

Feasibility study of enhanced mineralization based on LCA/TEA platform



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Outline and Target

Moonshot Goal 4 : Toward Carbon Neutral by 2050

Development of **LCA/TEA platform** to optimize the total system of **enhanced mineralization**: EM (Capture atmospheric CO₂ by enhanced mineralization of mafic rocks, etc., and accelerate the plant growth by soil application).

Current recommendation of enhanced mineralization

- Accurate CO₂ reductions cannot be accounted, and effects are unknown.
- No empirical data on utilization of mafic, basaltic rocks or carbonate.
- Slow reaction, economically disadvantageous(≐\$218/t-CO₂ by Fuss, 2018).

Outline of the project

- **Accurate accounting** of CO₂ reduction.
- Clarify the **optimal soil application method** of mafic rocks for plant growth.
- Development of **cost reducing technologies**.
- Development of **LCA/TEA platform**.



Mafic rocks

Worldwide abundant

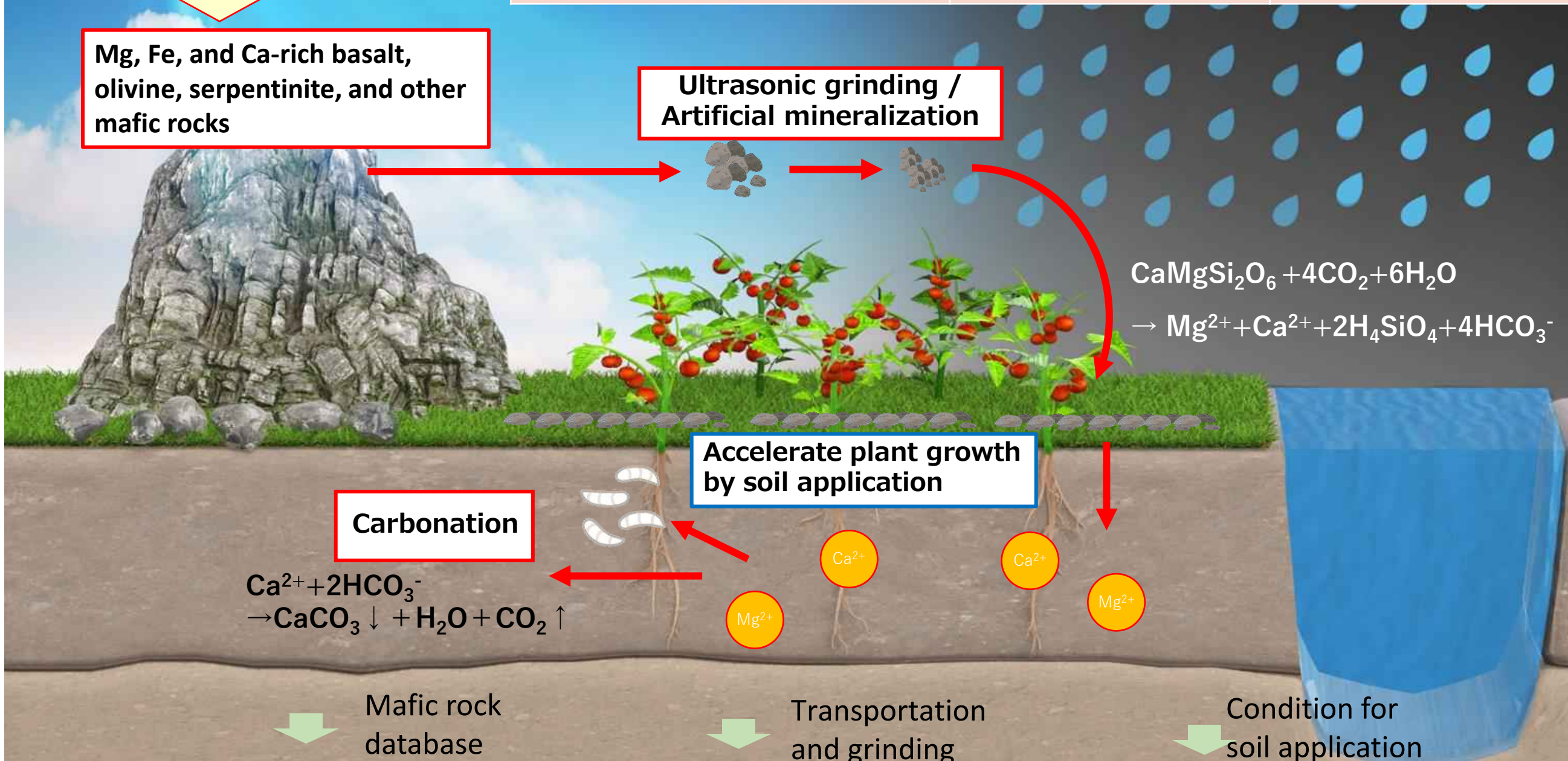


Accelerate plant growth

Resource recycling system for realization

**400 million t/y
of mafic rock
mined in 2050**

| Boundary | CO ₂ reduction (Mt/year) | Economic effect (TJPY/year) |
|---------------------------|-------------------------------------|-----------------------------|
| Carbonation(Japan) | 60~120 | 1.0~2.0 |
| Soil application (Global) | 40 | 0.7 |
| Total | 100~160 | 1.7~2.7 |



