International Institute for Carbon-Neutral Energy Research

CO_2 Capture & Utilization Revised Roadmap

July 2015

KYUSHU UNIVERSITY

wpi World Premier International Research Center Initiative

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

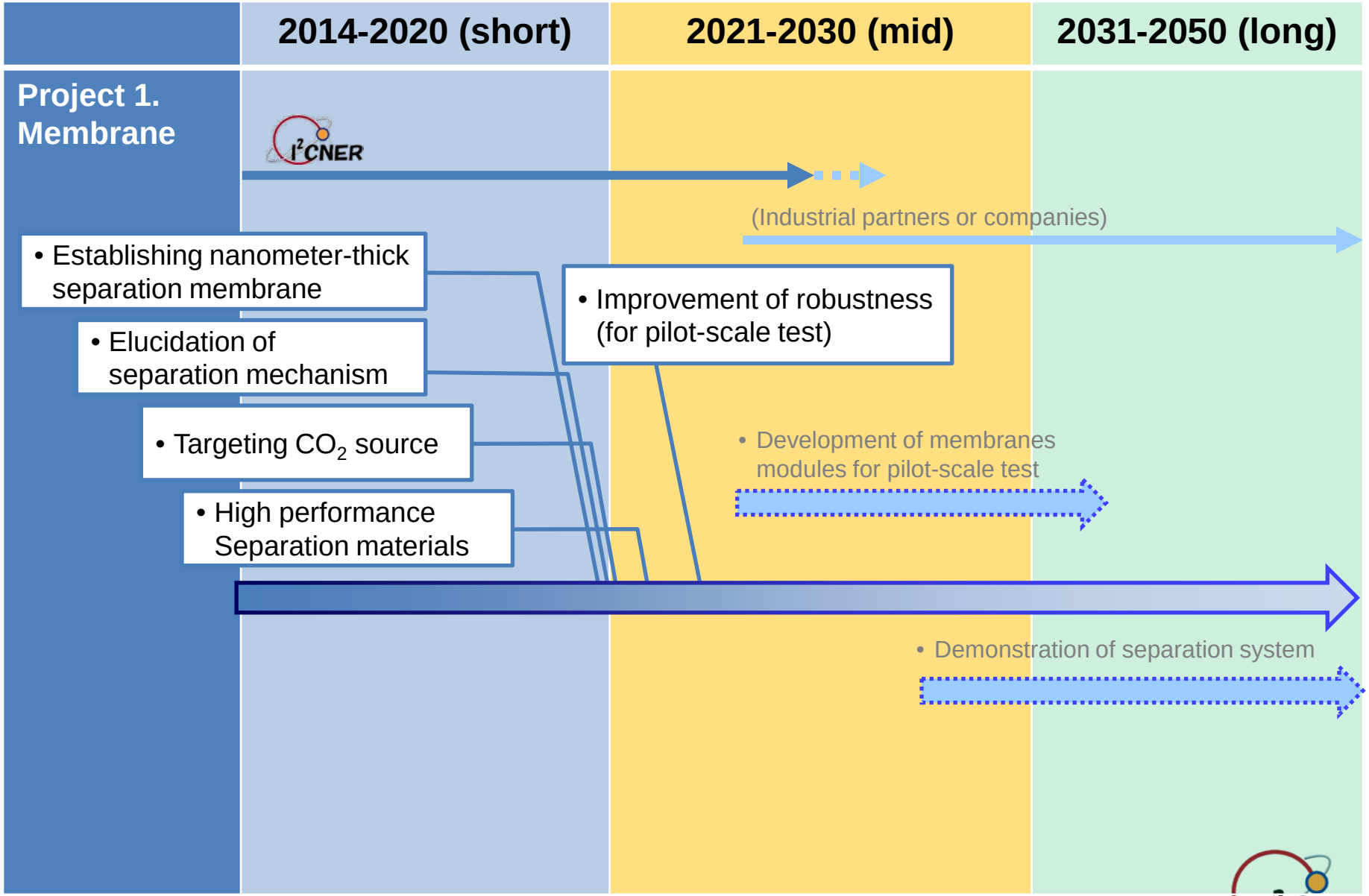
Division Objectives

- **Development of highly efficient materials for CO_2 separation in power generation and industrial processes.**
- **Creation of energy efficient and cost effective CO2 conversion system for (i) production of value-added chemicals, such as a liquid fuel or their intermediates, by and, or (ii) storage as renewable energy**

Division Projects, Objectives, and Research Efforts

	Projects	Objective	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 **(b) CO_2/N_2** (Post-combustion) • Fossil-fired plant **(c) CO_2/CH_4** • NG purification **(d) Other industries** • Cement (CO_2/N_2) • C-free H_2 production (CO_2/H_2)	• Develop ultra-thin membranes with high CO_2 permeation • Development of high-performance ceramic and polymeric membrane materials • Improvement of a membrane durability • Elucidation of molecular mechanism in a gas separation	S. Fujikawa I. Taniguchi B. Freeman
Conversion	**Project 2. Electrochemical conversion**	Develop novel catalysts and electrodes for the conversion of CO_2 into value-added fuels or their intermediates (e.g. CO, Methanol and hydrocarbon)	• 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 diluted CO_2 feed (flue gas, 15% CO_2)	P. Kenis Aided by N. Nakashima T. Fujigaya S. Lyth A. Gewirth

