Energy-saving production of organic urea and carbamates from atmospheric CO_2:

Life Cycle Perspectives on Combined Carbon Capture and Conversion Approaches

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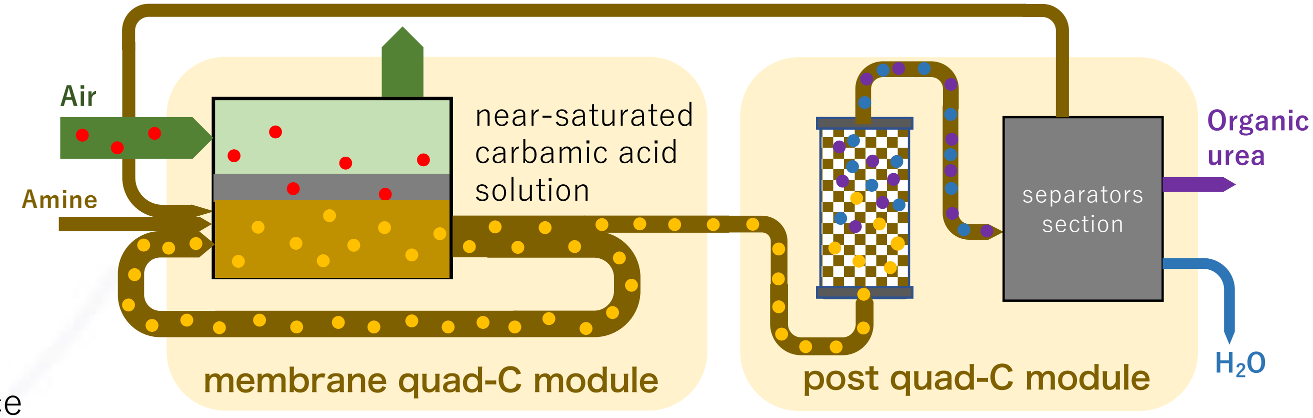
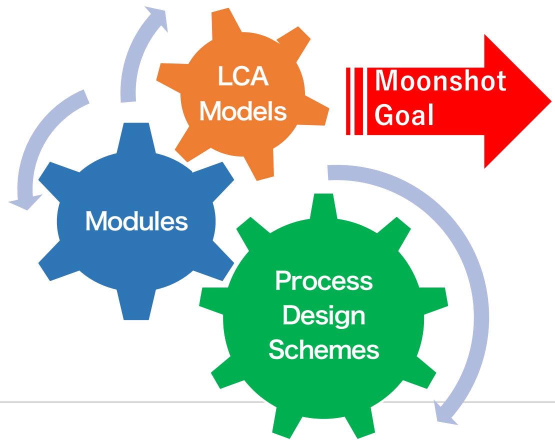
Combined Carbon Capture and Conversion (quad-C)

- **Characteristics**
  - **Low energy consumption**
    - no reduction of carbon in CO_2
      - Carbamides (organic ureas)
      - Carbamate esters (ex. PUR materials)
    - no CO_2 desorption
      - capture and conversion take place in a single process operation by using dual function materials
  - **Safety (non-phosgene route)**
    - Many utilize phosgene as the carbonyl source
      → Some start to utilize Urea, Carbonates, or **CO_2**
    - We utilize heterogeneous (solid) catalyst that makes the process simpler and more efficient



