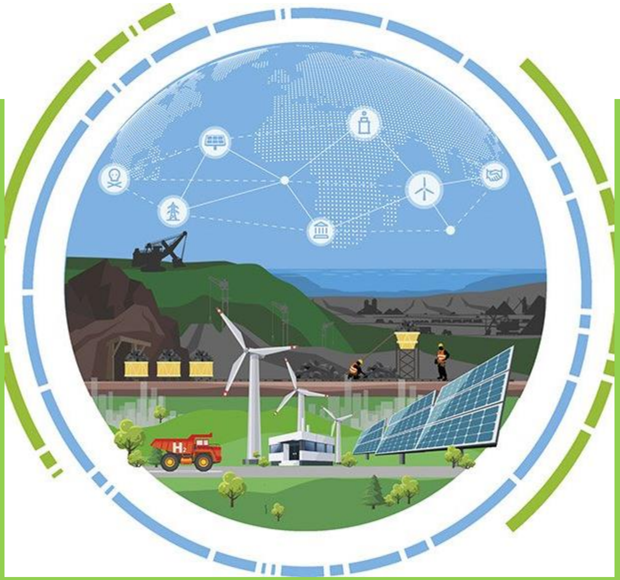
Decarbonization, Technologies and Way Forward



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18th August 2022

INDIA

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For India

1. Introduction

Decarbonization

Introduction

General Meaning

The word decarbonization refers to all measures through which a business sector, or an entity – a government, an organization – reduces its carbon footprint, primarily its greenhouse gas emissions, carbon dioxide (CO_2) and methane (CH_4), in order to reduce its impact on the climate.

Why is It required?

- The world is not on track to meet the Paris Agreement targets of limiting global warming to ideally 1.5°C. Current policies imply >3°C warming by the end of the century.
- This will be disastrous, and India will be among the countries most affected.
- The IPCC has estimated that to achieve the 1.5°C target the world as a whole must reach net zero CO_2 emissions by 2050.

2. COP26

India

UN – COP26

UN Climate Change Conference - 2021

COP26 brought together 120 world leaders and over 40,000 registered participants, including 22,274 party delegates, 14,124 observers and 3,886 media representatives.

What was Agreed?

- ***Recognizing the emergency***: Countries reaffirmed the Paris Agreement goal.
- ***Accelerating action***: CO_2 emissions must be reduced by 45 % to reach net zero around mid-century.
- ***Moving away from fossil fuels***: Phase-down of coal power.
- ***Delivering on climate finance***: Developed countries to fully deliver on the US$100 billion goal urgently.
- ***Stepping up support for adaptation***: Adapting to the impacts of climate change and building resilience.
- ***Completing the Paris rulebook***: Practical implementation of the Paris Agreement, Enhanced Transparency Framework, providing for common timeframes.
- ***Focusing on loss & damage***: Funding of activities to avert, minimize and address loss and damage associated with the adverse effects of climate change.
- ***New deals and announcements***: Supporting the objectives.