LCA/TEA Platform: Evaluate the total CO₂ reduction and cost of enhanced mineralization

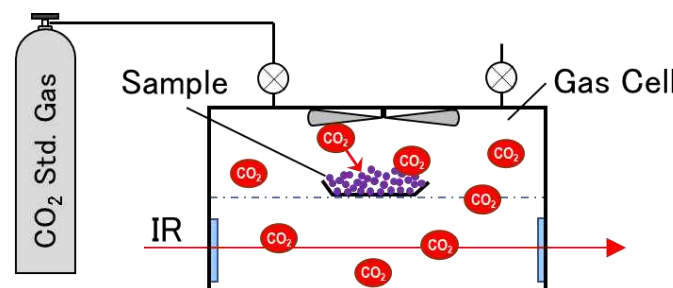
Theme 1&2 : Development of mafic rocks database and CO₂ fixation measurement technology

Account · Cost reduction · Application

- Development of the mafic rocks database in Japan, including chemical and mineral compositions, mining site information, etc.
- Measurement of CO₂ absorption under various control conditions, such as laboratory, long-term outdoor exposure conditions, and soil conditions.

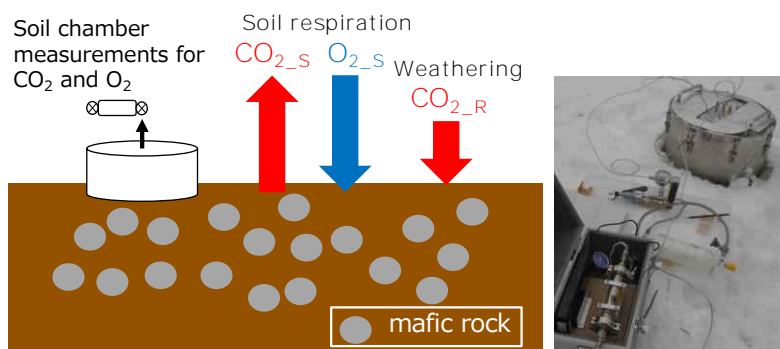


Distribution of mafic rocks in Japan (after AIST seamless geological map)



Preparation of CO₂ std gas whose concentration is suitable for evaluation of the CO₂ fixation.

Rock weathering experiments over 1 year on the roof of the office



Field observations to separate out soil respiration and weathering of mafic rock



【FY2023~24 objectives】

FY2023 : Construction of a prototype mafic rock database, based on field surveys at multiple locations and rock sample analysis results. Development of evaluation technologies for the CO₂ carbonation rate, fixed CO₂ amount, and the reduction of CO₂ concentration.

FY2024 : Additional field survey of mafic rocks and completion of mafic rock database with mining information. Evaluation of low-reactive mafic rocks, examination of carbonation inhibition factors, and chamber experiments to analyze the effects of carbonate spraying into soil.