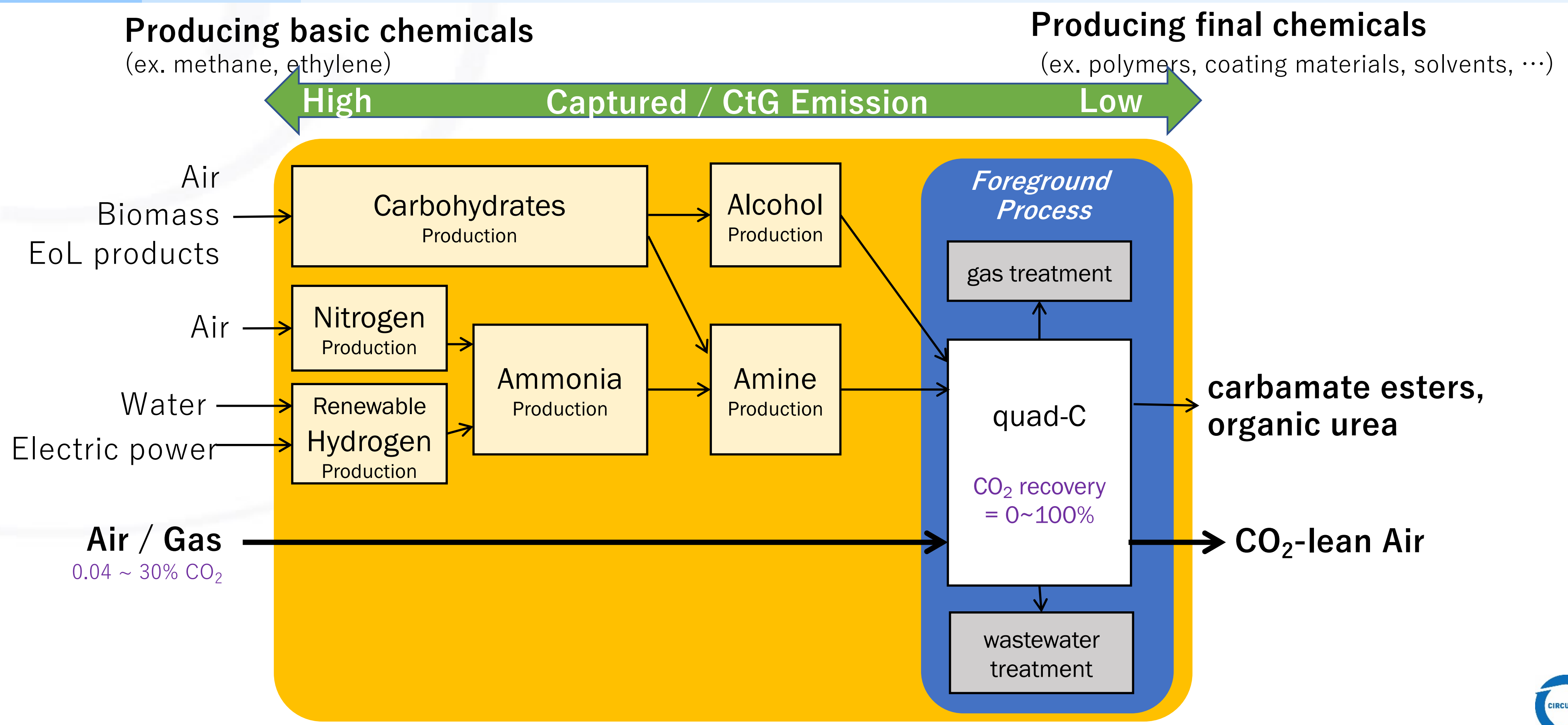
CO_2 + Amine → Carbamic acid

Carbamic acid → Organic urea + H_2O



Assist the process innovations for production of MANY chemicals from atmospheric CO_2.

Characteristics of chemicals from CO_2



Life Cycle Perspectives:
Indicators for Validation of C-balance

LCA for Validation of Carbon Balance

Chemicals		Fixed CO_2 when produced via DAC	Cradle to Gate emission for DAC	Opportunity for CO_2 utilization at End of Life
Abbrev.	**IUPAC name**	kg-CO_2 / kg-product	kg-CO_2 / kg-product	
EU	2-imidazolidinone	0.511	**9.7 – 11.0** quad-C@2020	Incineration Wastewater treatment Dissipation into atmosphere
Usage: Formaldehyde scavenger, Synthetic resins, Agrochemicals, etc.				

- This is lower than current method.
- Most of the emissions are from reactants and electric power.
  → will approach to zero, by 2050.
- Low energy consumption becomes important to reduce the competition with other purposes.

