International Institute for Carbon-Neutral Energy Research

CO_2 Capture & Utilization Revised Roadmap

January 2019

KYUSHU UNIVERSITY

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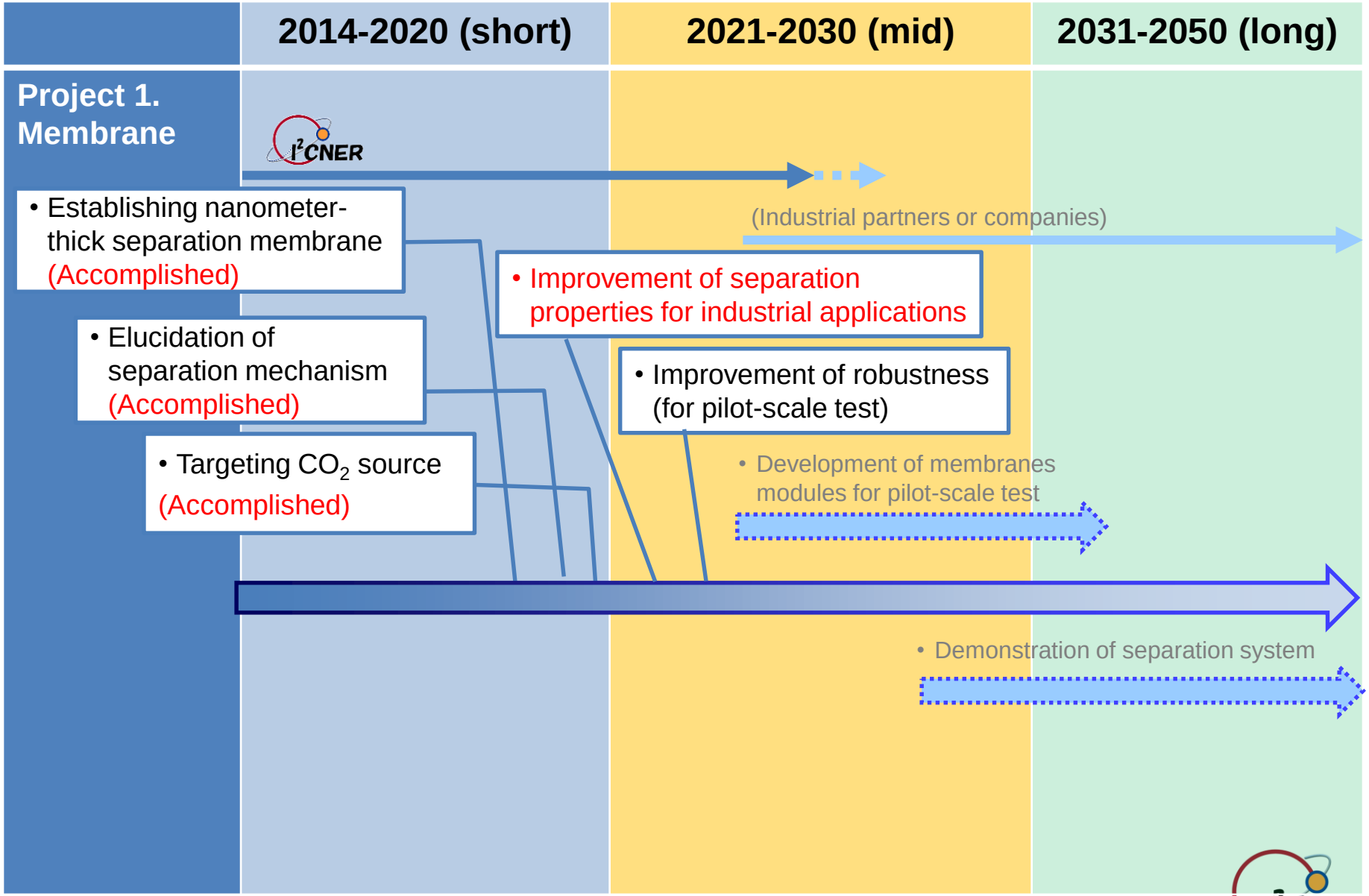
Division Objective

