How to evaluate technologies?

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Dr. of Chemical Engineering at the University of Tokyo, 1981
  Development of coal liquefaction technology.
  Evaluation study of CO2 mitigation technologies since 1986 and Life Cycle Assessment since 1993.

National Bureau of Standards, MD. USA (1984-1986)
International Institute for Applied Systems Analysis, Vienna, Austria.(1990-1992).

Director of Research Center of LCA, AIST (2001-2008)
  Development of Japanese LCA database and Impact Assessment method, LIME.

Co-chairs of ISO/TC207/SC5(Redition of ISO-14040 series) in 2005-2007
Chairperson of the project of Carbon Footprint of Products in Japan
Lead author of WGIII, Chapter 12 (Human Settlement) of IPCC AR5.

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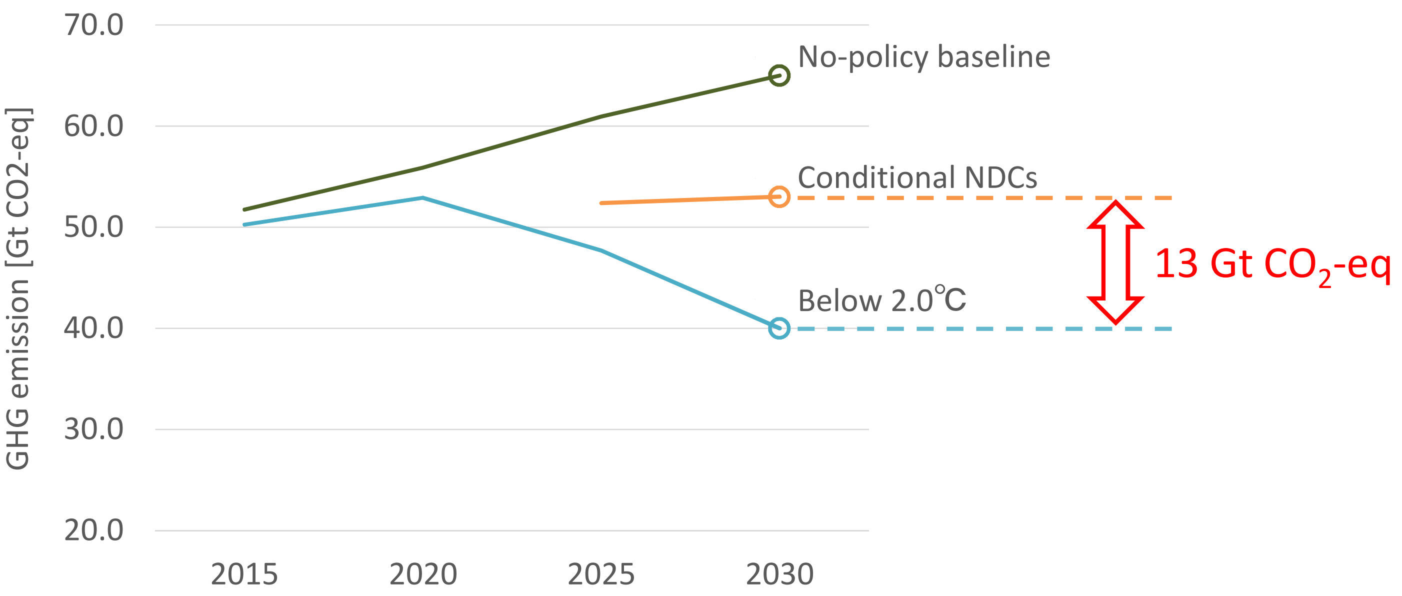
Necessity of additional countermeasures for global warming



Global greenhouse gas emissions under different scenarios and the emissions gap in 2030

Source: "Emissions Gap Report 2018" (United Nations Environment Programme, 2018)

Carbon Dioxide Removal Technologies

		Cost	Energy Requirements	Land Use	Water Consumption	Risk of Reversal	Verifiability	Implement Readiness
NATURAL	Reforestation & Enhanced Forest Management	Green	Green	Red	Orange	Orange	Green	Green
NATURAL	Wetland & Coastal Restoration	Green	Green	Green	Green	Orange	Orange	Green
NATURAL	Soil Carbon Restoration	Green	Green	Green	Green	Orange	Red	Orange
TECHNOLOGICAL	DACS	Red	Orange	Green	Green	Green	Green	Orange
TECHNOLOGICAL	Terrestrial Enhanced Weathering	Orange	Orange	Green	Orange	Green	Green	Orange
TECHNOLOGICAL	Ocean Alkalinity Modification	Orange	Orange	Green	Green	Green	Orange	Red
HYBRID	Hybrid Bioenergy with CCS (BECCS)	Orange	Green	Red	Orange	Green	Orange	Green
HYBRID	Bioenergy with Biochar Sequestration (BEBCS)	Orange	Green	Red	Orange	Orange	Red	Green

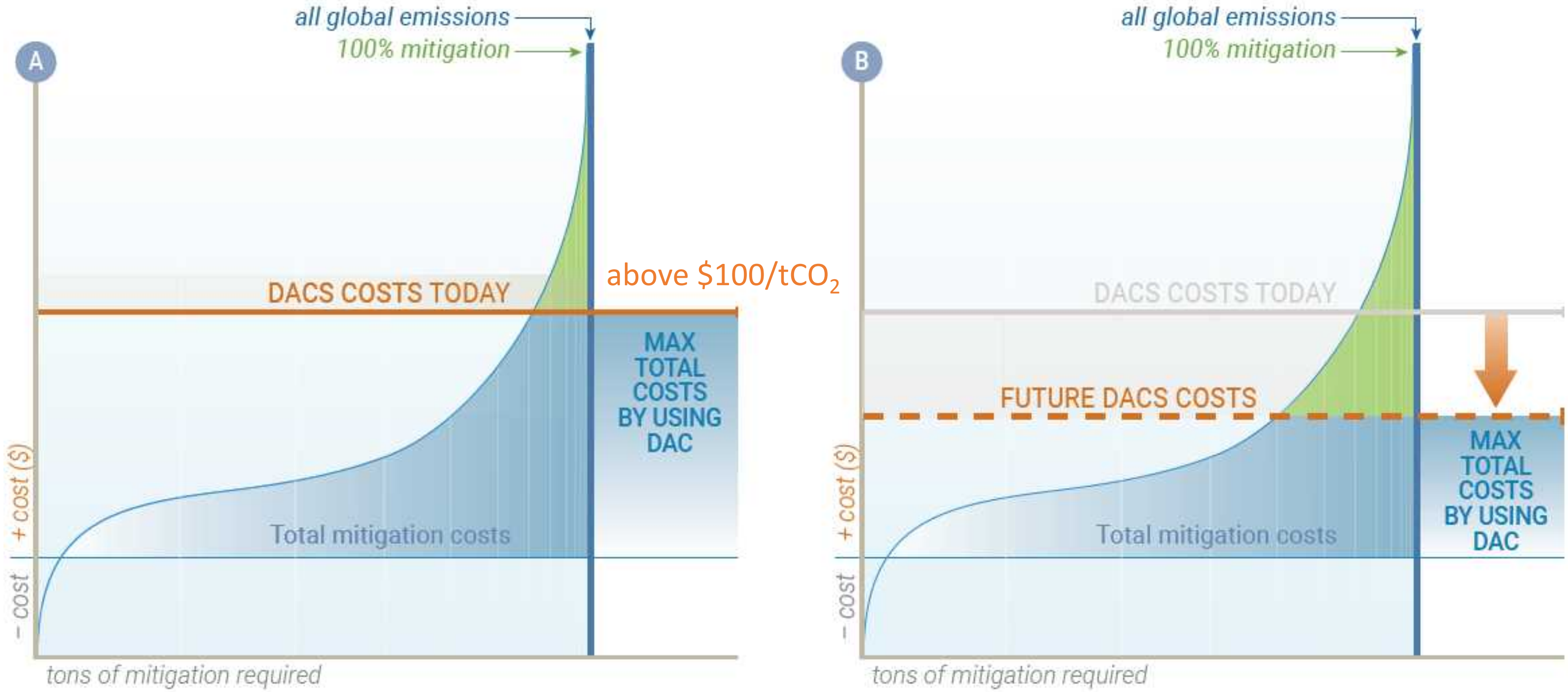
LEGEND: Green = Generally Acceptable/ Available; Orange = Exercise Caution; Red = Potentially Unacceptable/ Unavailable

Source: Direct Air Capture of Carbon Dioxide Roadmap (ICEF 2018)

