Journey of CO_2 Utilization (CCUS) and Development from lab to commercial scale goal to Net zero CO_2 emission

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Researcher

Central Research Development : SCGC

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Leading in **sustainable chemical innovations** and **manufacturing** that offers a full range of petrochemical products, SCGC is developing new technology and innovation to create high value-added products (HVA) and holistic service solutions to better meet diverse places and emphasis demands sustainable environmental stewardship.

We are committed to conduct business in line with ***Environmental, Social & Governance (ESG)*** *with*

Strategic ESG Directions

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Innovation Roadmap on CCUS

2020
- Ideation
- Proof of concept in Lab scale

2023
- Technology development in lab scale

2025
- Technology development Pilot/Demonstration plant

Partnership

2027
- Project Implementation

Partnership

2030
- Demonstration or Commercialization

20% CO_2 Reduction

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Technology Landscape

CO_2 Source

- Natural gas
- Coal
- Biomass
- Process emission
- Oil
- DAC

CO_2 Capture

- Absorption
- Adsorption
- Membrane
- Cryogenic

CO_2 Utilization

- Upgrading
- Catalyst Tech.
- Electrochemistry
- Bio-Conversion
- Co-polymerization

Product

- Methanol
- Olefins/Paraffins
- Jet-Fuels
- Bio-Fuels
- Carbonate
- Syngas
- H_2 production
- Carbon material
- Cement
- Urea
- Chemicals: Formic/ Formate Acitic acid

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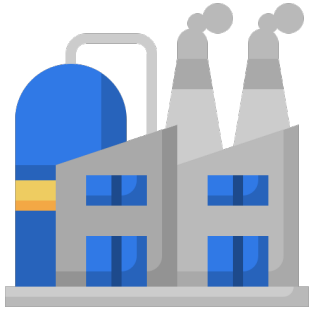
Limitations for CCUS Development

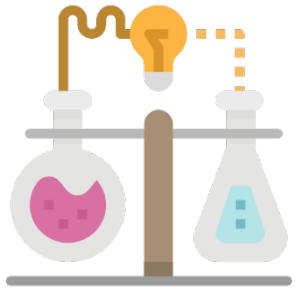


Commercialization

- Technology Implementation
- Technology Demonstration
- Technology owner

- Investment
- Technology selection

CO_2 Capture



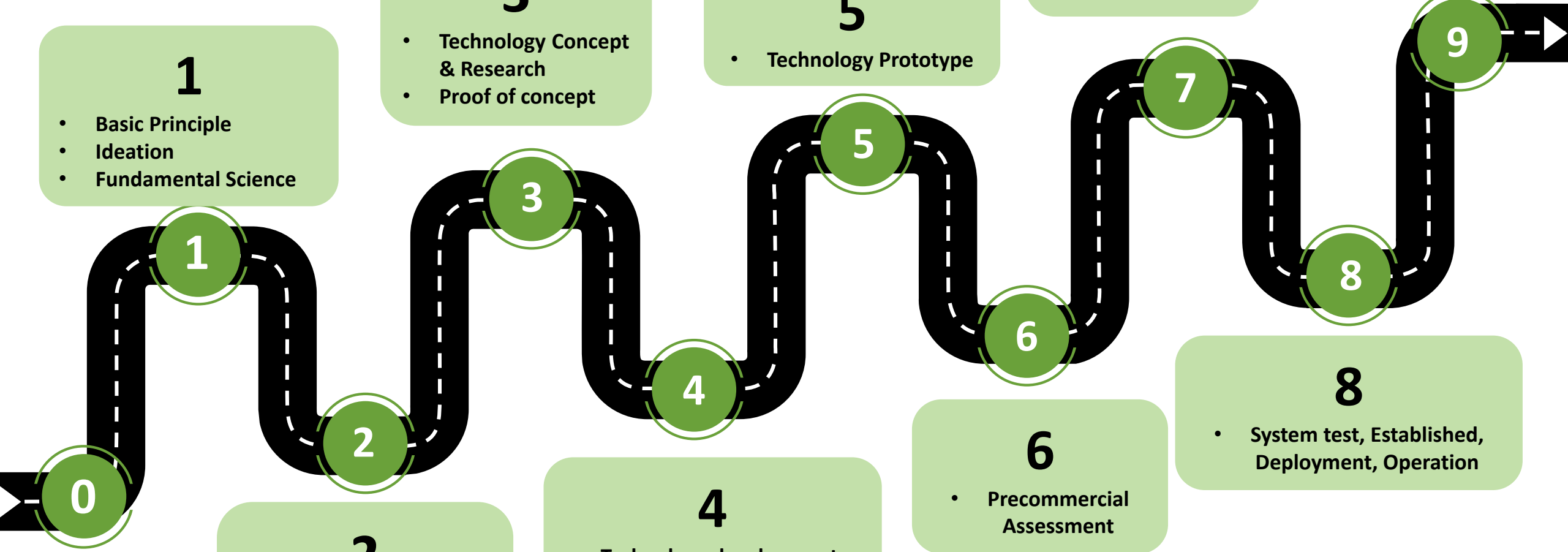
CO_2 Utilization

- Conversion
- Selectivity
- Stability
- Productivity
- Regeneration
- Feasibility
- Patent & Infringement