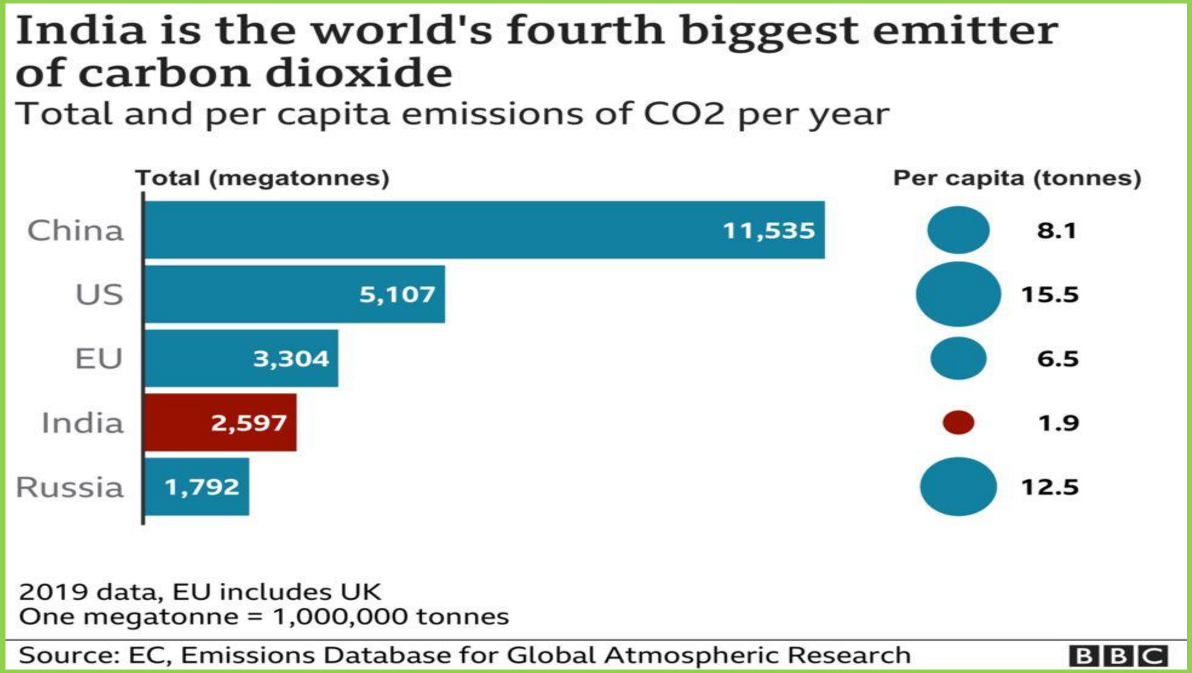
COP26 & India

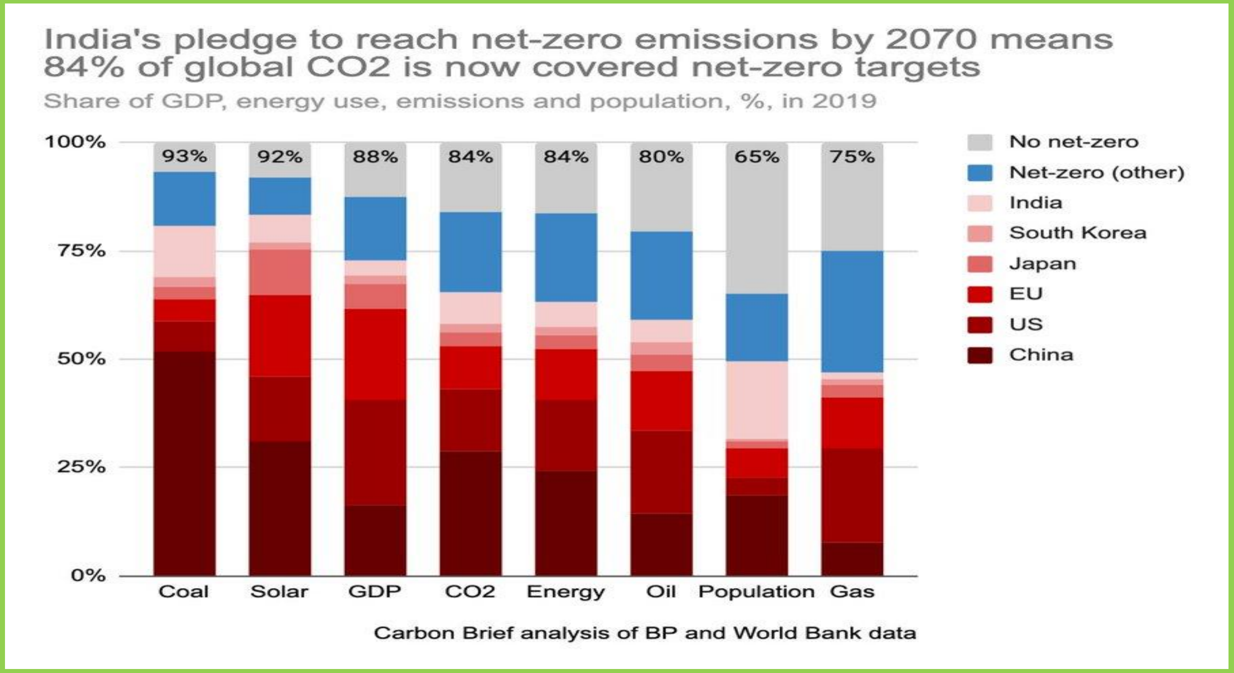
India's commitments for Net Zero

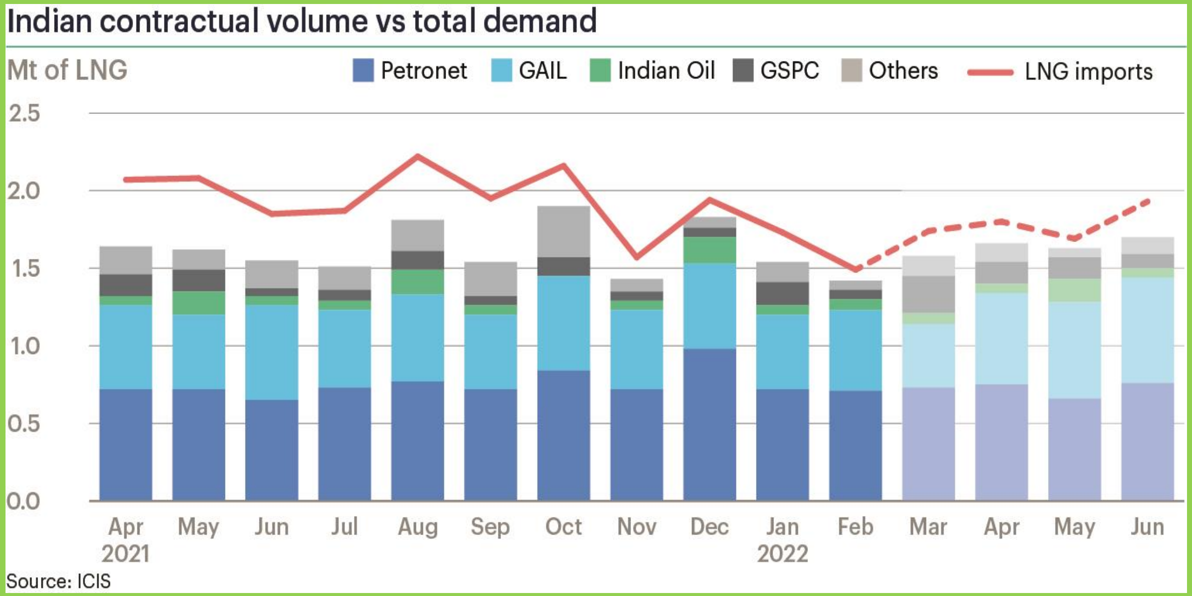
India announced in COP26 held in Glasgow (2021) that it will reach carbon neutrality by 2070 as part of a five-point action plan that included reducing emissions to 50% by 2030.

What's the commitments?

- By 2030, India will take its non-fossil energy capacity to 500 GW (currently 157.32 GW).
- By 2030, India will complete its 50% energy requirements by renewable energy.
- From now till 2030, India will reduce 1 Billion Tons of the projected carbon emissions.
- By 2020, India will reduce its economic carbon intensity below 45%
- By 2070, India will achieve the Net-Zero emission Target.







- As per CEEW, the Natural gas is one of the big bets for India's energy transition. Multiple efforts, including large-scale investments, have been undertaken to increase the share of natural gas in the primary energy mix to 15% by 2030
- There are also rising domestic gas prices, which are now priced at $6.1/MMBtu and likely to hit double digits as global gas markers start to feed into the price formula from October 2022.
- In the longer-term, the price could incentivise domestic gas exploration, but for consumers it means the availability of cheap gas is drying up