Carbon Dioxide Removal Technologies

Source: Direct Air Capture of Carbon Dioxide Roadmap (ICEF 2018)

Cost for CO2 Removal

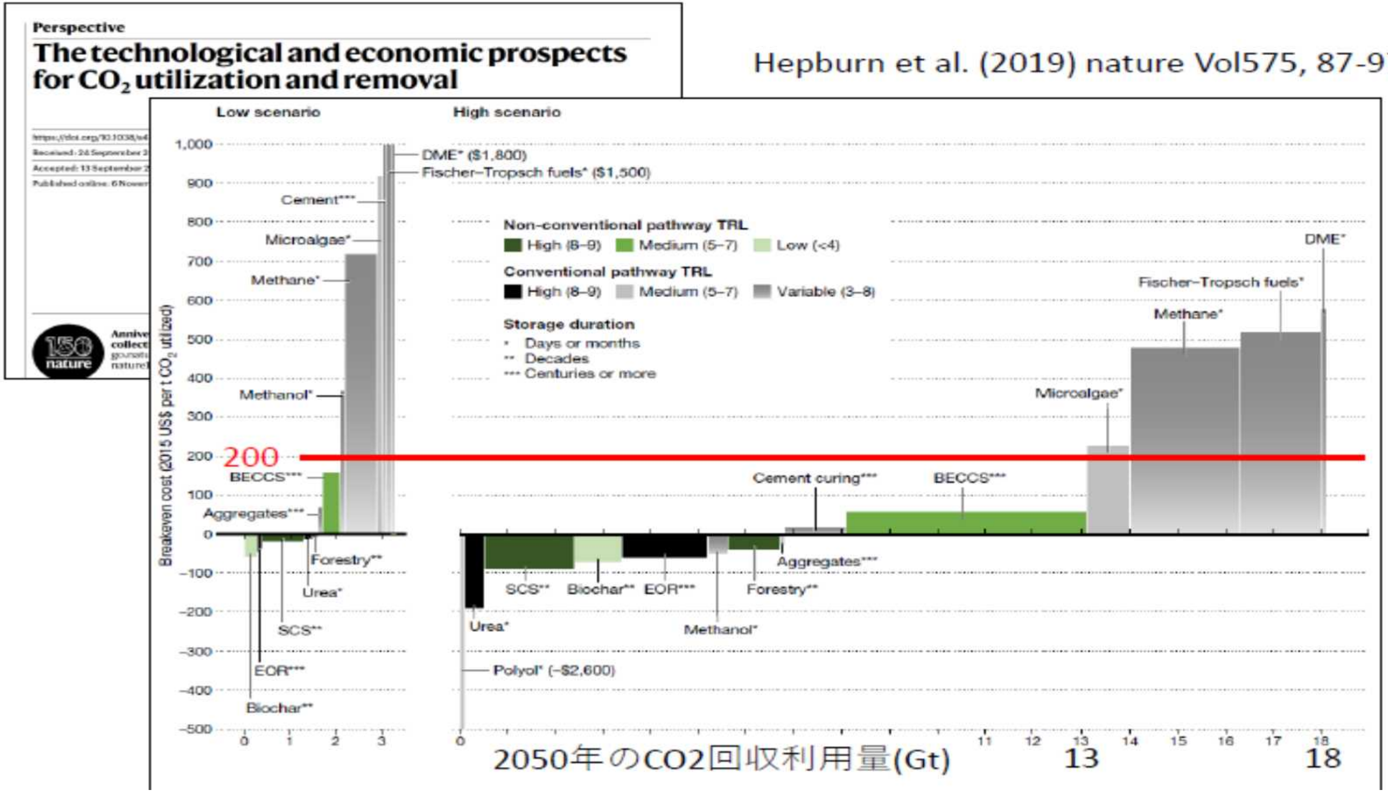


Relationship between cost and introduction amount of DAC

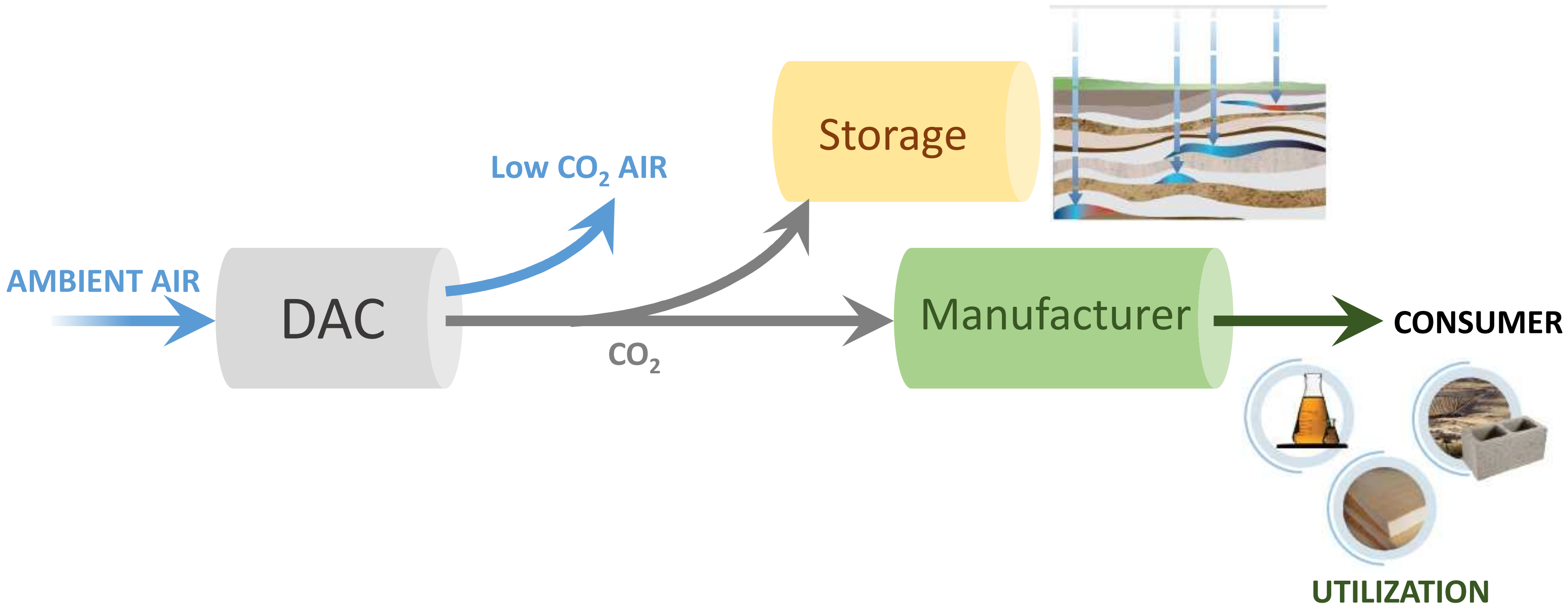
Source: Direct Air Capture of Carbon Dioxide Roadmap (ICEF 2018)