CO_2 Emission

- Large Amount of flue gas
- Low % CO2 concentration

Road to TRL



0
- Idea

1
- Basic Principle
- Ideation
- Fundamental Science

2
- Research to Prove Feasibility
- Application formation

3
- Technology Concept & Research
- Proof of concept

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- Technology development
- Experimental testing

5
- Technology Prototype

6
- Precommercial Assessment

7
- Technology Demonstration

8
- System test, Established, Deployment, Operation

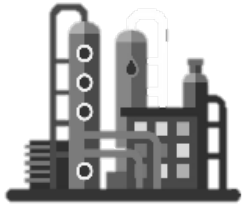
9
- Commercialization Competitive Product

Road to TRL 1-3 : Catalyst Development

Catalyst

Process Design

Pilot Unit



Commercialization

1 Pathway Reaction Study

Methanol Synthesis

$CO_2 + H_2 \rightarrow CH_3OH + H_2O$

$\Delta H_{298\ K} = -49.4\ kJ\ mol^{-1}$

Fischer Thropsch Synthesis

$nCO_2 + 3nH_2 \rightarrow C_nH_{2n} + 2nH_2O$

$CO_2 + H_2 \rightleftharpoons CO + H_2O$

$nCO + 2nH_2 \rightarrow C_nH_{2n} + nH_2O$

2 Catalytic synthesis

Formulation
Synthesis
Pelletization
Pretreatment

Minitab 19

3 Design of experiment

Operating conditions

Minitab 19

4 Catalytic performance testing

Reactor set up
Analysis set up

5 Characterization & Analyze

Fundamental study
Mechanism analysis

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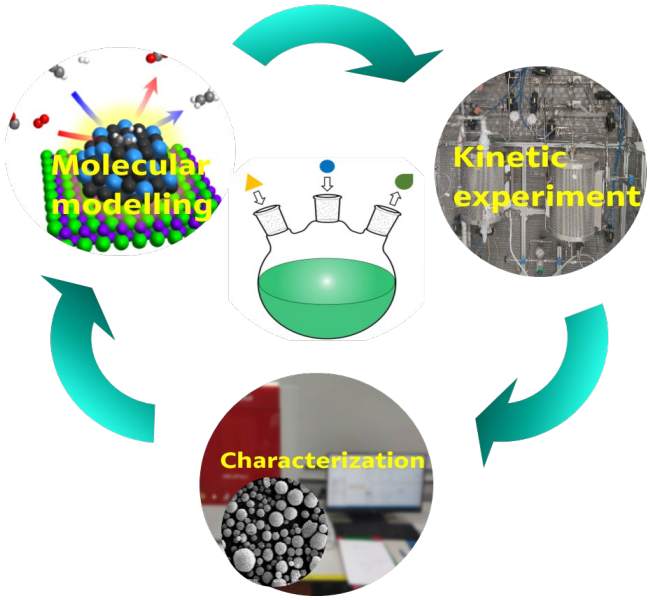
Road to TRL 1-3 on Catalyst Development

1 Prototype related to catalyst cost

Catalyst Design

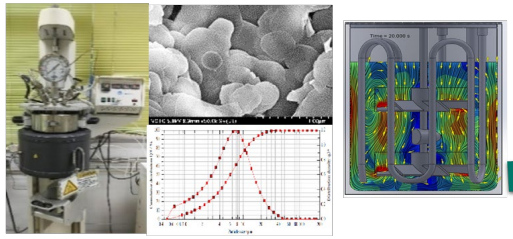


Key concepts

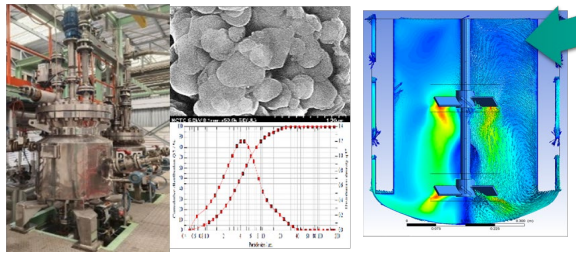
- ☑ Formulation
- ☑ Characterization
- ☑ Performance
- ☑ Regeneration

