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A Low Carbon Technology Road Map for Indian Cement Industry

Multi Criteria Analysis

for Selection of the Sustainable Low Carbon Technologies

by

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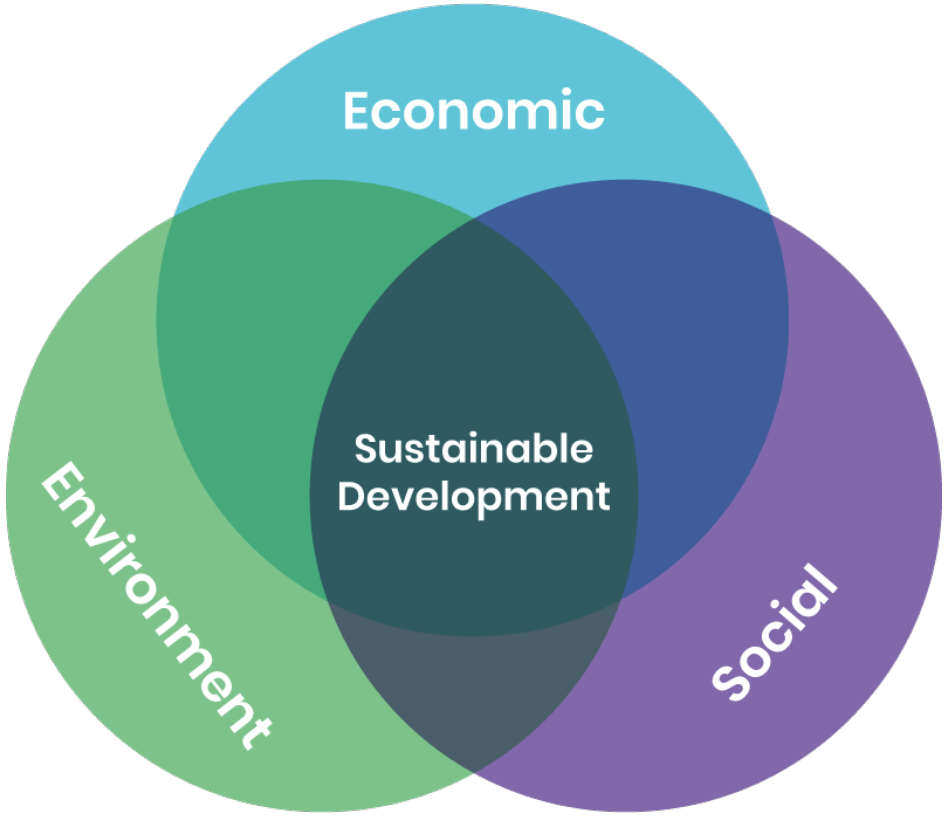
Presentation Outline

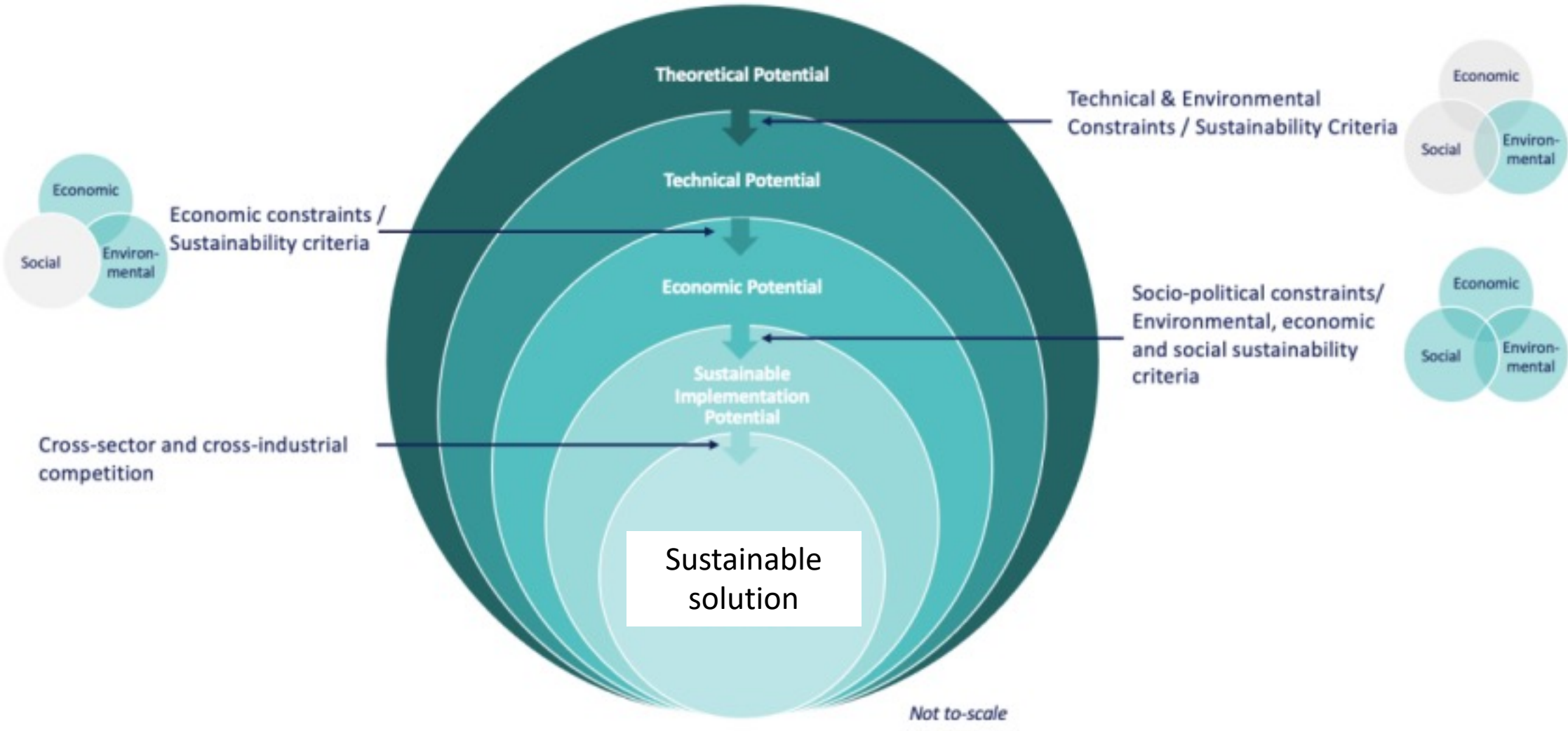
- Introduction - MCA
- Cement Industry & CO_2 emission
- Case Study – ADB/Dalmia Cement
- MCA- Salient points & Conclusion

