

# International Institute for Carbon-Neutral Energy Research



## Hydrogen Materials Compatibility Revised Roadmap

June 2017



KYUSHU UNIVERSITY



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ILLINOIS  
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# Division Objective

- Provide the basic science that enables optimization of the cost, performance, and safety of pressurized hydrogen containment systems.
  - Development and use of advanced capabilities (experimental and modeling) to identify fundamental mechanisms of hydrogen-affected fatigue, fracture, wear, and seizure in materials
  - Development of predictive performance models for materials subjected to hydrogen-affected fatigue, fracture, wear, and seizure
  - Development of next-generation monolithic and functionally graded materials having lower cost and improved performance (e.g., higher strength) while retaining resistance to hydrogen-induced degradation.

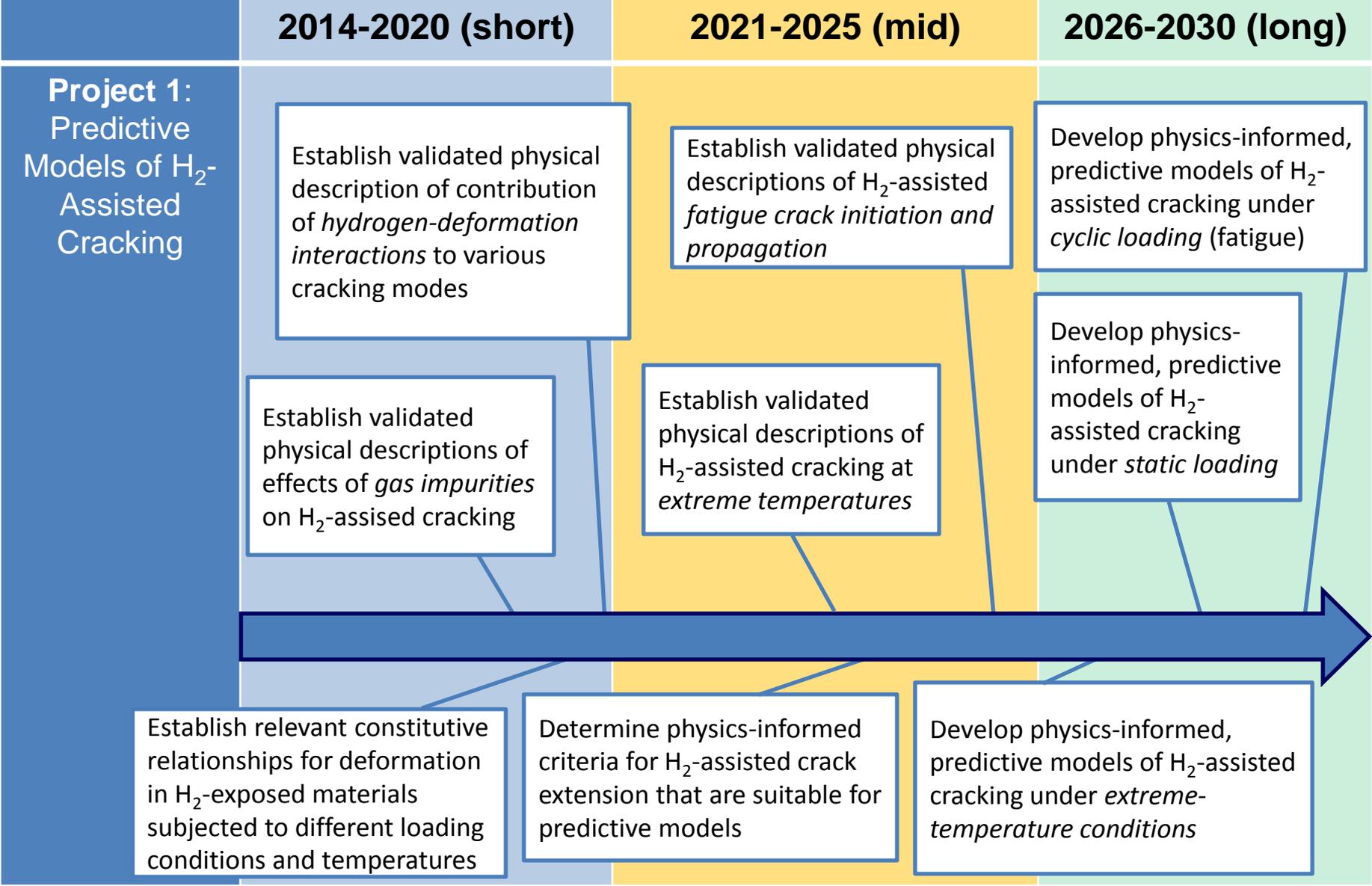
# Division Projects, Objectives, and Research Efforts (1)