Catalyst Powder Scale up

Bench scale



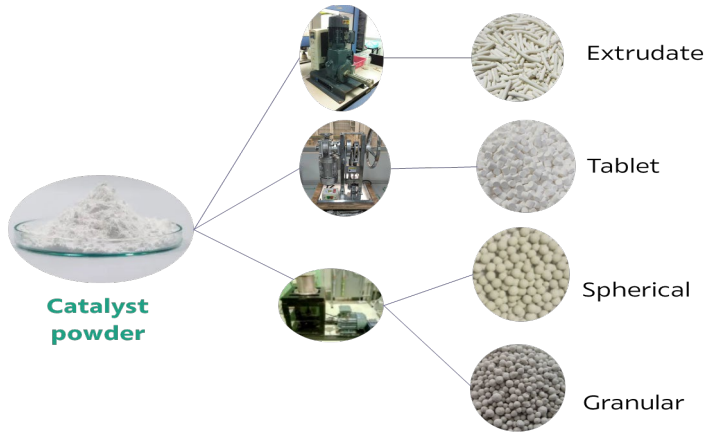
Pilot scale



Key concepts

- ☑ Raw material
- ☑ Scale ability
- ☑ Repeatability
- ☑ Specification
- ☑ Catalyst cost
- ☑ Production cost

Catalyst Pelletization



Key concepts

- ☑ Shape
- ☑ Crush strength
- ☑ Physical and chemical properties
- ☑ Performance
- ☑ Reactor design (d/d_L)

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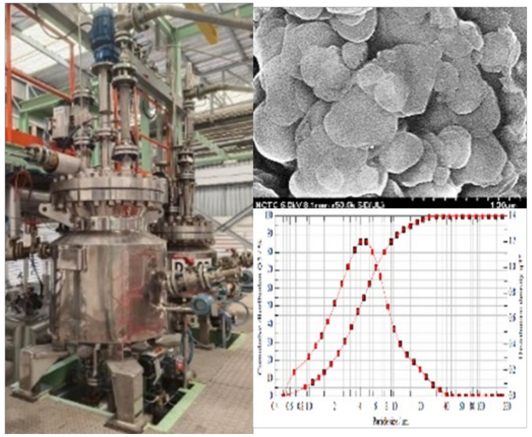
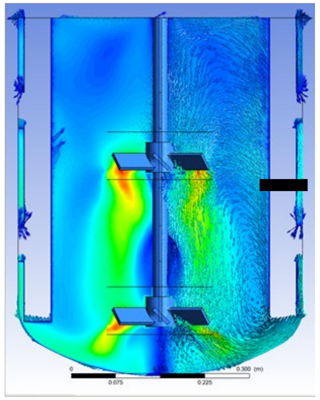
Road to TRL > 4 : Catalyst Development and Scale Up

Pilot scale





Commercialization

- Materials are common to preparing
- No special equipment or technique
- Raw material available in ton scale
- No toxic material
- Water treatment

Impact to

Equipment + Economic + Environment

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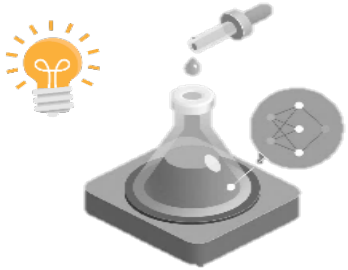
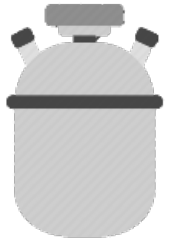
Road to TRL 1-3 : Process Design

