

# International Institute for Carbon-Neutral Energy Research



## Catalytic Material Transformation Revised Roadmap

February 2019



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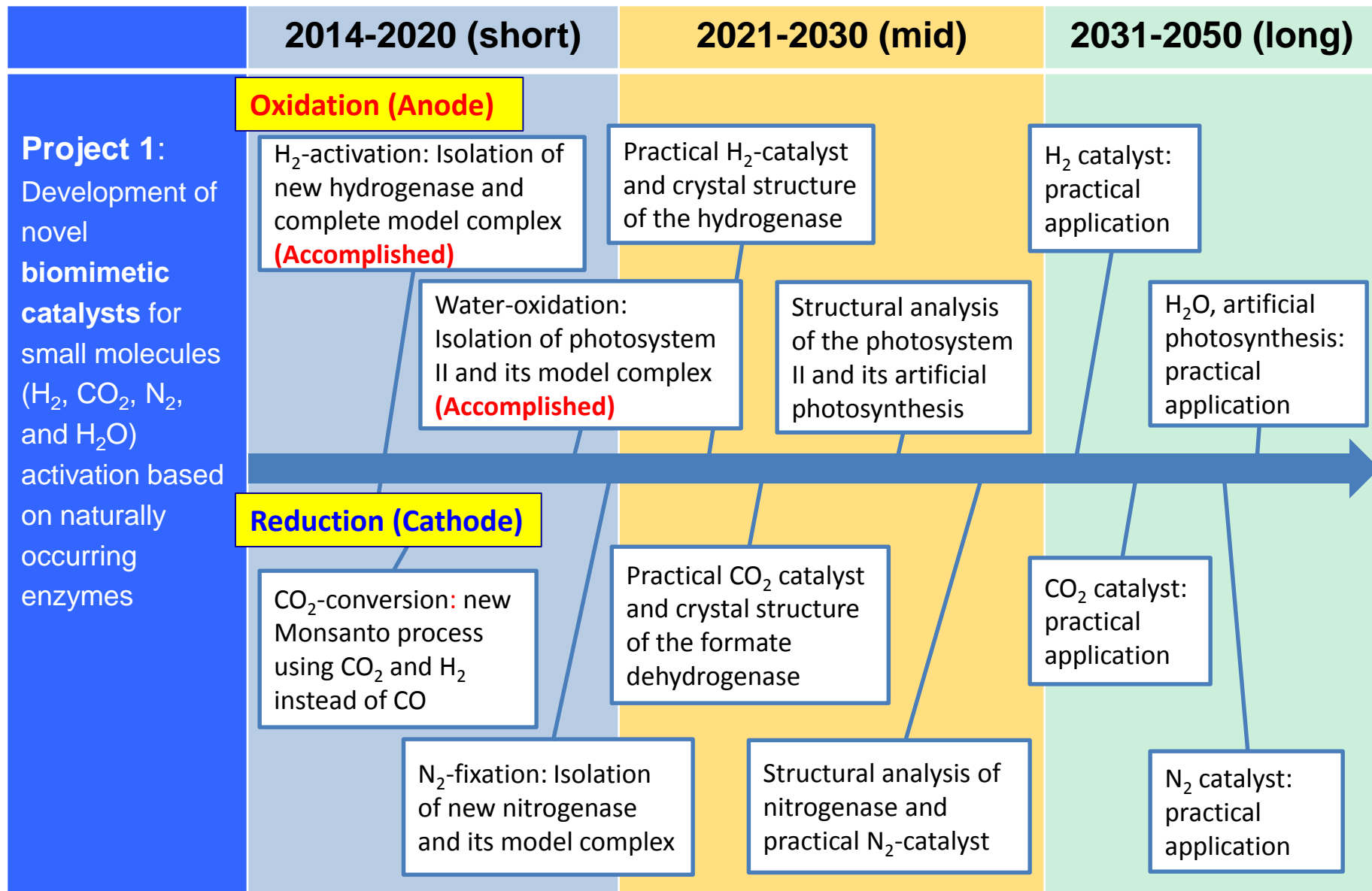
# Division Objectives

**Contribute to the creation of innovative carbon-neutral technologies by developing “*Novel Catalysts*” underlining aspects of both basic science and engineering**

- Activities are focused on investigating of catalysis-related ***Bio-inspired Systems for Fuel and Energy Generation and Sustainable Energy Transport and Storage Systems using Tailored Inorganic Nanocatalysts***
  - Development of bio-mimetic catalysts for small molecules (e.g., H<sub>2</sub>, N<sub>2</sub>, CO<sub>2</sub>, and H<sub>2</sub>O) activation based on naturally occurring enzymes
  - Production of clean fuels for carbon-neutral power generation cycles using bio-derived energy-carrying materials