Cost for CCU

Hepburn et al. (2019) nature Vol575, 87-97

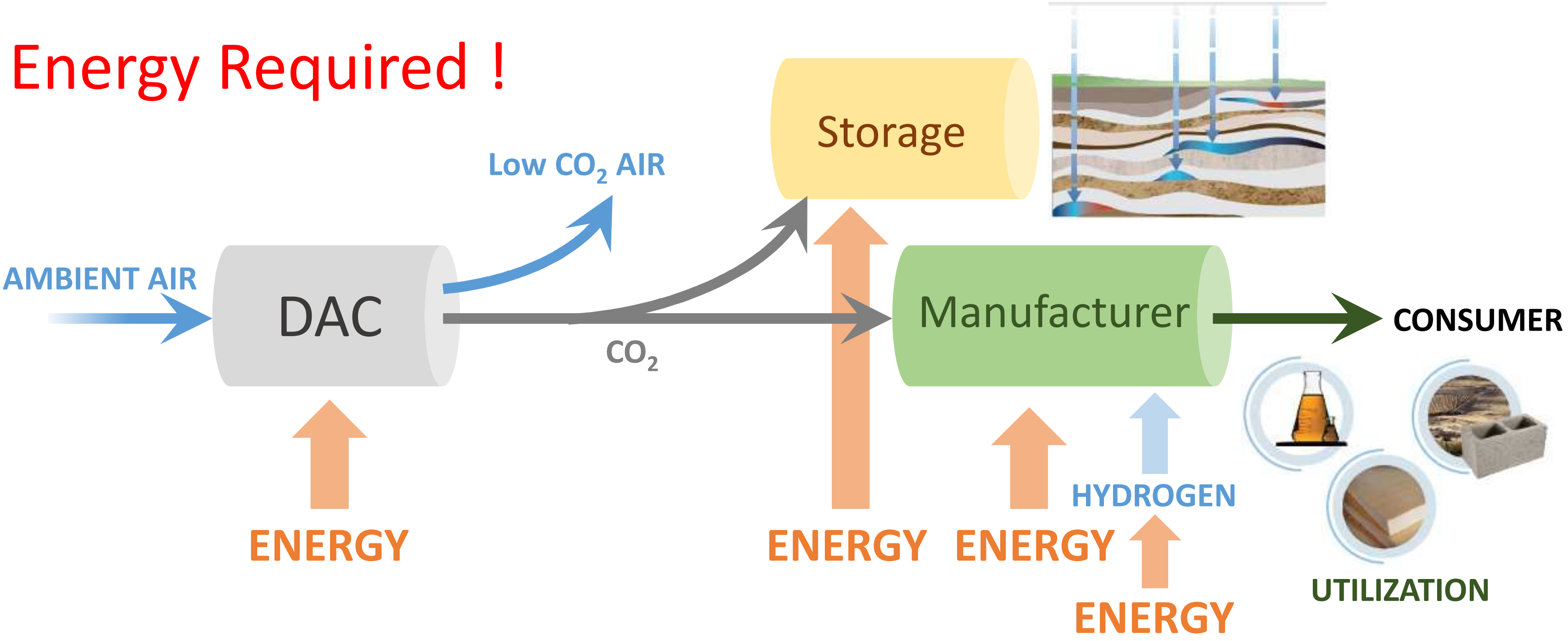


Direct Air Capture + CO_2 Utilization/CO_2 Storage



Direct Air Capture + CO_2 Utilization/CO_2 Storage

Energy Required !



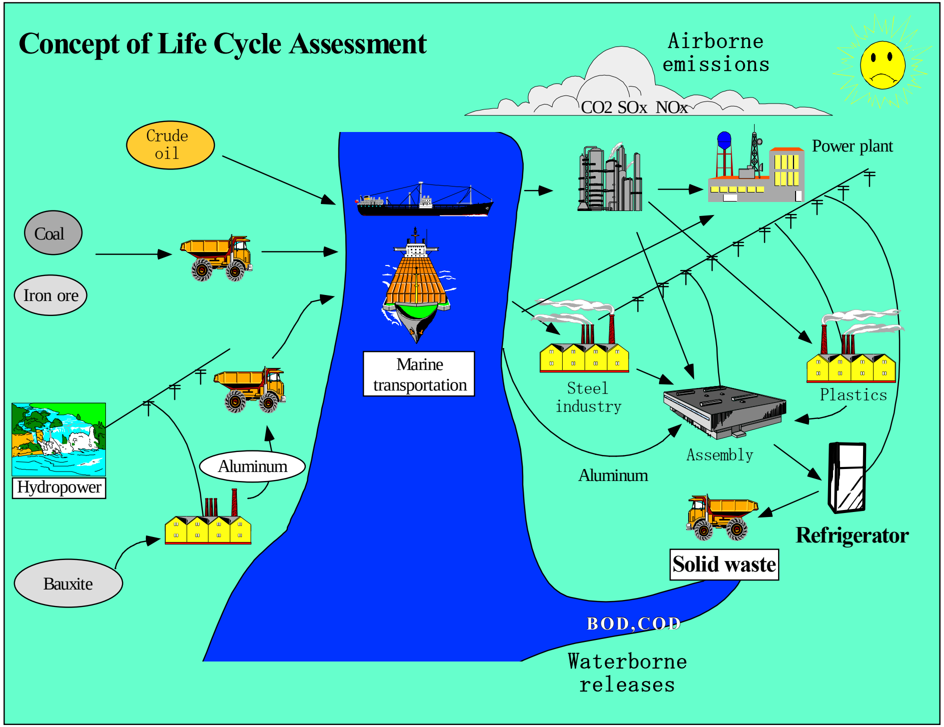
Energy resource should be zero/low CO_2 emission

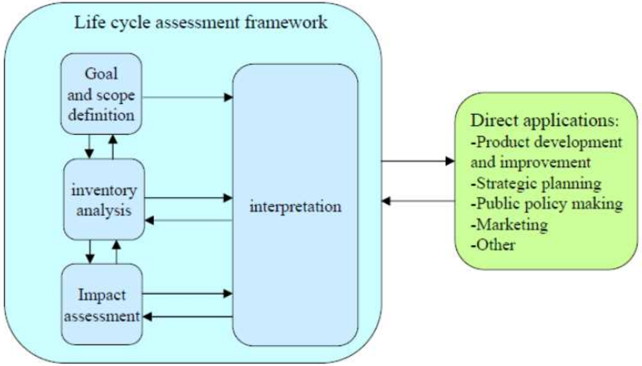
Direct Air Capture – Heat and Power

Company	Thermal energy / tCO_2 (GJ)	Power / tCO_2 (kWh)	Reference
Climeworks	9.0	450	Ishimoto 2017
Carbon Engineering	5.3	366	Keith 2018
Global Thermostat	4.4	160	Ishimoto 2017
APS 2011 NaOH case	6.1	194	APS 2011
Energy required to capture 100 million tCO2/year	440～990 PJ/year (Convert to Solar Water Heater) 190～428 km^2	16～45 TWh/year (Convert to photovoltaic) 55～154 km^2	

Source: Direct Air Capture of Carbon Dioxide Roadmap (ICEF 2018)

How to evaluate CO2 reduction?

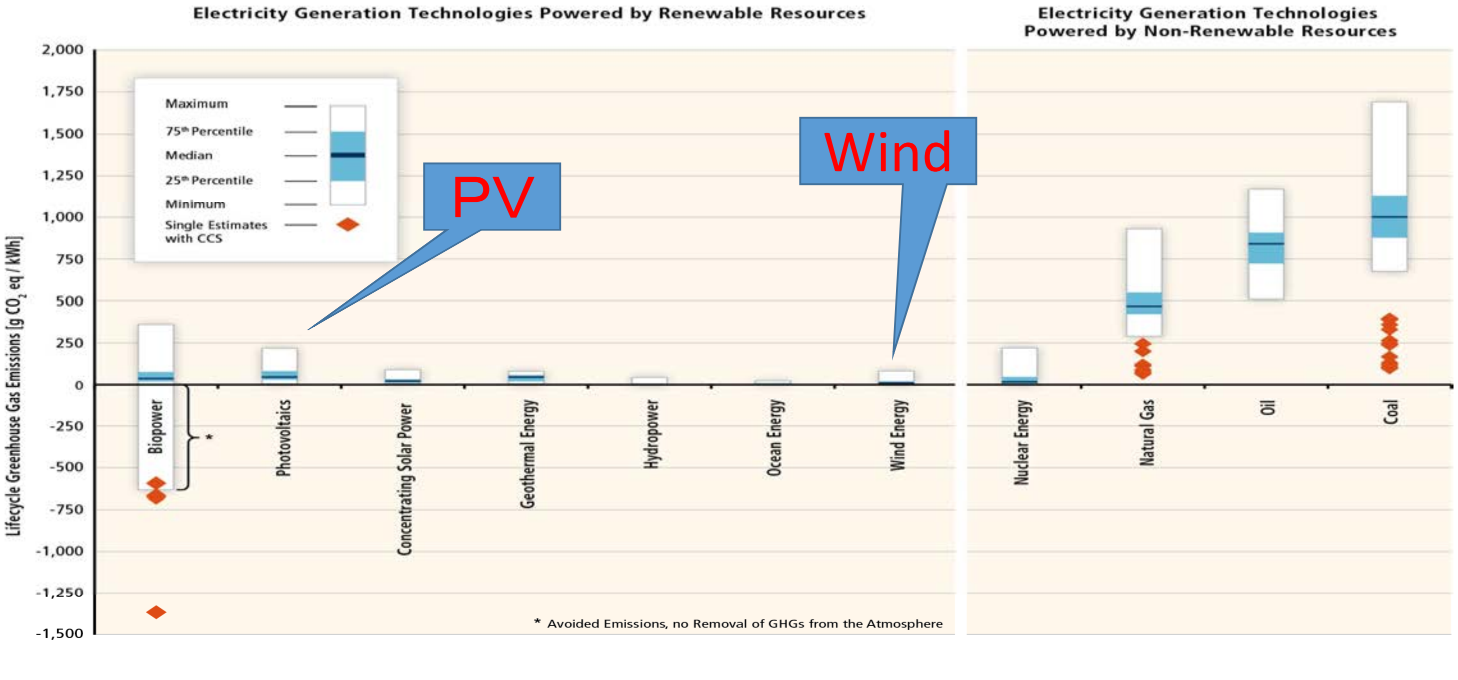




Life Cycle Assessment (LCA)