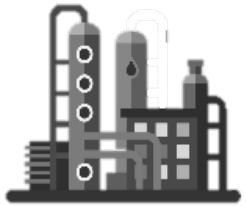


Catalyst

Process Design

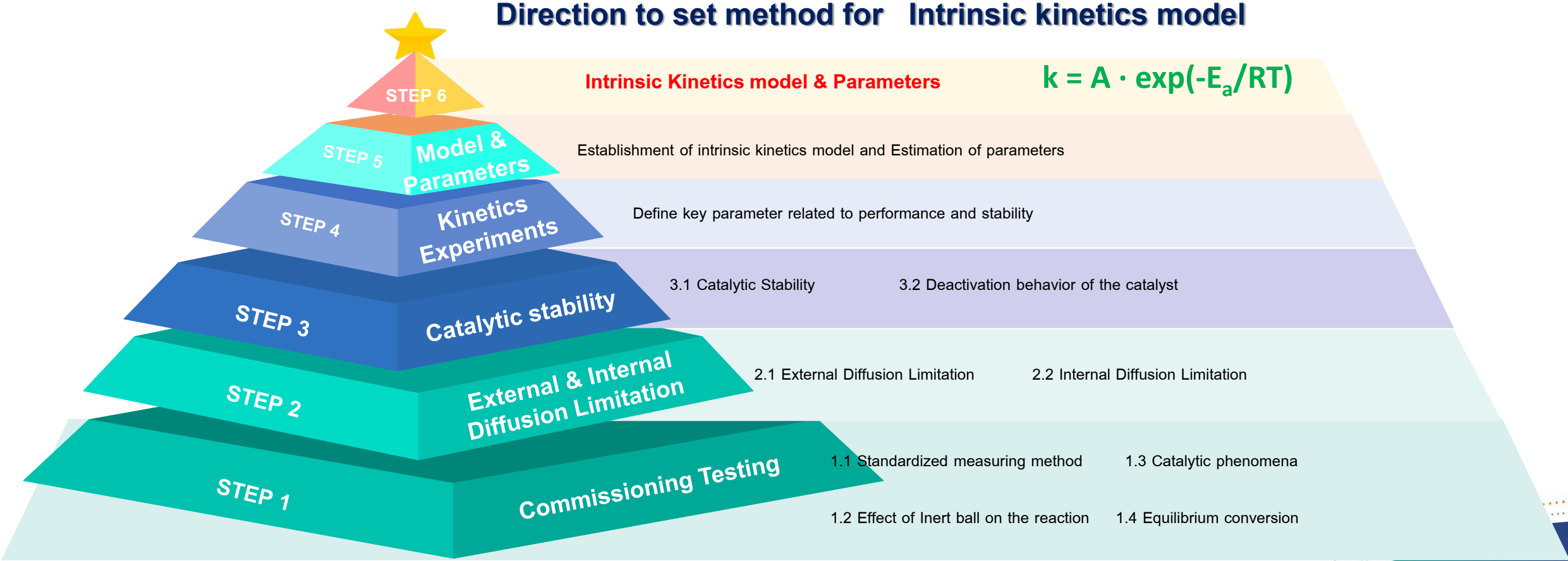


Pilot Unit



Commercialization

Direction to set method for Intrinsic kinetics model



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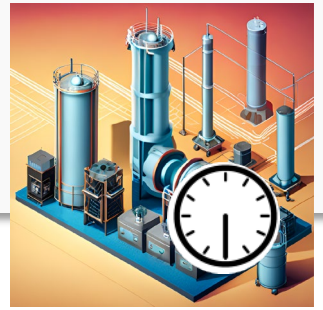
Importance Of Kinetic Model

with

Reliably reaction mechanism

Prototype of process design



Optimal process conditions

Feasibility of technology

What if *lacking* kinetic model ???

without

- Incomplete reaction pathways
- Inefficient process design
- Limit potential for process optimization
- Low accuracy & insufficient experimental data
- Risk of failure in feasibility study

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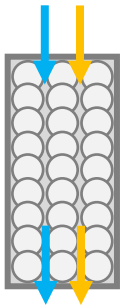
Road to TRL 1-3

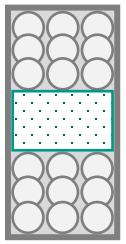
Catalyst

Feed gas

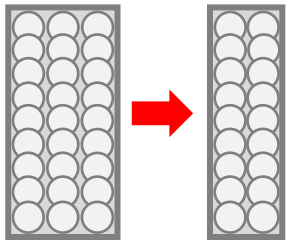
Inert gas



Gas Compositions & Mixtures



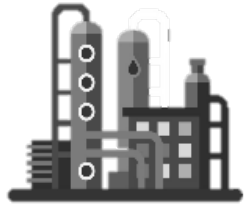
Binary Functional Material



Reactor Sizing

Process Design

Pilot Unit



Commercialization

Diffusion Prediction :

1. Intra-reactor
2. External
3. Internal

2 External Diffusion

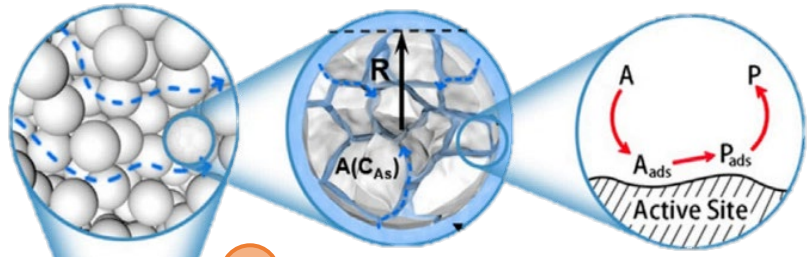
Avoiding

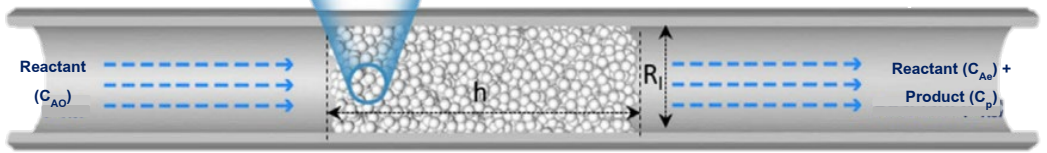
$$\frac{R_1}{R} > 10 \quad , \quad \frac{h}{R} > 50$$

