International Institute for Carbon-Neutral Energy Research

CO_2 Storage Revised Roadmap

February 2019

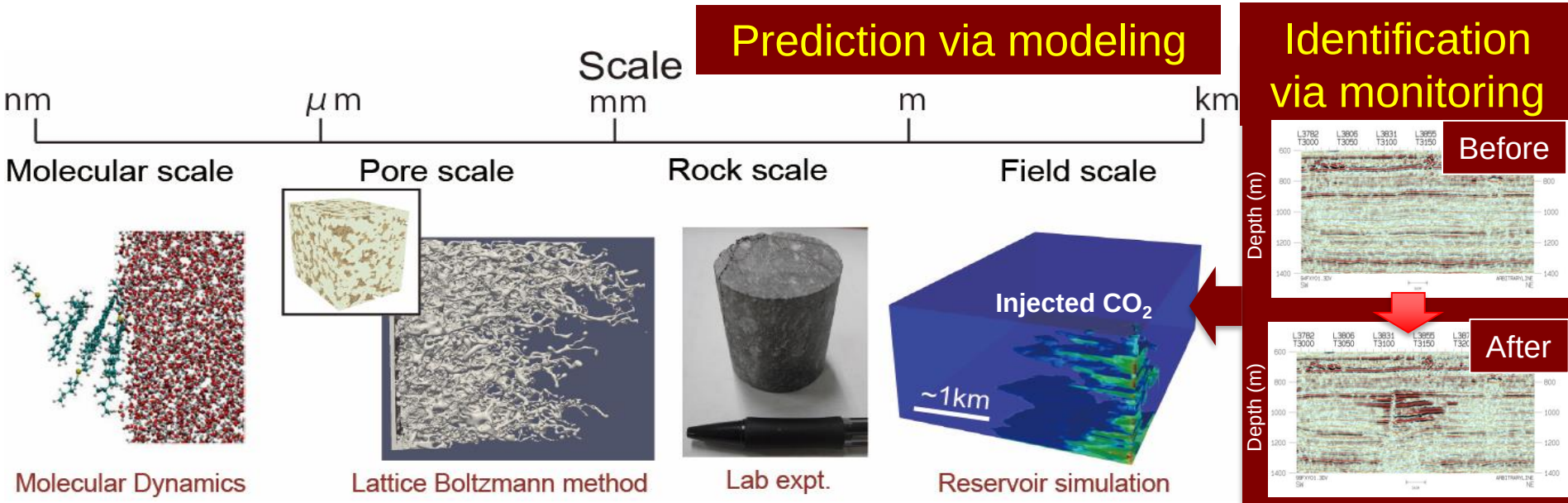
KYUSHU UNIVERSITY

wpi World Premier International Research Center Initiative

ILLINOIS

Division Objective

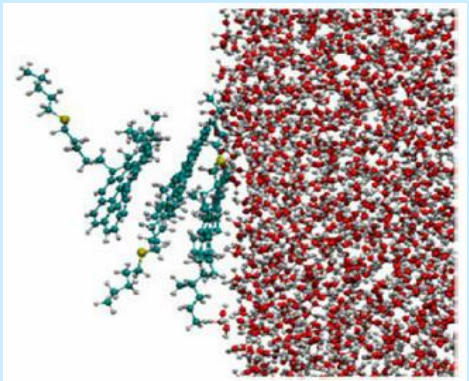
- **Accurately predict CO_2 fate for safe and enhanced CO_2 storage**
  - Modeling CO_2 behavior in a wide range of scales
- **Continuously identify CO_2 behavior for safe CO_2 storage**
  - Monitoring CO_2 behavior at the field-scale
- **Explore innovative CCS concepts suitable for geological formations typical of Japan (e.g. heterogeneous formation)**



Research Projects

Project 1
Molecular-scale CO_2 investigation (nm-μm)

Efforts:
- Evaluate influence of slip flow
- Model CO_2 reactions

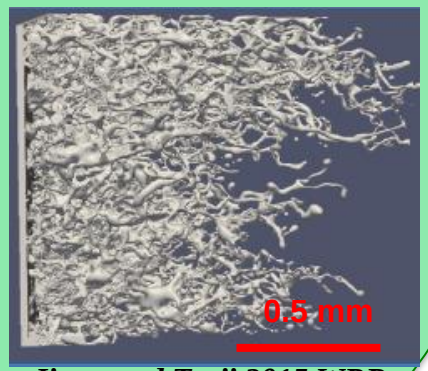


e.g. Jia et al. accepted, Sci. Rep.