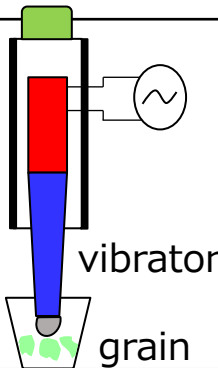
Theme 3 : Development of technology for accelerated enhanced weathering

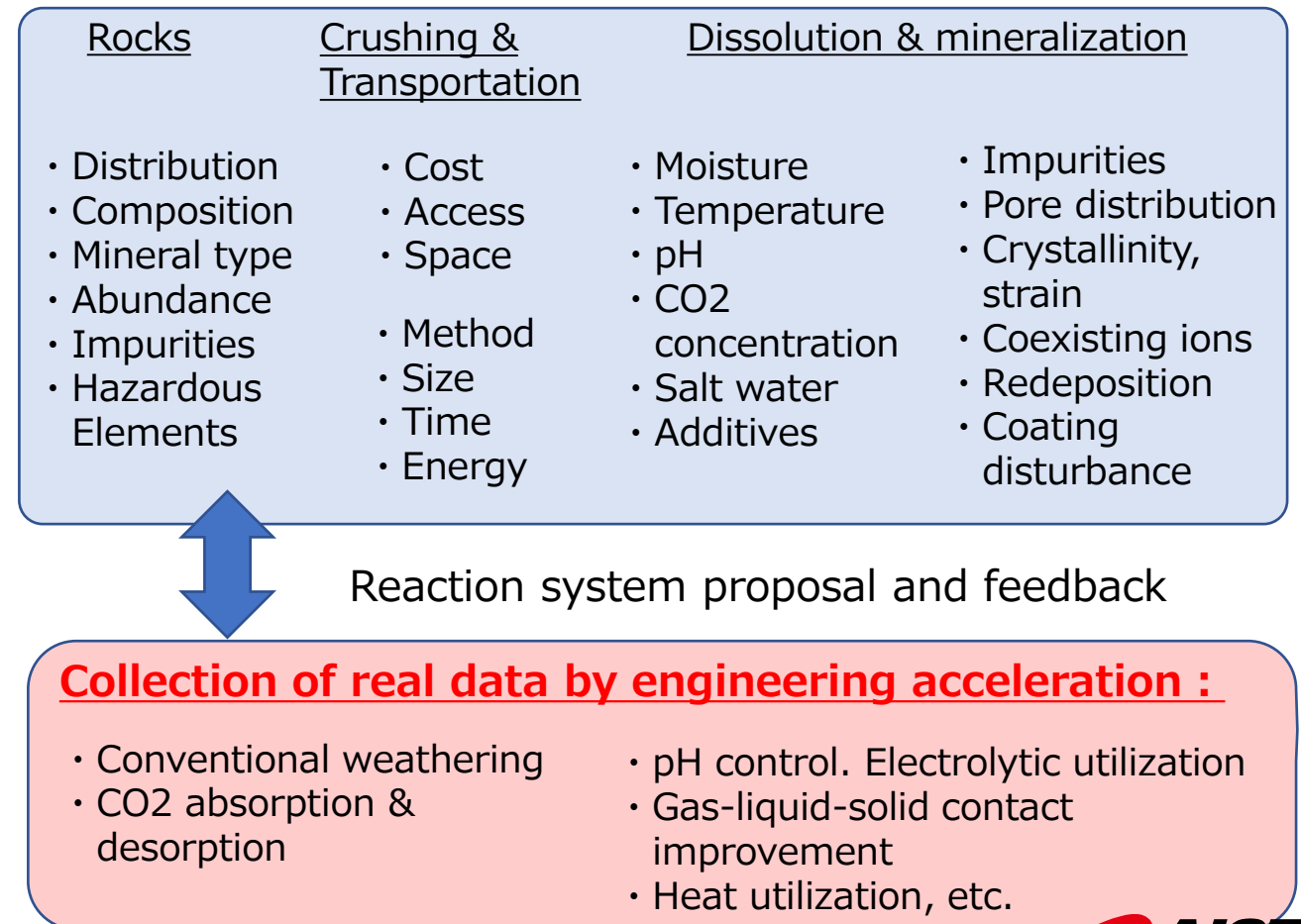
Account · Cost reduction · Application

- Reduce the CO₂ mineralization cost to half of the current cost by using an ultrasonic pulverization method.
- Investigation of the effect of humidity, temperature, etc., for demonstration of engineering reaction acceleration.

High-efficiency ultrasonic pulverization technology for enhanced weathering

Small grain size is an effective mean of promoting weathering. Development of high-efficiency pulverization technology is one of the important issues for practical use of weathering acceleration.

| Pulverization cost accounts for 70% of EW cost | Ball Mill | Ultrasonic grinder |
|--|---|--|
| Mafic rock pulverization  |  |  |
| Pulverization cost (kWh/t-rock) | 83 | 26 |



【FY2023~24 objectives】

FY2023 : Obtain the ultrasonic pulverization conditions for achieving 50% less pulverization energy and 40% higher yield in comparison to the conventional methods. Clarification of factors affecting dissolution and carbonation rates. Improvement of reaction methods.