3. Decarbonization

At a Glance

Decarbonization at a glance

Renewables

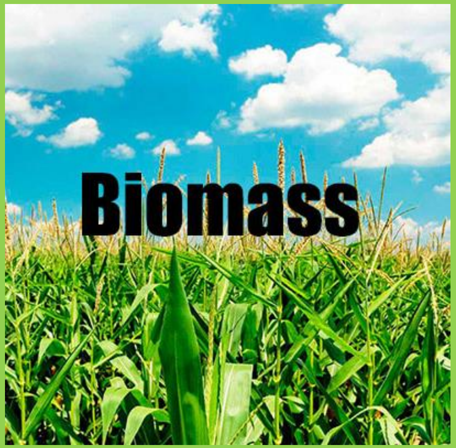
Segments

- Solar
- Wind
- BESS
- EV
- Hybrid

Green Hydrogen

Segments

- Fuel Cells
- Mobility
- Transportation



Biomass

Segments

- Bio-Fuels
- Bio-Energy
- Bio-Products

CCUS

Segments

- Power
- Oil & Gas
- Chemicals
- Industrials

Image Source: Google

4. CCUS

Value Chain & Technologies

4. CCUS & Its Value Chain

Emission Source

- Industrial Processes (>15% by vol)
- Power Plants (~ 10 % by vol) (≤ 5% by vol)
- Ambient Air (≤1% by vol)