Projects	Objectives	Research Efforts	Researchers
<b>Project 1:</b> Predictive Models of H <sub>2</sub> -Assisted Cracking	Develop physics-informed, predictive models of H <sub>2</sub> -assisted cracking in structural materials for technologically relevant loading conditions and temperatures	Establish comprehensive physical descriptions of H <sub>2</sub> -assisted cracking at the proper size scales  Establish relevant constitutive relationships for deformation in H <sub>2</sub> -exposed materials  Integrate physical descriptions and constitutive relationships into predictive model frameworks	Kubota, Matsuda, Kirchheim, Robertson, Sofronis, Somerday, Komoda, Aravas, Nagao, Ritchie
<b>Project 2:</b> Material Development for H <sub>2</sub> Service	Design cost-competitive materials for performance in H <sub>2</sub> service	Develop higher-strength, hydrogen-compatible stainless steels through advanced material processing methods  Characterize and improve hydrogen compatibility of welds  Develop and apply advanced surface coatings as hydrogen permeation barriers	Takaki, Kubota, Tsuchiyama, Yamabe, Macadre

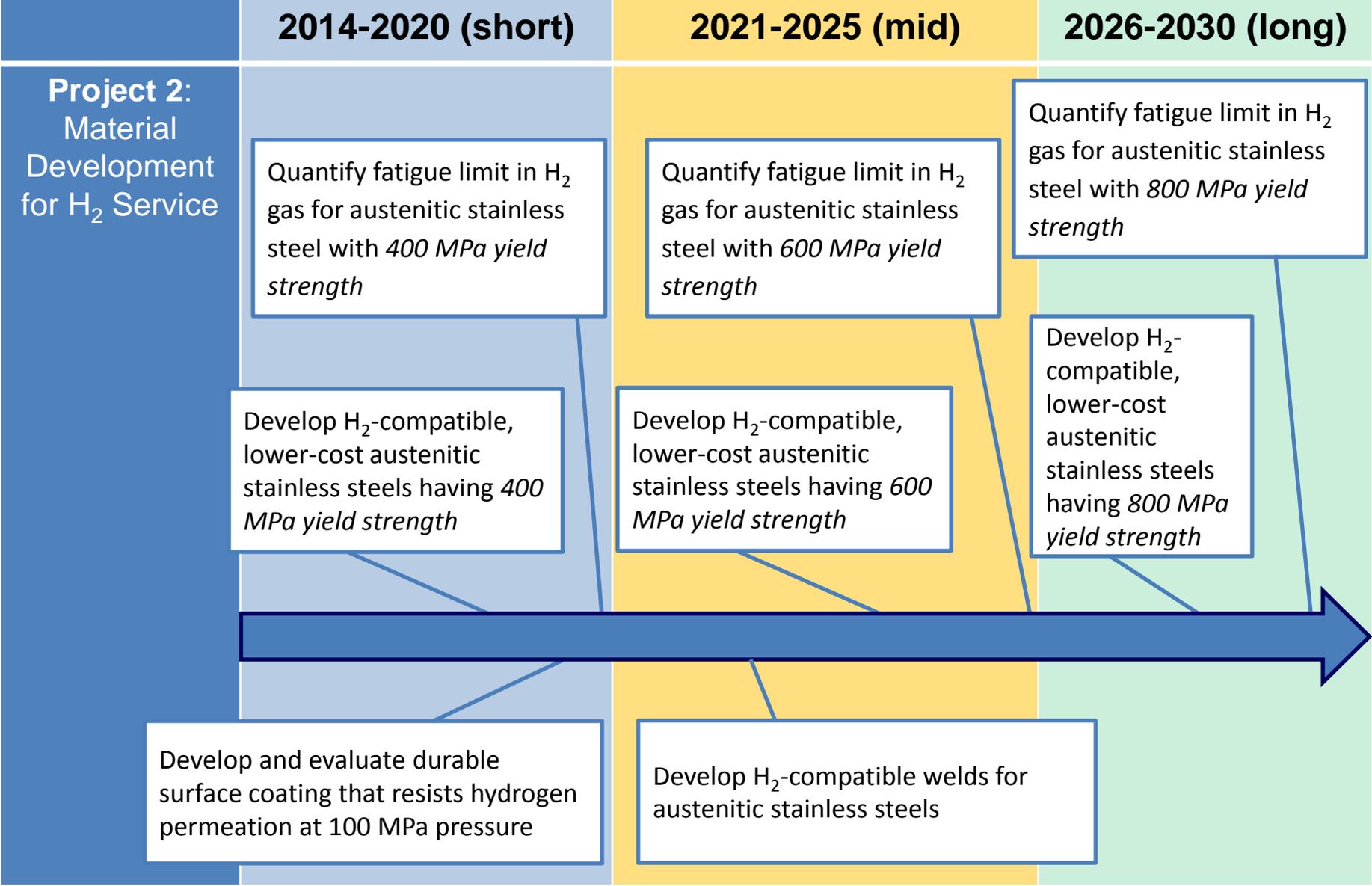
# Division Projects, Objectives, and Research Efforts (2)