Multi Criteria Analysis - Introduction



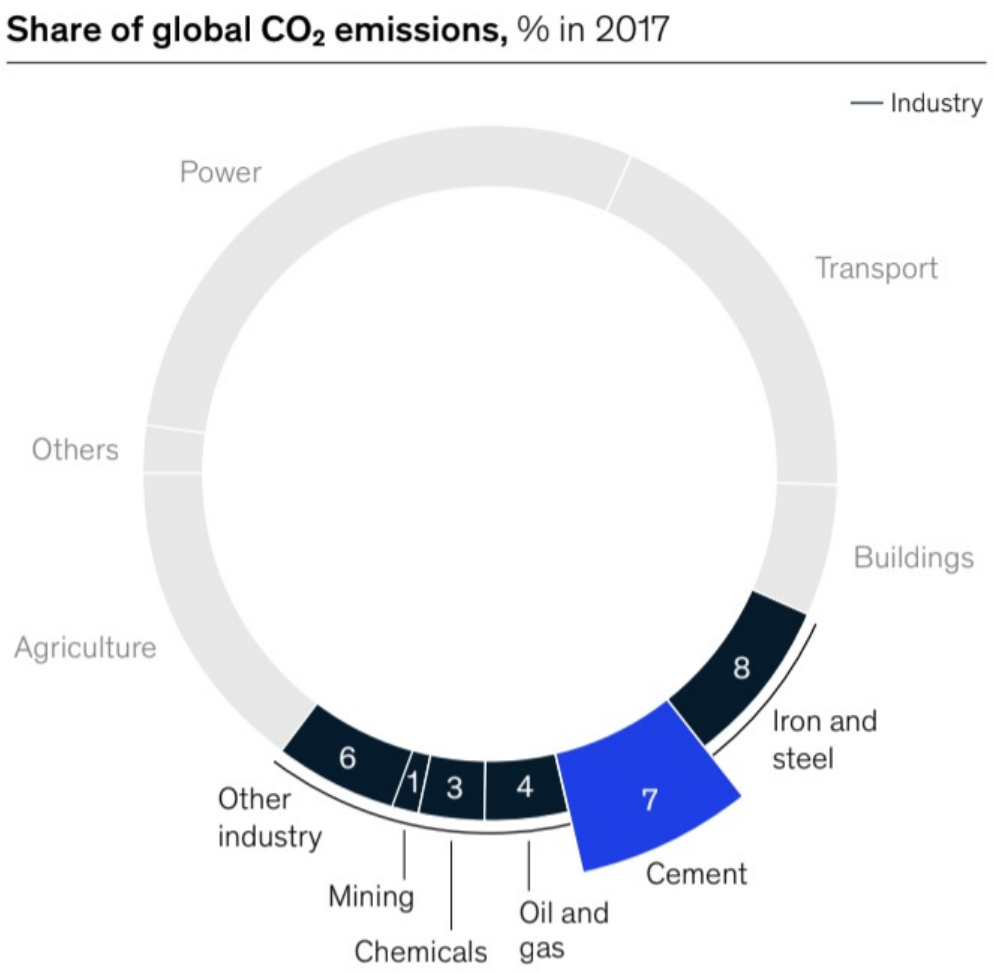
- Multi-Criteria Analysis (MCA) is a decision-making tool which establishes preferences based on an explicit set of pre-defined objectives.
- All impacts are assessed, whether they can be monetised or not, through the development of a scoring system.
- This can be used to screen, rank and short list potential options that can be appraised to identify the most optimum solution for the given set of criteria

Sustainable Solution Pathway



Source: adopted from Hoefnagels (2018), Sustainableshipping.org (2021)

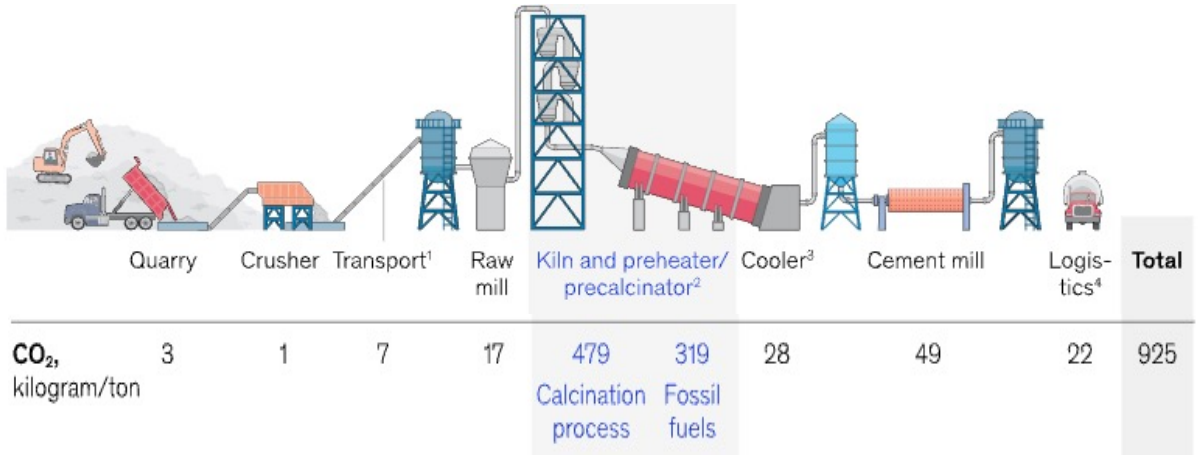
Cement Industry & CO_2 emission

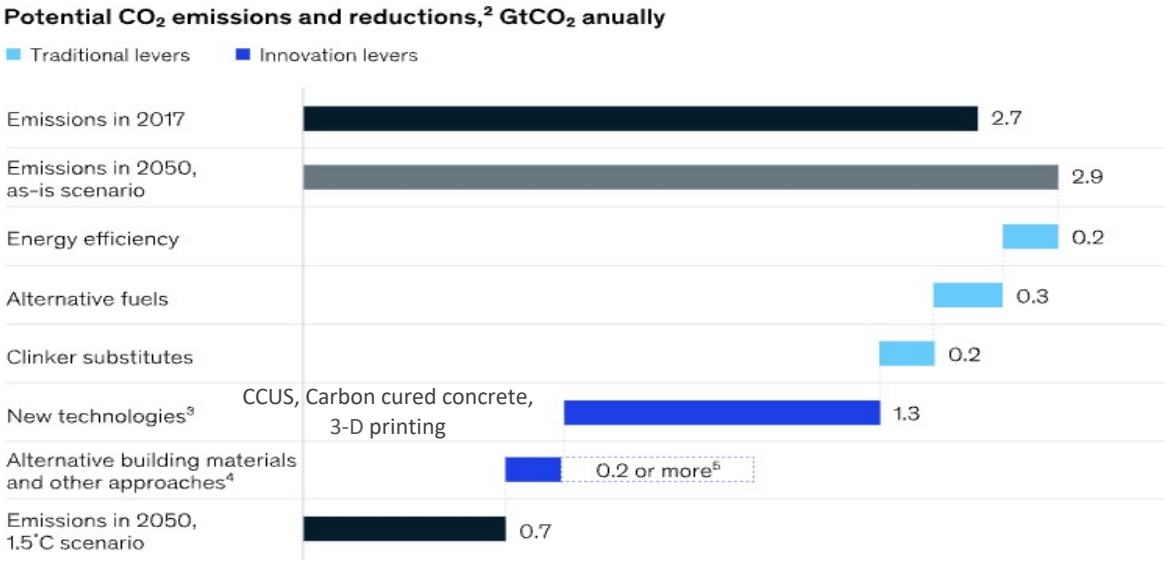


- Cement, second-most consumed product globally after potable water, for a reason: It is affordable, locally available and can be used in innumerable ways.
- Global production —> 4.2 Bn tons in 2020. Increase by 12-25% by 2050
- India produced over 0.32 Bn tons
- World is expected to build the equivalent of another New York City every month for the next 40 years.
- Hard-to-abate CO2 emitting industry. Major CO2 emission is process centric CO2

Sources: World cement 2022, Marta G. Plaza et. al 2020, McKinsey

Cement Industry





Source: adopted from McKinsey (2020)

- Cement industry, being "Hard-to-abate" CO_2 emitter, finding a sustainable CO_2 mitigation solution is a challenge
- Innovative technologies essential to mitigate CO_2
- Multiple CO_2 abatement technologies available at various Technology Readiness Level (TRL)
- Proper due diligence is a Must
- MCA considers multiple performance factors and organizational priorities and helps arrive at Most Optimum Solution in transparent and consistent manner.