Capture Technology

- Pre and Post-Combustion CCS
- Direct Air Capture

Process & Conditioning

- Scrubbing
- Dehydration
- Pressurization
- Liquifying

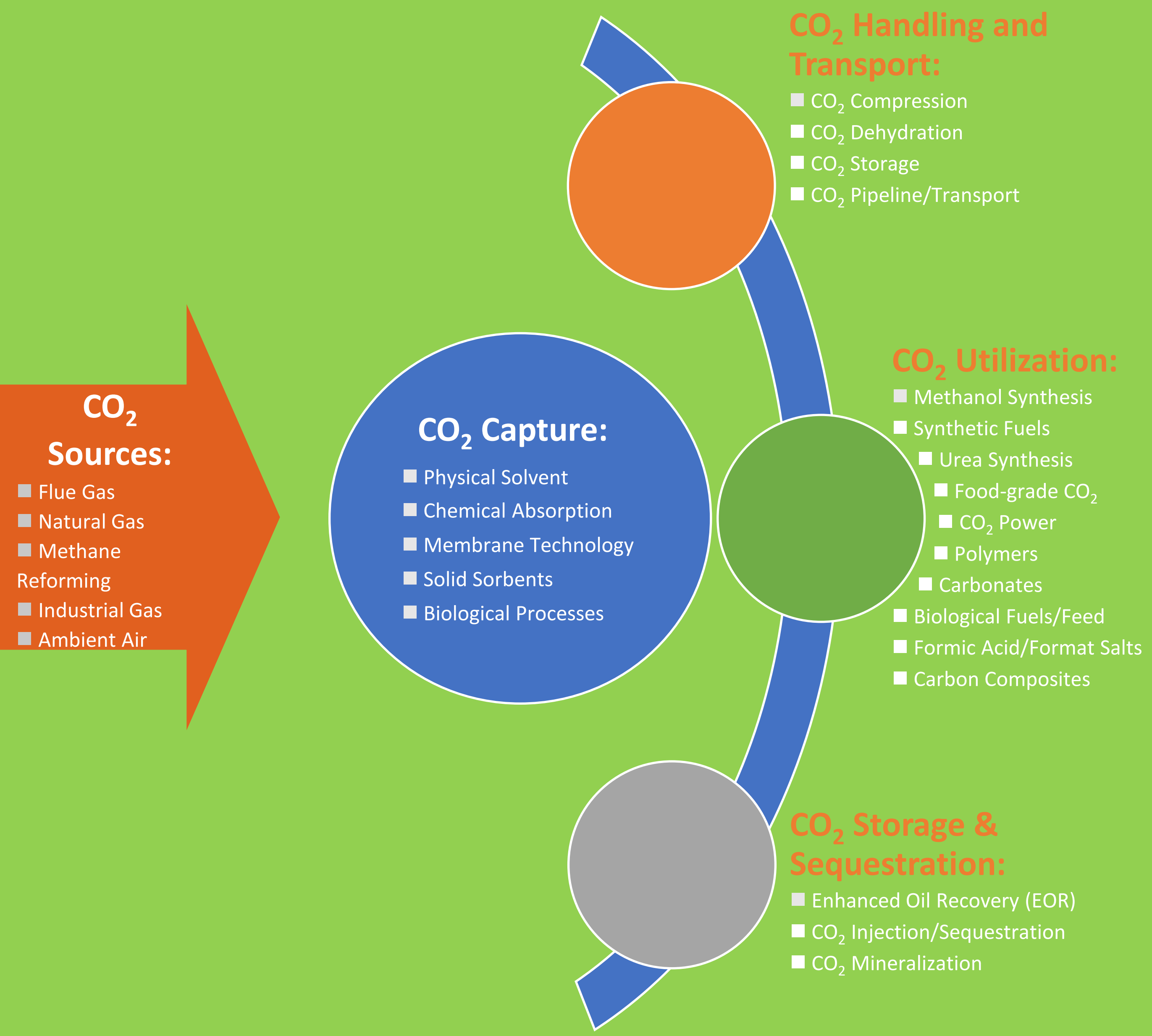
Transport

- Pipeline Conveyance
- Trucking
- Rail
- Ship

Utilization & Storage

- Enhanced Oil Recovery (EOR)
- Mineralization
- Building Materials
- CO_2 Catalytic Conversions
- Underground Storage

CCUS Value Chain



Point Source Carbon Capture and Sequestration (CCS)

- Pre & Post-Combustion CCS technologies using chemical solvents, physical absorbers and membranes

Direct Air Capture (DAC) Technology

- Negative Emissions Technology (NET) with limited commercial application & experience

CO_2 Storage and Utilization

- Underground geological sequestration of CO_2 (EOR and/or saline reservoirs)
- CO_2 used as feedstock for industrial processes, stand-alone product manufacturing and services

Various commercialized Amine-Based Solvents and Technologies

Abrev.	Name	Advantages	Disadvantages	Solvent Technology
MEA	Mono ethanol amine	- High chemical reactivity to CO_2 - Cheap and safe to handle - Utilized on most post-combustion chemical absorption commercial applications to-date	- High energy requirements for stripping/solvent regeneration - Low-medium absorption capacity - Oxidative and thermal degradation - High volatility and piping corrosion	- Fluor's Econamine FG & Econamine FG Plus - Shell Cansolv Technologies - Mitsubishi KM CDR & KS-1 proprietary hindered amine - Lummus MEA absorption process
aMDEA	Activated Methyl diethanol amine	- High stability toward thermal and oxidative degradation - Increased carbon dioxide loading	- Low absorption capacity - Low reactivity	- BASF/Linde OASE®, blue activated MDEA
Advanced Amine Blends & Solvents		- Regeneration energy requirements less than 60% in comparison to MEA - Optimized solvent composition achieves high absorption efficiency - Higher resistance to solvent degradation	- Dependent on inhibitors and catalysts to achieve higher perfromance - Lacking large-scale application demonstration	- Aker Solutions Novel Solvent - Ion Engineering Advanced Liquid Absorbent System (ALAS)
Amine-promoted buffer salt		- Lower vapor pressure - Lower specific reboiler duty than 30 wt.% MEA, - Resistant to oxidative degradation	- Relatively high viscosity, limiting mass transfer capacities and causing solvent pumping issues - Limited demonstrations	- Carbon Capture Solutions (CCS) Limited APBS-CDRMax™