ISO 140040/44 (2006)

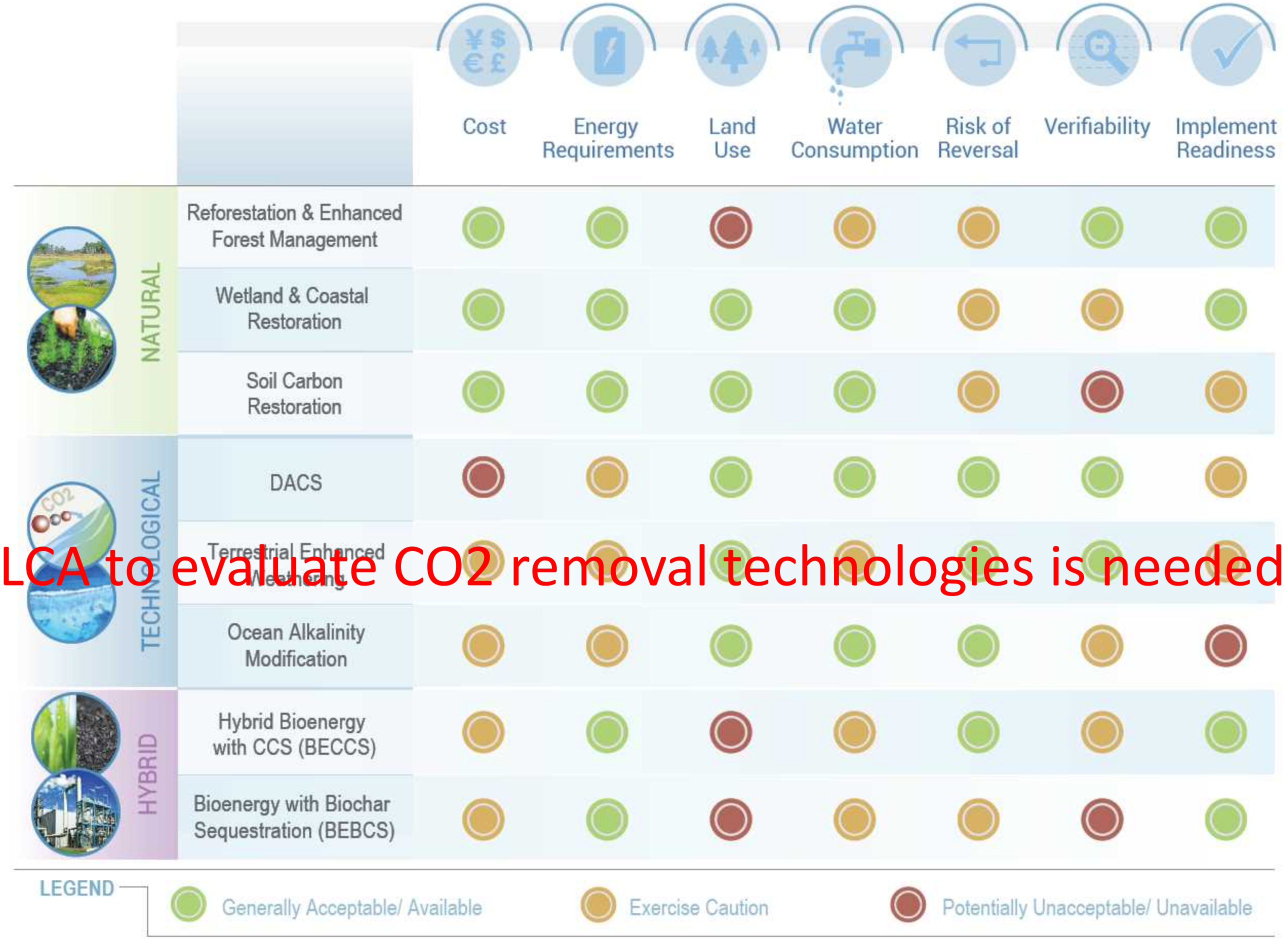
Carbon footprint of power generation plants



	Biopower	Photovoltaics	Concentrating Solar Power	Geothermal Energy	Hydropower	Ocean Energy	Wind Energy	Nuclear Energy	Natural Gas	Oil	Coal
Count of Estimates	222(+4)	124	42	8	28	10	126	125	83(+7)	24	169(+12)
Count of References	52(+0)	26	13	6	11	5	49	32	36(+4)	10	50(+10)

Ref.) IPCC, 2011: Summary for Policymakers. In: IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow (eds)], Cambridge University Press. Figure SPM.XX

Carbon Dioxide Removal Technologies



The guideline of LCA to evaluate CO2 removal technologies is needed.

Source: Direct Air Capture of Carbon Dioxide Roadmap (ICEF 2018)

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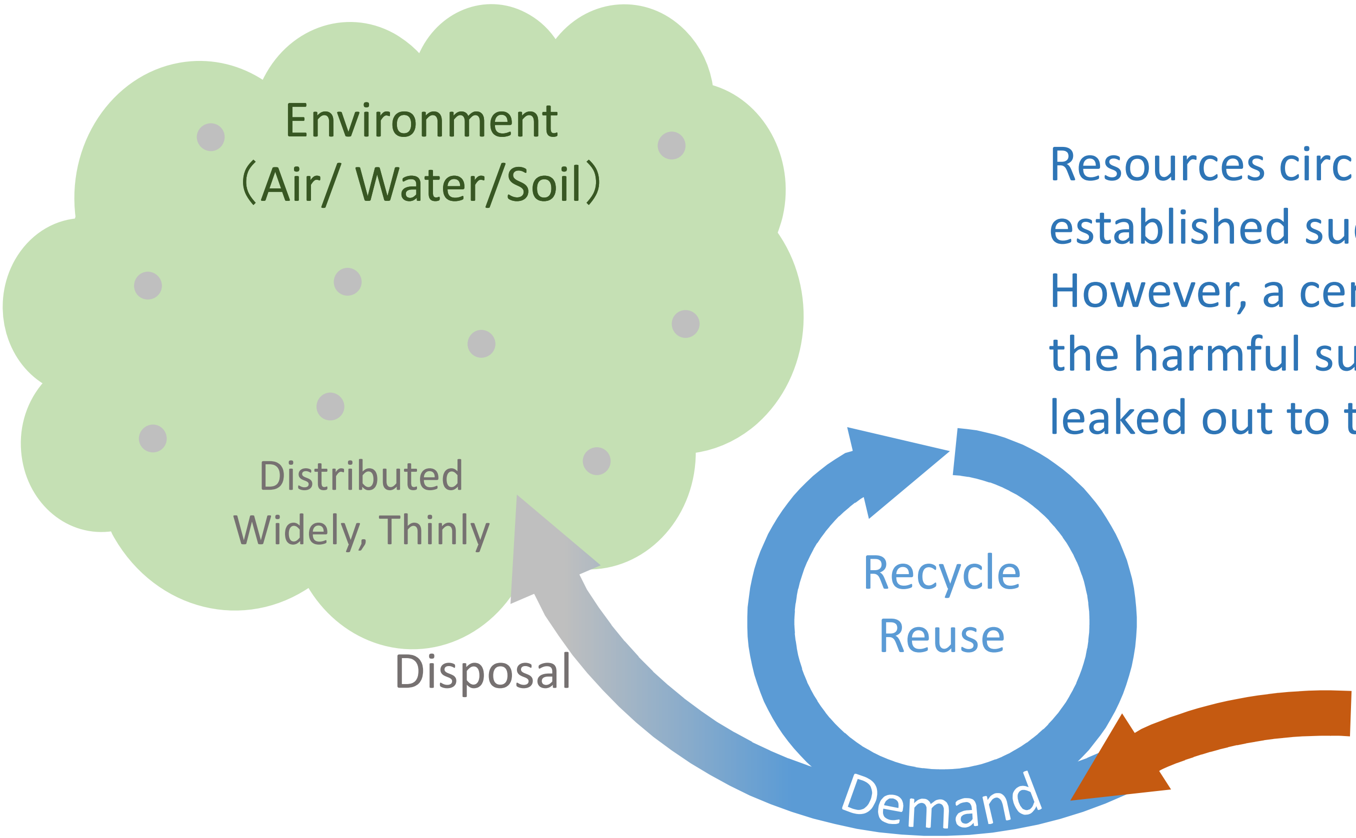
1. What is needed to evaluate CO2 removal technologies?