MCA Case Study

CO_2 Utilization

Product Selection using MCA

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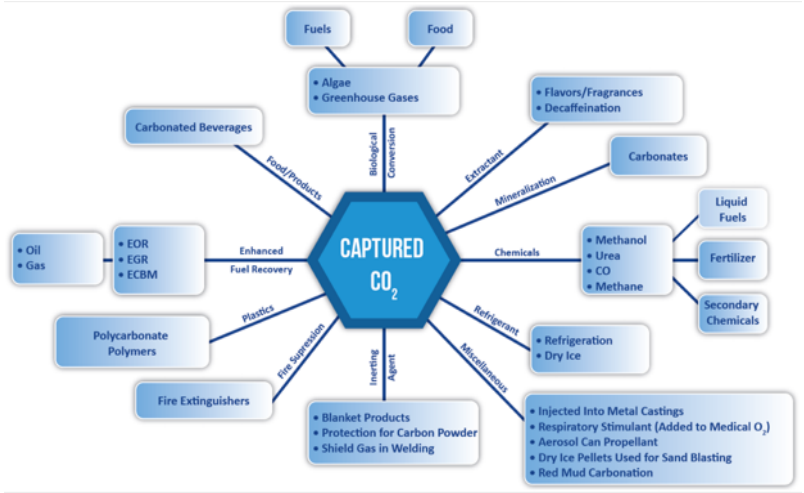
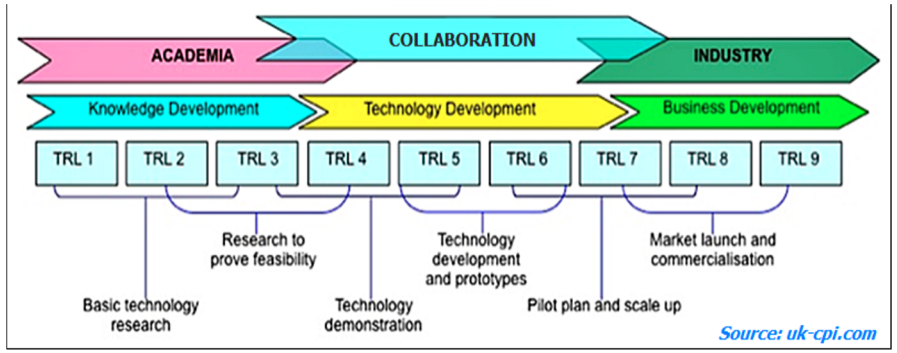
Source: Bhujade R. ADB 2021

CO_2 Utilization Selection Approach

Multiple pathways and products



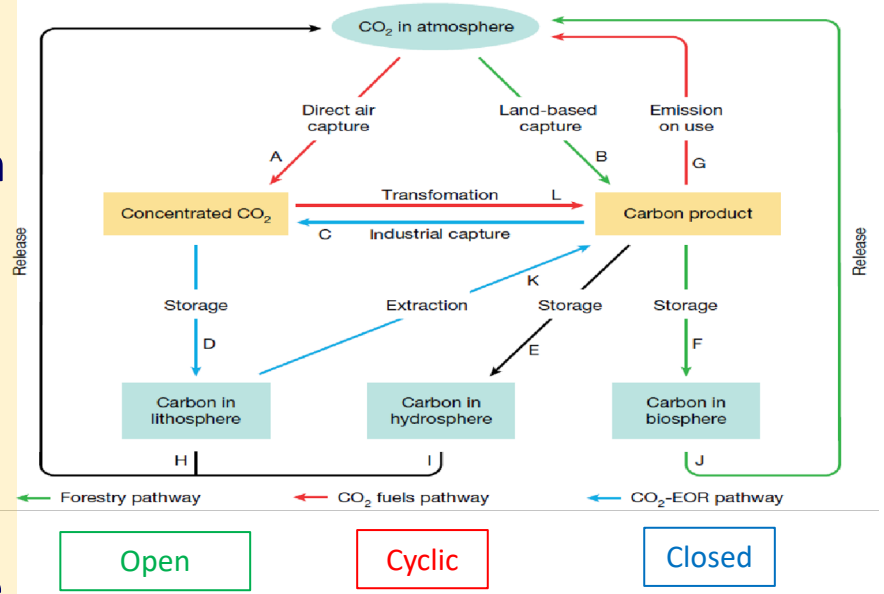
Technology Readiness Level



Graphic Sources: Refer to ADB report by Bhujade R.

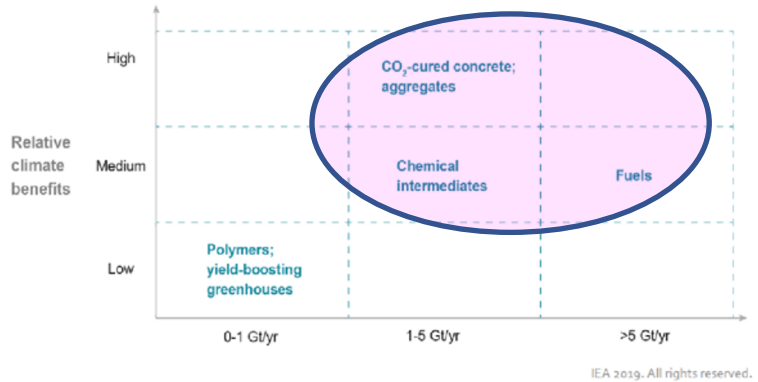
- Technology overview
  - Use w/o conversion or with Conversion
- Implementation
  - Within short term
  - TRL 7+
- Fate of C
  - Carbon neutral/ -ve
- CU Potential
  - Significant/Impactful
- Economics
  - Sustainable

Fate of CO_2 captured and Utilized



Open | Cyclic | Closed

Potential to make Climate Impact



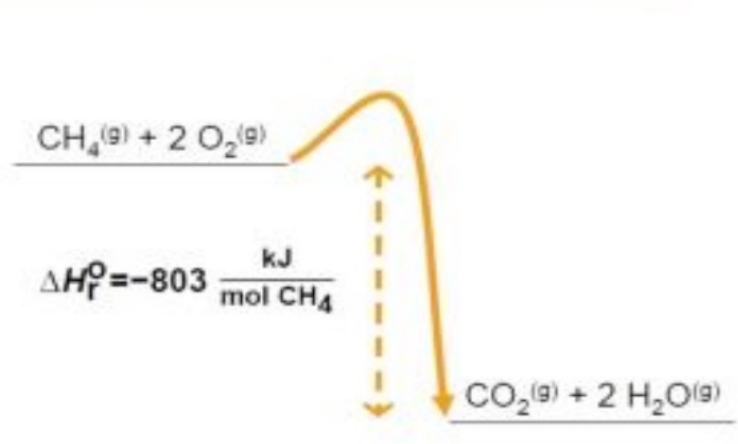
Multiple pathways and lower TRL of Innovative technologies make product selection more challenging