# Division Projects, Objectives, and Research Efforts

Projects	Objectives	Research Efforts	Researchers
<p><b>Project 1:</b> Development of novel biomimetic catalysts for H<sub>2</sub>, CO<sub>2</sub>, N<sub>2</sub>, and H<sub>2</sub>O activation based on naturally occurring enzymes</p>	<p>Development and characterization of new catalysts for alternative lower cost and more energy efficient pathways for energy generation: H<sub>2</sub> activation, CO<sub>2</sub> conversion, N<sub>2</sub> fixation, and solar based water oxidation.</p>	<ul style="list-style-type: none"> <li>• Development of new biological and its synthetic catalysts of H<sub>2</sub>-activation</li> <li>• New catalysts of CO<sub>2</sub>-conversion</li> <li>• Development of new biological and its biomimetic catalysts of N<sub>2</sub>-activation</li> <li>• Artificial photosynthesis of water oxidation</li> </ul>	<p>Ogo Yoon Matsumoto Yatabe Uchida <del>Tsugawa</del> <del>Nga</del> Rauchfuss</p>
<p><b>Project 2:</b> Development toward carbon-neutral power cycles</p>	<p>Development of catalysis for fuel oxidation and regeneration and production of novel materials for carbon neutral power generation cycles.</p>	<ul style="list-style-type: none"> <li>• Development of selective electrooxidation catalysts</li> <li>• Development of efficient reduction catalysts</li> </ul>	<p>Yamauchi Sadakiyo Kitano <del>Yu-Sun</del> Takashi Fukushima Cui Xuedong</p>



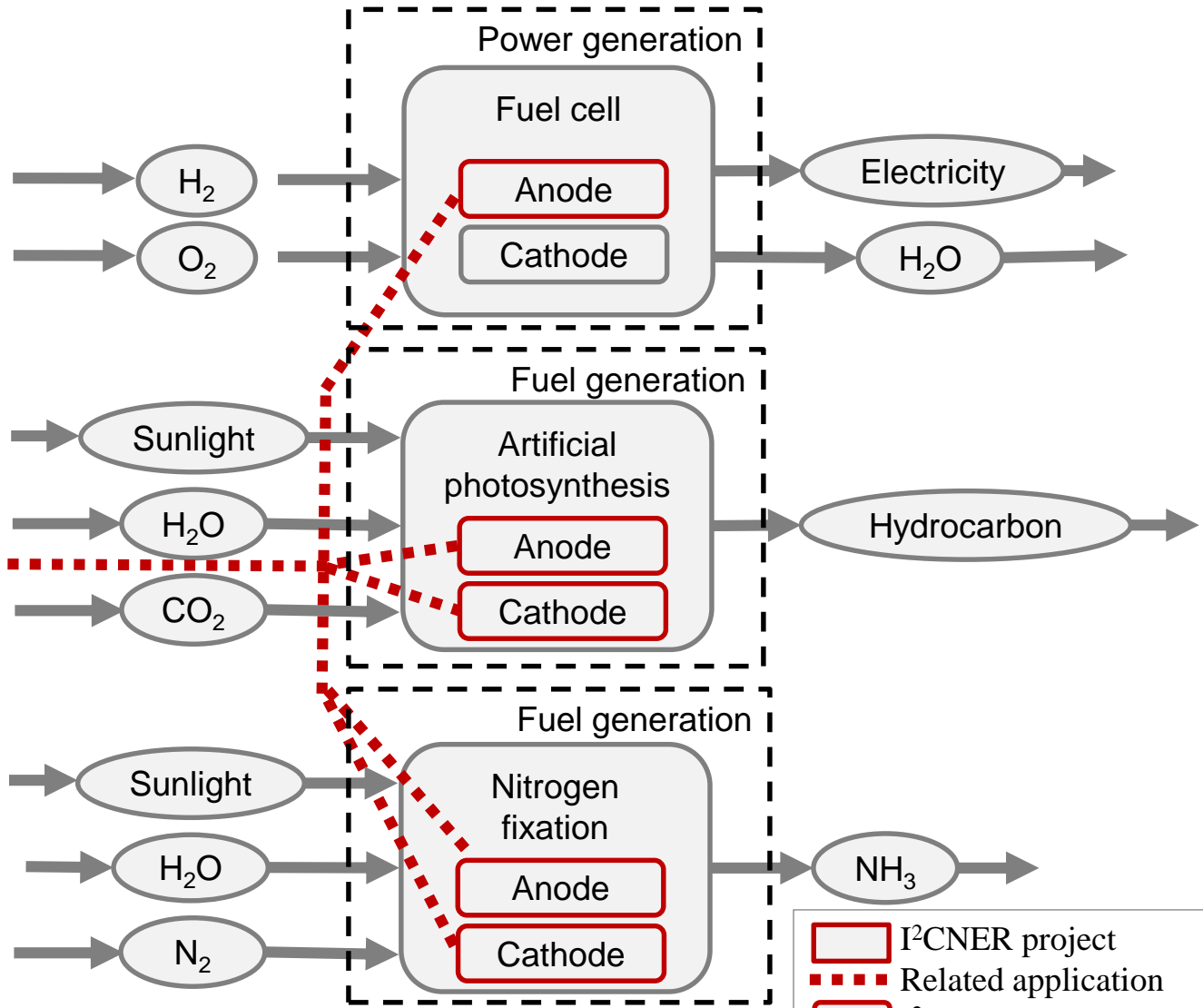
	2013-2020 (short)	2021-2030 (mid)	2031-2050 (long)
<b>Project 2:</b> development toward carbon-neutral power generation cycles	Exploring novel catalysts; Fuel regeneration by electroreduction: $\eta=50\%$ <b>(Accomplished)</b>	R&D for power charge; Fuel regeneration by electroreduction: $\eta=70\%$	Technology transfer; Fuel regeneration by electroreduction: $\eta=90\%$
	Exploring novel catalysts; Non-platinum catalysts: $50 \text{ mW} \cdot \text{cm}^{-2}$ <b>(Accomplished)</b>	R&D for power discharge using liquid carrier; Power generation: $500 \text{ mW} \cdot \text{cm}^{-2}$	Practical use; Power generation cycle without $\text{CO}_2$ emission