2. Conceptual pathway for realizing of Cool Earth and Clean Earth

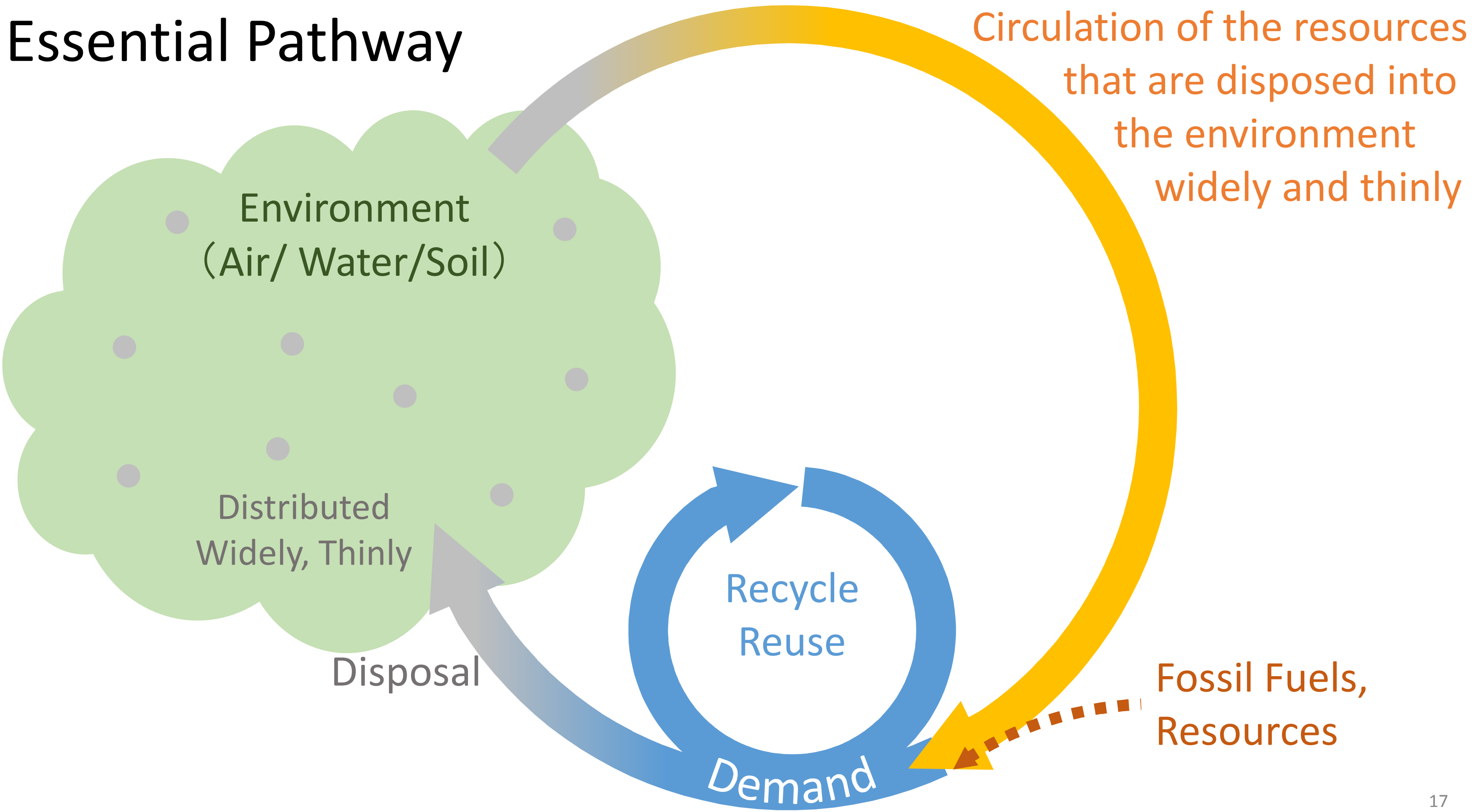
3. Summary

Current status

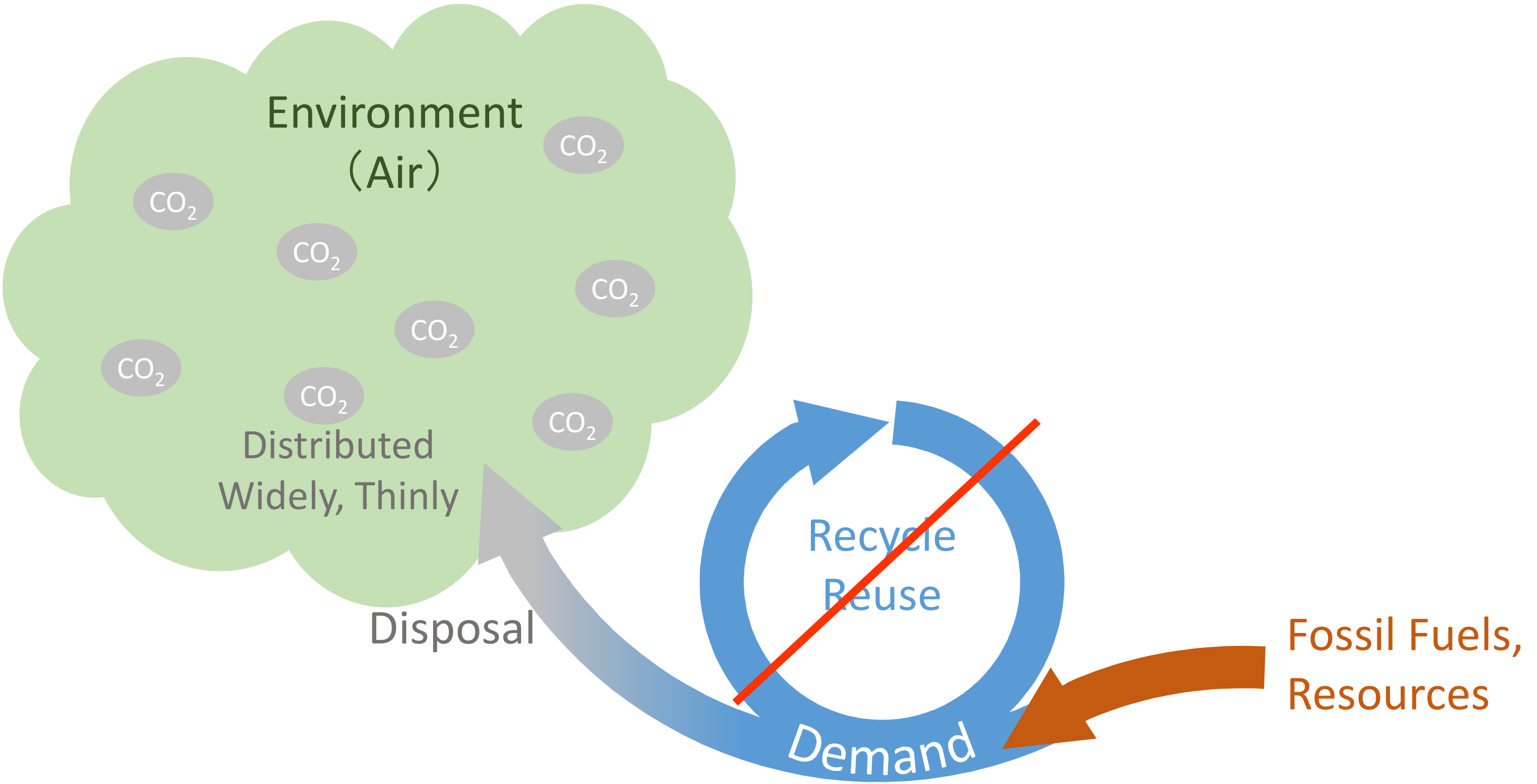


Resources circulation has been established such as recycling. However, a certain amount of the harmful substances are leaked out to the environment.