FY2024 : Develop a continuous automatic-ultrasonic pulverizer. Collection of various experimental information on dissolution and carbonation rates, mass balance of effluent ions and reaction residues, and energy consumption.

Theme 4 : Analysis for the effect of applying rock powder to soil on plant growth and microbiome diversity

Account · Cost reduction · Application

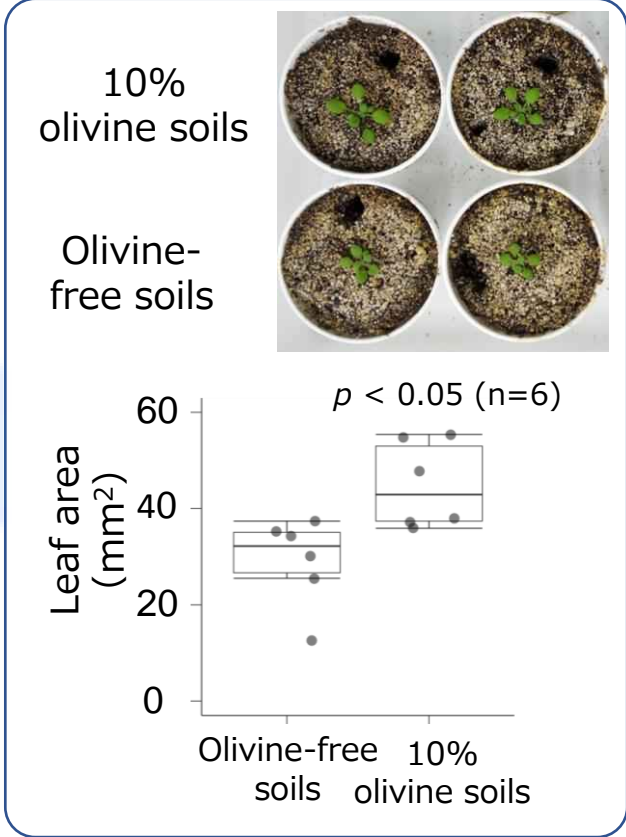
- Measurement of the growth rate and photosynthetic activity of plants and soil environment such as pH in soil including mafic, basaltic rocks or carbonate minerals.
- Evaluation for the effect on CO₂ fixation and microbial activity in soil including finely-crushed rocks in the field.

Lab test : Time-course observations of plant growth rate in soil including various rocks powdered in different sizes



RIPPS (RIKEN Integrated Plant Phenotyping System)

Arabidopsis and Micro-Tom plants are subjected to the RIPPS monitoring



Optimization of the application conditions to increase plant growth rate

Miyako Island, Okinawa
Cassava and yam cultivation



Field test : Analysis for the effect of rock powder on plant growth, microbial diversity, and CO₂ fixation efficiency in soil



【FY2023~24 objectives】

FY2023 : Plant growth monitoring of RIPPS to find a better particle size, rock type and application conditions of crushed rocks in soil by using Arabidopsis and MicroTom plants. Analysis of growth rate of crops and microbial population dynamics during application of crushed rocks to soil in the field.

FY2024 : Optimization of the particle size, rock type and application condition of crushed rocks in soil to maximize CO₂ fixation efficiency and plant growth in the field. The multiple omics analysis to reveal the molecular mechanism underlying plant growth improvement by the treatment of rock powder.