Milestones


2014-2020 (short)
2021-2030 (mid)
2031-2050 (long)
Project 1.
Membrane
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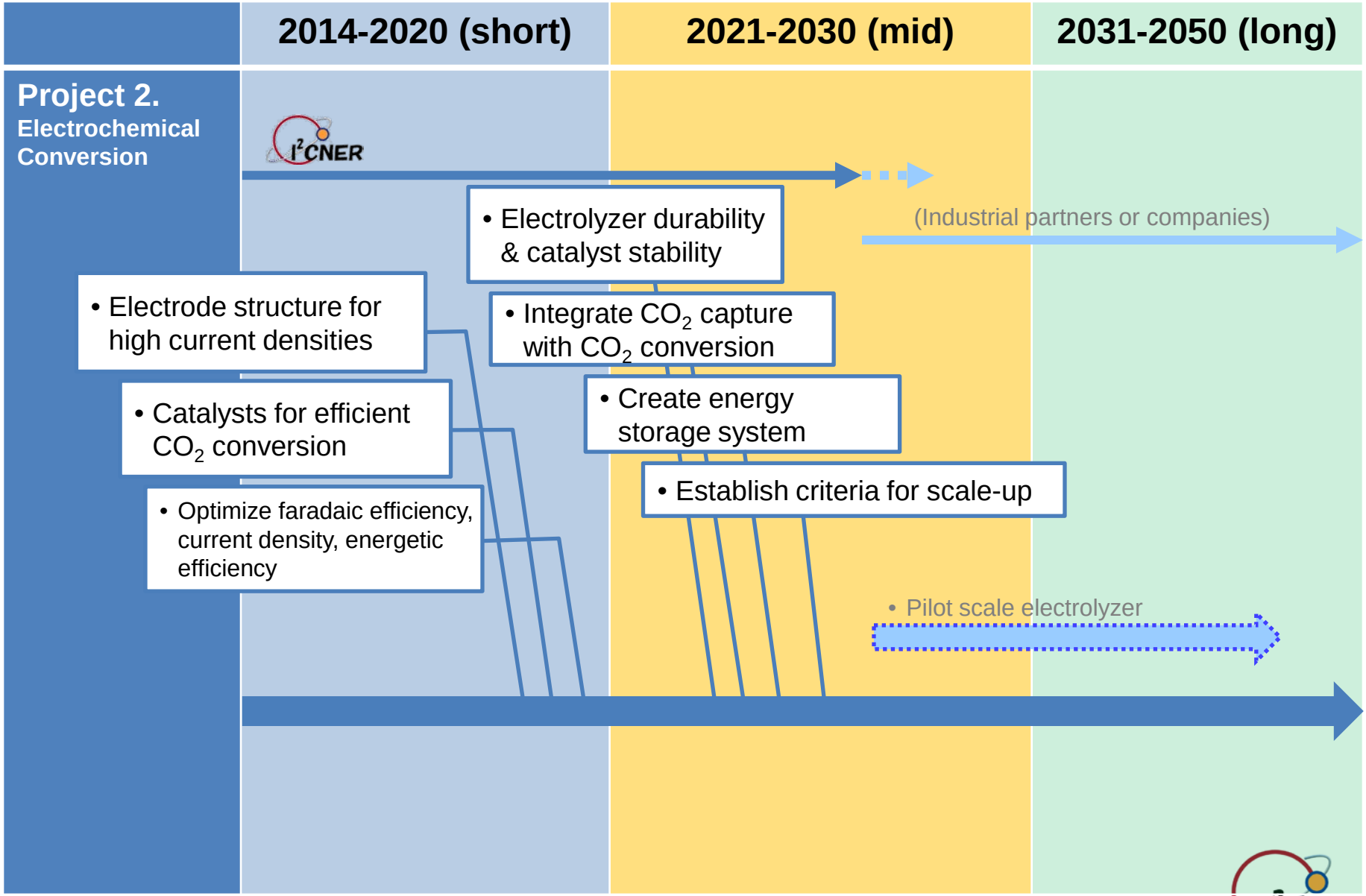
(Industrial partners or companies)
• Establishing nanometer-thick separation membrane
• Elucidation of separation mechanism
• Targeting CO_2 source
• High performance Separation materials
• Improvement of robustness (for pilot-scale test)
• Development of membranes modules for pilot-scale test
• Demonstration of separation system

Milestones


2014-2020 (short)
2021-2030 (mid)
2031-2050 (long)
Project 2.
Electrochemical Conversion
I²CNER
• Electrolyzer durability & catalyst stability
(Industrial partners or companies)
• Electrode structure for high current densities
• Integrate CO_2 capture with CO_2 conversion
• Catalysts for efficient CO_2 conversion
• Create energy storage system
• Optimize faradaic efficiency, current density, energetic efficiency
• Establish criteria for scale-up
• Pilot scale electrolyzer

Ultimate Targets

	Ultimate targets	Current Benchmark
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: 100GPU* Selectivity: 30 @$p(CO_2)$ 10 atm ➢ CO_2/N_2 (Post-combustion) CO_2 permeance: 4000 GPU Selectivity: 40	➢ CO_2/H_2 (Pre-combustion) CO_2 permeance: 41GPU Selectivity: 87 @$p(CO_2)$ 3 atm (Ohio state Univ., USA) ➢ CO_2/N_2 (Post-combustion) CO_2 permeance: 1000 GPU Selectivity: 40 (MTR, USA)
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 MeOH Hydrocarbons	➢CO production Faradaic Efficiency: 80~85% Energy Efficiency: >70% Current Density: 250mA/cm^2 ➢Energy storage Overall efficiency >35% (otherwise wasted intermittent renewable energy → chemical for storage → electrical energy) *∗Benchmarks for other chemical are necessary*

*1 GPU = 7.5 x 10^{-12} m^3(STP)/(m^2 s Pa)

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