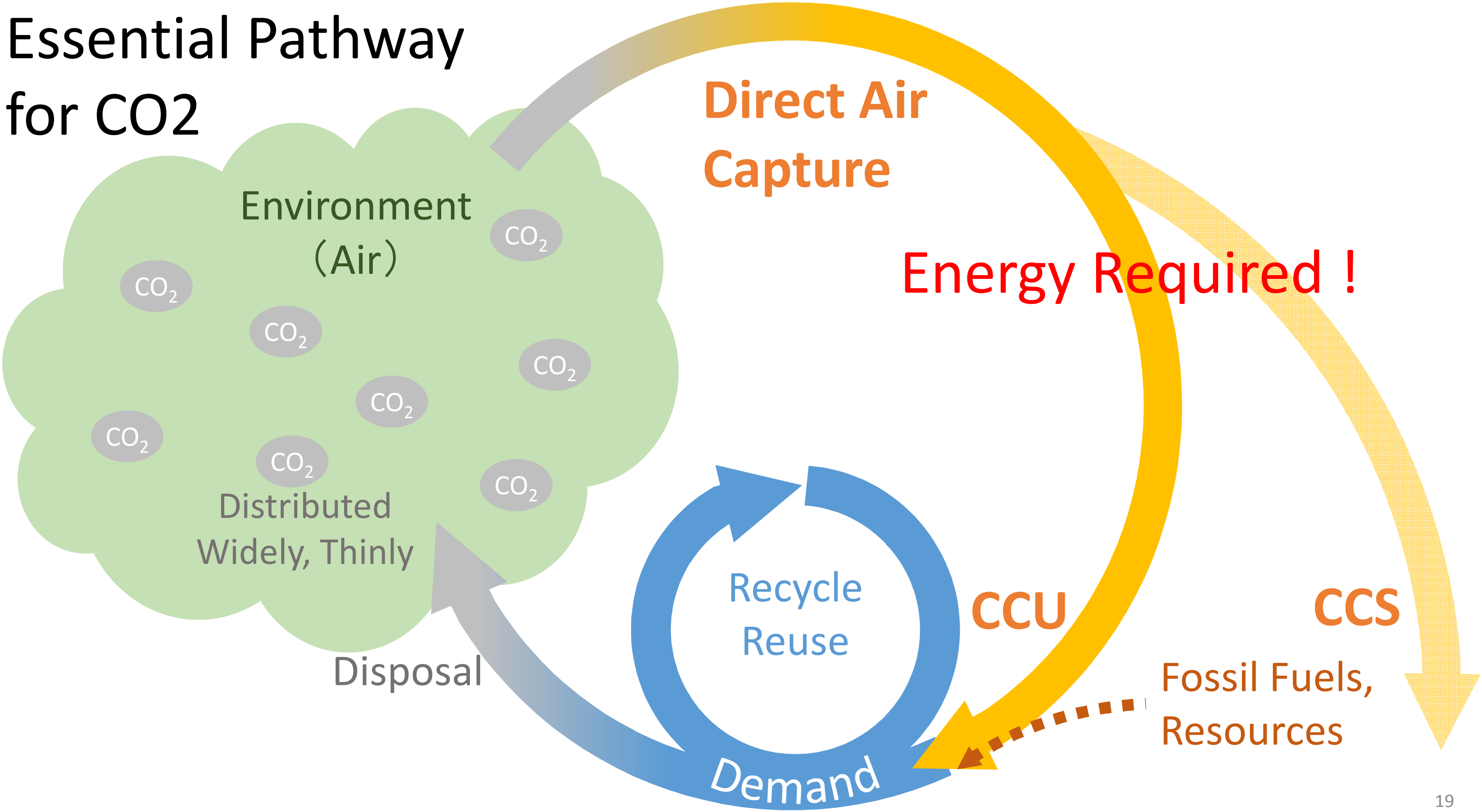
Essential Pathway



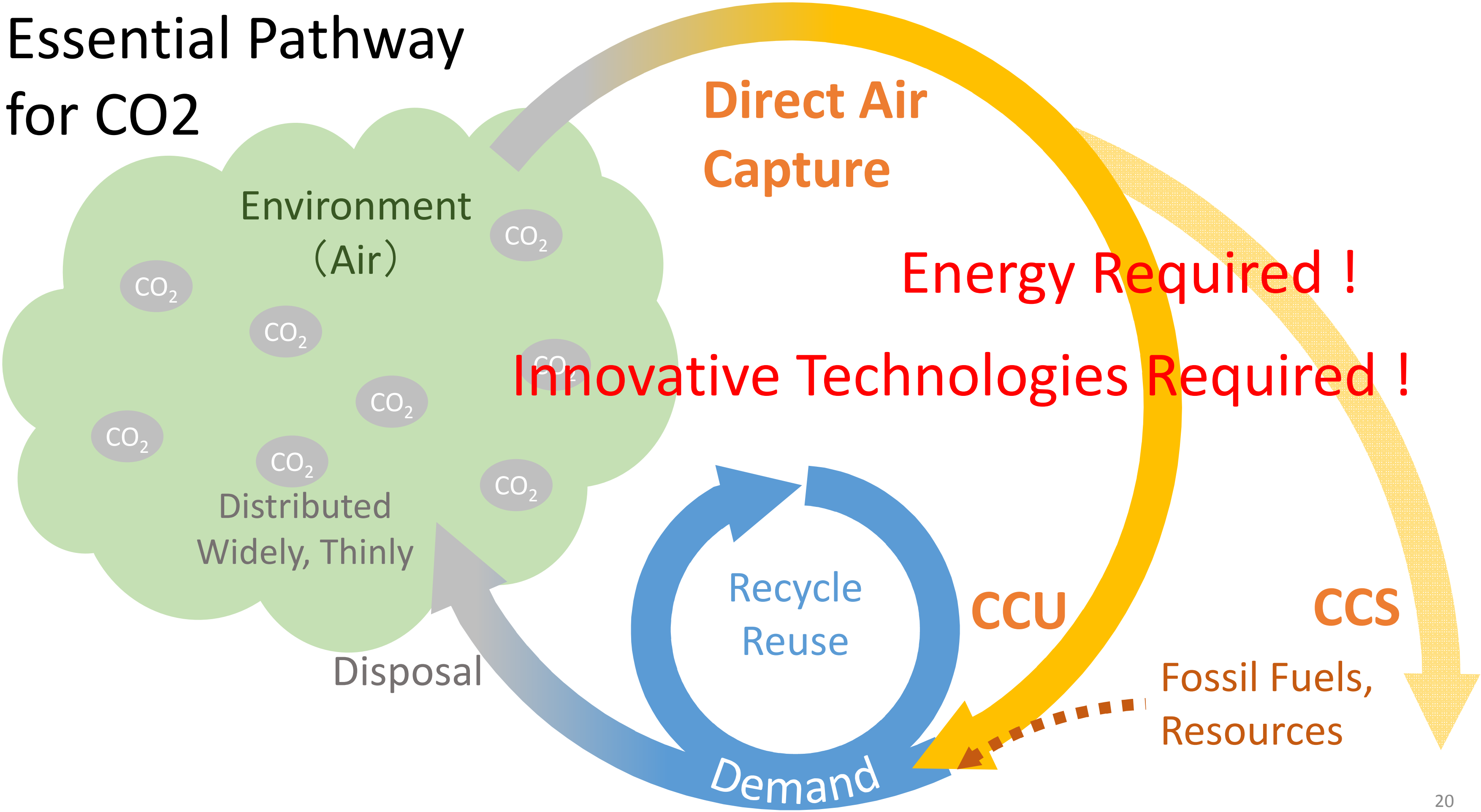
Current status : Case of CO2



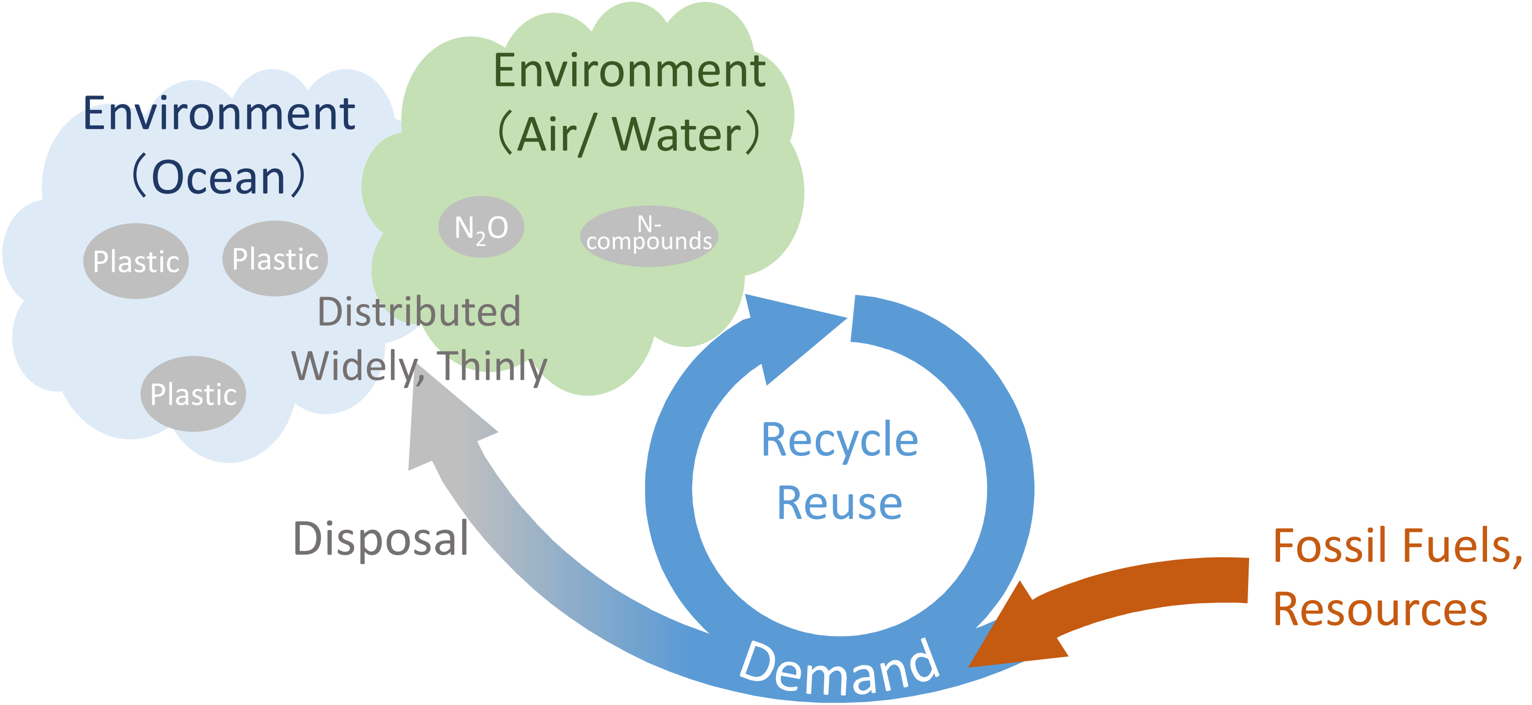
Essential Pathway for CO2



Essential Pathway for CO2