- **The development of highly efficient materials for CO_2 separation in power generation and industrial processes.**
- **The creation of energy efficient and cost effective CO_2 conversion systems for (i) production of value-added chemicals, such as a liquid fuel or their intermediates, or (ii) storage for renewable energy**

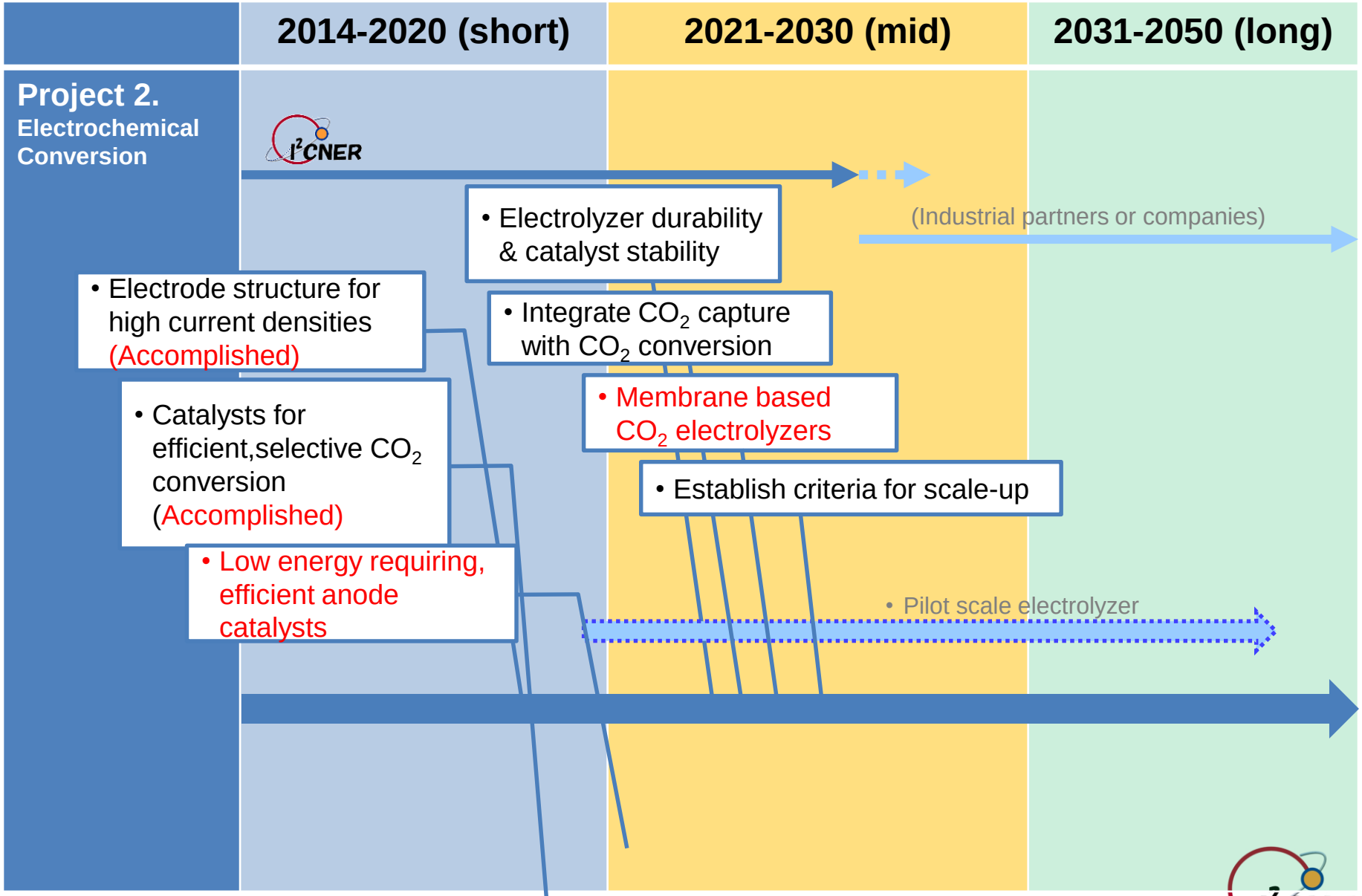
Division Projects, Objectives, and Research Efforts