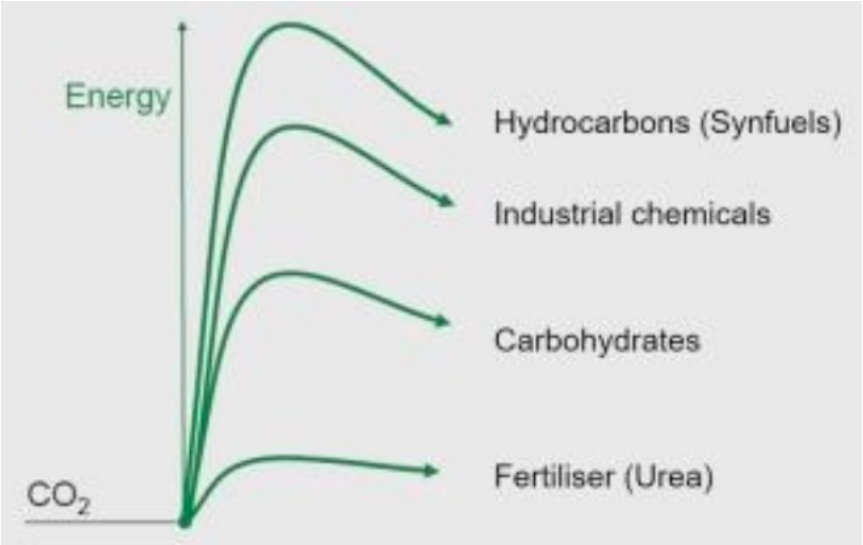
CO_2 Utilization – Emerging Technology companies

Source: Issam Dairanieh, CCCU Compendium, ADB, 2020

Investment of over $ 18000 Mn committed by Governments, Corporates and VCs for CCU projects

Thermodynamics of CO_2

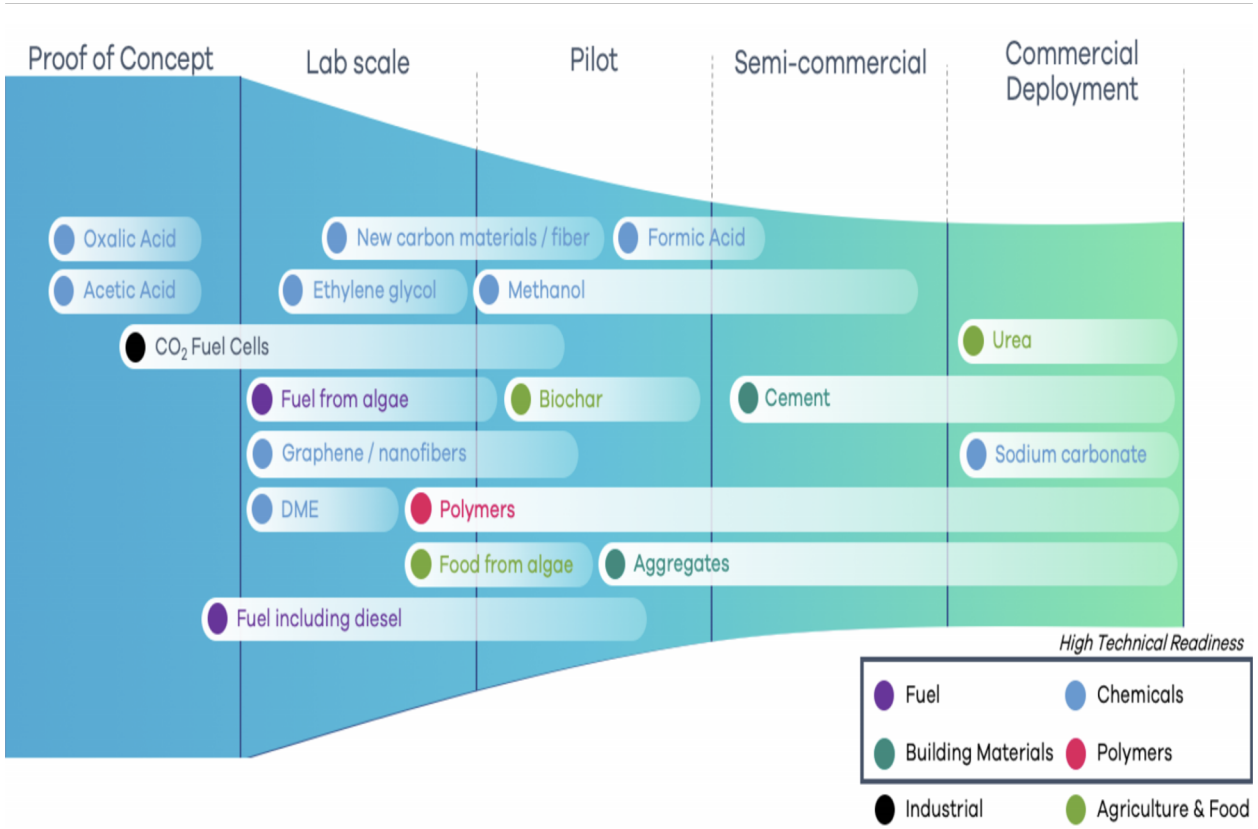




- Thermodynamics provides a quantitative measure for chemical conversion of CO2
- Energy generation from conventional fuels produces CO2 – the extremely stable compound
- Converting CO2 back to fuel or chemicals requires energy.
- Providing required energy using fossil will generate more CO2 !
- Only workable option is to use renewable energy and green hydrogen