Nitrogen / Marine litter plastics



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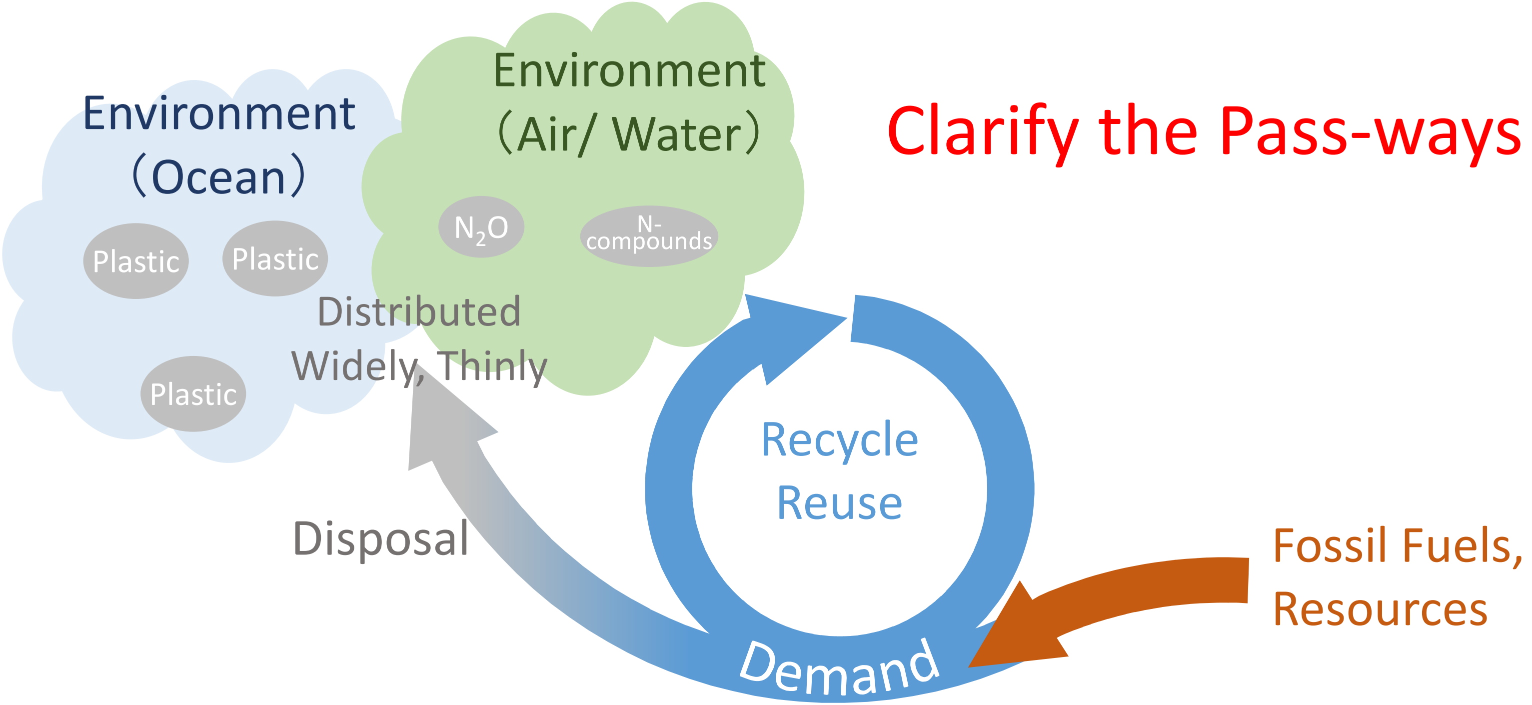
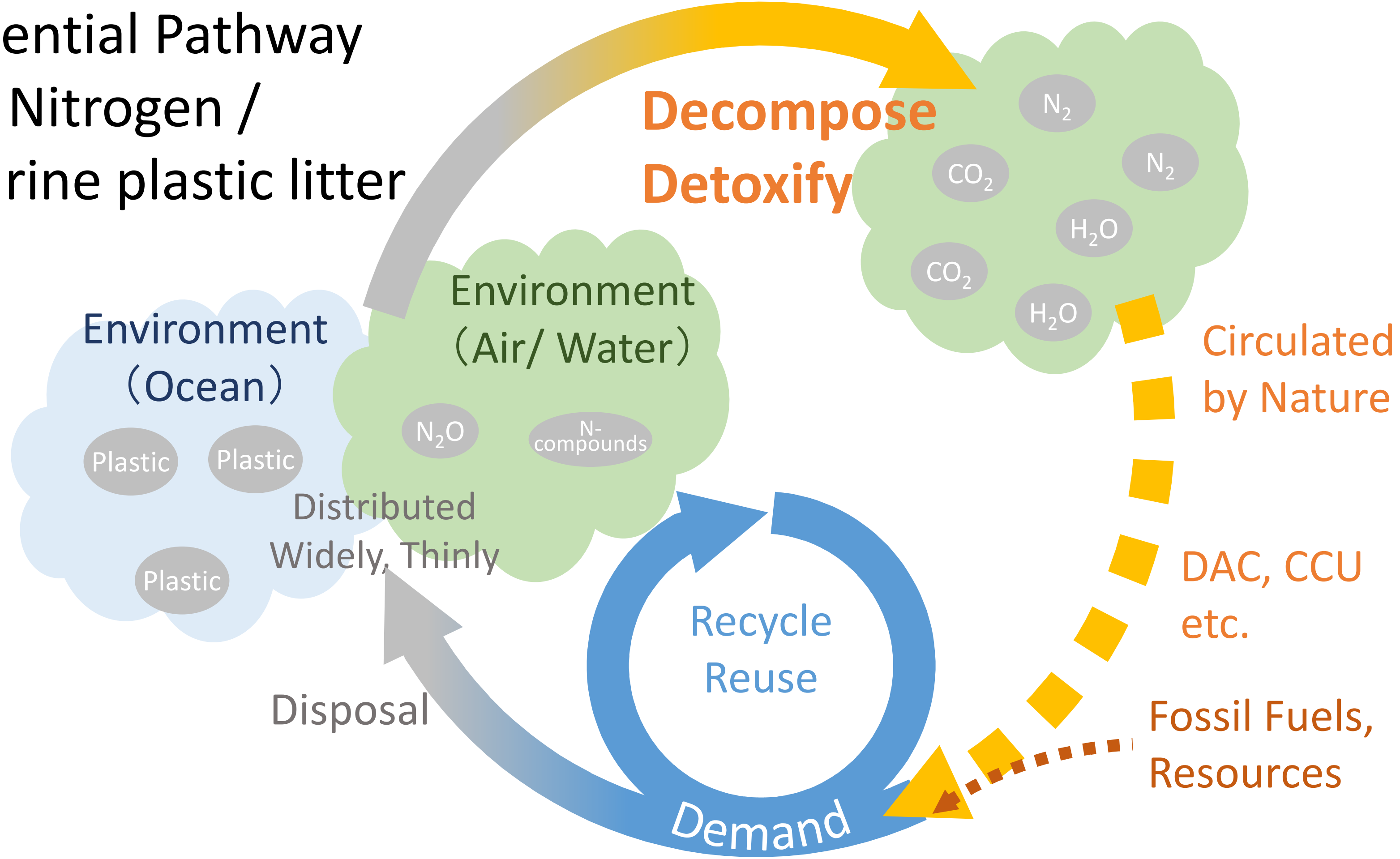
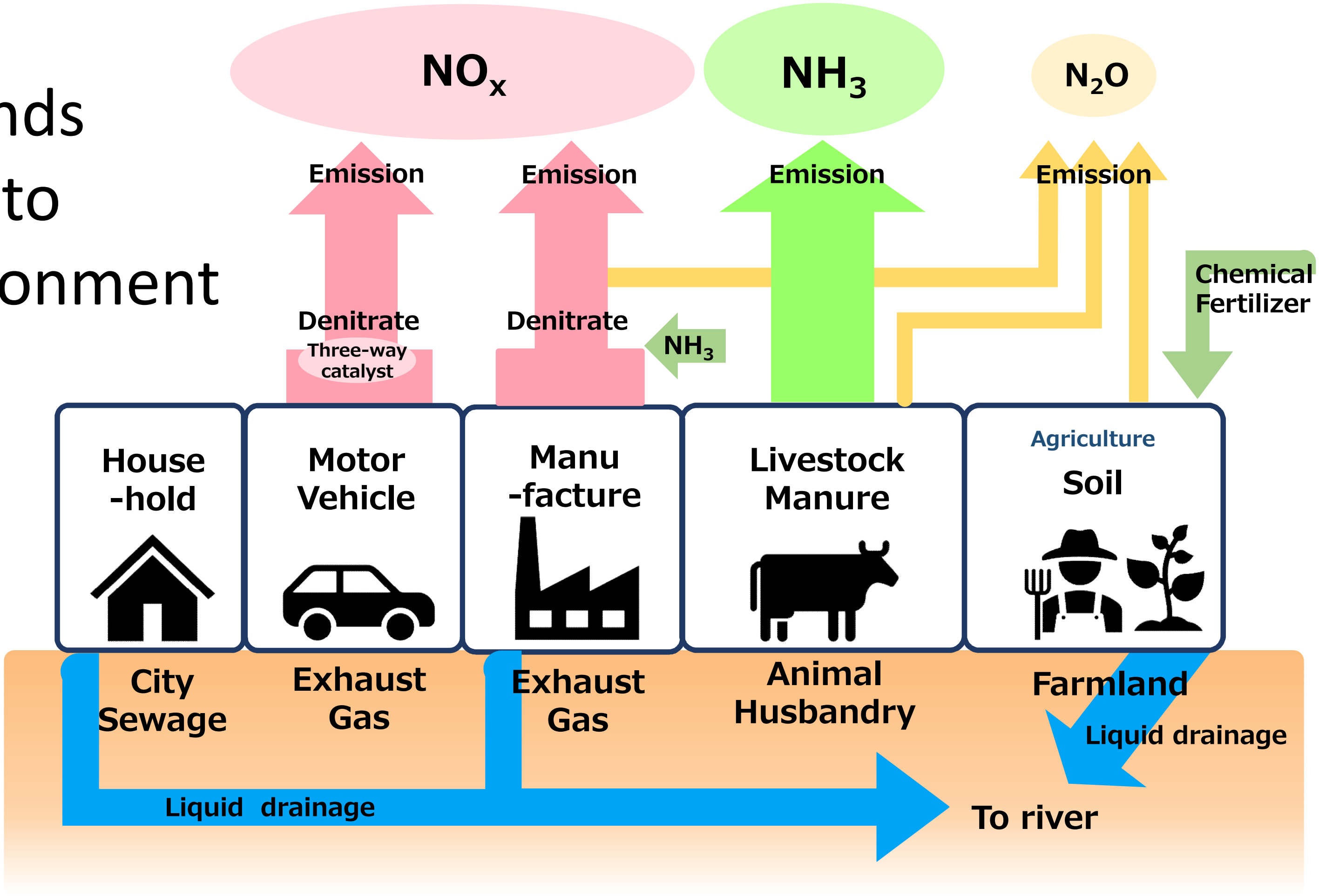