1 Intra-reactor

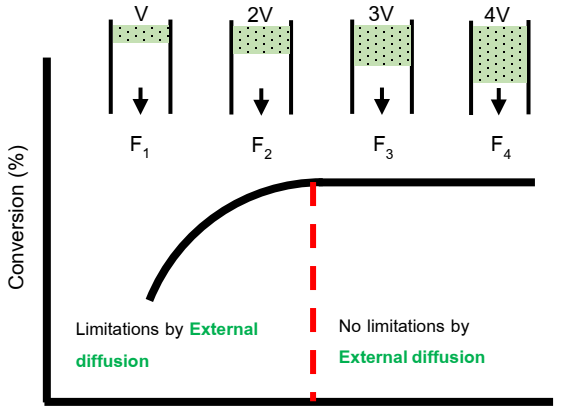
3 Internal Diffusion

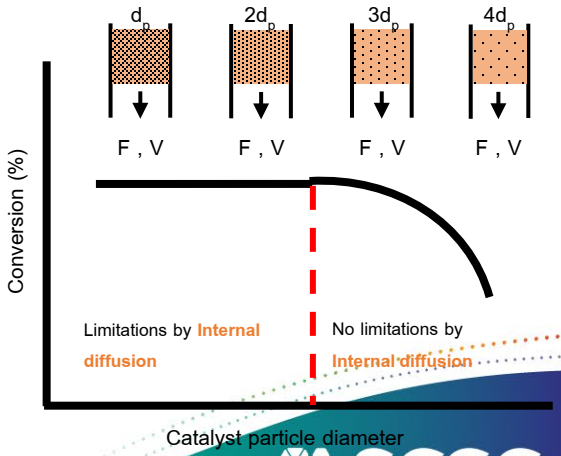
Adsorption/desorption and reaction





Approximately 75% to 80% of all heterogeneous reaction mechanisms are **Surface reaction** limited.





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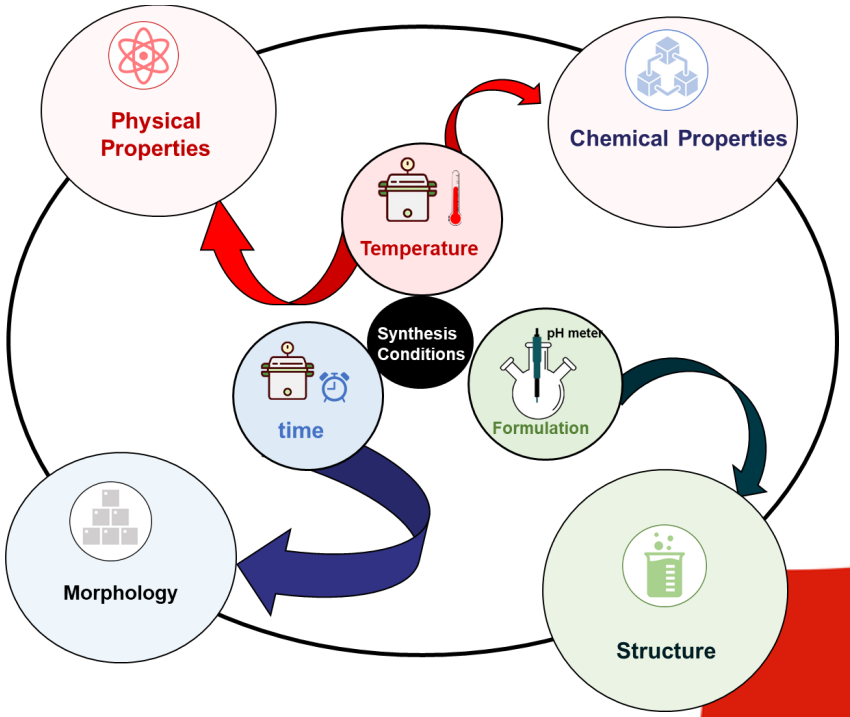
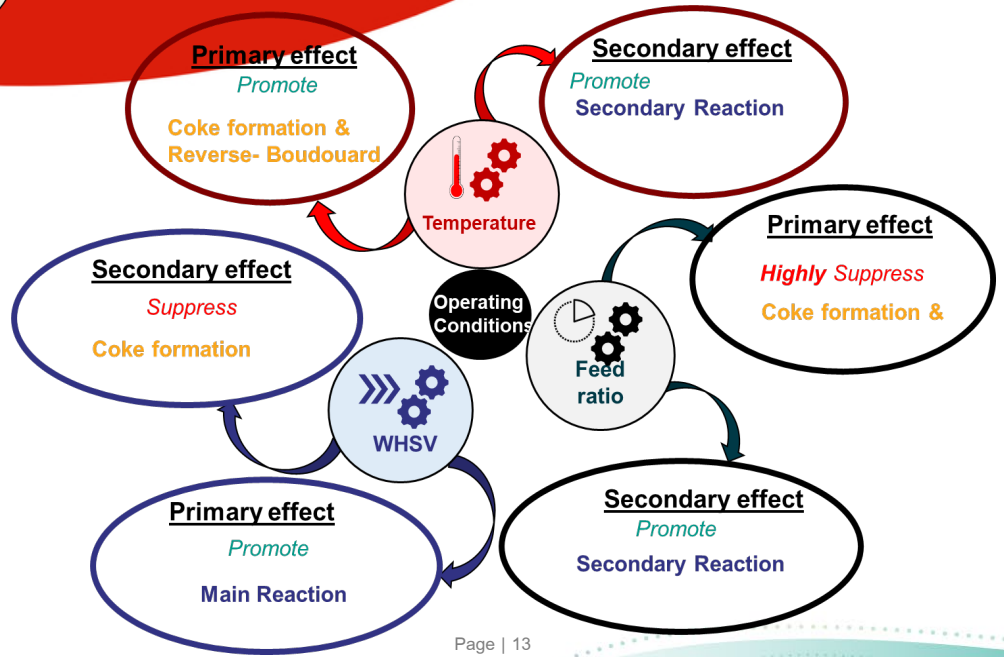
Road to TRL 1-3