Source: Chris Venter 2021 et. al, Brudermüller, 2019

CO_2 Utilization Technology maturity

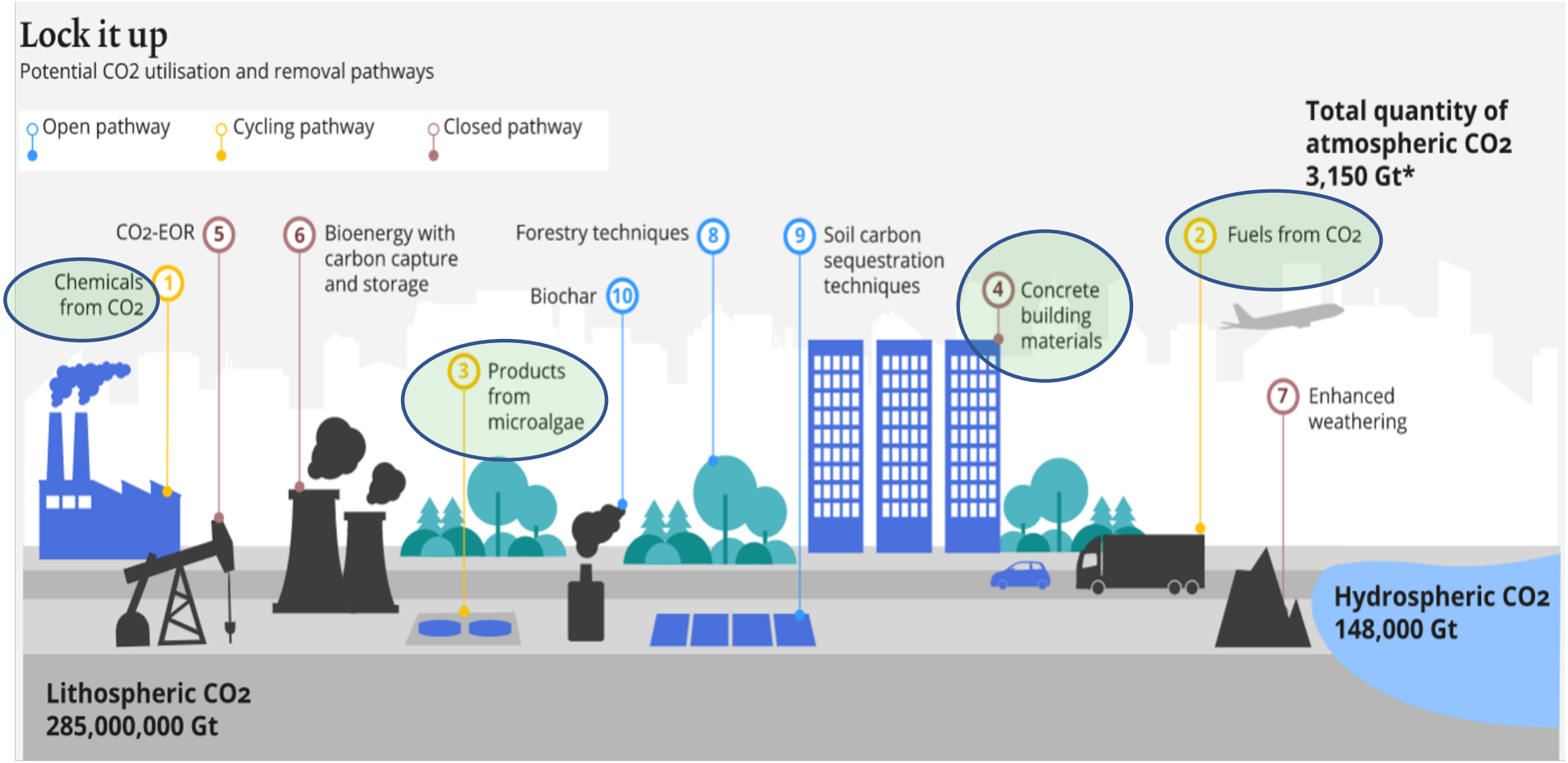


- **Essential elements for commercialization**
  - Technology readiness Level (TRL)
  - Policy drivers
  - Market readiness
- **TRL of potential options:**
  - TRL 1–3, Research
  - TRL 4–5, Pilot
  - TRL 6-7, Demonstration
  - TRL 8: First-of-a-kind commercial demo
  - TRL 9: Actual system proven in an operational and competitive environment
- **Investment potential**
  - Triple Helix Scenario – means good investment opportunity
  - CO_2-based building material, Specialty chemicals
  - Direct Air Capture, expected as a game changer

https://demoplants.bioenergy2020.eu/explanations.html;Issam Dairanieh, CCCU Compendium, ADB, 2020

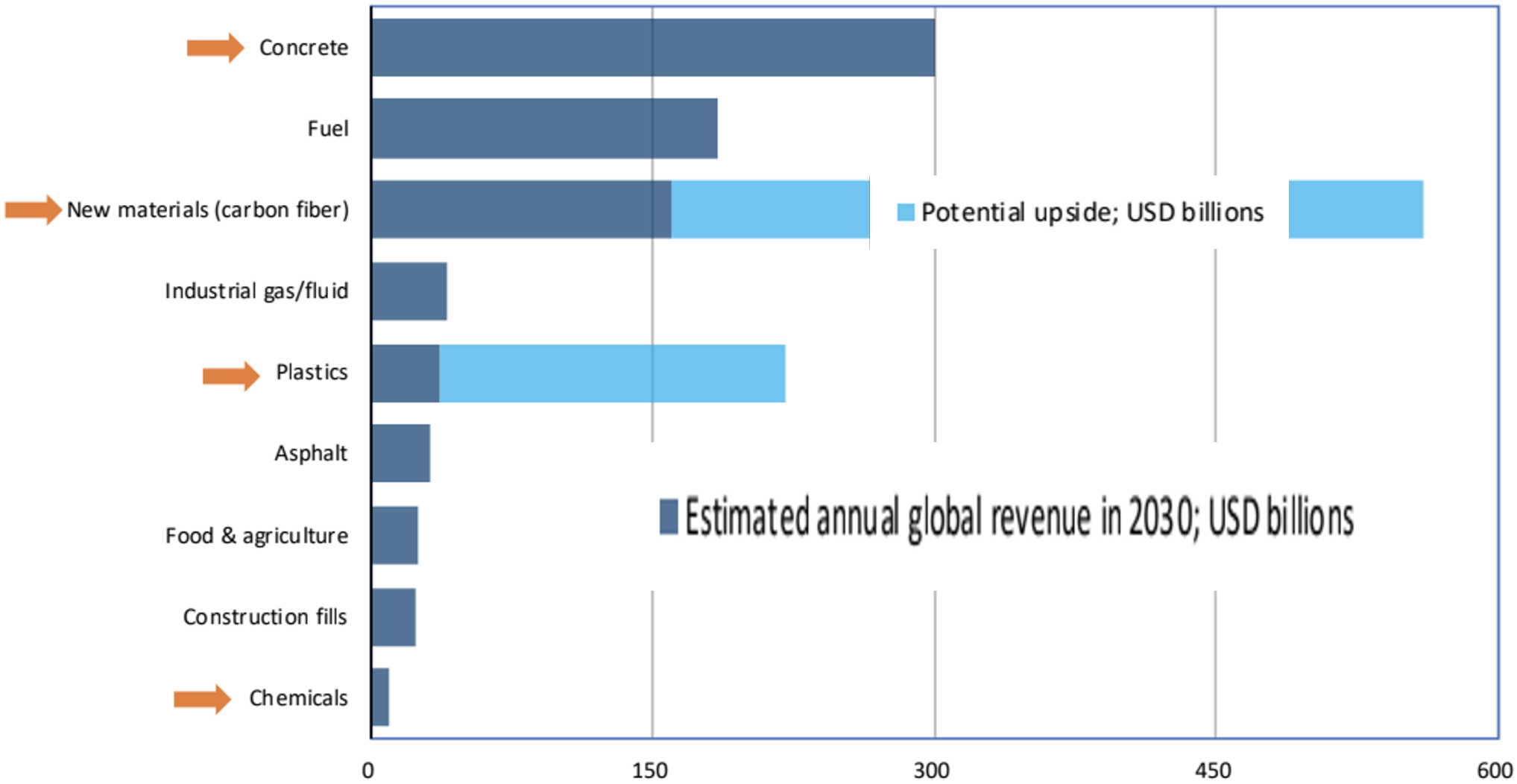
TRL decides the timeframe for commercial deployment of the technology