Navier-Stokes with "slip flow"
Molecular dynamics

Project 2
Pore-scale CO_2 investigation (μm-cm)

- Model CO_2 behavior to increase storage capacity and security by enhanced trapping
- Coupled hydrological and geomechanical modeling

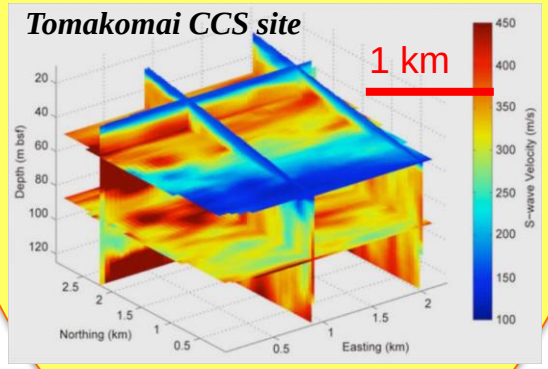


Jiang and Tsuji 2015 WRR

Navier-Stokes
(project 1 in FY2015)

Project 3
Field-scale CO_2 investigation (m-km)

- Construct geologic model with high resolution
- Develop effective monitoring
- Quantitative monitoring (CO_2 saturation)



Ikeda and Tsuji 2015 JGGC

Darcy flow

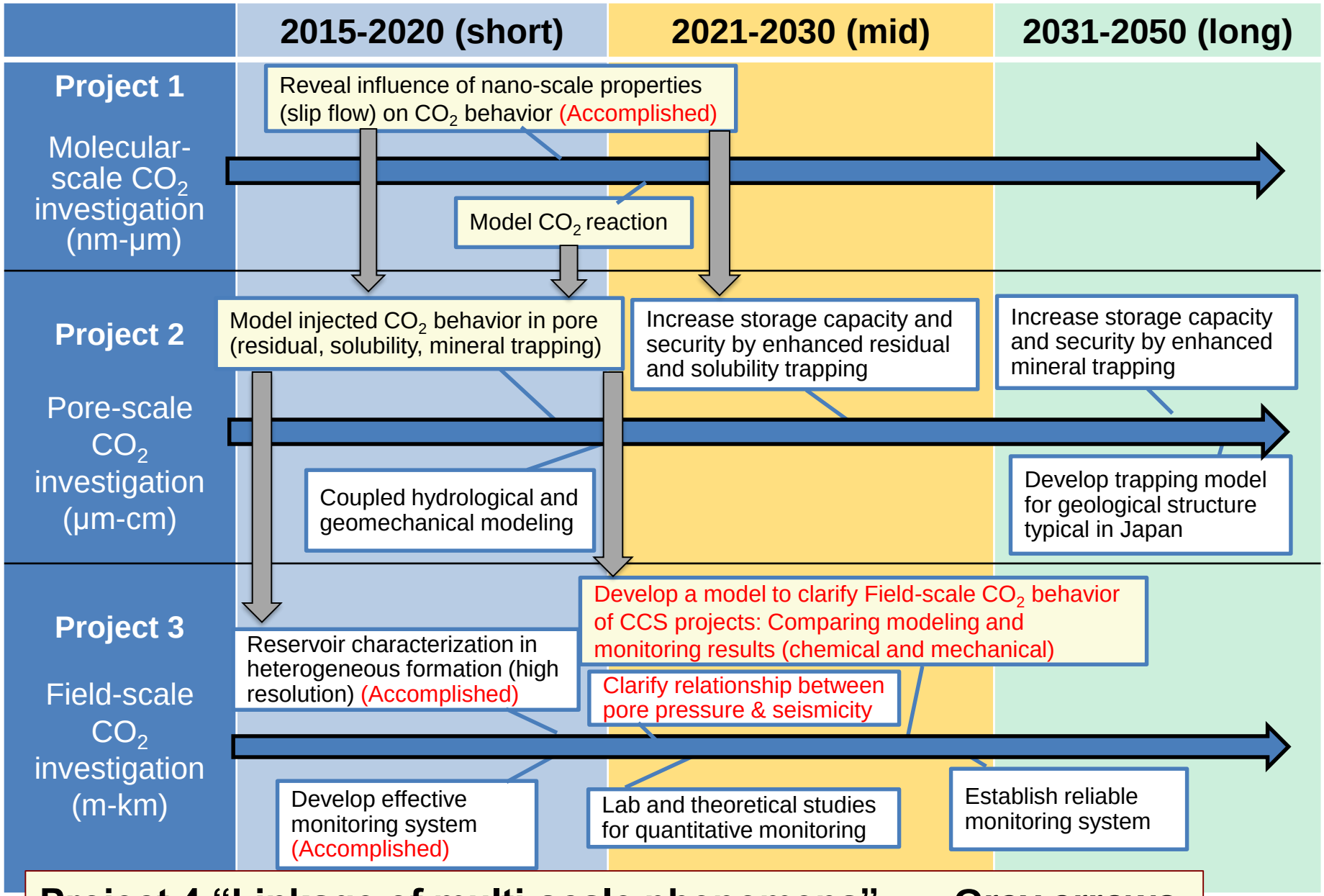
Geophysical monitoring
(project 2 in FY2015)