Conceptual Development

Target : TRL =3-4



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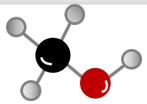
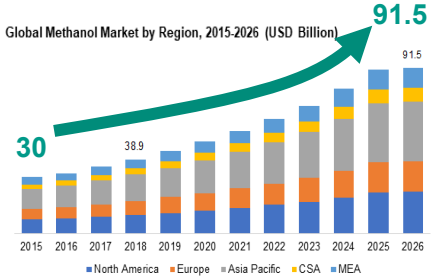
Project Show Case: CO_2 to Methanol

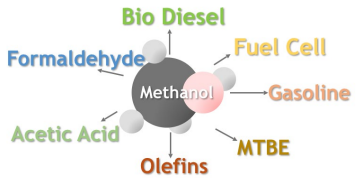
Innovation towards Carbon Neutrality

Market size





Applications



Challenges

- Low CO_2 conversion
- Impurities in feed:
  CH_4, H_2O, H_2S, NO_x, etc.
- High investment
- Purification and specification
- Low activity

SCGC Technology

CO_2 Conversion

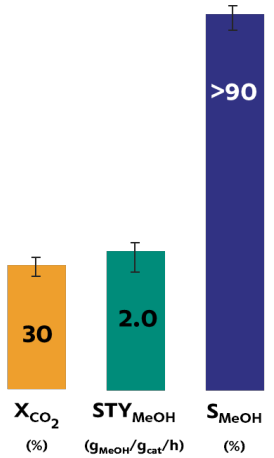
more than **30 %**

Methanol Selectivity

more than **90 %**

STY Methanol

up to **2** $g_{MeOH}\ g_{cat}^{-1}\ h^{-1}$



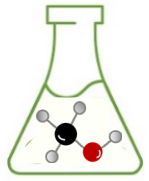
On-going development

CO_2 + H_2

CO, H_2O,

CH_4, H_2S, NO_x

Performance development



CO_2-derived methanol

in Lab-scale

TRL 4

Future Aspect

Need to do on

Start up project

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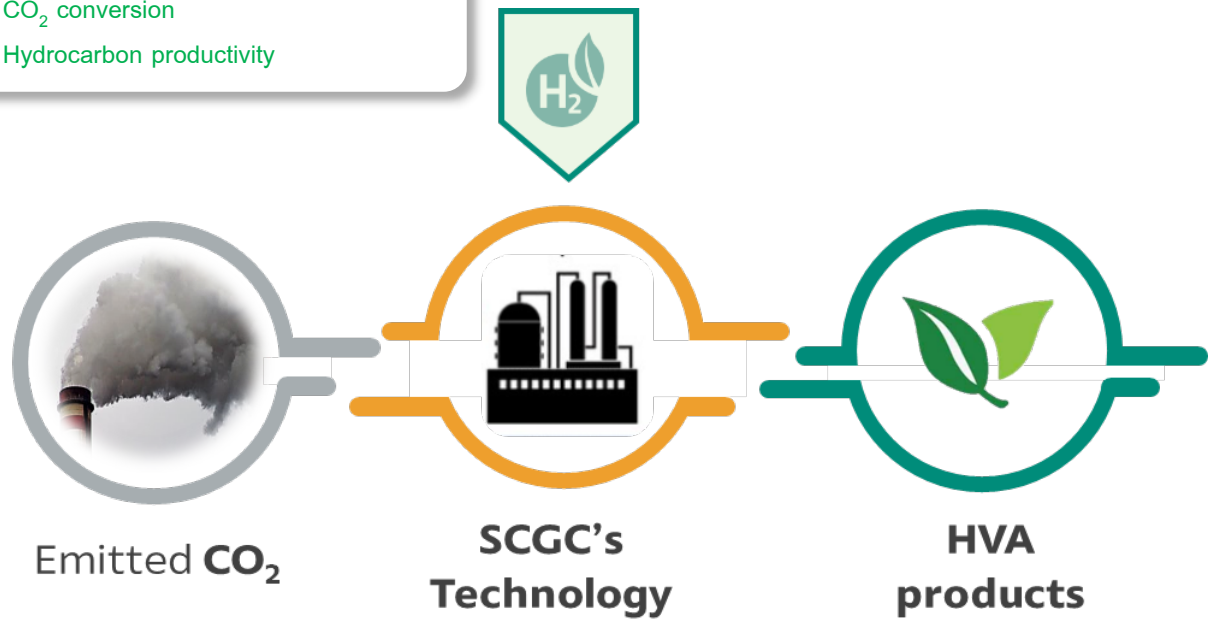
Project Show Case: CO_2 to Olefins