Projects	Objectives	Research Efforts	Researchers
<p><b>Project 3:</b> Environmental Effects on Friction and Tribological Failures</p>	<p>Develop physics-based, comprehensive predictive models for friction and tribo-failures in order to improve reliability of tribological components in hydrogen-producing environments</p> <p>Develop physics-based, comprehensive predictive models for friction and wear in order to improve energy efficiency of machinery across technology sectors</p>	<p>Establish comprehensive description of mechanical and chemical processes at tribo-interface of metals, polymers, ceramics and coatings under sliding in H<sub>2</sub></p> <p>Establish comprehensive description of hydrogen-assisted tribo-failure as well as methodologies to prevent hydrogen permeation and failure</p> <p>Establish comprehensive description of friction, lubrication and surface failures in both dry and lubricated contact in various environment</p>	<p>Sugimura, Sawae, Tanaka, Yagi, Matsunaga, Morita, Yamaguchi, Saravanan, Niste</p>

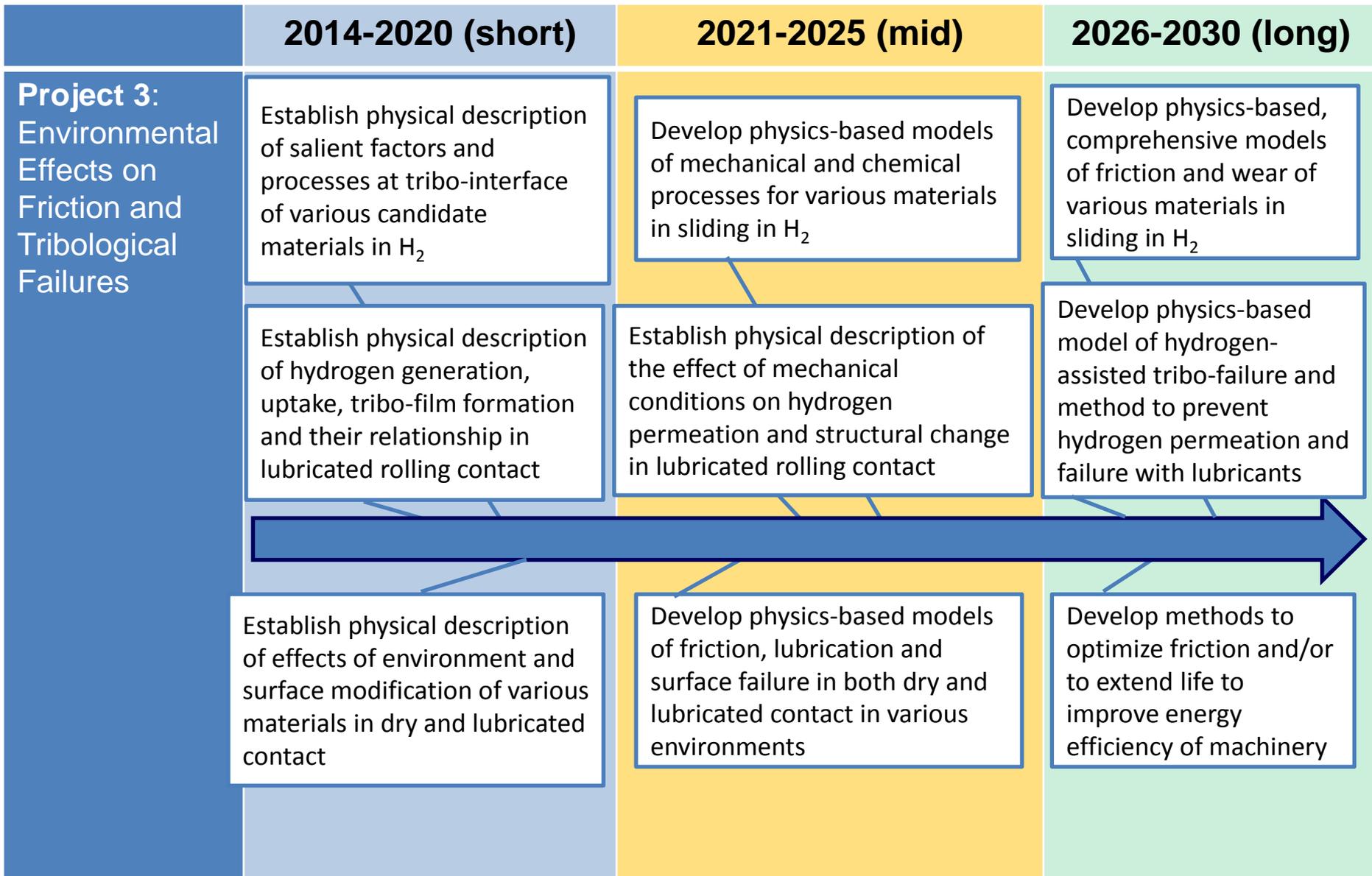
# Milestones (1)