Clarify the Pass-ways !

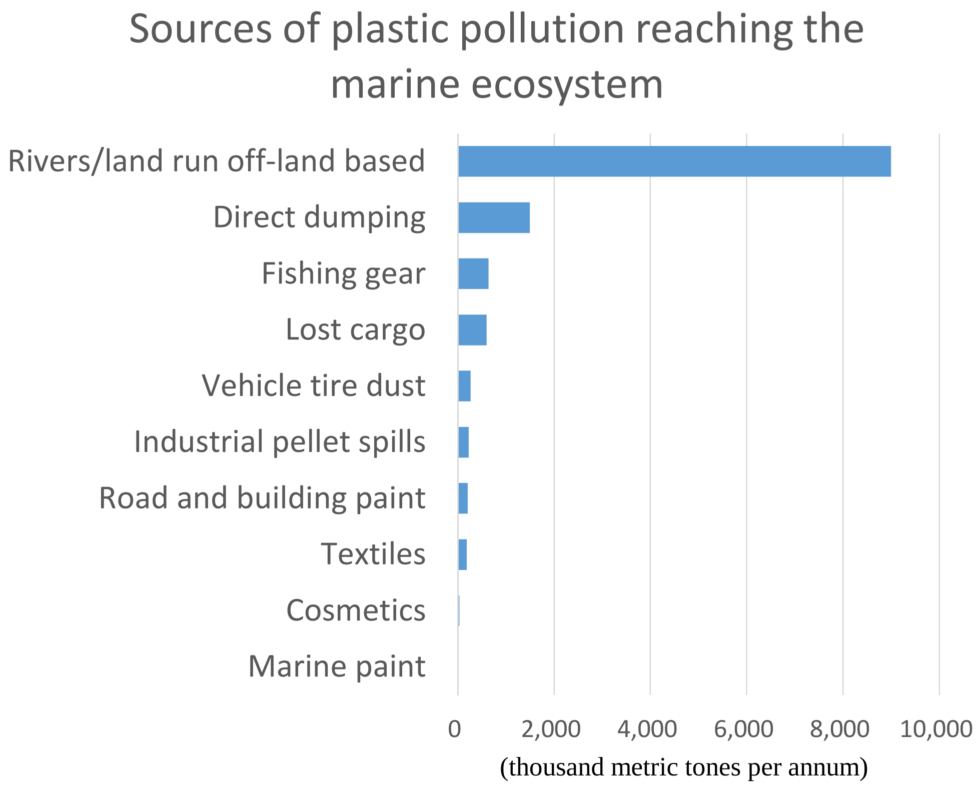
Essential Pathway for Nitrogen / Marine plastic litter



Nitrogen Compounds released to the environment



Marine plastic litter



Source: Jenna R, et al. “Plastic waste inputs from land into the ocean”, Science, vol. 347 Issue 6223, pp. 768-771, February 2015.

Summary

1. What is needed to evaluate negative emission technologies?

   ・How much energy is required?

   ・What type of energy we can use?

→ Life Cycle Assessment is needed.

2. Conceptual pathway for realizing of Cool Earth and Clean Earth

   ・The emission pathways of GHGs are clear, but

→ The pathways of Nitrogen and Marine plastics must be identified.