Theme 5 : Development of LCA/TEA platform of enhanced mineralization

Account · Cost reduction · Application

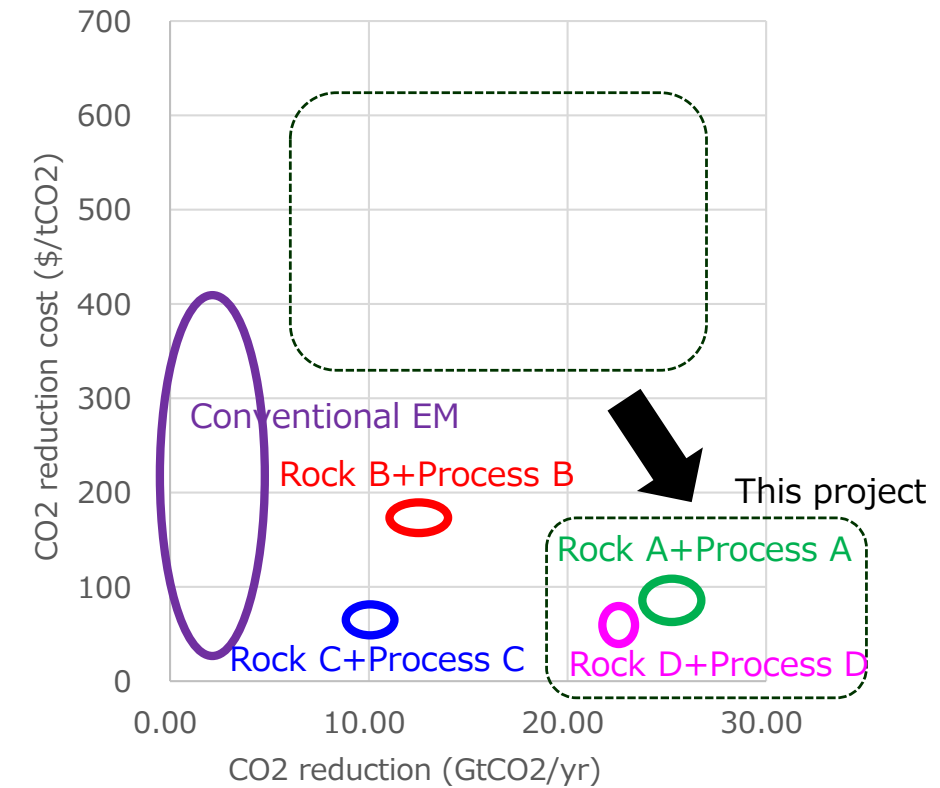
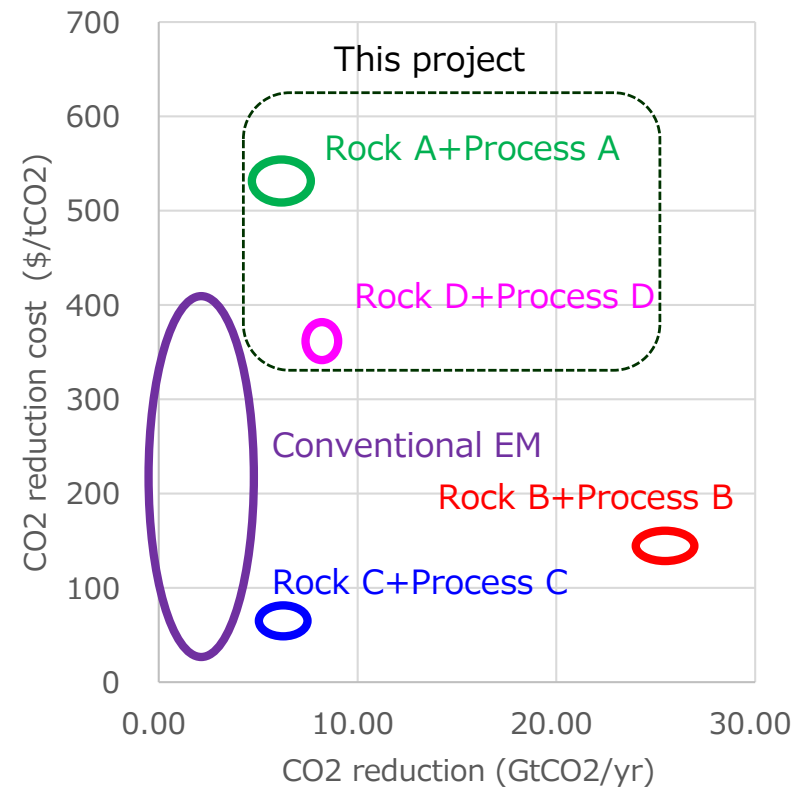
- Development of LCA/TEA platform for evaluating annual CO₂ reduction considering temporal aspect.
- Evaluation and optimization of total system to reduce the CO₂ reduction cost.