Innovation towards Carbon Neutrality

Improvement Challenges:

- ✓ Low CO_2 conversion
- ✓ Low Hydrocarbon productivity

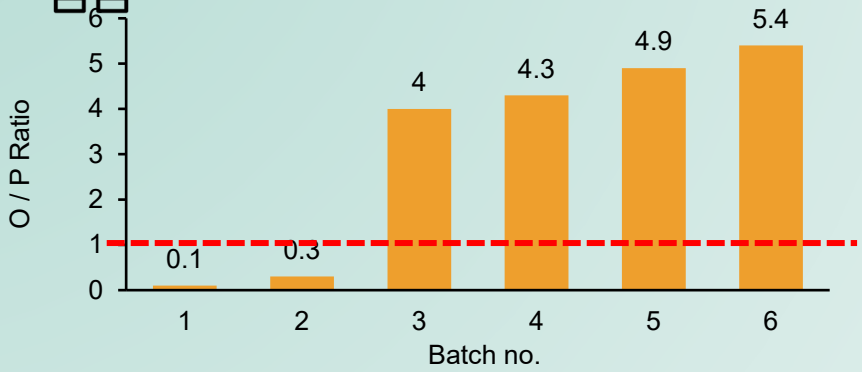


DECARBONIZABLE

Carbon conversion up to **63%**

VALUEABLE

Olefins, Chemicals, Fuels, Naphtha

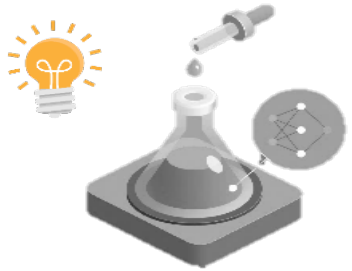


SUSTAINABLE

Potentially provide **carbon neutral**

TRL 1 2 3 4 5 6 7 8 9

Road to TRL >4 :



Catalyst

Process Design

Pilot Unit

Commercialization

Summary

Scale up ≠ Pilot Unit by Increasing Reactor Size → Feasibility, Investment, Productivity

Scale up = Start up, Collaboration, Partnership in order to solve on investment and economic → Implementation and Commercialization

C
- Feasibility
- Productivity
- Demonstration
- Economic
- Utilization
- Patent
- Licensing
- Partnership
- Construction
- Provider

C
- Investment
- Supplier
- Material Supplier

U
- Process Design
- Fundamental
- Pilot test
- Application
- Carbon Credit
- Owner
- Market size
- LCA
- Reactor Design

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BCG-CO_2 Innovation Roadmap

❑ Commercialization

2030

❑ Technology development Pilot/Demonstration plant

❑ Project Implementation

2025

2027

PARTNERSHIP

PARTNERSHIP

❑ *Ideation*

❑ *Proof of concept in Lab scale*

2020

2023

❑ Technology development in lab scale

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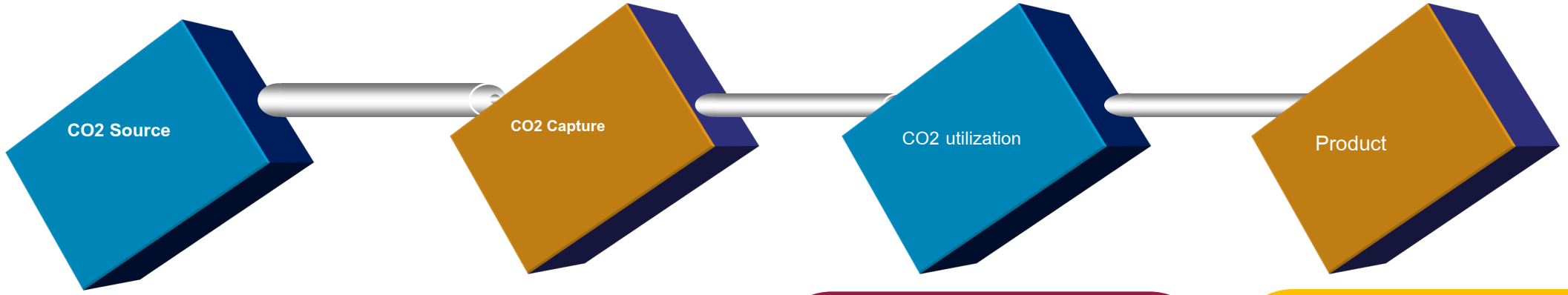
Technology Landscape