CO_2 Fate - Utilization and Removal Pathways



Source: Adopted from Cameron Recycling CO2, Mega online, Feb 2020

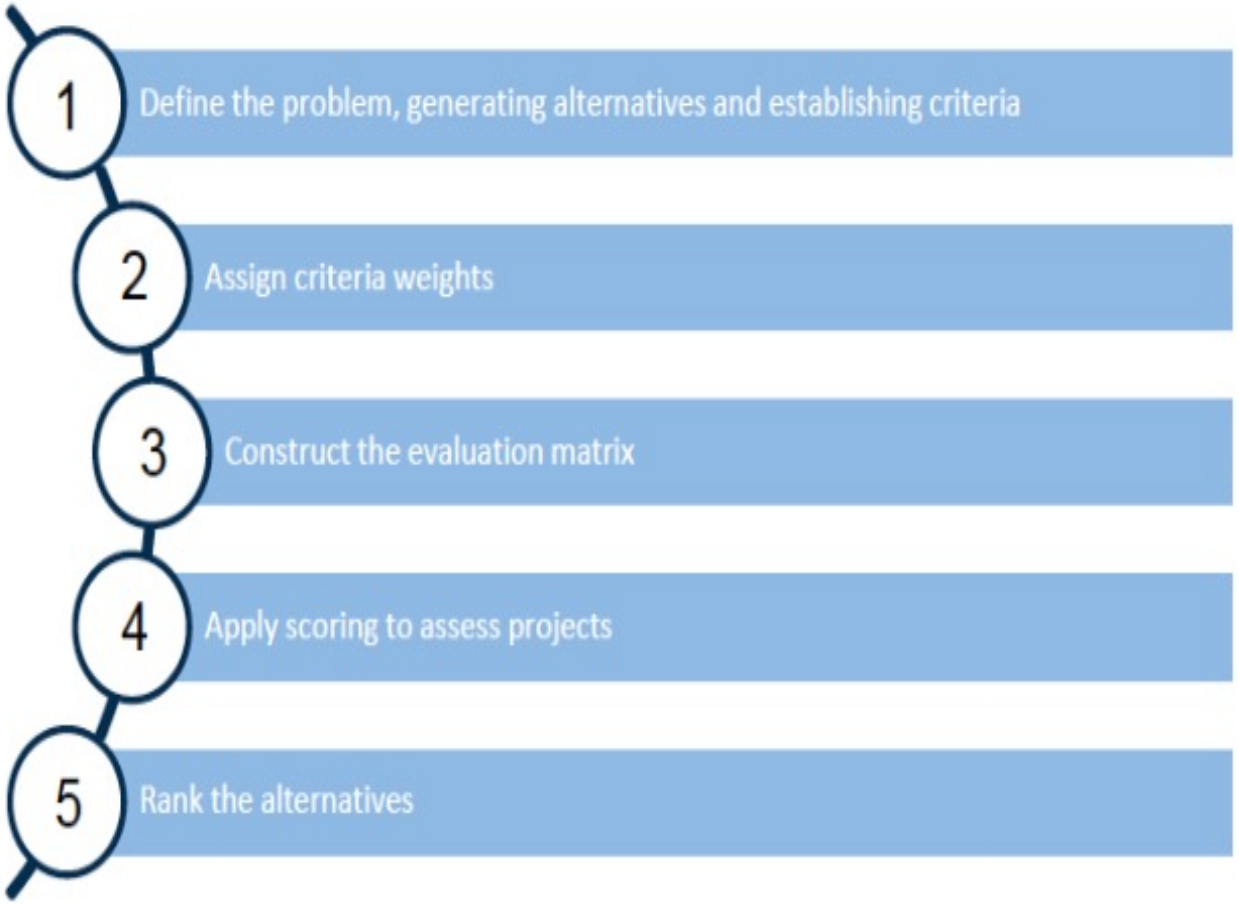
CO_2 Utlilization - Market potential



Source: The Global CO2 Initiative, 2017, Issam Dairanieh, CCCU Compendium, ADB, 2020

Large market potential of CO2 derived products make CO2 as a valuable resource

Multi Criteria Analysis – Key steps & Methods

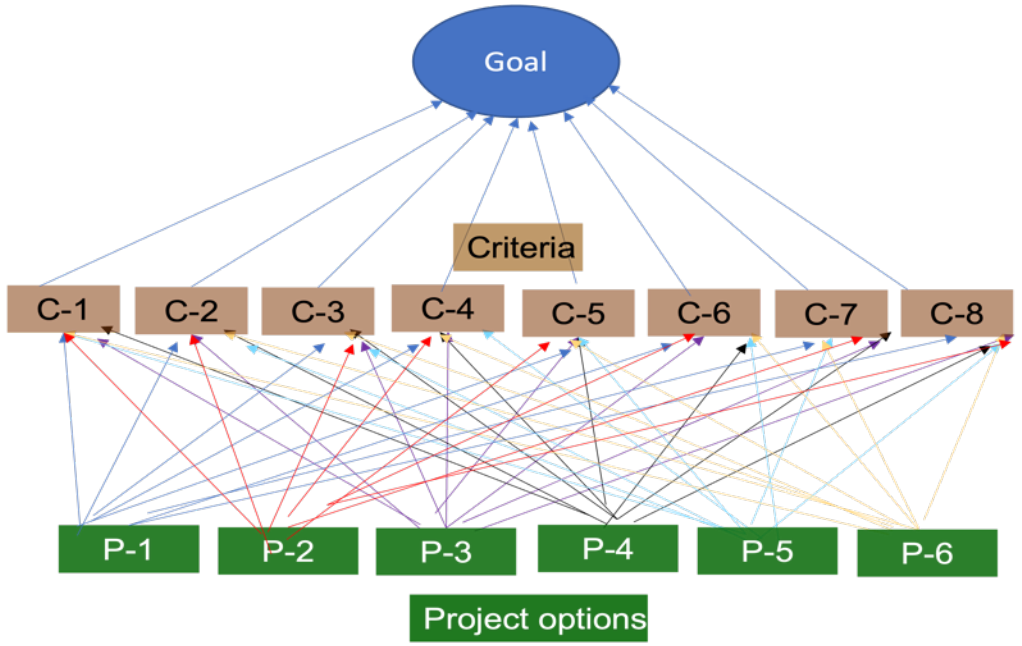


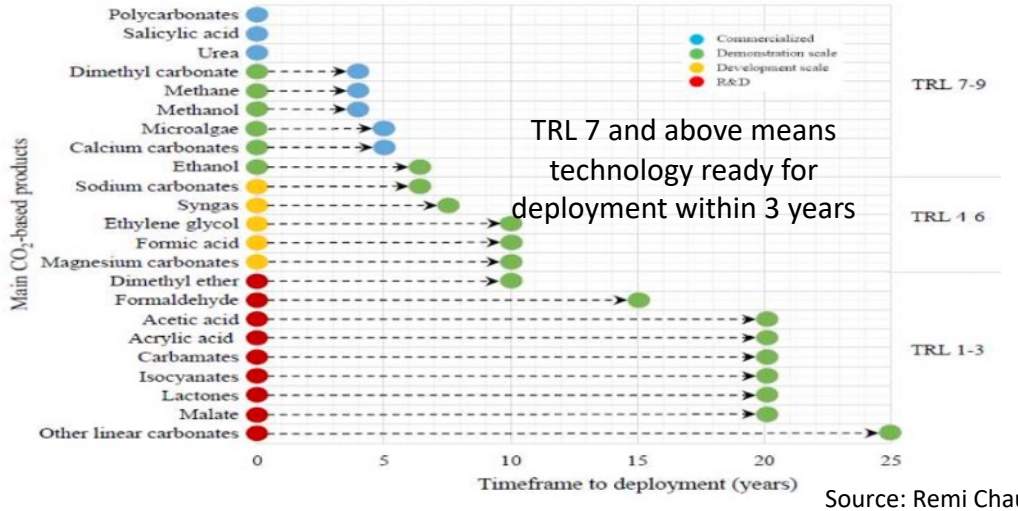
- Non-compensatory methods:
  - LexiMin and LexiMax
- Aggregation-based methods. Relatively decisive
  - Weighted Sum Model
  - Analytical Hierarchy Process
- Elimination and choice expressing reality approach.
- Outranking method – when qualitative data is available
- Hybrid methods – Combination of Data mining/ML and MCA methods

The complexity and extent of data availability decide the type of MCA technique to be used

How Is Urea selected ? Multi Criteria Analysis (MCA)