Development of LCA/TEA platform

Input Data
Composition of mafic rocks, grinding energy, mineralization conditions, etc.,



Output Data
Lifecycle CO₂ emission
CO₂ reduction
CO₂ reduction cost
Evaluation of annual amount until 2050



2030 Annual cost and CO₂ reduction by LCA/TEA tool  

[FY2023~24 objectives]

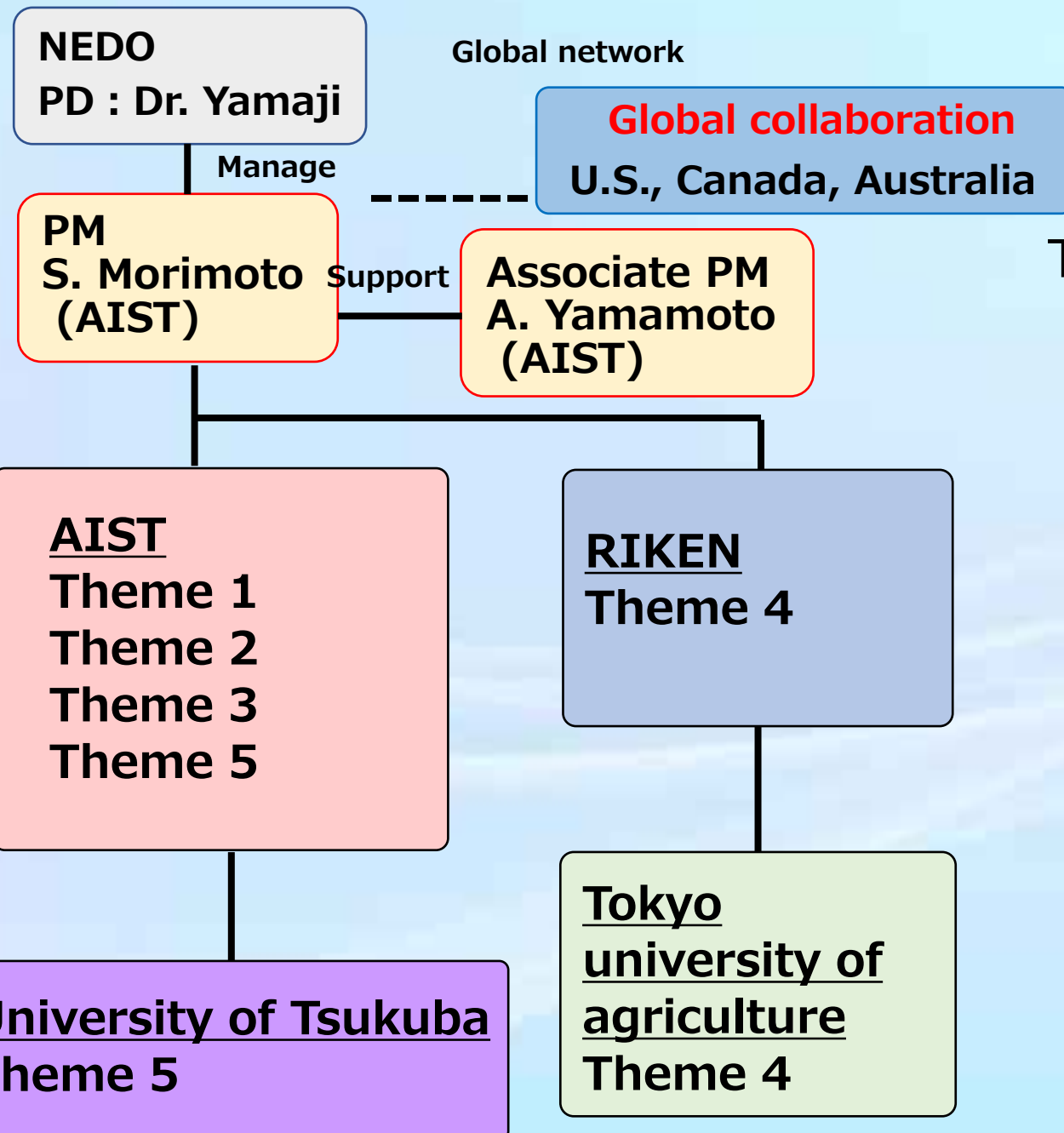
FY2023 : Collect inventory foreground data of enhanced mineralization system from the progress of this project. Create the base tool of LCA/TEA. Examine the current situation of negative emission technologies by PEST analysis for future scenario.

FY2024 : Develop LCA/TEA platform for evaluating cost and CO₂ reduction of enhanced mineralization. Create future scenario for future background data. Case study of total system for optimization.

Project formation and schedule

- Data management by collecting project results through a common data format.
- Form a committee with outside experts to determine the direction of the project.
- Create global collaboration through a “Mission innovation”.

Project formation



Project schedule