	Ultimate targets	Current Benchmark	Techlgy / Application
<p><b>Project 1:</b> Development of novel biomimetic catalysts for small molecules (H<sub>2</sub>, CO<sub>2</sub>, N<sub>2</sub>, and H<sub>2</sub>O) activation based on naturally occurring enzymes</p>	<ul style="list-style-type: none"> <li>• H<sub>2</sub> catalyst: low cost and highly efficient practical application</li> <li>• CO<sub>2</sub> catalyst: low cost and highly efficient practical application</li> <li>• Artificial photosynthesis: low cost and highly efficient system</li> <li>• N<sub>2</sub> catalyst: low cost and highly efficient practical application</li> </ul>	<ul style="list-style-type: none"> <li>• Ogo first synthesized a functional biomimetic H<sub>2</sub>-catalyst (Science 2013)</li> <li>• Ogo &amp; Yoon first constructed the PEFC with 637-times higher activity H<sub>2</sub>-biocatalyst than platinum (ACIE 2014)</li> <li>• Ogo &amp; Yoon first determined the crystal structure of NAD<sup>+</sup>-reducing [NiFe] hydrogenase (Science 2017)</li> <li>• Ogo group first succeed in creating the biomimetic fuel cells and solar cells using a new catalyst (ChemCatChem 2017)</li> <li>• Ogo group first synthesized a catalyst enabling H<sub>2</sub> and CO activation (ACIE 2017)</li> </ul>	<ul style="list-style-type: none"> <li>• H<sub>2</sub> catalyst of PEFC</li> <li>• CO<sub>2</sub> reduction for hydrocarbon production</li> <li>• Artificial photosynthesis of water oxidation</li> <li>• Ammonia production system</li> </ul>
<p><b>Project 2:</b> Development toward carbon-neutral power generation cycles</p>	<ul style="list-style-type: none"> <li>• Fuel regeneration by electroreduction: 80%</li> <li>• Power generation cycle without CO<sub>2</sub> emission</li> <li>• Competitive cost</li> </ul>	<ul style="list-style-type: none"> <li>• Yamauchi first regenerated alcohol (fuel) by electroreduction: &gt;95% Faradaic efficiency (Energy Environ. Sci 2015).</li> <li>• None</li> <li>• Yamauchi first circulated electric power using an alcohol/carboxylic acid couple without CO<sub>2</sub> emission (Energy Environ. Sci 2015).</li> </ul>	<ul style="list-style-type: none"> <li>• Electricity storage and energy (electricity) import using liquid storage material</li> </ul>

# Role & Contribution through Technology

- The role of this division toward a CNS is to produce / use energy by the development of a new catalyst for:
  1. fuel generation (hydrocarbon, NH<sub>3</sub>) device from sun light, contributing to providing cheap **low carbon fuel**
  2. Power generation device (fuel cell) using hydrogen, contributing to **efficiency increase** of fuel cell
  3. energy transport and storage systems to transport and store renewable electricity, contributing to **efficient use of renewable** energy and **import of low carbon energy** (electricity)

**Project 1**  
 Development of novel biomimetic catalysts for small molecules ( $H_2$ ,  $CO_2$ ,  $N_2$ , and  $H_2O$ ) activation based on naturally occurring enzymes



- I<sup>2</sup>CNER project
- Related application
- I<sup>2</sup>CNER project technology
- Technology /end user
- Energy flow
- Type of energy