# Milestones (2)



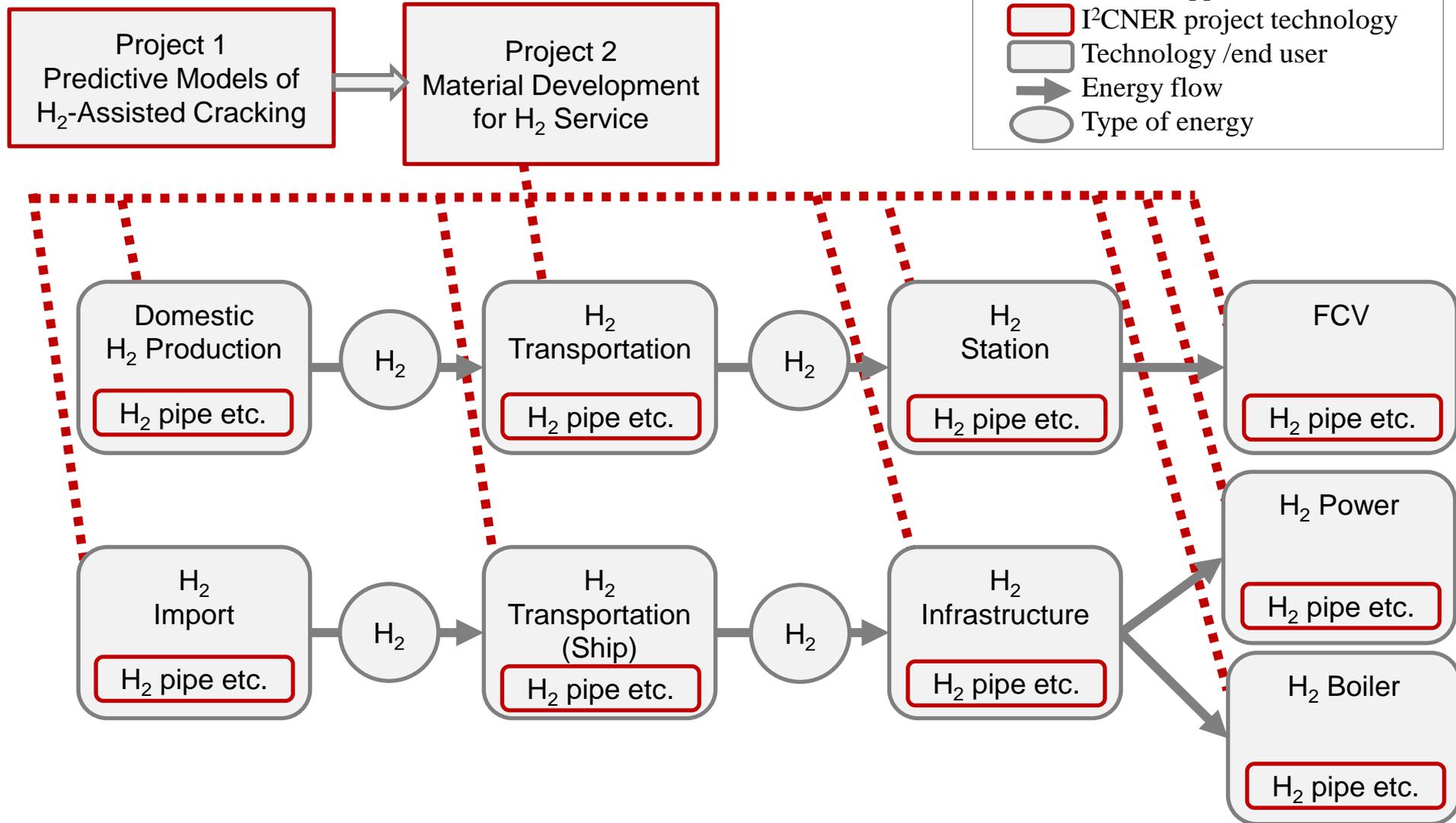
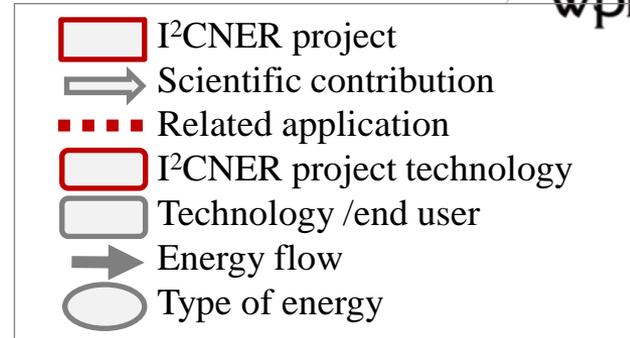
# Milestones (3)