	Projects	Objectives	Research Efforts	Researchers
Capture	**Project 1. Membrane**	Develop novel membrane technology to separate CO_2 from the mixture or **(a) CO_2/H_2** (~~Pre-combustion~~) • IGCC/IGFC~~/NGTCC~~ • C-free H_2 production **(b) CO_2/N_2** (~~Post-combustion~~) • Thermal power plant • Steelworks • Cement • Direct Air Capture **(c) CO_2/CH_4** • NG purification • Biogas upgrading ~~**(d) Other industries**~~ ~~• Cement (CO_2/N_2)~~	• Develop ultra-thin membranes with high CO_2 permeation • Development of high-performance ~~ceramic and polymeric~~ membrane materials • Improvement of membrane durability • Elucidation of molecular mechanism in a gas separation	S. Fujikawa I. Taniguchi B. Freeman T. Kunitake
Conversion	**Project 2. Electrochemical conversion**	Develop novel cathode catalysts and electrodes for the conversion of CO_2 into value-added fuels or their intermediates (e.g. CO, CH_4, ~~M~~Ethanol, Ethylene and other hydrocarbons) Develop low energy requiring	• Improve performance of precious-metal catalysts though use of different supports (C, CNT, TiO_2) • Explore metal-free catalysts • Develop high performance, durable electrodes • Study performance with a	P. Kenis Aided by N. Nakashima T. Fujigaya A. Gewirth M. Yamauchi S. Lyth

Milestones (1)



Milestones (2)



Ultimate Targets

	Ultimate targets	Current Benchmark	Technology/ Application
Project 1. Membrane	Demonstration of a highly efficient separation system to remove CO_2 from pressured gas containing CO_2 ➢ CO_2/H_2 (Pre-combustion)* CO_2 permeance: 100 GPU Selectivity: 30 (single cascade) CO_2 permeance: 30 GPU Selectivity: 125 (tandem cascade) @$p(CO_2)$ 10 atm ➢ CO_2/N_2 (Post-combustion)* CO_2 permeance: 4000 GPU Selectivity: 40 (*But these numbers are still under investigation, since they depend on separation processes.)	➢ CO_2/H_2 (Pre-combustion) CO_2 permeance: 206 GPU Selectivity: 103 @$p(CO_2)$ 12 atm (Ohio state Univ., USA) ➢ CO_2/N_2 (Post-combustion) CO_2 permeance: 2000 GPU Selectivity: 50 (MTR, USA) **(1 GPU = 7.5 x 10^{-12} m^3(STP)/(m^2 s Pa))**	• CO_2 capture from flue gas of coal / natural gas power generation for CCS / CCUS system
Project 2. Electrochemical Conversion	Demonstration of a highly efficient electrochemical CO_2 conversion system (electrolyzer), driven by renewable energy, and able to produce value-added chemicals (i.e., fuels or their intermediates) ➢ CO production Faradaic Efficiency: >90% Energy Efficiency: >60% Current Density: > 500 mA/cm^2 ➢ Production of other chemicals Ethanol Ethylene Other Hydrocarbons	➢CO production Faradaic Efficiency: >90% Energy Efficiency: >70% Current Density: 600 mA/cm^2 (I2CNER) ➢Ethylene & Ethanol production Faradaic Efficiency: ~80% Energy Efficiency: ~50% Current Density: 200 mA/cm^2 (I2CNER) ~~➢Energy storage~~ ~~Overall efficiency >35%~~	• Fuel production using CO_2

Role & Contribution through Technology

- **Role of this division toward CNS is to create:**
  1. **low energy penalty and low cost CO_2 capture system from flue gas of coal / natural gas power generation for CCS / CCU&S system by the development of novel membranes, contributing to CCS deployment through energy and cost savings in the CO_2 capture stage**
  2. **energy efficient and cost effective CO_2 conversion systems for the production of liquid fuels or their intermediates to substitute fossil fuel**

Technology/Application