Challenges of Post-Combustion Carbon Capture

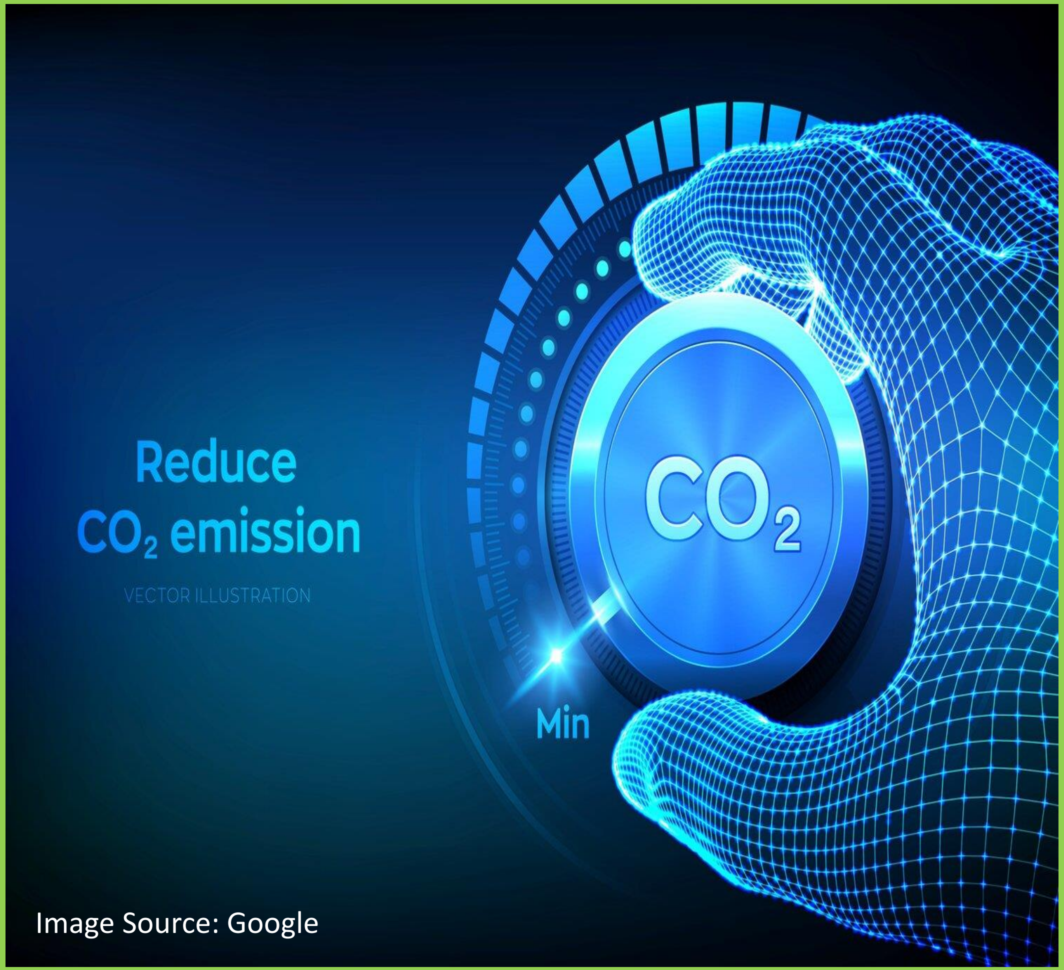


Image Source: Google

- Amine-based chemical absorption method is the most proven and commercial ready technology for majority of post-combustion applications

- High energy consumption during CO_2 removal process and compression of CO_2 product gas
- Corrosion due to presence of chemicals requires resistant metallurgy selection.
- Scale up from pilot to commercial CO_2 Capture capacity.
- Degradation of solvent/sorbent in the presence of O_2, SO_2, NOX and other impurities
- If integrated, steam and power extraction impacts host site plant performance, output and efficiencies
- Increased CAPEX and OPEX costs to existing operations
- Accommodating increased plant footprint can be challenging for existing sites
- Differential benefits of commercial solvents
- Flexibility for Next-Gen solvents

Direct Air Capture (DAC) Technology

- Negative Emissions Technology (NET)
- DAC process involves two major steps:
  1. Air contact with solvent/solid adsorbers
  2. Regeneration of solvent/solid adsorbers
- Two main types of media used:
  - Aqueous based solutions
  - Solid Adsorbers/Sorbents
- Limited commercial experience
- California LCFS credit eligible