Background Emission Inventories @current

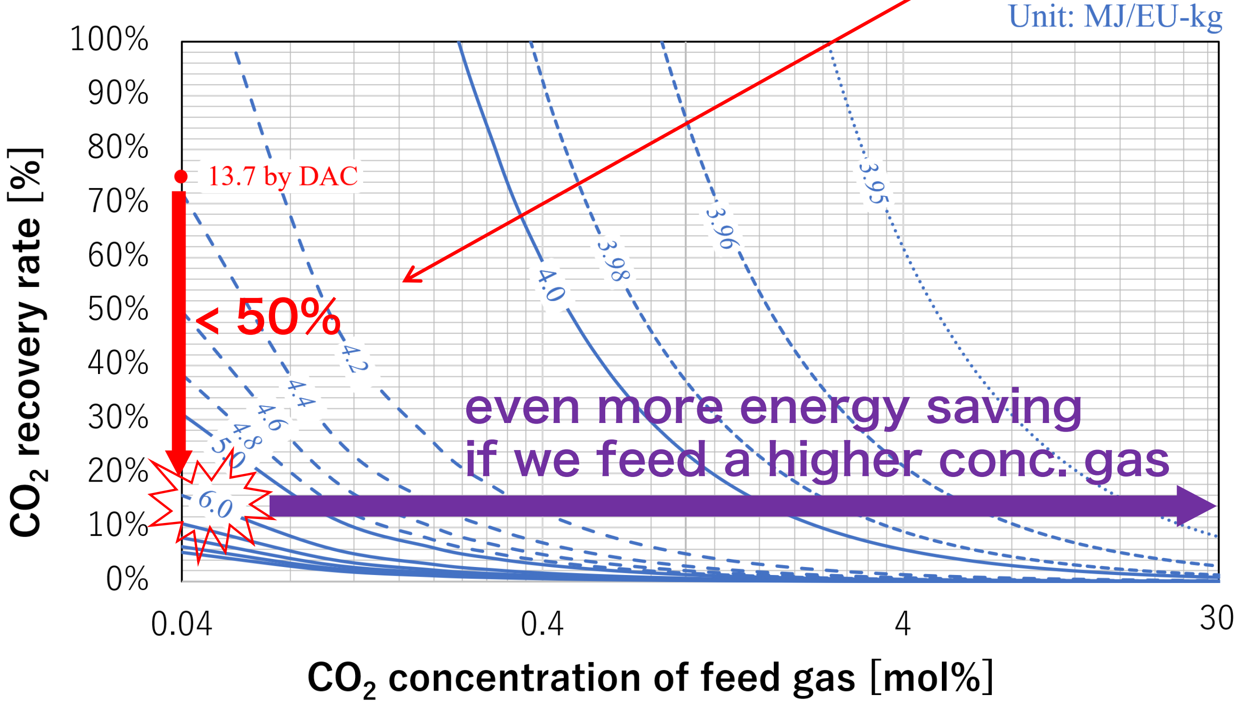
- EDA: **5.47** kg-CO_2 eq. /kg-EDA
- Elec. Power: **0.594** kg-CO_2 eq. /kWh

NEDO recommends …
0.158 @2030
0.00665 @ 2040

Life Cycle Perspectives:
Providing insights to module design

✓ Even with CO_2 recovery = 15%
our process will consume only < 50%
the energy compared to the benchmark*.
* DAC pilot by Carbon Engineering (CO_2 recovery = 75%)
+ Our catalytic converter for Ethylene Urea production

More compact
(= more economically attractive)
modules should be designed.



Future vision of quad-C based DAC-U

SUPPLEMENTARY

Outputs:
To develop quad-C processes tuned for 4 chemicals

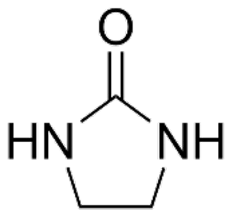
→ demonstrate at project pilot and commercial pilot
→ sufficient variety to cover major module combinations

To provide process design templates

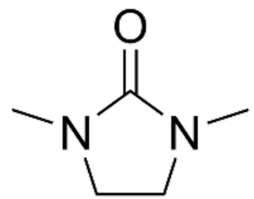
→ assist process innovations for other chemicals

Outcomes

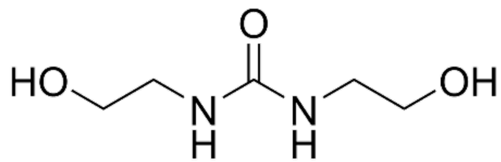
Producing most of the carbamate esters and organic ureas using quad-C processes.



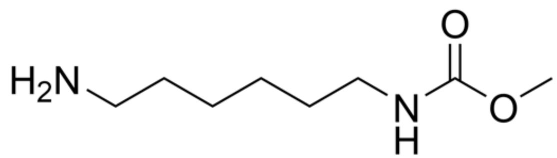
formaldehyde scavenger, agrochemicals, etc.



Aprotic solvent



(potential) PUR raw material



precursor for PUR raw material (i.e., HDI)