHNOLOGY GAP/DRIVE

• Syngas is an important feedstock for Petrochemicals
• Fossil sources are depleting around the world
• Explore alternative feedstock’s for future need
• Non-hydrocarbon based technology

OBJECTIVES

➢ Reduce CO₂ using ‘S’ to produce CO and SO₂.
➢ Produce H₂ / syngas by water gas shift reaction.
➢ Utilize SO₂ in H₂SO₄ production.
PROCESS SCHEME

APPLICATIONS
• Fertilizers
• Chemicals
• Performance Chemicals
• Metals

$S + CO_2 (>1000 \, ^\circ C)$

$SO_2 + CO$

$SO_2 + 0.5 O_2$

$SO_3$

$H_2O$

$H_2 + CO_2$

$H_2 + CO_2 - CO_2$

$H_2$

$xH_2 + yCO + zCO_2 - CO_2$

$xH_2 + yCO$ (Synthesis Gas)

$H_2SO_4$ (Sulfuric Acid)
TECHNICAL APPROACH

Reaction Pathways

<table>
<thead>
<tr>
<th>Reactions</th>
<th>ΔH kcal/mol</th>
</tr>
</thead>
<tbody>
<tr>
<td>4CO₂ + 1.325 S₂ =&gt; 3.35CO + 0.65COS + 2SO₂</td>
<td>82.2</td>
</tr>
<tr>
<td>3.35CO + 3.35H₂O =&gt; 3.35CO₂ + 3.35H₂</td>
<td>-29.9</td>
</tr>
<tr>
<td>0.65COS + 0.975 O₂ =&gt; 0.65CO₂ + 0.65SO₂</td>
<td>-85.4</td>
</tr>
<tr>
<td>2.65SO₂ + 1.325O₂ =&gt; 2.65SO₃</td>
<td>-62.2</td>
</tr>
<tr>
<td>Net</td>
<td>-95.3</td>
</tr>
</tbody>
</table>

Catalyst formulation

Two main criteria have been selected to drive formulation of potential catalyst:

• Thermal stability of material (either oxide and sulfide)

  MOₓ + S₂(g) → MSᵧ + SO₂

  MSᵧ + CO₂ → MOₓ + CO + SO₂

• An material that exhibit ability to switch easily from oxide to sulfide and vice-versa

  Overall
  
  1.34S₂ + 2.28O₂ + 3.356H₂O => 3.35H₂ + 2.64SO₃
  
  or

  Overall
  
  S₂ + 1.7O₂ + 2.5H₂O => 2.5H₂ + 2SO₃
Total control over CO and COS selectivity by controlling the CO₂ conversion

Catalyst maintained CO₂ conversion however, selectivity varied over 10 days due to transformation in catalyst composition, which could be overcome to better catalyst design with higher temperature and mechanical stability.
WE HAVE A CLEAR AMBITION

✓ To be successful in CO₂ emission reduction and achieve our targets
✓ We believe that innovation is our roadmap to success and leadership
✓ Bring state of the art material solutions
THANK YOU