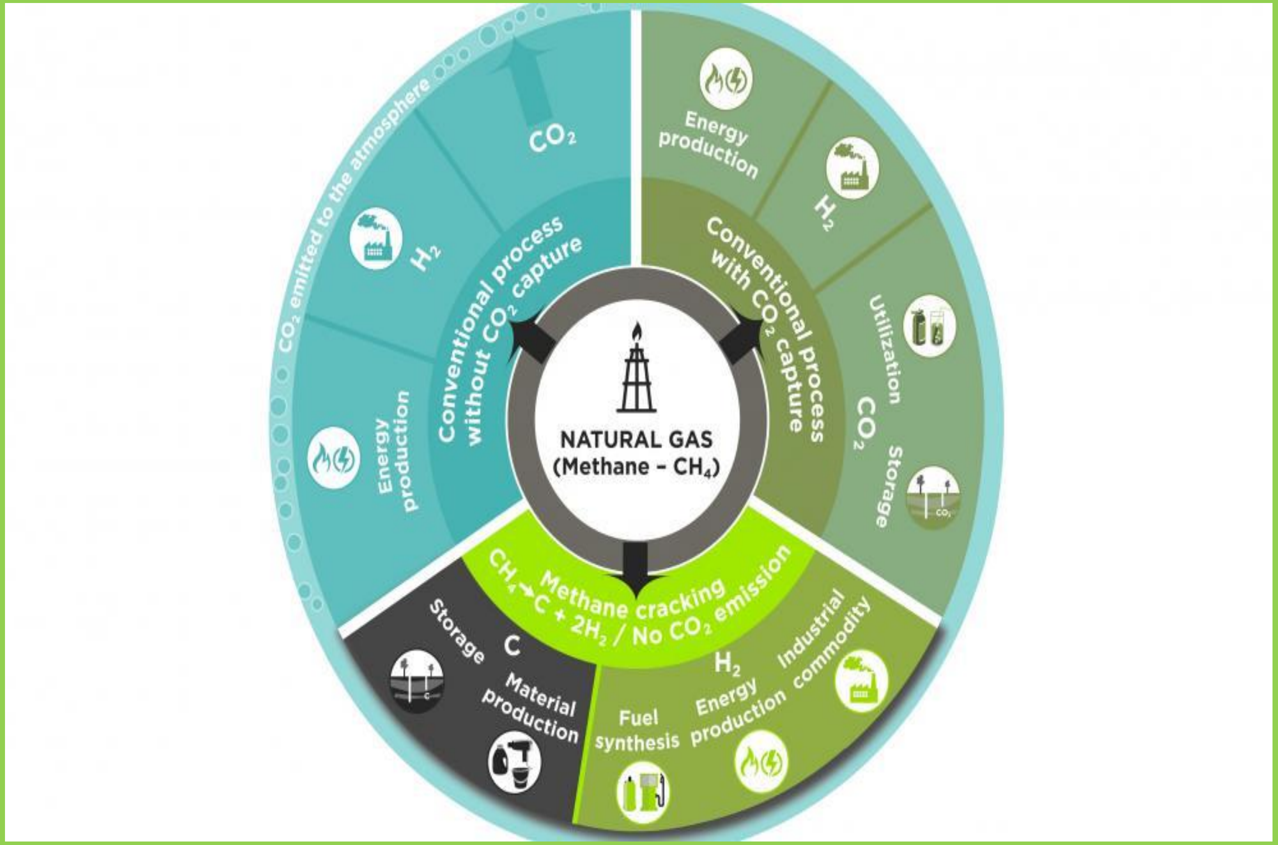


Image Source: Google

- Hybrid DAC coupled with power and heat generation units can achieve overall net zero emission electricity production and removal of atmospheric CO_2

5. Way Forward

Decarbonization for India

Way Forward

India’s Climate Finance

- India's efforts though will have to be supported by the availability of climate finance from developed countries. Without foreign capital, on concessional terms, this transition will prove to be difficult.
- India demands approx. USD 1 trillion of climate finance as soon as possible and will monitor not just climate action, but deliver climate finance.
- Most importantly, India has called, once again, for a change in lifestyle.