Project 4: Linkage of multi-scale phenomena
Try to identify the important mechanisms for upscaling

Division Projects, Objectives, and Research Efforts

Projects	Objectives	Efforts	Researchers
Project 1 Molecular-scale CO_2 investigation (nm-μm)	Reveal CO_2 interactions and reactions in order to enhance CO_2 trapping	- Reveal influence of nano-scale properties (e.g. slip flow) on CO_2 behavior (Accomplished) - Model CO_2 chemical reactions	Tsuji Jia, Tsuji
Project 2 Pore-scale CO_2 investigation (μm-cm)	Reveal CO_2 trapping mechanisms in order to predict CO_2 fate and enhance CO_2 trapping	- Understand/model injected CO_2 behavior (residual, solubility, mineral trapping) - Increase storage capacity and security by enhanced trapping - Coupled hydrological and geomechanical modeling for induced seismicity prediction	Christensen, Kitamura, Tsuji, Jiang, Diogo Christensen, Kitamura, Tsuji, Jiang, Diogo Tsuji, Kitamura, Jiang, Ikeda
Project 3 Field-scale CO_2 investigation (m-km)	Reveal field-scale heterogeneous geological properties and CO_2 behavior	- Field-scale reservoir characterization (Identify heterogeneity) (Accomplished) - Develop effective monitoring system - Quantitative monitoring (prediction of CO_2 saturation and reactions)	Tsuji, Ikeda, Andri Tsuji, Ikeda, Andri Kitamura, Tsuji, Ikeda, Andri
Project 4 Linkage of multi-scale phenomena	Investigate scale dependence in order to include smaller-scale phenomena into larger-scale CO_2 behaviors	- Identify important mechanisms in each scale - Upscale for accurate field-scale predictions	All member

Milestones



Project 4 "Linkage of multi-scale phenomena" → Gray arrows

Ultimate Targets

	Ultimate targets	Current Benchmarks	Technology/ Application
Project 1 Molecular-scale CO_2 investigation (nm-μm)	• Model reaction and interaction of CO2	• Molecular-scale investigation is still new in earth science. • Multiphase flow at nano-scale has not been well revealed.	• Contribute to Project 2 • CO_2 mineralization modeling
Project 2 Pore-scale CO_2 investigation (μm-cm)	• Develop predictive framework for accurate reservoir characterization (pre-injection) and long-term CO_2 fate (post-injection) • **Increase storage capacity by >20% and security by enhanced residual, solubility and mineral trapping**	• Current pore-scale models cannot capture dynamic nature of CO_2 migration nor do they embody interconnected nature of pore system and impact on CO_2 migration. • **Residual CO_2 trapping is <30% in Nagaoka CCS project.** CO_2 trapping has not been controlled in CCS.	• CO_2 migration model for CO_2 storage and monitoring in CCS
Project 3 Field-scale CO_2 investigation (m-km)	• **Establish reliable monitoring system to investigate field-scale CO_2 behavior and saturation** ➢ Cost-effective monitoring (80% cost reduction) ➢ Continuous monitoring (Detect minor change in reservoir; detect 5% CO_2 saturation) ➢ Quantitative monitoring ➢ Classify between natural and CO2 induced earthquakes	• Injected CO_2 can be clearly monitored by time-lapse seismic survey. Current monitoring cost is over US$ several million. • Accuracy of monitoring is not enough to detect small amount of injected CO_2 because of long data acquisition interval (usually 5 years). Continuous monitoring system could help to identify the minor change in reservoir. • Continuous monitoring system has been proposed by LBNL, but the performance is not enough. No other institute develop the continuous monitoring system. • Limited precedential research exists for pore pressure and seismicity relationship	• CO_2 migration model for CO_2 storage and monitoring in CCS
Project 4 Linkage of multi-scale	• Include influence of smaller-scale properties upon field-scale CO_2 behavior	• Current field-scale predictions do not capture CO_2 migration because pore-scale phenomena not accurately modeled in the simulations.	• CO_2 migration model for CO_2 storage and

Role & Contribution through Technology

- **Role of this division toward CNS is to create**
  1. **digital rock CO_2 model coupled with monitoring technology to find prospective CO_2 storage sites, predict CO_2 migration in geological reservoirs and help conduct cost effective CO_2 monitoring, contributing to providing low carbon electricity through CCS deployment**
  2. **CO_2 mineralization model to enhance CO_2 trapping in geological reservoirs, contributing increase of reliability of CCS**

Technology/Application