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Obstacle

- Conversion
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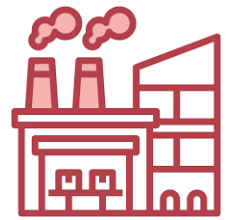
- Technology Implementation
- Technology owner
- Investment
- Feasibility/Economic
- Partnership



Commercialization

- Investment
- Technology selection

CO_2 Utilization

CO_2 Capture

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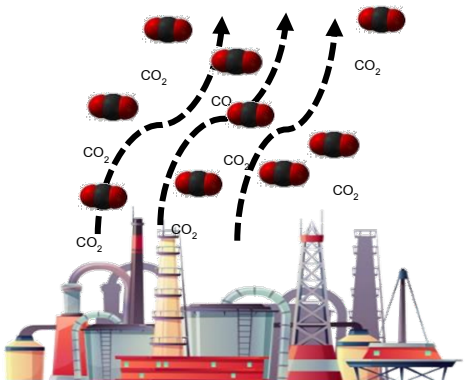

CO_2 Emission

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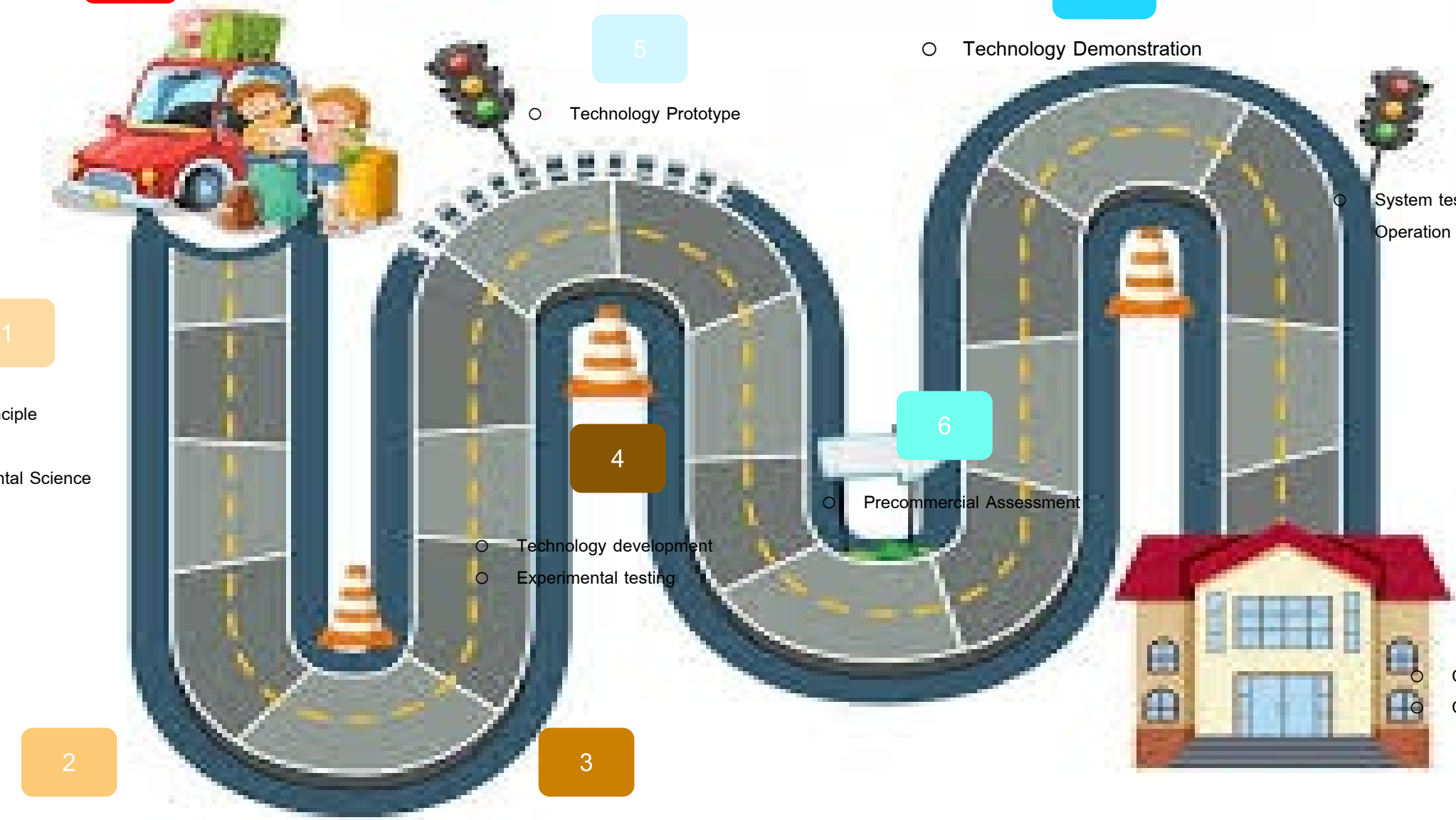
Road to TRL



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