#	Parameter	Weightage
1	**TRL (7 and above)**	**40**
2	**Capex, INR/t CO_2**	10
3	**Opex, INR/t CO_2**	10
4	**ROI/Payback time**	10
5	**Market Demand**	13
6	Electrical, kWh/t CO_2	8
7	Steam, GJ/t CO_2	4
8	Avoidance of CC	5
	Total Score	100





TRL 7 and above means technology ready for deployment within 3 years

Source: Remi Chauvy et. Al. 2019

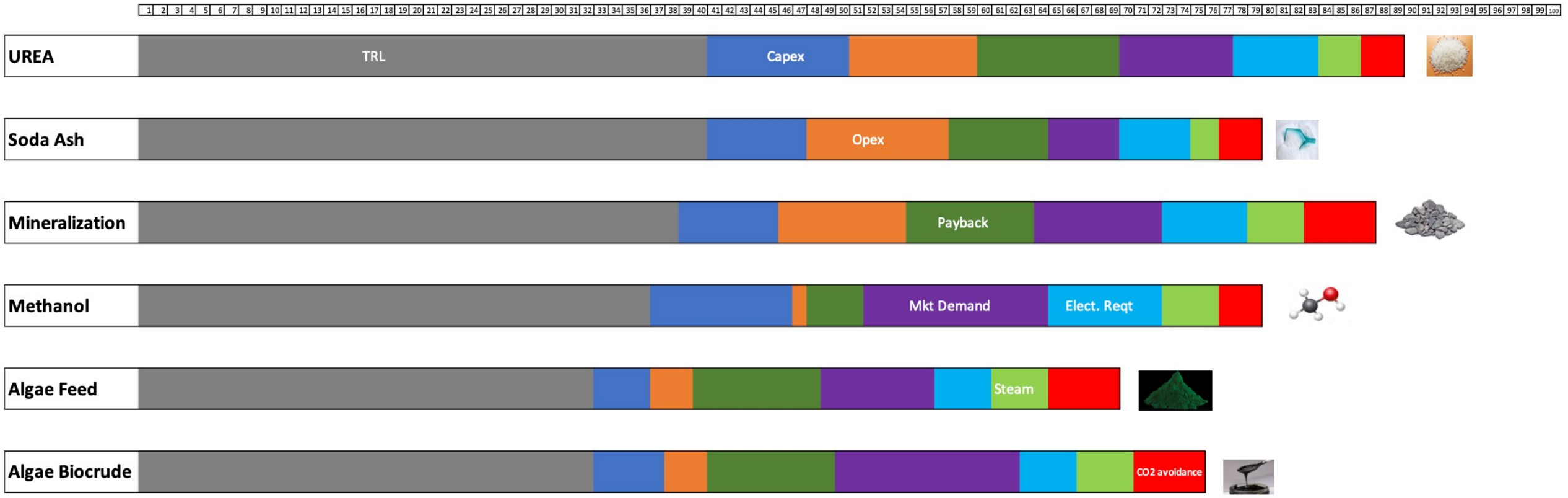
Economic parameters and TRL contribute over 70 % of the total weightage

Projects under evaluation – Tech features

#	Description	Urea	Soda Ash	Mineralization	Methanol	Algae feed	Algal Biocrude
	Process	Generic	Modified Salvay	Carbonation	Hydrogenation	Photosynthesis	PS+HTL
	Tech Status	Commercial	Commercial	Commercial/Demo	Pilot plant	Pilot plant	Pilot plant
1	TRL	**9**	**9**	8 to 9	7 to 9	5 to 8	5 to 8
2	CO_2 purity	High purity	High purity	10-100%	High purity	10-100%	10-100%
3	Major feedstocks	NH_3	Brine, NH_3	Mineral/residues	H_2	Nutrients	Catalyst
5	Market Demand	++	+ Large	Very large +++	+++	++	+++
6	Electrical Demand	Yes	Yes	Yes	Yes	Yes	Yes
7	Steam Demand	Yes	Yes	Not essential	Yes	Not essential	Not essential
8	Avoidance of CC	No	No	Possible	No	Possible	Possible
9	**Unique features**	Govt. subsidies on product pricing. Low GHG reduction potential	Low GHG reduction potential	*High GHG reduction regulatory reqts. Double benefits: Product replacement and CO_2 permanent removal*	**Low C carrier** of H2 **in liquid form**. Wide applications as fuel/ feedstock. **"Renewable power, the Key"**	Effluent/non-potable water (Large water handling) Large land area (non-agri)	Additional flexibility with HTL. No drying of feed. Co-processing of different wastes possible

Source: Adopted from Bhujade R. ADB, 2021

MCA – *Individual* Score for CO_2 Utilization projects



Source: Adopted from Bhujade R. ADB, 2021

Urea and Mineralization are top-ranking options for short term implementation

Urea chemistry

Integrated Urea Plant

Ammonia Production

Reaction 1:
$\mathbf{CH_4} + H_2O \rightarrow CO + 3\ H_2$

Reaction 2:
$CO + H_2O \rightarrow \mathbf{CO_2} + H_2$

Reaction 3:
$3\ H_2 + N_2 \rightarrow \mathbf{2\ NH_3}$

Urea Synthesis

Reaction 4:
$\mathbf{CO_2} + \mathbf{2\ NH_3} \rightarrow NH_2COONH_4$

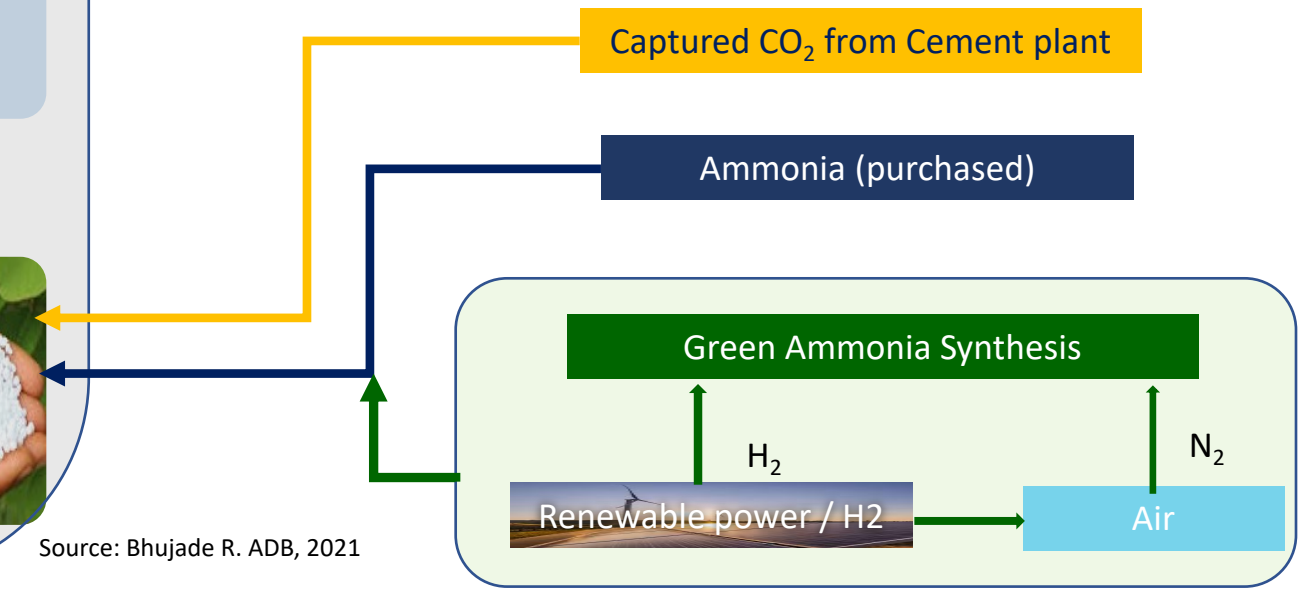
Reaction 5:
$NH_2COONH_4 \rightarrow \mathbf{NH_2CONH_2} + H_2O$