Steps Needed to Achieve Net Zero

- According to the Council on Energy, Environment and Waters implications of a Net-zero Target for India's Sectoral Energy Transitions and Climate Policy' study, India's total installed solar power capacity would need to increase to over 5,600 gigawatts to achieve net-zero by 2070.
- The usage of coal, especially for power generation, would need to drop by 99% by 2060, for India to achieve net-zero by 2070.
- Consumption of crude oil, across sectors, would need to peak by 2050 and fall substantially by 90% between 2050 and 2070.
- Green hydrogen could contribute 19% of the total energy needs of the industrial sector.

Table 1 Total investment, gap, and support for India's net-zero target scenarios

	Total investment		Investment gap		Investment support	
	Aggregate from 2020 till the respective net-zero year	*Average annual from 2020 till the respective net-zero year*	Aggregate from 2020 till the respective net-zero year	*Average annual from 2020 till the respective net-zero year*	Aggregate from 2020 till the respective net-zero year	*Average annual from 2020 till the respective net-zero year*
2040 peak - 2070 net-zero	10,103	202	3,546	71	1,419	28
2030 peak - 2060 net-zero	8,266	207	4,181	105	1,672	42
2030 peak - 2050 net-zero	5,724	191	3,407	114	1,363	45

Source: CEEW-CEF analysis

Note: Amounts in constant 2020 USD billion

- As per a CEEW report, along with the sectoral deployment of different technologies, India's net-zero commitment will require immense capital investment in infrastructure.
- To mobilize USD 10.1 trillion of investments and bridge the investment gap of USD 3.5 trillion, under the 2070 net-zero pathway, India would need investment support worth USD 1.4 trillion until 2070.
- Net-zero commitments by developing countries will require international banks, insurers, asset managers managing USD 130 trillion in collective assets to deliver on their pledges.
- Investment support measures can play a critical role in ensuring this capital flows as required.

Table 6 Quantifying the investments

	Total investment		Investment gap		Investment support	
	Aggregate from 2020 till the respective net-zero year	*Average annual from 2020 till the respective net-zero year*	Aggregate from 2020 till the respective net-zero year	*Average annual from 2020 till the respective net-zero year*	Aggregate from 2020 till the respective net-zero year	*Average annual from 2020 till the respective net-zero year*
Power	8,412	168	3,098	62	1,239	25
Mobility	198	4	--	--	-	--
Industrial	1,494	30	448	9	179	4
Total 2040 peak - 2070 net-zero	**10,103**	**202**	**3,546**	**709**	**1,419**	**28**
Power	6,865	172	3,799	95	1,520	38
Mobility	128	3	--	--	--	--
Industrial	1,273	32	382	10	153	4
Total 2030 peak - 2060 net-zero	**8,266**	**207**	**4,181**	**105**	**1,672**	**42**
Power	4,854	162	3,168	106	1,267	42
Mobility	71	2	--	--	--	--
Industrial	799	27	240	8	96	3
Total 2030 peak - 2050 net-zero	**5,724**	**191**	**3,407**	**114**	**1,363**	**45**
Power	9,751	163	1,252	21	501	8
Mobility	277	5	--	--	--	--
Industrial	1,866	31	560	9	224	4
Total 2050 peak - 2080 net-zero	**11,894**	**198**	**1,812**	**30**	**725**	**12**
Power (until 2070)	4,523	90	497	10	199	4
Mobility (until 2070)	202	4	--	0	--	--
Industrial (until 2070)	15	0	5	10	2	0
Total Reference (until 2070)	**4,741**	**95**	**501**	**10**	**200**	**4**

Source: CEEW-CEF analysis and compilation based on Chaturvedi, Vaibhav, and Ankur Malyan. 2021. Implications of a net-zero target for India's sectoral energy transitions and climate policy. New Delhi: Council on Energy, Environment and Water.

Note: Amounts in constant 2020 USD billion

THANK YOU