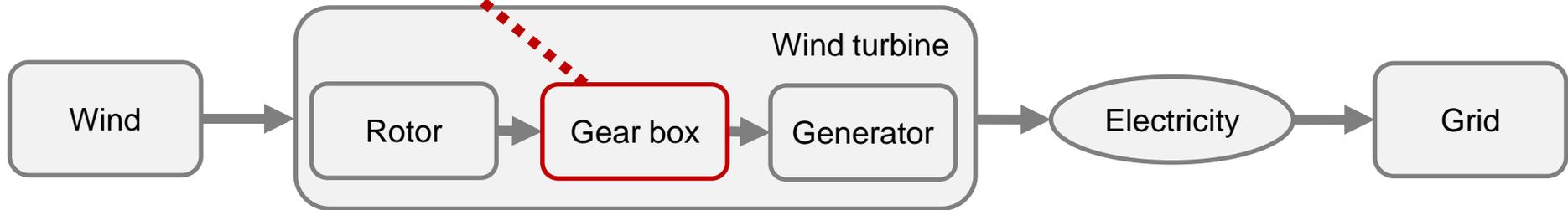
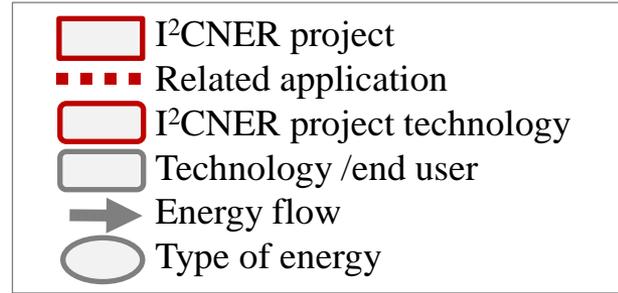
	Ultimate targets	Current benchmark	Technology/ Application
Project 1: Predictive Models of H <sub>2</sub> -Assisted Cracking	Physics-informed, predictive models that quantify H <sub>2</sub> -assisted cracking as a function of material, environmental, and mechanical variables	Engineering models for quantifying component failure in H <sub>2</sub> service	Life prediction of H <sub>2</sub> containment components and material design for H <sub>2</sub> service
Project 2: Material Development for H <sub>2</sub> Service	Materials designed specifically for high performance in hydrogen service	Adapting commercial materials (e.g. SUS316L stainless steel) for hydrogen service	Cost-effective, high-performance stainless steels for H <sub>2</sub> service including FCV, hydrogen station and hydrogen import system
Project 3: Environmental Effects on Friction and Tribological Failures	Physics-based predictive modeling approach for design and materials selection of tribological systems applied in a range of energy technologies	Empirical approach for design and materials selection of tribological systems in hydrogen and other service environments	High reliability tribological systems (e.g. valves and compressors in hydrogen infrastructure and rolling bearings in wind turbine gear box)  Reducing energy loss by improving friction components (e.g. in IC engines)

# Role & Contribution through Technology

- Role of this division toward CNS is to create
  1. low cost and higher strength stainless steel retaining resistance to hydrogen-induced degradation, **underpinning the hydrogen economy**
  2. low friction components to **reduce energy loss** in various machinery and high-reliability tribological components to reduce tribological failure relating to **increased capacity ratio** in energy facilities such as wind turbines



Project 3  
Environmental Effects  
on Friction and  
Tribological Failures



Note: this is an example of the application of Project 3