NG / Coal

$\mathbf{2\ NH_3} + \mathbf{CO_2}$

- Conventionally, Urea plants are integrated plants: Ammonia is produced at the same site as CO_2, with NG or Coal as a feedstock

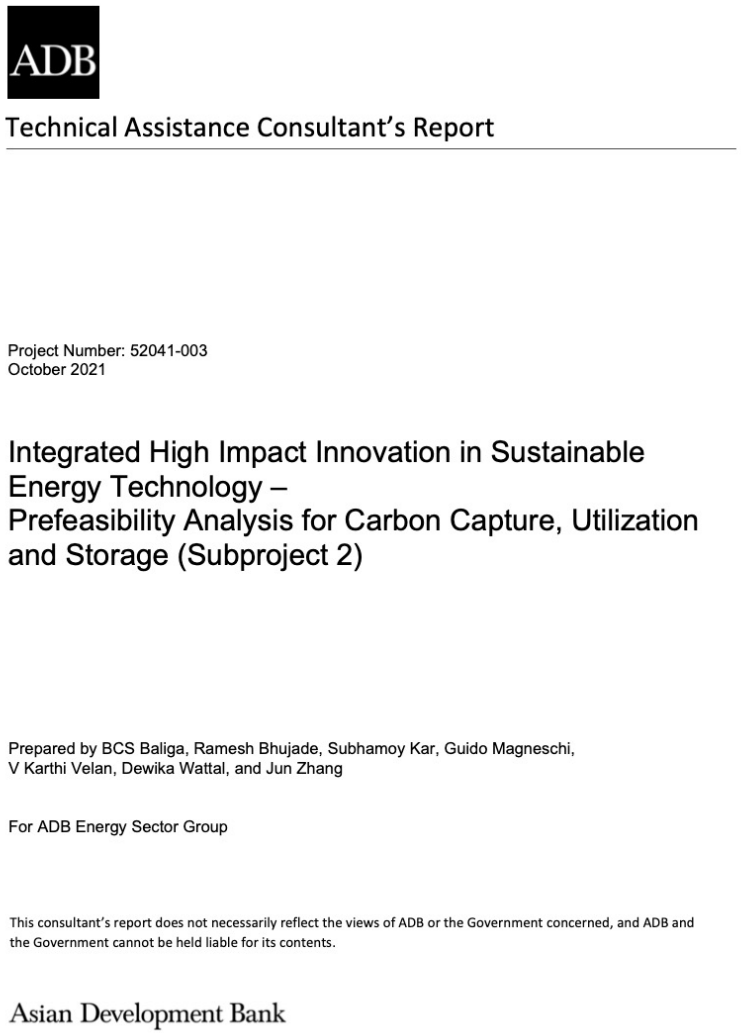
- Stand-alone CO_2 utilization plant will need ammonia as a feed



Source: Bhujade R. ADB, 2021

Technology is matured & optimized over the decades for resource optimization and process safety

CO2 Utilization Pathway Selection: Case study Summary



ADB

Technical Assistance Consultant's Report

Project Number: 52041-003
October 2021

Integrated High Impact Innovation in Sustainable Energy Technology –
Prefeasibility Analysis for Carbon Capture, Utilization and Storage (Subproject 2)

Prepared by BCS Baliga, Ramesh Bhujade, Subhamoy Kar, Guido Magneschi, V Karthi Velan, Dewika Wattal, and Jun Zhang

For ADB Energy Sector Group

This consultant's report does not necessarily reflect the views of ADB or the Government concerned, and ADB and the Government cannot be held liable for its contents.

Asian Development Bank

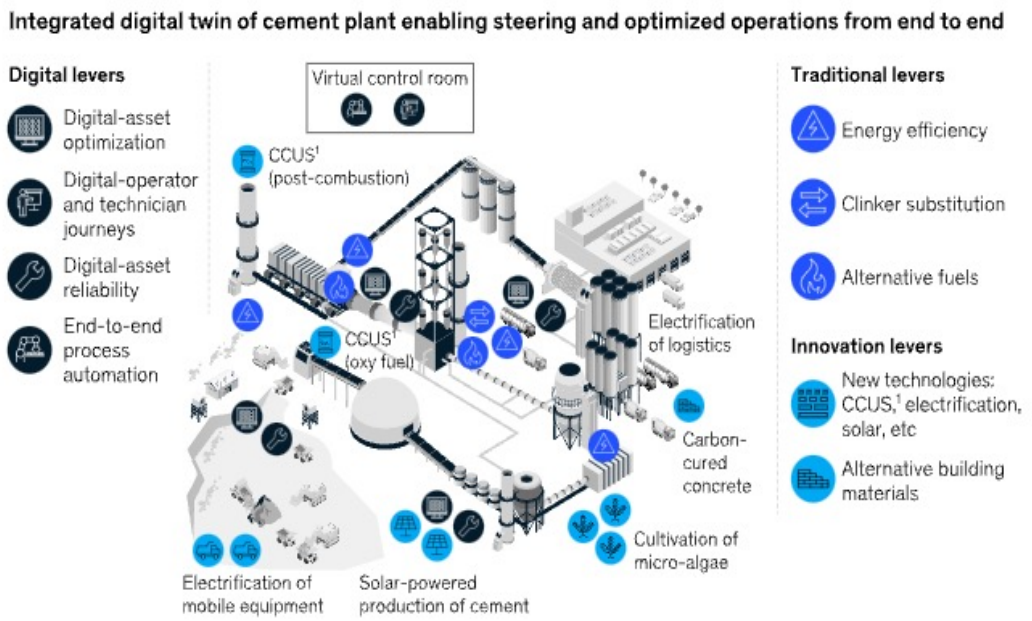
Source: Bhujade R. ADB 2021

- Multiple CO2 Utilization pathways at various TRL
- Hundreds of publications, and technology developers claiming various benefits makes CO_2-derived product selection challenging
- Multi-Criteria analysis (MCA) helped decide most suitable CO_2 utilization strategy.
- Major criteria, as set for pre-feasibility: TRL (7 plus), Economic viability, Market potential and GHG reduction potential
- Technology pathways & products short listed:
  - Soda ash, Urea, Mineralization, Methane, Methanol, Algae,
- Products ranking through MCA and client-specific requirements (Economic details in the published report)
  - **Short term**: Urea, Soda ash
  - Medium term: Mineralization, Methanol
  - Long term: Algae to fuel and feed

MCA model developed by ADB consultant team can be used as a tool for screening of CO_2 utilization technologies

MCA – Salient features & Conclusion

Cement plants of future – Green & Digitally enabled



Source: Graphics adopted from McKinsey analysis, 2020

- Subjectivity reduces and transparency comes in with MCA in decision making.
- Provides directional guidance for decision making, when there are multiple and competing options
- MCA is most appropriate for assessment of innovation technologies at lower TRL. Insufficient data at lower TRL makes decision making more challenging.
- MCA techniques are distinguished from each other principally in terms of how they process basic information. Choice of MCA type depends on complexity of the scenario
- MCA results need revisit when basis changes and significant time is lapsed after the original study

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